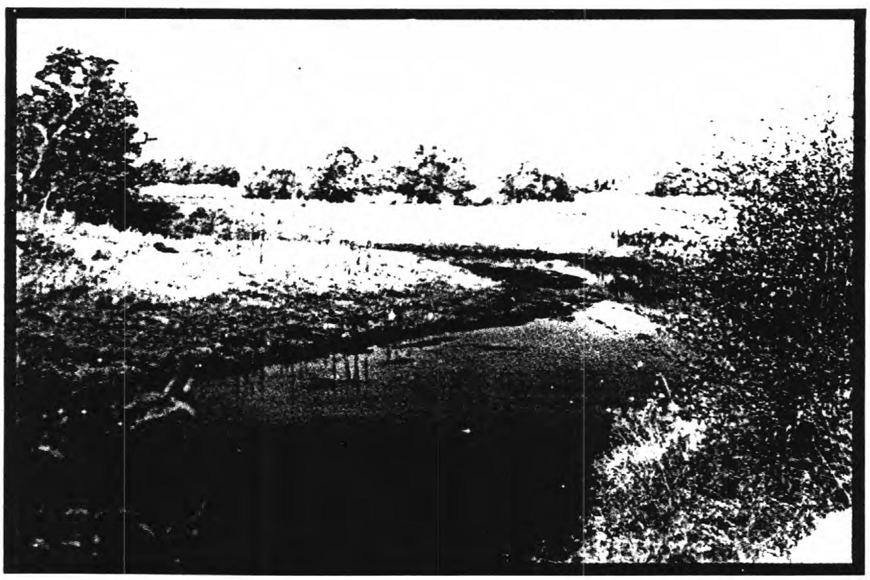
METHODS FOR CHARACTERIZING STREAM HABITAT AS PART OF THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

U.S. Geological Survey

Open-File Report 93-408



COVER PHOTOGRAPHS: (top) Aerial view of land use along the Kansas River, near Topeka, Kansas;
(bottom) riparian habitat along Satus Creek at Satus, Washington.

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By Michael R. Meador, Cliff R. Hupp, Thomas F. Cuffney, and Martin E. Gurtz

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Raleigh, North Carolina

1993

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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CONVERSION FACTORS

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Area	
square meter (m^2)	10.76	square foot

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ABSTRACT

Stream habitat is characterized in the U.S. Geological Survey's National Water-Quality Assessment Program as part of an integrated physical, chemical, and biological assessment of the Nation's water quality. The goal of stream habitat characterization is to relate habitat to other physical, chemical, and biological factors to describe water-quality conditions. To accomplish this goal, environmental settings are described at sites selected for water-quality assessment. In addition, spatial and temporal patterns in habitat are examined at local, regional, and national levels. Although habitat characterization is an important component of a number of Federal, State, and local water-quality assessment programs, no current set of habitat evaluation procedures meets the objectives of the habitat assessment component of the National Water-Quality Assessment Program.

Evaluation of stream habitat is based on a spatially hierarchical framework that incorporates habitat data at basin, segment, reach, and microhabitat scales. This framework provides a basis for national consistency in collection techniques while allowing flexibility in habitat assessment within individual study units. Procedures are described for collecting habitat data at basin and stream segment scales that include use of geographic information system data bases, maps, and aerial photographs. Data collected at the stream reach scale include more than 34 riparian and instream habitat characteristics evaluated during one-time site visits, and surveys of the channel and riparian area during repeated sampling.

INTRODUCTION

Background

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program is designed to assess the status of and trends in the Nation's water quality and to develop an understanding of the major factors that affect observed water-quality conditions and trends (Hirsch and others, 1988; Leahy and others, 1990). This assessment is accomplished by collecting physical, chemical, and biological data at sites that represent major natural and human factors (for example, ecoregion, land use, stream size, hydrology, and geology) that are thought to control water quality in the river basin. These data are used to provide an integrated assessment of water quality within selected environmental settings, assess trends in water quality, and investigate the influence of major natural and human factors on water quality.

Documentation of stream habitat is an essential component of many water-quality assessment programs (Osborne and others, 1991). Environmental assessments are sometimes made to determine consequences of alteration of stream habitat as a result of proposed impoundment, channelization, or land use. Habitat assessment provides baseline information on environmental settings so that changes resulting from human or natural causes can be identified, estimated, or predicted. In addition, habitat assessment can assist in identification of limiting physical and(or) chemical factors critical to biological communities.

Physical, chemical, and biological attributes of a stream, when combined with the environmental requirements of aquatic organisms, influence the presence or absence of a given organism in a stream. Habitat characteristics influence species distributions at different spatial scales. For example, fish species distribution is affected by climate (Tonn, 1990), stream gradient (Sheldon, 1968), and particle size of substrate within a specific section of stream (Hynes, 1975).

Although habitat evaluation is an essential component of water-resource investigations, little uniformity in concept or methodology exists (Osborne and others, 1991). Despite this fact, many State and regional assessment programs incorporate habitat data (Osborne and others, 1991). However, manuals that provide guidelines for conducting habitat evaluations (for example, Bovee, 1982; Platts and others, 1983; Hamilton and Bergersen, 1984; Platts and others, 1987) often have a regional or single-purpose focus. Therefore, no current set of habitat evaluation procedures meets the objectives of water-resource investigations conducted as part of the NAWQA Program.

The goal of stream habitat characterization as part of NAWQA is to relate habitat to other physical, chemical, and biological factors to interpret water-quality conditions. To accomplish this goal, environmental settings are described at sites selected for water-quality assessment. In addition, spatial and temporal patterns in habitat are examined at local, regional, and national levels. An integrated data base provides information to generate additional hypotheses and address specific questions at local, regional, and national levels. No single document can encompass all stream habitat variables that are encountered across the Nation. Therefore, the methods described in this document must be continuously tested and refined, and new methods evaluated.

Purpose and Scope

This document provides detailed procedures for characterizing stream habitat as part of the USGS's NAWQA Program. These procedures allow for appropriate habitat descriptions and standardization of measurement techniques to facilitate unbiased evaluations of habitat influences on water-resource conditions at local, regional, and national levels.

A conceptual framework for evaluating stream habitat is provided that establishes a basis for consistency in collection techniques and allows for flexibility in the assessment of habitat at individual sites. Procedures are described for collecting habitat data at basin and stream segment scales using geographic information system (GIS) data bases, maps, and aerial photographs. Data collected at the stream reach scale include riparian and instream habitat characteristics evaluated during one-time site visits, and surveys of the channel and riparian area during repeated sampling. Forms for recording these data are presented.

NATIONAL WATER-QUALITY ASSESSMENT SAMPLING DESIGN

The NAWQA sampling design emphasizes a multidisciplinary approach, using physical, chemical, and biological tools to provide multiple lines of evidence with which to evaluate water-quality conditions. For surface waters (streams and rivers) NAWQA focuses on a broad spectrum of attributes and sampling approaches to collect data on (1) hydrology; (2) inorganic constituents (major ions, trace elements, nutrients), physical measurements (suspended sediment, conductance, temperature), radionuclides, and organic contaminants in water; (3) trace elements and organic contaminants in bed material and aquatic biota; (4) ecological information (fish, benthic invertebrate, and algal communities); and (5) stream habitat evaluation.

The program is organized into 60 study units on the basis of hydrologic systems (major river basins and large parts of aquifers). Each study unit conducts water-quality investigations for 4 to 5 years, followed by 5 years of low-level monitoring, with the cycle repeated perennially (Leahy and others, 1990). Study-unit investigations consist of four main components: (1) retrospective analysis and reconnaissance; (2) occurrence and distribution assessment; (3) assessment of long-term trends and changes; and (4) source, transport, fate, and effect studies.

Retrospective Analysis and Reconnaissance

Retrospective analysis and reconnaissance efforts provide information to aid in the focus of NAWQA issues and in the design of NAWQA studies. The retrospective analysis is designed to provide an historical perspective on water-quality conditions and biota within a study unit and to assist in the identification of major natural and human factors within that study unit. Analysis of retrospective information on water-quality conditions, biota, and natural and human influences within the study unit also provides baseline information to assist in identification of candidate sampling locations. However, sampling locations are not chosen until a reconnaissance is conducted or an exploration and evaluation of candidate sampling locations are completed.

A reconnaissance consists of a rapid site assessment that includes evaluations of such factors as stream access, stream habitat conditions, proximity of a site to major natural or human influences, and methods and equipment appropriate for conducting various types of sampling at that location. A reconnaissance is conducted to familiarize project personnel with basin characteristics of the study unit and to evaluate candidate locations for subsequent sampling of biological, chemical, and physical characteristics of streams. This subsequent, integrated sampling effort is known as an occurrence and distribution assessment.

Occurrence and Distribution Assessment

The occurrence and distribution assessment is conducted to characterize geographic and seasonal distributions of water-quality conditions in relation to major natural and human features. This assessment is designed to fill crucial gaps in existing data for each study unit. The design of water-quality investigations conducted during the occurrence and distribution assessment represents a balance between maximum flexibility of study units to target issues of local importance, and national consistency in constituents measured, sampling approaches, and spatial and temporal resolution to allow for comparisons among study units. The occurrence and distribution assessment serves as a basis for designing field activities to evaluate long-term changes in water-quality conditions and studies of source, transport, fate, and effects.

Assessment of Long-term Trends and Changes

Assessment of long-term trends and changes in selected water-quality characteristics will be designed on the basis of results of the retrospective analyses, reconnaissance, occurrence and distribution assessment, and the concurrent development of information on the environmental framework. Temporal (for example, decadal) changes in the relations among physical, chemical, and biological factors will be interpreted in the context of changes in landscape features and human activities.

Source, Transport, Fate, and Effect Studies

Source, transport, fate, and effect studies are conducted to test hypotheses and examine specific issues about characteristics and causes of water-quality alteration. These studies are targeted for high-priority water-quality issues for individual study units and the Nation. The accumulation of results from these studies among study units enables the linking of broad assessments of status and trends to specific causes and processes by example and inference. Source, transport, fate, and effect studies are designed by and unique to individual study units and are conducted at a wide range of spatial and temporal scales.

STREAM HABITAT SAMPLING DESIGN

The stream habitat sampling design provides a framework for characterizing stream habitat at multiple spatial scales. The challenge of integrating stream habitat data into an assessment of physical, chemical, and biological factors relates to the problem of spatial scale when studying habitat. Hynes (1975) supported the view that relations among physical, chemical, and biological components of streams are determined not just within the context of a stream, but also within the broader context of the surrounding watershed. Therefore, to adequately examine the relations among physical, chemical, and biological attributes of streams, evaluating stream habitat must be accomplished within a systematic framework that accounts for multiple spatial scales.

Framework for Characterizing Stream Habitat

A framework for evaluating stream habitat must be based on a conceptual understanding of how stream systems are organized in space and how they change through time (Lotspeich and Platts, 1982; Frissell and others, 1986). Among physiographic regions, or among streams within a region, different geomorphic processes control the form and development of basins and streams (Wolman and Gerson, 1978). Therefore, researchers have recognized the importance of placing streams and stream habitats in a geographic, spatial hierarchy (Godfrey, 1977; Lotspeich and Platts, 1982; Bailey, 1983).

A spatially hierarchical approach to describing environmental settings and evaluating stream habitat was proposed by Frissell and others (1986). The approach used by NAWQA is a modification of the spatial hierarchy as developed by these authors. The approach proposed by Frissell and others (1986) included five spatial levels--stream, segment, reach, pool/riffle, and microhabitat--referred to as "systems." The modified approach used in the NAWQA Program consists of a framework that integrates habitat data at four spatial scales: basin, stream segment, stream reach, and microhabitat (fig. 1). This approach differs from the scheme proposed by Frissell and others (1986) in that (1) the term "system" is not used, (2) basin is used to refer to stream system, and (3) the pool/riffle system is omitted as a scale to be evaluated but is incorporated into the definition of stream reach.

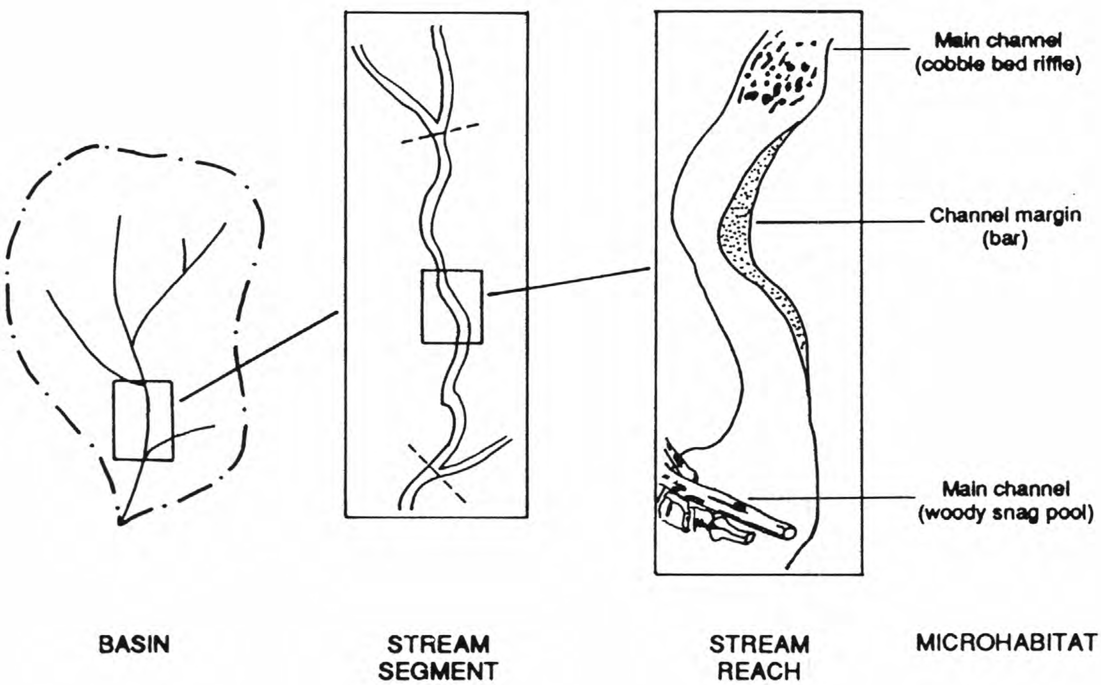

Figure 1.--Spatial hierarchy of basin, stream segment, stream reach, and microhabitat (modified from Frissell and others, 1986).

Selection of Sampling Sites

Sampling sites are generally chosen to represent the set of environmental conditions deemed important to controlling water quality in the study unit. Sites should represent combinations of natural and human factors thought to collectively influence the physical, chemical, and biological characteristics of water quality in the study unit and to be of importance locally, regionally, or nationally. Two distinct types of sampling sites are established as part of NAWQA--fixed sites and synoptic sites.

Fixed sites are typically located at or near USGS gaging stations where continuous discharge measurements are available. At these sites, broad suites of physical, chemical, and biological characteristics are measured, along with characterizations of fish, benthic invertebrate, and algal communities. Synoptic sites are typically nongaged sites where one-time measurements of a limited number of physical, chemical, and biological characteristics are made with the objective of answering questions regarding source, occurrence, or spatial distribution.

METHODS FOR CHARACTERIZING STREAM HABITAT

The methods used for evaluating stream habitat at the various scales combine existing information from sources such as GIS data bases and maps with field-collected data on instream and riparian features. These methods provide a basis for national consistency yet allow flexibility in habitat assessment at all scales of the hierarchy.

Basin Characterization

The term "basin" denotes the area drained by all surface waters located upstream of a selected site. The development of stream habitat is influenced to a large degree by basin-scale spatial factors including physiographic province, geology, and climate (Schumm and Lichty, 1965; Frissell and others, 1986; Klingeman and MacArthur, 1990). Thus, the basin is a convenient unit for characterizing the environmental setting of selected sites (Leopold and others, 1964). Evaluation of basin-wide natural and human factors also enhances an understanding of the comparative biogeographic patterns in biological communities (Biggs and others, 1990; Quinn and Hickey, 1990).

The GIS data bases are a primary component of basin characterization. For the aggregation of data among study units, data related to basin-level variables must be gathered from data bases with national coverage. Scales for national coverage maps generally range from 1:24,000 to 1:7,500,000 resolution for many data bases of basin-scale characteristics. For analysis of data at the study-unit level, local coverage maps and aerial photographs generally provide better resolution per data base and are more current than national coverage maps. Also, nondigital coverages may provide valuable information for individual study units. Thus, two levels of data-base coverage are required for basin characterization to ensure the use of the most complete basin-level information at the greatest resolution for individual study units, as well as to allow comparisons of basin characterizations among study units.

A basin characterization is conducted at fixed and synoptic sites using a form such as the one presented in figure 2. Instructions for completing a basin characterization form are detailed below, with the numbers corresponding to the items as presented in figure 2.

Basin Characterization Form

Page __ of __

1. **Study Unit** _ _ _ _

2. **Date** _ _ -- _ _ -- _ _
Month -- Day -- Year

3. **Station Name** ____________________

4. **Station Identification Number** ____________________

5. **Investigators** ____________________

____

6. **Reference Location** ____________________

latitude deg _ _ min _ _ sec _ _ longitude deg _ _ _ min _ _ sec _ _

7. **Drainage Area** ____________ 8. **Drainage Density** ____________

9. **Drainage Texture** ____________ 10. **Drainage Shape** ____________

11. **Stream Length** ____________ 12. **Basin Relief** ____________

13. **Storage** ____________

	National coverage			Local coverage		
	Type	Percent	Scale	Type	Percent	Scale
14. **Ecoregion**	_ _	____	1:7,500,000	_ _	____	________
	_ _	____	1:7,500,000	_ _	____	________
	_ _	____	1:7,500,000	_ _	____	________
15. **Physio. Prov.**	_ _	____	1:7,500,000	_ _	____	________
	_ _	____	1:7,500,000	_ _	____	________
	_ _	____	1:7,500,000	_ _	____	________

Figure 2.--Form for conducting a basin characterization (page 1).

Basin Characterization Form

Page __ of __

Study Unit __ __ __ __

Date __ __ -- __ __ -- __ __
Month -- Day -- Year

	National coverage			Local coverage		
	Type	Percent	Scale	Type	Percent	Scale
16. Land Use	__ __	______	1:250,000	__ __	______	____________
	__ __	______	1:250,000	__ __	______	____________
	__ __	______	1:250,000	__ __	______	____________
17. Geologic Type	__ __	______	1:2,500,000	__ __	______	____________
	__ __	______	1:2,500,000	__ __	______	____________
	__ __	______	1:2,500,000	__ __	______	____________
18. Soil Type	__ __	______	1:7,500,000	__ __	______	1:250,000
	__ __	______	1:7,500,000	__ __	______	1:250,000
	__ __	______	1:7,500,000	__ __	______	1:250,000
19. Pot. Nat. Veg.	__ __	______	1:3,100,000	__ __	______	____________
	__ __	______	1:3,100,000	__ __	______	____________
	__ __	______	1:3,100,000	__ __	______	____________
20. Wetlands	__ __	______	1:24,000	__ __	______	____________
	__ __	______	1:24,000	__ __	______	____________
	__ __	______	1:24,000	__ __	______	____________

21. Mean Annual Precipitation ____________
Calculation method ____

Figure 2.--Form for conducting a basin characterization (page 2).

1. **Study unit**: Use the code (table 1) designated for each study unit.
2. **Date:** Record the date as month, day, year.
3. **Station name**: List the USGS station name or create a station name for the site.
4. **Station identification number:** List the USGS station identification number for the site.
5. **Investigators:** Self explanatory.
6. **Reference location**: Briefly describe reference location. The reference location should be a permanent structure such as a USGS gage or a bridge. When a permanent structure is not present, a semipermanent marker (such as an iron pipe) is installed at a site. The reference location serves as a classification variable, providing a geographic marker linking habitat data collected at the basin level with data collected at subsequent levels of the spatial hierarchy. Record the latitude and longitude of the reference location.
7. **Drainage area:** Delineate drainage basin boundaries on a 1:24,000-scale 7.5-minute quadrangle map (7.5' map) and calculate the drainage area of the basin upstream of the reference location. For items 7 through 13, if the information cannot be obtained realistically from 7.5' maps, then collect the data at 1:250,000-scale resolution.
8. **Drainage density:** Measure the cumulative length of all perennial streams and canals in the basin upstream of the reference location, as noted on a 7.5' map. Then divide the cumulative length by the drainage area to calculate drainage density.
9. **Drainage texture:** Drainage texture is an expression of the closeness of spacing of stream channels in the basin upstream of the reference location and is calculated by determining the basin contour with the most crenations, as noted by visual inspection of a 7.5' map. Following that contour, determine the number of channel crossings. Divide the number of stream channel crossings by the length of the perimeter of the basin.
10. **Drainage shape:** To determine drainage shape, measure the basin length, square it, and divide it by the drainage area, using a 7.5' map.
11. **Stream length:** Measure the length of the stream from the headwaters to the reference location, as noted on a 7.5' map.
12. **Basin relief:** Determine the highest elevation in the basin minus the elevation of the reference location as noted on a 7.5' map.
13. **Storage:** Determine the cumulative area of the drainage that is composed of stored water, including reservoirs, lakes, ponds, swamps, and wetlands, using a 7.5' map.
14. **Ecoregion:** Record up to three of the spatially dominant ecoregions for the basin upstream of the reference location and the percentage of the basin that each occupies. Omernik (1987) identified relatively homogeneous ecological regions of the United States based on regional patterns of spatially variable combinations of land use, mineral availability (soils and geology), potential natural vegetation, and physiography. Ecoregions have been compiled at two map scales, a national map at 1:7,500,000-scale resolution and regional maps at 1:2,500,000-scale resolution. State maps may also be available. The national coverage scale (1:7,500,000) is provided; record the local coverage scale of the highest resolution available.
15. **Physiographic province:** Coverage of a national map of physiographic provinces is available as a GIS data base and is derived from 25 physiographic provinces representing distinct areas that have common topography, rock types and structure, and geologic and geomorphic history. Record up to three of the spatially dominant physiographic provinces for the basin, upstream of the reference location, and the

Table 1.--*Codes for National Water-Quality Assessment Program study units*

Study Unit	Code	Study Unit	Code
Albemarle-Pamlico Drainage	ALBE	Northern Rockies Intermontaine Basins	NROK
Allegheny and Monongahela Basins	ALGH	Oahu	OAHU
Apalachicola-Chattahoochee-Flint River Basin	ACFB	Ozark Plateaus	OZRK
Central Columbia Plateau	CCPT	Potomac River Basin	POTO
Central High Plains	CHPL	Puget Sound Drainages	PUGT
Central Nebraska Basins	CNBR	Red River of the North	REDN
Central Oklahoma	COKL	Rio Grande Valley	RIOG
Cheyenne and Belle	CHEY	Sacramento Basin	SACR
Chicot-Evangeline	CHEV	San Joaquin-Tulare Basins	SANJ
Connecticut, Housatonic, and Thames River Basins	CONN	Santa Ana Basin	SANA
Cook Inlet	COOK	Santee Basin and Coastal Drainage	SANT
Delaware River Basin	DELR	South Central Texas	SCTX
Delmarva Peninsula	DLMV	South Platte River Basin	SPLT
Eastern Iowa Basins	EIWA	Southeastern New England	SENE
Georgia-Florida Coastal Plain	GAFL	Southern Arizona	SOAZ
Great and Little Miami River Basin	MIAM	Southern Florida	SOFL
Great Salt Lake Basin	GRSL	Southern High Plains	SHPL
Hudson River Basin	HDSN	Southern Illinois	SILL
Kanawha-New River Basin	KANA	Trinity River Basin	TRIN
Kansas River Basin	KANS	Upper Arkansas River	UARK
Kentucky River Basin	KNTY	Upper Colorado River Basin	UCOL
Lake Erie-Saint Clair Drainage	LERI	Upper Illinois River Basin	UIRB
Long Island-New Jersey Coastal Plain	LINJ	Upper Mississippi River Basin	UMIS
Lower Susquehanna River Basin	LSUS	Upper Snake River Basin	USNK
Lower Tennessee River Basin	LTEN	Upper Tennessee River Basin	UTEN
Mississippi Embayment	MISE	Western Lake Michigan Drainages	WMIC
Mobile River	MOBL	White River Basin	WHIT
Nevada Basin and Range	NVBR	Willamette Basin	WILL
New Hampshire and Southern Maine Basins	NHME	Yakima River Basin	YAKI
North Platte Basin	NPLT	Yellowstone River Basin	YELL

percentage of the drainage area that each province occupies. The national coverage scale (1:7,500,000) is provided; record the local coverage scale of the highest resolution available.

16. **Land use:** Use the Geographic Information Retrieval and Analysis System (GIRAS) data base to record land use. GIRAS data are based on the Anderson classification system (Anderson and others, 1976), which uses four-letter codes to describe a two-stage hierarchy of land use. For example, in the code reference UR-Re, UR pertains to the Level I designation of "URBAN OR BUILT-UP LAND." The second two letters following the hyphen, Re, indicate the Level II category of "Residential." Modifications made with respect to the Anderson system are as follows: (1) under the Level I category of "AGRICULTURAL," the Level II category of "Cropland and Pasture" has been separated into two categories, and cropland has been further separated into irrigated and nonirrigated types; (2) the Level I classes of "WATER," "TUNDRA," and "PERENNIAL SNOW OR ICE" have been deleted; and (3) the Level II categories "Mixed," "Other," and "Beaches" have been deleted. For example:

Level I		
UR	URBAN OR BUILT-UP LAND	
	Level II	
	Re	Residential
	Co	Commercial and services
	In	Industrial
	Ic	Industrial and commercial complexes
	Tr	Transportation, communications, and utilities
AG	AGRICULTURAL	
	Ci	Cropland-irrigated
	Cn	Cropland-nonirrigated
	Pa	Pasture
	Or	Orchards, groves, vineyards or nurseries
	Fe	Confined feeding operations
RA	RANGELAND	
	He	Herbaceous
	Sh	Shrub and brush
FO	FOREST LAND	
	De	Deciduous
	Ev	Evergreen
WE	WETLAND	
	Fo	Forested
	Nf	Nonforested
BA	BARREN LAND	
	Ds	Dry salt flats
	Sa	Sandy areas
	Ex	Bare exposed rock
	Sm	Strip mines, quarries, and gravel pits
	Tr	Transitional areas

Using the abbreviations listed above, record up to three of the spatially dominant Level II land uses and the percentage of the basin upstream of the reference location occupied by each. The national coverage scale (1:250,000) is provided; record the local coverage scale of the highest resolution available.

17. **Geologic type:** A national map of bedrock geology at 1:2,500,000-scale resolution is available from GIS data bases. Identify up to three of the spatially dominant geologic rock units (units are based on age and kind; see King and Beikman, 1974) within the basin and report the percentage of the basin upstream of the reference location occupied by each. The national coverage scale (1:2,500,000) is provided; record the local coverage scale of the highest resolution available.

18. **Soil type:** Two soil-type data bases are available through the Soil Conservation Service: the National Soil Geographic Data Base (NATSGO) and the State Soil Geographic Data Base (STATSGO). Each represents a different resolution of soil mapping, but each data base is linked to soil interpretations that provide information on the proportionate extent of component soils and their properties. Attributes include particle-size distribution, bulk density, available water capacity, soil reaction, salinity, and percentage of organic matter. The NATSGO data base provides a general description of soils, based on major land-resource area boundaries which were developed from State general soil maps. The NATSGO map is available in ARC/INFO format at 1:7,500,000-scale resolution. The STATSGO data base is derived from soil survey maps and, where soil surveys are unavailable, geology, topography, vegetation, and climate data are used with satellite imagery to classify soils. These data are compiled by State at 1:250,000-scale resolution. Identify up to three of the spatially dominant soil types within the basin upstream of the reference location and report the percentage of the drainage area occupied by each. The national coverage scale (1:7,500,000) and the local coverage scale (1:250,000) for STATSGO data are provided.

19. **Potential natural vegetation:** Potential natural vegetation is defined as vegetation that would exist today if man were removed from the scene (Küchler, 1970). Characterizing potential natural vegetation provides important baseline information for evaluating the influence of human activities on vegetation within a basin. A classification of potential natural vegetation is based on whether plants are woody or herbaceous. If woody, they are further classified as broadleaf or needleleaf, evergreen or deciduous. For these vegetation classes, dominant species are listed. National coverage data on potential natural vegetation is available from GIS data bases at 1:3,100,000-scale resolution. Record up to three of the spatially dominant types of potential natural vegetation for the basin upstream of the reference location and the percentage of the drainage area that each occupies. The national coverage scale (1:3,100,000) is provided; record the local coverage scale of the highest resolution available.

20. **Wetlands:** The U.S. Fish and Wildlife Service's National Wetlands Inventory is designed to determine the status of and trends in wetlands throughout the United States (Frayer and others, 1983; Dahl and Johnson, 1991). Wetlands are defined on the basis of plant types, soils, and frequency of flooding. The map is structured using a hierarchical classification, with the highest levels described as Marine, Estuarine, Riverine, Lacustrine, or Palustrine. Each of these systems has subsystems for which classes are identified on the basis of substrate material and flooding regime or vegetative form. Approximately 70 percent of wetlands in the United States have been mapped at 1:24,000-scale resolution. Approximately 20 percent of compiled 1:24,000-scale resolution maps have been digitized and are available in the Map Overlay Statistical System (MOSS) format. Identify up to three of the spatially dominant wetland types within the basin upstream of the reference location and report the percentage of the drainage area occupied by each. The national coverage scale

(1:24,000) is provided; record the local coverage scale of the highest resolution available.

21. **Mean annual precipitation:** Use National Weather Service information to record mean annual precipitation for the basin. Methods for calculating mean annual precipitation can vary among sites. Therefore, record how mean annual precipitation was calculated for the basin.

Segment Characterization

A stream segment is defined as that part of a stream bounded by tributary junctions (fig. 1) or discontinuities, such as major waterfalls, landform features, significant changes in gradient, or point-source discharges (Frissell and others, 1986). Teti (1984) demonstrated that water chemistry patterns vary where tributaries converge. In addition, Burns and others (1984) suggested that stream segments represented discrete units based on changes in benthic invertebrate communities below tributary junctions. Thus, a segment should be a distinct stream unit that is relatively homogeneous with respect to physical, chemical, and biological properties.

A segment characterization is conducted at fixed and synoptic sites using 7.5' maps or recent aerial photographs. A form for conducting segment characterizations of streams is presented in figure 3. The instructions for completing a segment characterization form are detailed below, with the numbers corresponding to the items as presented in figure 3.

1. **Study unit**: Use the code (table 1) designated for each study unit.
2. **Date:** Record the date as month, day, year.
3. **Station name**: List the USGS station name, if available, or create a station name for the site.
4. **Station identification number:** List the USGS station identification number for the site.
5. **Investigators**: Self-explanatory.
6. **Reference location**: Briefly describe reference location, and record its latitude and longitude. The reference location should be a permanent structure such as a USGS gage or a bridge. When a permanent structure is not present, a semipermanent marker (such as an iron pipe) is installed at a site. The reference location serves as a classification variable, providing a geographic marker linking habitat data collected at the segment level with data collected at other levels of the spatial hierarchy. Record the latitude and longitude of the reference location.
7. **State:** Record the U.S. Postal Service two-letter designation for the state.
8. **County:** Record the full name of the county (or parish).
9. **Township:** Record the township designation, if available.
10. **Range:** Record the appropriate range designation, if available.
11. **Section:** Provide the appropriate two- or three-digit number of the section, if available.
12. **Quad**: Record the name and year of the appropriate 7.5' map that includes the reference location.
13. **Segment code:** The U.S. Environmental Protection Agency's River Reach data base (RF3) is a GIS national hydrographic data base of surface-water features that contains code numbers for each stream segment. Record the segment code number that corresponds to the study segment.

Segment Characterization Form

Page __ of __

1. **Study Unit** _ _ _ _

2. **Date** _ _ -- _ _ -- _ _
Month -- Day -- Year

3. **Station Name** ____________________

4. **Station Identification Number** ____________________

5. **Investigators** ____________________

____

6. **Reference Location** ____________________

latitude deg _ _ min _ _ sec _ _ longitude deg _ _ _ min _ _ sec _ _

7. **State** _ _ 8. **County** ____________________ 9. **Township** _ _ _

10. **Range** _ _ _ 11. **Section** _ _ _ 12. **Quad** name __________ year ______

13. **Segment Code** __________ 14. **Segment Length** __________

15. **Elevation** ______ **from:** __________

16. **Sideslope Gradient:** **Measurement 1** ______
Measurement 2 ______
Measurement 3 ______
Mean ______

17. **Segment Gradient** __________ 18. **Channel Sinuosity** __________

19. **Stream Order** __________ 20. **Downstream Link** __________

21. **Water Management Feature**

type _ _ **distance** ____ **upstream** ____ **downstream** ____

type _ _ **distance** ____ **upstream** ____ **downstream** ____

type _ _ **distance** ____ **upstream** ____ **downstream** ____

type _ _ **distance** ____ **upstream** ____ **downstream** ____

Figure 3.--Form for conducting a segment characterization.

14. **Segment length:** Using a map wheel (or GIS), record the approximate length of the stream segment.
15. **Elevation:** Record the elevation at the reference location. Also record source of data, for example, a 7.5' map or a benchmark on a bridge.
16. **Sideslope gradient:** Sideslope gradient is based on the cross-sectional profile of the valley segment. Make three gradient measurements within 300 m horizontal distance of the channel at positions representative of the sideslope gradient along the segment. These measurements and their mean are recorded.
17. **Segment gradient:** Determine the gradient of the segment from a 7.5' map.
18. **Channel sinuosity**: Channel sinuosity is the ratio of channel length between two points on a channel to the straight-line distance between the same two points (Schumm, 1963; Platts and others, 1983). The value is useful for comparisons of habitat conditions among or within streams. In general, low sinuosity indicates steeper channel gradient, uniform cross sections, limited bank cutting, and limited pools. High sinuosity is associated with less steep gradients, asymmetrical cross sections, overhanging banks, and bank pools on the outside of meanders. Channel sinuosity reflects the amount of meandering and, hence, the diversity of habitat. Using a map wheel (or GIS), measure the sinuous and straight-line distances of the entire segment. If the segment is less than 2 km, a minimum distance of 2 km is measured starting at the downstream node of the segment and proceeding upstream.
19. **Stream order**: Stream order is a classification of streams based on tributary junctions (Horton, 1945) and has proven to be a useful indicator of stream size, discharge, and drainage area (Strahler, 1957). On a topographic map showing all intermittent and perennial streams in a basin, the smallest unbranched tributaries are designated order 1. Where two first-order streams join, a second-order stream segment is formed; where two second-order segments join, a third-order segment is formed, and so on. The major difficulty in determining stream order is deciding what constitutes a first-order stream. Leopold and others (1964) defined a first-order stream as the smallest unbranched tributary that appeared on a 7.5' map. Using a 7.5' map, find the smallest unbranched tributary upstream of the reference location, designate it as first order, and record the appropriate stream order for the segment. For irrigation canals and other "artificial" systems, "NA" is recorded for stream order.
20. **Downstream link:** Record the downstream link number of the segment. The downstream link number describes the relation of a given stream segment to upstream and downstream influences within a basin and, therefore, indicates the spatial location of a stream within a basin (Osborne and Wiley, 1992). Downstream link number is the magnitude of the link of the next downstream confluence. For example, the segment immediately downstream from the confluence of two headwater tributaries has a downstream link of 2. If a headwater tributary flows into a stream with a downstream link of 2, then the segment immediately downstream from the confluence of these two streams has a downstream link of 3, and so on. For irrigation canals and other "artificial" systems, "NA" is recorded for downstream link.

21. **Water management feature:** Record the type(s) of water management feature(s) nearest the segment and the distance from the reference location. Also note whether the feature is upstream of or downstream from the reference location. Include as many water management features as appropriate. Water management feature types are noted using the following two-letter codes:

Bridge	BR
Channelized area	CA
Diversion	DV
Feedlot	FL
Hydropower	HP
Impoundment	IM
Industrial outflow	IO
Low-head dam	LH
Natural lake	NL
Storm sewer	SS
Streambank stabilization	SB
Thermal discharge	TD
Waste-water treatment	WT
Other	OT

Reach Characterization

A stream reach (fig. 1) is the least clearly defined unit in the spatial hierarchy (Frissell and others, 1986). Although a stream segment is a discrete unit that should represent a uniform set of physical, chemical, and biological conditions within a stream, its length (often more than several kilometers) prohibits effective field collection of data. Therefore, the stream reach is chosen as the principal sampling unit to collect physical, chemical, and biological data. The type of reach characterization conducted is dependent upon the type of site (fixed or synoptic). However, the factors considered in selecting a stream reach are the same for all sites.

Selecting a Stream Reach

The type and distribution of geomorphic channel units are the most important factors in selecting a stream reach. Geomorphic channel units are fluvial geomorphic descriptors of channel shape and scour pattern that are widely used in habitat assessment surveys (Orth, 1982; Ohio Environmental Protection Agency, 1989). The development of specific sequences of geomorphic channel units is a fundamental stream process (Ying, 1971; Beschta and Platts, 1986). Identification of geomorphic channel units is important because it classifies stream habitat at a spatial scale relevant to most biota in streams (Frissell and others, 1986). Three types of geomorphic channel units are considered when selecting a stream reach--pools, riffles, and runs (fig. 4).

The stream reach should include at least two examples each of two types of geomorphic channel units. Only those geomorphic channel units that are greater than 50 percent of the channel width are considered when the length of the reach is determined. The

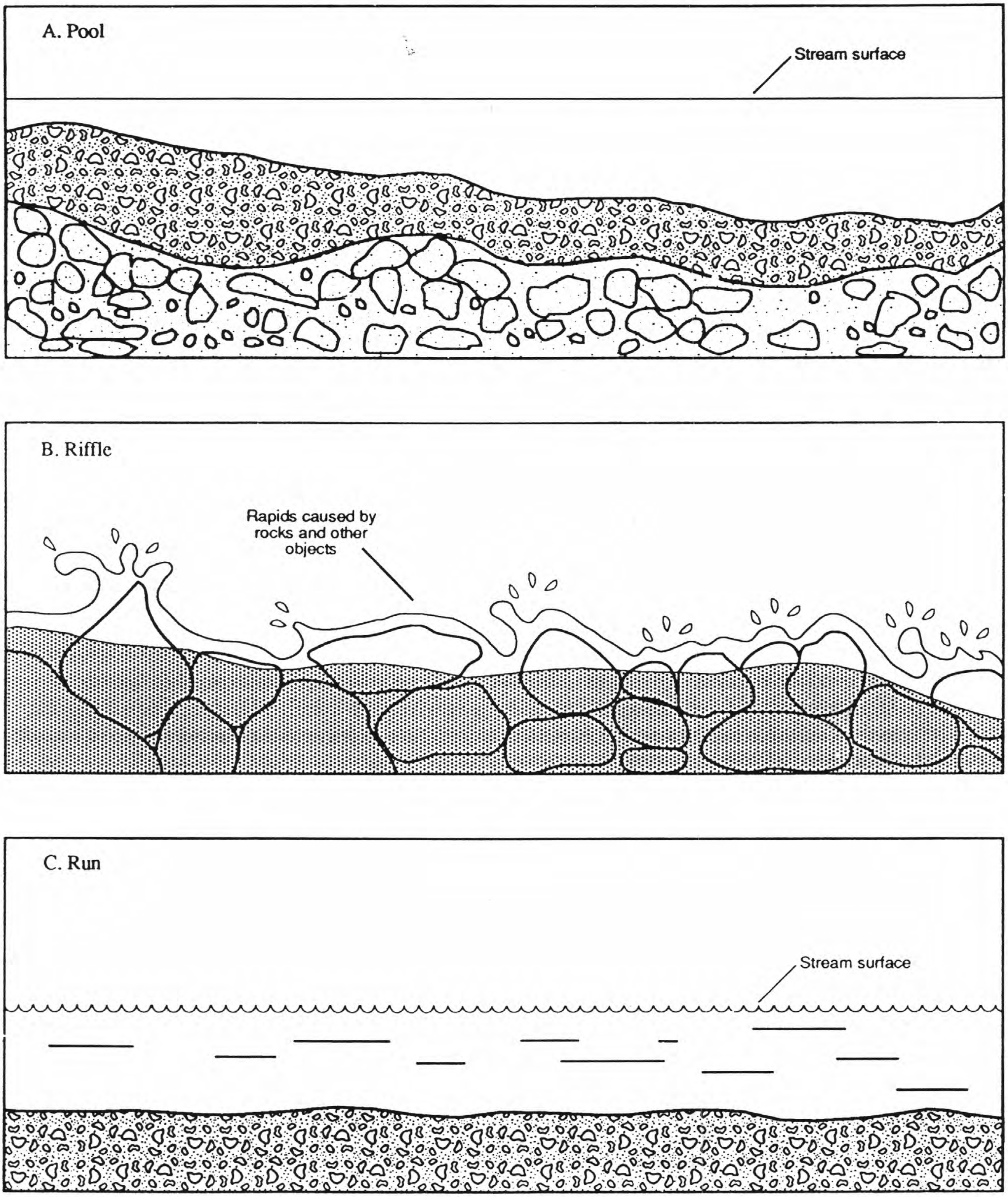

Figure 4.--Diagram of the three main geomorphic channel units: (A) pool--a part of the stream with reduced velocity, commonly with water deeper than surrounding areas; (B) riffle--a part of the stream where the water flows swiftly over completely or partially submerged obstructions to produce surface agitation; and (C) run--a slow moving, relatively shallow body of water with moderately low velocities and little or no surface turbulence (modified from Bisson and others, 1982).

sequence of geomorphic channel units included in the reach should reflect the sequence of geomorphic channel units in the segment. For example, the geomorphic channel units near the reference location may include a pool and a sequence of riffles and runs. If the pool is present only at the reference location and nowhere else in the segment, the pool is not included in the selected reach.

Repeating geomorphic channel units are not present in all streams. In some cases, the entire stream segment consists of only one geomorphic channel unit. When two examples each of two types of geomorphic channel units are not present, the length of the sampling reach is 20 times the channel width. In meandering streams, 20 times the channel width includes one complete meander wavelength (Leopold and others, 1964). Channel width is measured at a location that is representative of the stream (not an anomalously wide or narrow location).

Regardless of the geomorphic channel units present or the channel width, minimum and maximum length criteria are used. A minimum length of reach is necessary to ensure the collection of representative samples of biological communities, whereas a maximum reach length is needed to limit reach length to a distance that prevents unnecessary sampling and minimizes crew fatigue (and associated reduction of sampling efficiency).

Minimum and maximum length criteria for the reach are dependent upon the influence of stream depth on collection methods when sampling streams. Stream reaches are generally classified as wadeable or nonwadeable. Wadeable reaches are those reaches where an investigator can wade from one end of the reach to the other, even though the reach may contain pools that cannot be waded. Nonwadeable reaches are those reaches where an investigator cannot wade from one end of the reach to the other. Minimum reach lengths of 150 m in wadeable reaches and 500 m in nonwadeable reaches are recommended to ensure the collection of a representative sample of the fish community (Meador and others, 1993) and, therefore, are recommended for a corresponding habitat characterization. In most wadeable reaches, a maximum reach length of 300 m is sufficient for adequately characterizing habitat and providing representative samples of biological communities. However, in relatively wide (greater than about 30 m) wadeable streams, a maximum reach length of 500 m should be considered (Meador and others, 1993). A maximum reach length criterion of 1,000 m should be considered for nonwadeable reaches (Meador and others, 1993).

The investigator must evaluate a number of factors before selecting the reach. In general, the reach is located upstream of a bridge or other man-made channel alterations to minimize their influence on stream habitat. When compelling reasons dictate that the reach must be downstream from a bridge or other feature, then the reach must be established far enough downstream from the bridge to avoid such hydraulic effects of bridges as scour holes and over-widened channels. In general, the geomorphic features of the reach should be representative of the segment. Thus, knowledge of the geomorphic channel units of the segment is important.

The combination of geomorphic channel units, channel width, and minimum and maximum length criteria must be considered when the reach is selected. For example, if the presence of two examples of each of two types of geomorphic channel units results in a wadeable reach length less than 150 m, then the minimum length criteria of 150 m is established. However, if possible, the reach should incorporate whole geomorphic units. Therefore, unless the 150-m boundary of the reach is located at a transition between geomorphic channel units, then the reach length should extend to the next transition between geomorphic channel units. If more than one geomorphic channel unit is present but the length of two geomorphic channel units exceeds the recommended maximum length criteria, then the reach should be located so that nearly equal parts of the geomorphic channel units are included.

Once a boundary of the reach has been determined, a semipermanent marker is installed on a surface not subject to frequent inundation. The marker may consist of a capped iron pipe or concrete reinforcing bar driven about 60 cm into the ground. The part extending out of the ground is painted an easily seen color to facilitate location at a later date. If conditions do not permit the use of a marker driven into the ground, a hole can be drilled in an adjacent rock or tree and a standard carriage bolt inserted and painted as the marker. The length of the reach is then determined and a semipermanent marker is installed at the opposite reach boundary. Upon delineation of reach boundaries, a reach characterization of stream habitat is conducted. The procedures used to conduct the reach characterization depend upon the type of site.

Fixed Sites

Fixed sites usually number less than 15 per study unit and are sampled continuously over time. Therefore, approaches to the collection of habitat data that allow for characterization of the status of and trends in habitat are necessary at fixed sites. To accomplish a spatial and temporal characterization of habitat, two levels of reach characterization are considered: a first-level reach characterization that provides for relatively rapid, consistent data collection within and among study units, and a second-level reach characterization that provides a balance between detailed descriptions of stream habitat and study unit flexibility in data-collection efforts.

First-level reach characterization:

Once the reach has been selected, the first-level reach characterization is conducted using a form such as that presented in figure 5. The instructions for completing the reach characterization form are detailed below, with the numbers corresponding to the items as presented in figure 5.

1. **Study unit**: Use the code designated for each study unit.
2. **Date:** Record the date as month, day, year.
3. **Station name**: List the USGS station name or create a station name.
4. **Station identification number:** List the USGS station identification number for the site. If more than one reach is characterized at the station, then assign a reach identification name or number.
5. **Investigators**: Self-explanatory.

Reach Characterization Form

Page __ of __

1. **Study Unit** ___ ___ ___ ___

2. **Date** __ __ -- __ __ -- __ __
Month -- Day -- Year

3. **Station Name** ______________________________

Reach Identification Number ______________________________

4. **Station Identification Number** ______________________________

5. **Investigators** ______________________________

____

6. **Reach Conditions** ______________________________

____

Stage __________ Method: ADR ________ Staff ________ Tape-down ________

7. **Reference Location** ______________________________

latitude deg __ __ min __ __ sec __ __ longitude deg __ __ __ min __ __ sec __ __

Photograph ________

8. **Reach Boundary Nearest To Reference Location**

Upstream ____ **Downstream** ____ **of reference location**

Distance from reference location __________

Boundary marker left bank ___ right bank ___

Boundary marker description ______________________________

9. **Channel Width At Reach Boundary** ____ x 20 = ______

10. **Geomorphic Channel Units**

Type	Length
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______

Figure 5.--Form for conducting a reach characterization (page 1).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___ **Date** __ __ -- __ __ -- __ __
Month -- Day -- Year

11. Reach Length ____

Reach Boundary Furthest From Reference Location:

Boundary marker left bank ____ right bank ____

Boundary marker description ____

12. Stream Type: straight _____ meandering _____ braided _____ channelized _____ pool/riffle _____

	Transects					
	1	2	3	4	5	6
13. Distance From The Reach Boundary Nearest Reference Location	___	___	___	___	___	___
14. Channel Width	___	___	___	___	___	___
15. Bank Width						
Left	___	___	___	___	___	___
Right	___	___	___	___	___	___
16. Flood-plain Width						
Left	___	___	___	___	___	___
Right	___	___	___	___	___	___
			POINT 1			
Distance from left edge of water	___	___	___	___	___	___
17. Depth	___	___	___	___	___	___
18. Velocity	___	___	___	___	___	___
19. Bed Substrate						
Dominant	___	___	___	___	___	___
Subdominant	___	___	___	___	___	___
Silt (yes/no)	___	___	___	___	___	___
20. Embeddedness	___	___	___	___	___	___

Figure 5.--Form for conducting a reach characterization (page 2).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___

Date __ __ -- __ __ -- __ __
Month -- Day -- Year

	Transects					
	1	2	3	4	5	6
POINT 2						
Distance from left edge of water	___	___	___	___	___	___
17. Depth	___	___	___	___	___	___
18. Velocity	___	___	___	___	___	___
19. Bed Substrate						
Dominant	___	___	___	___	___	___
Subdominant	___	___	___	___	___	___
Silt (yes/no)	___	___	___	___	___	___
20. Embeddedness	___	___	___	___	___	___
POINT 3						
Distance from left edge of water	___	___	___	___	___	___
17. Depth	___	___	___	___	___	___
18. Velocity	___	___	___	___	___	___
19. Bed Substrate						
Dominant	___	___	___	___	___	___
Subdominant	___	___	___	___	___	___
Silt (yes/no)	___	___	___	___	___	___
20. Embeddedness	___	___	___	___	___	___
21. Canopy Angle						
Left bank	___	___	___	___	___	___
Right bank	___	___	___	___	___	___
Canopy angle	___	___	___	___	___	___
22. Aspect	___	___	___	___	___	___

Figure 5.--Form for conducting a reach characterization (page 3).

Reach Characterization Form

Page __ of __

Study Unit __ __ __ __ **Date** __ __ -- __ __ -- __ __
Month -- Day -- Year

23. Habitat Features (Type and Amount)

Transects

1	2	3	4	5	6
__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____
__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____
__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____
__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____
__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____	__ __ ____

24. Bar/Shelf/Island (B)/(S)/(I)

Transects

	1	2	3	4	5	6
Type	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
Width	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
Substrate (Dominant)	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
Substrate (Subdominant)	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
Percentage of vegetation cover (Woody)	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
Percentage of vegetation cover (Herbaceous)	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __

Transects

	1	2	3	4	5	6
25. Bank Angle						
Left	__	__	__	__	__	__
Right	__	__	__	__	__	__
26. Bank Height						
Left	__	__	__	__	__	__
Right	__	__	__	__	__	__
27. Bank Vegetation Stability						
Left	__	__	__	__	__	__
Right	__	__	__	__	__	__

Figure 5.--Form for conducting a reach characterization (page 4).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___ **Date** __ __ -- __ __ -- __ __
Month -- Day -- Year

	Transects					
	1	2	3	4	5	6
28. Bank Shape						
Left	___	___	___	___	___	___
Right	___	___	___	___	___	___
29. Bank Erosion						
Left	___	___	___	___	___	___
Right	___	___	___	___	___	___
30. Bank Substrate						
Left						
(Dominant)	___	___	___	___	___	___
(Subdominant)	___	___	___	___	___	___
Right						
(Dominant)	___	___	___	___	___	___
(Subdominant)	___	___	___	___	___	___

31. Bank Woody Vegetation

	Transect 1				Transect 2			
	Species	Distance	/	DBH	Species	Distance	/	DBH
Left	__ __ __ __	____	/	____	__ __ __ __	____	/	____
	__ __ __ __	____	/	____	__ __ __ __	____	/	____
	__ __ __ __	____	/	____	__ __ __ __	____	/	____
	__ __ __ __	____	/	____	__ __ __ __	____	/	____
Right	__ __ __ __	____	/	____	__ __ __ __	____	/	____
	__ __ __ __	____	/	____	__ __ __ __	____	/	____
	__ __ __ __	____	/	____	__ __ __ __	____	/	____
	__ __ __ __	____	/	____	__ __ __ __	____	/	____

Figure 5.--Form for conducting a reach characterization (page 5).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___

Date __ __ -- __ __ -- __ __
Month -- Day -- Year

	Transect 3 Species	Distance	/	DBH	Transect 4 Species	Distance	/	DBH
Left	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
Right	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____

	Transect 5 Species	Distance	/	DBH	Transect 6 Species	Distance	/	DBH
Left	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
Right	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____
	_ _ _ _	____	/	____	_ _ _ _	____	/	____

32. Photodocumentation

Transect		1	_	6
Exposure number				
	Upstream	_	_	_
	Transect	_	_	_
	Downstream	_	_	_
Aspect		_	_	_
Camera height		_	_	_
Bank (left or right)		_	_	_

Camera type ________ **Film type** ________ **ASA** ________ **Lens size** ______

Exposure ________ **Filter(s)** ________ **Focal length** ____ **Lighting** ______

Figure 5.--Form for conducting a reach characterization (page 6).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___

Date __ __ -- __ __ -- __ __
Month -- Day -- Year

33. Diagrammatic Map

Figure 5.--Form for conducting a reach characterization (page 7).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___

Date __ __ -- __ __ -- __ __
Month -- Day -- Year

34. Aquatic and Riparian Vegetation Species

Aquatic Vegetation

Submerged	Emergent	Floating

Riparian Vegetation

Bank		Flood plain	
Herbaceous	Woody	Herbaceous	Woody

Figure 5.--Form for conducting a reach characterization (page 8).

Reach Characterization Form

Page __ of __

Study Unit ___ ___ ___ ___

Date __ __ -- __ __ -- __ __
Month -- Day -- Year

35. Comments ____

Figure 5.--Form for conducting a reach characterization (page 9).

6. **Reach conditions:** Note the general conditions of the reach. Be sure to note factors such as recent flood history, beaver activity, and weather conditions. Also record stage height and the method for determining stage height.
7. **Reference location:** Provide a general description of the reference location (for example, "gage on left bank just below Highway No. 1462 bridge"). The reference location should be a permanent structure such as a USGS gage or a bridge. When a permanent structure is not present, a semipermanent marker (such as an iron pipe) is installed at a site. The reference location serves as a classification variable, providing a geographic marker linking habitat data collected at the reach level with data collected at other levels of the spatial hierarchy. Record the latitude and longitude of the reference location. Also check if a photograph of the reference location is made. If a bridge is present, additional photographs, facing upstream of and downstream from the center of the bridge, further serve to document the reach.
8. **Reach boundary nearest to reference location:** Note whether the reach boundary nearest to the reference location is upstream of or downstream from the reference location. Using a tape measure or rangefinder, record the distance from the reach boundary to the reference location. In addition, record whether the semipermanent boundary marker is located on the left or right bank (looking downstream) at this reach boundary and provide a brief description of the boundary marker (for example, "iron bar, painted orange, about 2 m from the wetted channel").
9. **Channel width at reach boundary**: Channel width is the horizontal distance measured from left edge of water to right edge of water along the existing water surface. To provide consistency in measurement, protruding logs, boulders, stumps, or debris surrounded by water are included in the measurement of the water surface. Islands are not included in the measurement. Any solid accumulation of inorganic sediment particles protruding above the water and supporting woody vegetation is considered an island. Measure the channel width and multiply times 20.
10. **Geomorphic channel units**: Record all geomorphic channel units that are greater than 50 percent of the channel width, and the length of each. These data provide information on spatial dominance and diversity of geomorphic channel units. Use additional space as needed.
11. **Reach length**: Record the reach length. In addition, indicate where the semi-permanent boundary marker at the boundary furthest from the reference location is located, and record a general description of the boundary marker.
12. **Stream type**: Record the stream type represented by the reach. Stream type relates to the character of a channel, which may be straight, meandering, braided, channelized, or pool and riffle (Leopold and Wolman, 1957). Leopold and Wolman (1957) recognized that stream types are not distinct, but represent a continuum of channel configurations which are a function of flow, the quantity and character of the sediment, and the composition of bed and bank material. Therefore, stream type conveys information regarding channel form, processes, and geomorphic channel units.

Stream transects are established to collect the information required to complete items 13 through 35. Six transects, as a minimum, are established throughout the reach with two transects established at or near each boundary (fig. 6). If the reach is established on the basis of the presence of two examples of each of two types of geomorphic channel units, the remaining four transects are established at the middle of each geomorphic channel unit. If the reach is defined on the basis of channel width, then the remaining four transects are evenly spaced throughout the reach. Transects are oriented perpendicular to streamflow. Drawing a simple map, as shown in figure 6, and marking transect locations when establishing the locations of the reach boundaries and transects facilitate subsequent sampling efforts.

13. **Distance from the reach boundary nearest to the reference location:** This distance is measured as the channel distance from the transects to the reach boundary nearest to the reference location.
14. **Channel width:** Measure the channel width along the transect from left edge of water to right edge of water.
15. **Bank width:** Banks include geomorphic features, such as some channel shelves, and are flooded on average more than once every 1 to 3 years (Hupp, 1986). Banks are bounded by the channel bed and the flood plain (fig. 7). Thus, bank width is the distance between the channel bed and the flood plain. This distance is measured with a tape measure or rangefinder.
16. **Flood-plain width:** The flood plain is a relatively flat surface that is flooded on average once every 1 to 3 years (Leopold and others, 1964). The flood plain is bounded by higher features, such as terraces, that are flooded on average once every 3 or more years, and riparian features that are flooded more than once every 1 to 3 years (Hupp, 1986). Thus, flood-plain width is measured as the distance between the significant changes in slope that distinguish the flood plain from terraces and riparian features (fig. 7). If this distance is less than 50 m, it can be measured with a tape measure or rangefinder. However, if the flood-plain width is greater than 50 m, it is determined from maps or aerial photographs, and indicated as greater than 50 m on the form.

For items 17 through 20, data are collected at three points along each transect. These points should correspond to the thalweg, and to two locations that are equally spaced along the transect (or three equally spaced locations if no thalweg is apparent). At each point, record the distance from the left edge of water and note if the point is located in the thalweg by including the letter "T" next to the distance.

17. **Depth:** In wadeable reaches, water depth between the water surface and the bed substrate is measured with a wading rod and recorded. In nonwadeable reaches, a sounding line or hydroacoustic depth meter may be necessary to determine depth. When using a hydroacoustic depth meter, the investigator maneuvers the boat along the transect with the meter operating, so as to produce a continuous recording of water depth along the transect. Three depth measurements, one at the thalweg and two at locations equally spaced along the transect, can be determined from the hydroacoustic chart.

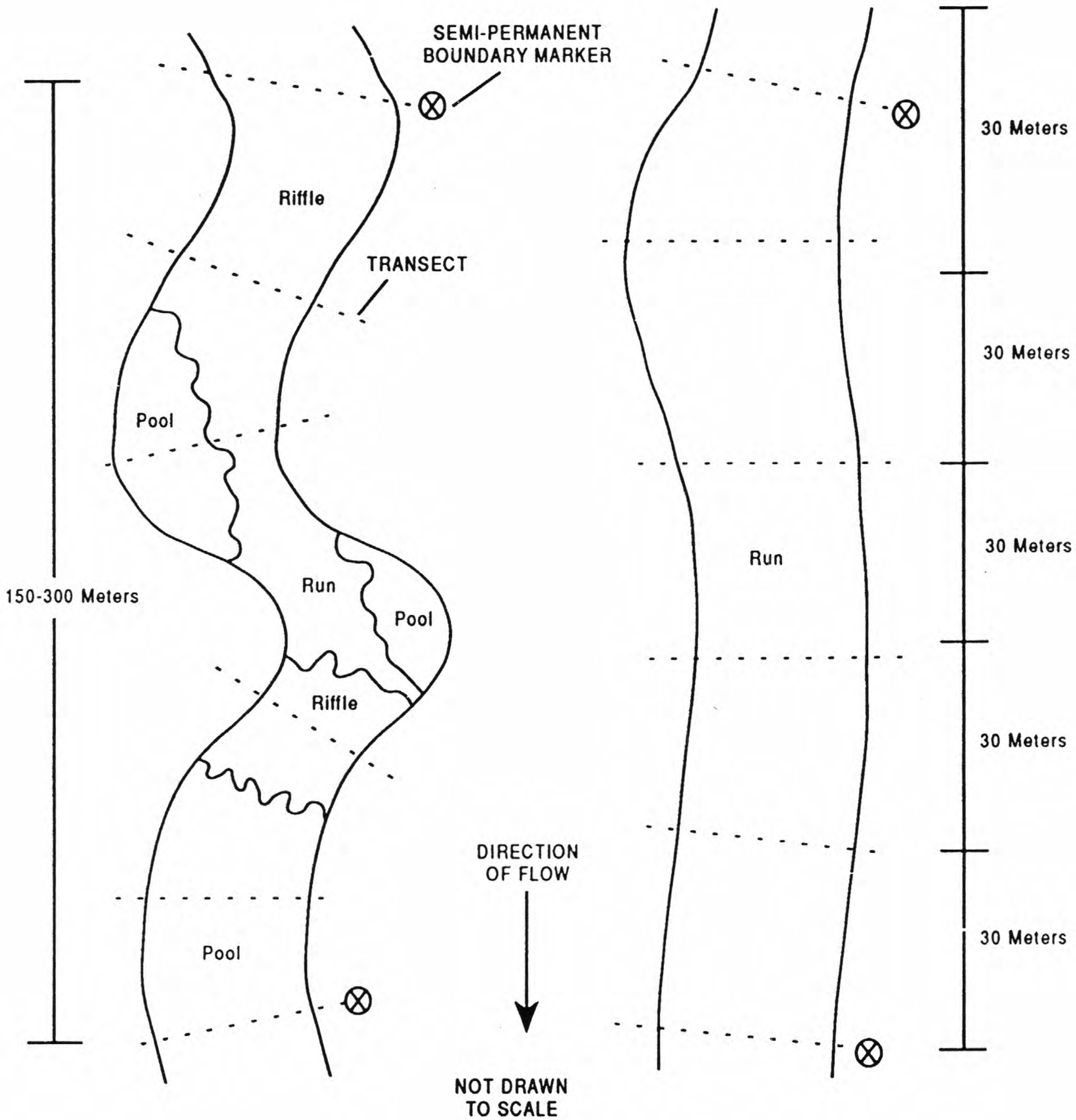

Figure 6.--Example of locations of transects within a reach.

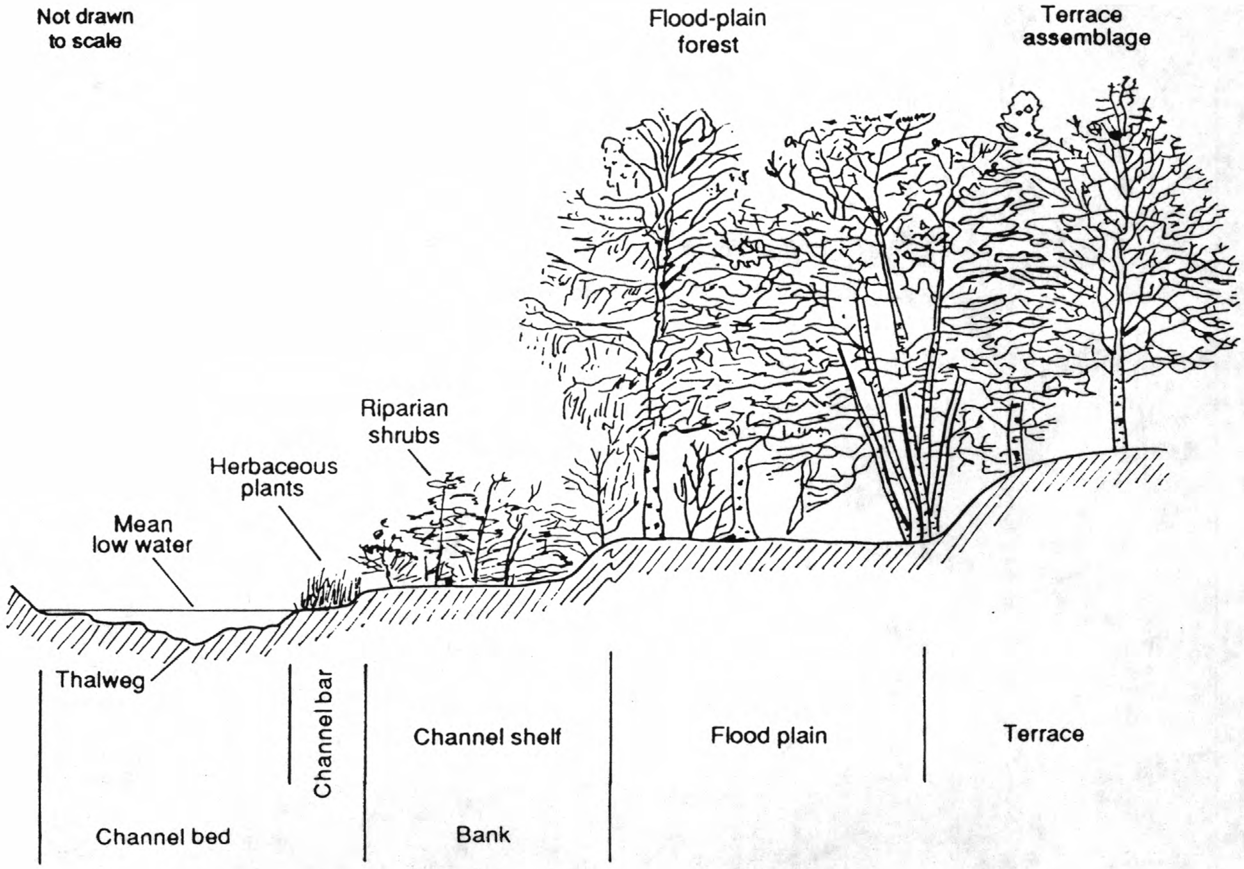

Figure 7.--Diagram of the relative position of geomorphic features along streams (modified from Hupp, 1986).

18. **Velocity:** In wadeable reaches, record velocity using a Price AA current meter, pygmy meter, or Gurley meter. In nonwadeable reaches, use a velocity meter appropriate for velocity determinations at that site. Velocity is recorded at 60 percent depth where depth is less than 1 m. At depths greater than or equal to 1 m, two velocity measurements, one at 20 percent depth and the other at 80 percent depth, are recorded.

19. **Bed substrate:** Determine the spatially dominant and subdominant substrates. Substrate types are noted using the following codes:

Bedrock	BR	Solid rock forming a continuous surface
Boulder	BO	Rounded stones over 256 mm in diameter or large slabs more than 256 mm in length
Cobble	CO	Stones from 64-256 mm in diameter
Gravel	GV	Mixture of rounded course material from 2-64 mm in diameter
Sand	SA	Materials 0.06-2.0 mm in diameter; gritty texture when rubbed between fingers
Silt	SI	Generally fine material 0.004-0.06 mm in diameter; feels "greasy" when rubbed between fingers
Hardpan	HP	Particles less than 0.004 mm in diameter; usually clay, forming a dense, gummy surface that is difficult to penetrate
Marl	MA	Calcium carbonate, usually greyish-white, often containing fragments of mollusc shells
Detritus	DE	Unconsolidated organic material including sticks, wood, and other partially or undecayed coarse plant material
Muck	MU	Black, fine, flocculent, completely decomposed organic matter (does not include sewage sludge)
Artificial	AR	Substrates such as rock baskets, trash, or concrete

Also note whether or not the substrate is covered lightly with silt.

In turbid wadeable reaches and in nonwadeable reaches, a sample of the substrate is obtained by using an appropriate device such as a shovel, Ponar sampler, or Ekman dredge. In turbid wadeable reaches and in nonwadeable reaches, the presence of boulders and bedrock cannot be determined by sampling. However, in turbid wadeable reaches, the presence of these substrate types can be determined by touch. In nonwadeable reaches where sampling devices cannot yield a substrate sample, acoustic recording of the stream bottom along the transect can detect boulders and bedrock.

20. **Embeddedness:** The attribute of embeddedness refers to the degree that the larger substrate particles (boulder, cobble, or gravel) are surrounded or covered by fine sediment (sand, or finer). As the percentage of embeddedness decreases, biotic productivity is thought to decrease (Platts and others, 1983). Embeddedness is measured by rating the percentage of the surface area of the larger-sized particles (by visual estimation) covered by fine sediment. The following rating is used for measuring how much of the surface area of the larger-sized particles is covered by fine sediment:

5 Less than 5 percent of surface area of gravel, cobble, and boulder particles covered by fine sediment
4 Five to 25 percent of surface area of gravel, cobble, and boulder particles covered by fine sediment
3 Twenty-six to 50 percent of surface area of gravel, cobble, and boulder particles covered by fine sediment
2 Fifty-one to 75 percent of surface area of gravel, cobble, and boulder particles covered by fine sediment
1 Over 75 percent of surface area of gravel, cobble, and boulder particles covered by fine sediment
0 No gravel, cobble, or boulder particles present

To determine how much of the surface area of large particles is covered in order to provide a rating, select five relatively large (gravel to boulder size) substrate particles at the three sampling points along the transect and examine them on the sides. Note the percentage of each particle's height that was buried in sediment by the extent of discoloration on the particle. The rating is based on the percentage of coverage of fine sediment as determined from the average percentage of coverage for the five particles. In turbid wadeable reaches and in nonwadeable reaches, a sample of the substrate is obtained using an appropriate device such as a shovel, Ponar sampler, or Ekman dredge.

21. **Canopy angle**: Canopy angle is formed by the angles from mid-point of the transect (midpoint of the channel width) to the visible horizon. From the midpoint of the transect, use a clinometer to determine the angle from the line of sight of the investigator to the tallest structure (for example, tree, shrub, building, or grass) on the left bank (in the general area of the transect). The same procedure is done at the right bank. The sum of these angles is computed and subtracted from 180 degrees. The result is the canopy angle (fig. 8).

22. **Aspect:** Record the aspect (0 to 360 degrees) of the downstream flow of the stream using a compass. At the midpoint of the transect, face downstream and point a compass parallel to streamflow. Record the compass reading.

23. **Habitat features:** Determine the type and amount (two-dimensional area) of all habitat features that are partly or wholly within a 2-m zone on either side of the transect. Habitat features consist of any mineral or organic matter that produces shelter for aquatic organisms to rest, hide, or feed, and include natural features of a stream such as large boulders, woody debris, undercut banks, and aquatic macrophyte beds, as well as artificial structures such as discarded tires, appliances, and parts of automobiles. Habitat features are not counted when they are in insufficient depth (usually less than 20 cm). For example, a woody debris accumulation in 5 cm of water is not considered to be a significant habitat feature. Habitat-feature type is noted using the following two-letter code:

Woody snags	WD
Overhanging vegetation (terrestrial)	OV
Undercut banks	UB
Boulders	BO
Sloughs	SL
Macrophytes-emergent	ME
(These are macrophytes that are rooted to the bottom but have parts that extend above the surface.)	
Macrophytes-submerged	MS
(These are macrophytes that grow under water and up to the water surface. Some submerged macrophytes may have seed heads that extend above the surface. However, unlike emergent macrophytes, submerged macrophytes are dependent upon the water column for support.)	
Macrophytes-floating	ML
(These are macrophytes that float in or on the water and obtain nutrients from the water rather than from the soil.)	
Rubbish (human produced)	RU
Other	OT
None	NO

In turbid wadeable reaches and in nonwadeable reaches, only those habitat features that are easily determined are recorded.

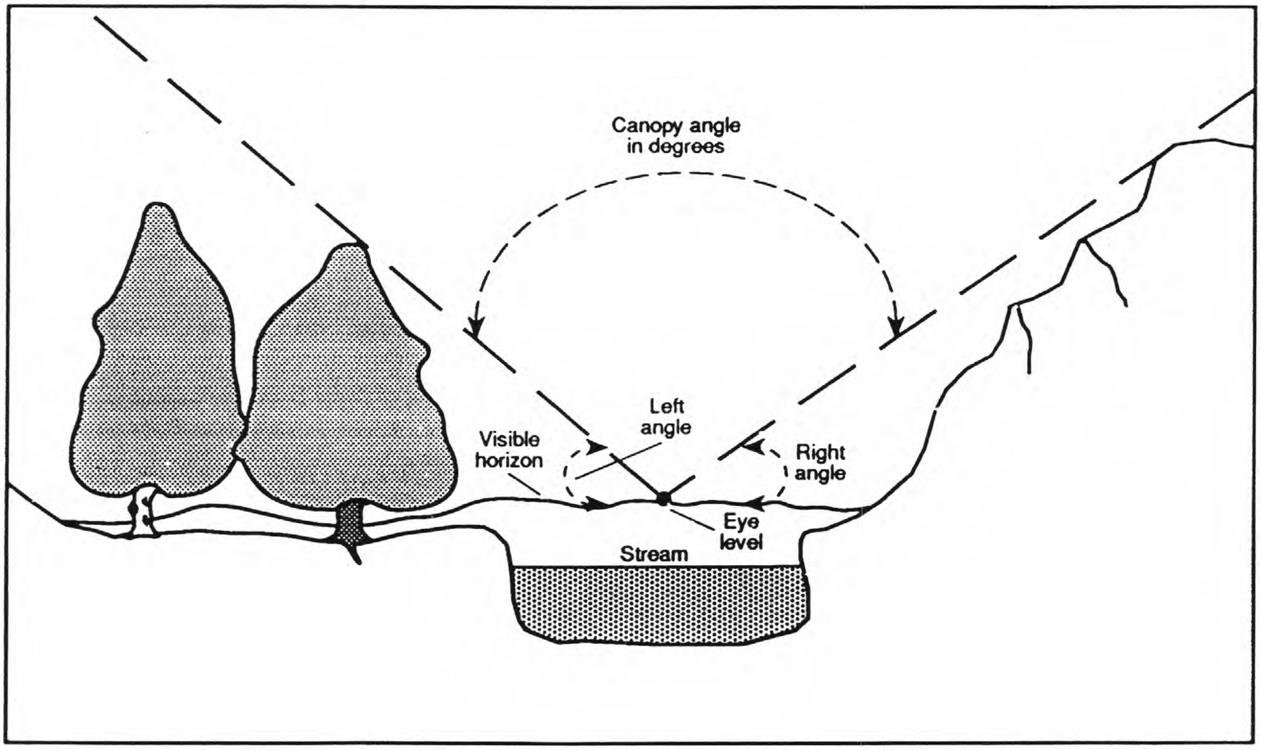

Figure 8.--Measurement of canopy angle in degrees, based on measurements of the angles formed from the line of sight to the visible horizon (modified from Platts and others, 1983).

24. **Bar/Shelf/Island:** If channel bars, shelves, or islands are present, measure width using a tape measure or rangefinder. Channel bars are the lowest prominent geomorphic feature higher than, but within, the channel bed (Hupp and Osterkamp, 1985). Channel bars are typically devoid of woody vegetation and consist of relatively coarse sand, gravel, and cobbles. Shelves are bank features extending nearly horizontally from the flood plain to the lower limit of persistent woody vegetation (Hupp and Osterkamp, 1985). Shelves are most common along relatively high-gradient streams. Determine the spatially dominant and subdominant substrates along the transect for the bars, shelves, and islands that occur, using the codes for determining bed substrate (number 19). Also estimate the percentage of coverage of woody and herbaceous vegetation for the entire bar/shelf/island. If bars, shelves, or islands are absent, record "0" for each width measurement.
25. **Bank angle**: A clinometer is used to measure the angle formed by the downward-sloping bank as it meets the stream bottom. The angle is determined directly from a clinometer placed on top of a surveyor's rod or meter stick that is aligned parallel to the bank along the transect. The clinometer reading is subtracted from 180 degrees to produce the bank angle. If the height and shape of the bank are such that more than one angle is produced, then an average of three readings is recorded. Both left bank and right bank (facing downstream) angles are recorded.
26. **Bank height**: Determine the left and right distance from the channel bed to the top of the bank. A surveyor's rod and hand level can be used if this distance can be measured directly. If the bank height cannot be measured directly, then it can be estimated. Note that the bottom of the bank is the deepest part of the channel. At large, nonwadeable reaches, topographic maps may be useful in determining bank height.
27. **Bank vegetation stability:** Bank vegetation stability is an assessment of the ability of bank vegetation to resist erosion (Platts and others, 1987). Bank vegetation stability is evaluated using a rating based on four classes that represent percent coverage of the bank surface. The rating includes only that part of the bank that is within 2 m of either side of the transect, to the top of the bank.

Rating	Description
4	Over 80 percent of the bank surface is covered by vegetation in vigorous condition or by boulders and cobble. If the bank is not covered by vegetation, it is protected by materials that do not allow bank erosion.
3	Fifty to 79 percent of the bank surface is covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are protected by materials that allow only minor erosion.
2	Twenty-five to 49 percent of the bank surface is covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are covered by materials that give limited protection.
1	Less than 25 percent of the bank surface is covered by vegetation or by gravel or larger material. That area not covered by vegetation provides little or no control over erosion, and the bank is usually eroded each year by high-water flows.

28. **Bank shape:** Record the shape of the left and right banks as:

Concave upward	CC
Linear	LN
Convex upward	CV

29. **Bank erosion:** Bank erosion is a function of factors such as riparian vegetation, permeability of the substrate, and tensile strength and cohesiveness of the soil. Consequently, bank erosion can influence the structure of the stream channel (Leopold and Wolman, 1957). The types of bank material movement, if present, are noted. These types include mass wasting (debris avalanche, rotational failure, and slab failure), and cut-bank scalloping (fig. 9). Indicate the presence of bank erosion for the left and right banks using the following code:

Debris avalanche	DA
Rotational failure	RF
Slab failure	SL
Cut-bank scalloping	CB
None	NO

30. **Bank substrate**: Determine the spatially dominant and subdominant substrate types (described above in number 19) that are present in an area of the bank that is within 2 m of either side of the transect, to the top of the bank. This procedure is done for the left and right banks.
31. **Bank woody vegetation:** The point-centered quarter method is used to evaluate density and dominance of bank woody vegetation (Mueller-Dombois and Ellenberg, 1974). Sampling points are established on both banks at the ends of the transect so as to include dominant bank woody vegetation. Four quarters are established at a sampling point at the intersection of two perpendicular lines, one of which is the transect line (fig. 10). Trees and shrubs are included in the analysis. Trees are distinguished from shrubs in that trees are at least 2 m high and have a diameter at breast height (dbh) of at least 3 cm. The sampled trees or shrubs are identified to species, and the distance from the sampling point to the nearest tree or shrub in each quarter is measured, along with its dbh (fig. 10). To record the species, use a four-letter code based on the first two letters of the scientific name for the genus and the first two letters of the species (for example, "BENI" is recorded for *Betula nigra*). Where bank woody vegetation is growing in narrow strips or rows, the two closest trees or shrubs on either side of the sampling point are measured. Where a single tree or shrub has developed many separate trunks, an average dbh for three trunks is recorded, along with the total number of trunks.
32. **Photodocumentation**: Stream conditions at three transects, including the transects at or near the reach boundaries and one transect representative of reach conditions, are photographed. Semipermanent markers are established at these locations to facilitate taking repeat photographs. Color photographs, preferably slides, are taken that include upstream, transect, and downstream views of the channel and should include a scale reference in the image. Use of the same type of film at all sites and at a site over time increases comparability of repeat photographs and reduces variability related to film development. The inclination and aspect of the camera lens are important and are measured with a compass. A level camera is preferred to an inclined one because inclination complicates the perspective of the view and makes accurate duplication of repeat photographs difficult. The aspect of the camera is noted by pointing a compass at the central aiming point in the view and recording the compass reading. Camera lens size, camera type, exposure, film type, and other appropriate documentation information for taking 35-mm color photographs are recorded on the reach form.

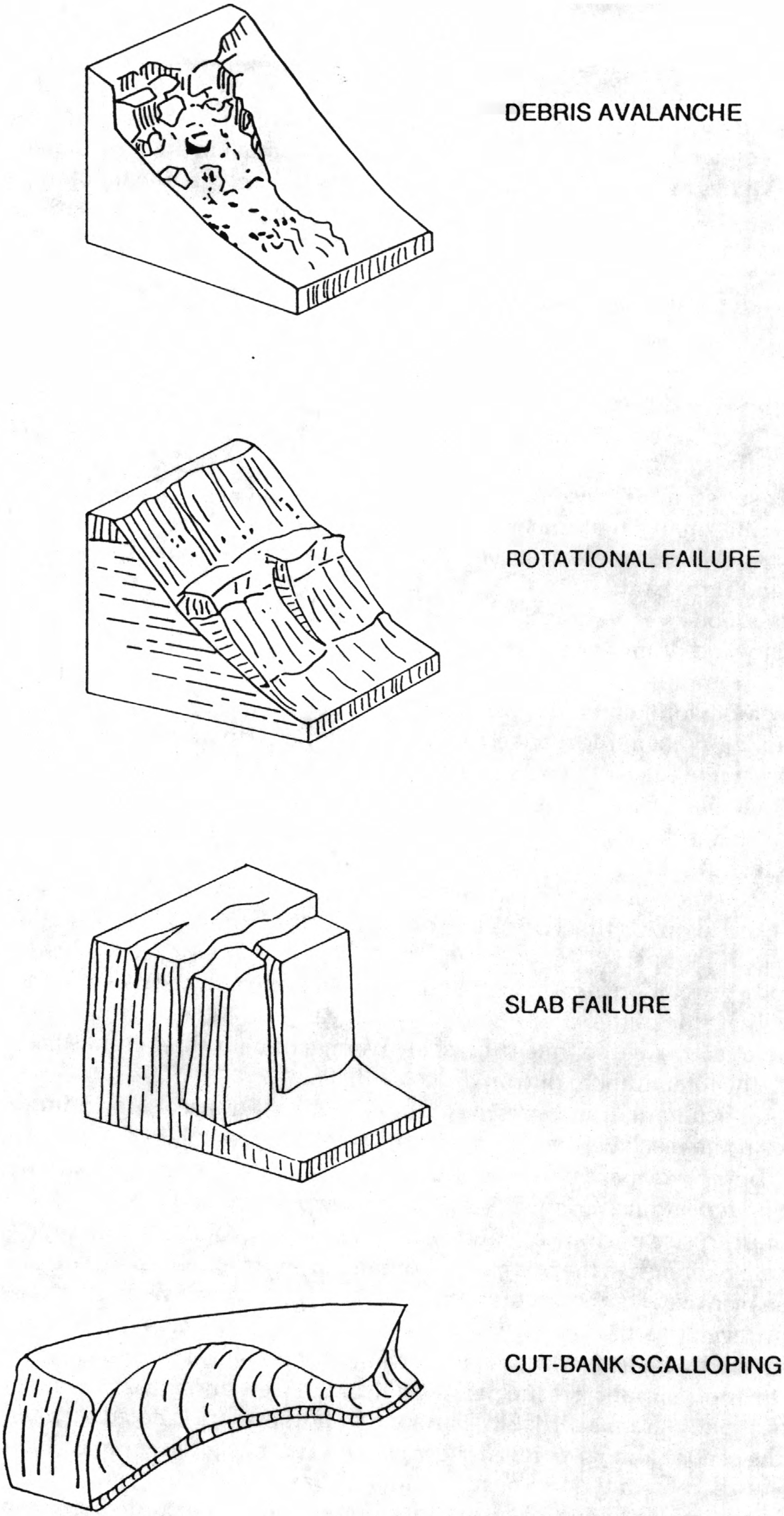

Figure 9.--Diagram of types of bank erosion (modified from Leopold and others, 1964).

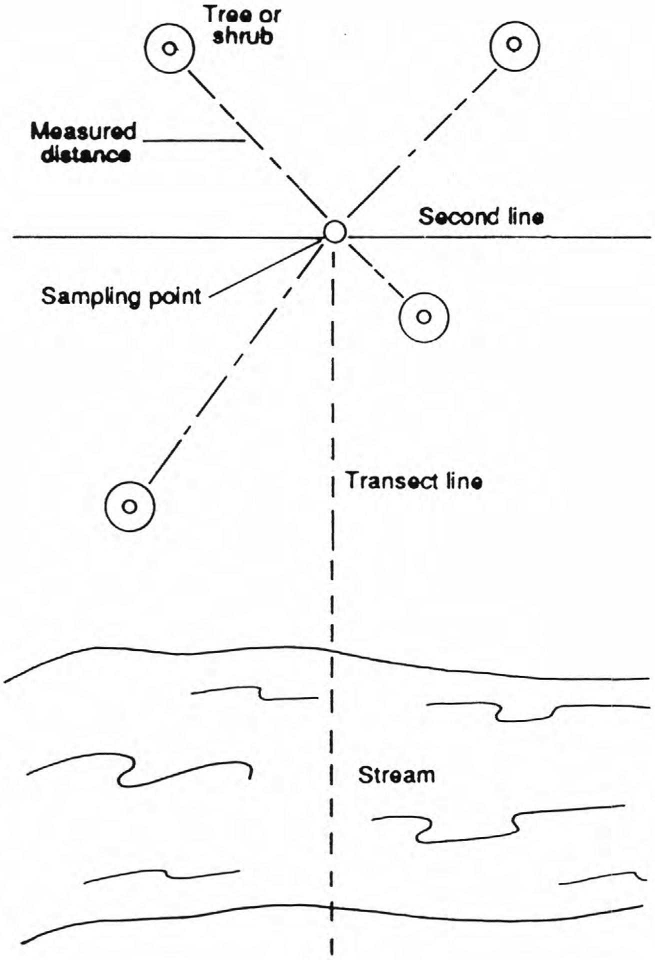

Figure 10.--Diagram showing point-centered quarter method used to evaluate density and dominance of bank woody vegetation.

Photographs are taken facing upstream, facing perpendicular to the channel, and facing downstream, from either the left or right banks.

33. **Diagrammatic mapping:** Draw a schematic or representative map of the reach. The map should include location of geomorphic channel units, habitat features, and bank and flood-plain land use. Indicate the stream type and general shape of the channel (fig. 11).

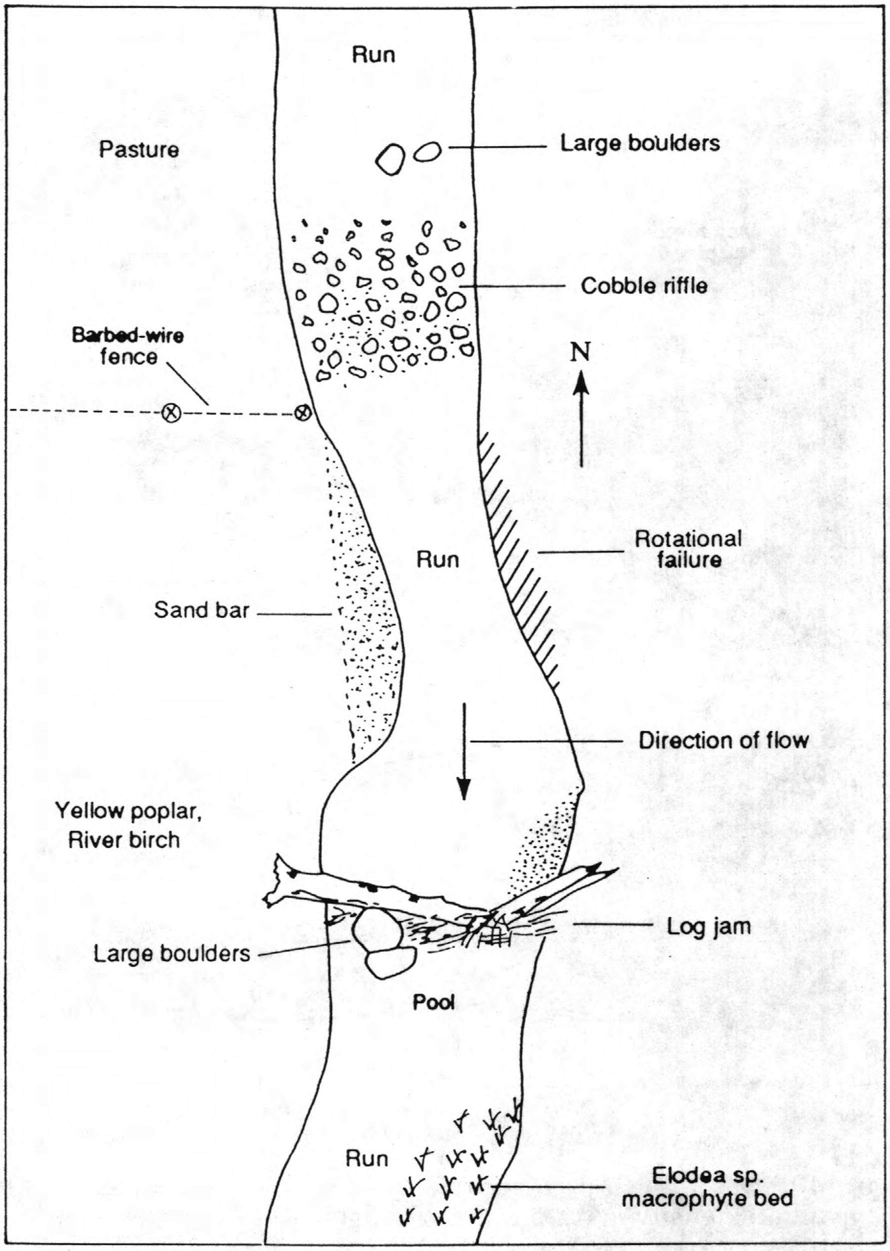

Figure 11.--Diagrammatic stream map indicating important stream characteristics such as land use, geomorphic channel units, habitat features, and bank conditions, to approximate scale.

34. **Aquatic and riparian vegetation species:** Record the species name of all common aquatic (submerged, emergent, and floating) and riparian (bank--herbaceous and woody, and flood plain--herbaceous and woody) species. Be sure to note the five most common for each category.
35. **Comments:** Include any pertinent ancillary information concerning habitat assessment at this reach.

Second-level reach characterization

A second-level reach characterization also is conducted at all fixed sites. This is a detailed reach characterization and is designed to provide additional quantitative data on geomorphic and hydraulic properties that are critical to the evaluation of temporal changes in the environmental setting and stream habitat. The second-level reach characterization consists of an analysis of hydraulic properties and channel geometry plus additional components tailored to enhance an understanding of temporal changes. The analysis of channel geometry consists of longitudinal profiles of the water surface, flood plain, and channel bed; cross-sectional surveys with levels; a map of the reach; and a quantitative analysis of bed and bank materials. Additional suggested components of the second-level reach characterization include permanent plot vegetation analysis and detailed quantitative mapping of habitat features throughout the reach. Study unit personnel are responsible for developing an appropriate form for recording the second-level reach characterization.

The longitudinal profile of the channel bed is conducted along the thalweg (or the approximate center of the channel if a thalweg is not apparent) on the basis of channel-bed elevations recorded at intervals equal to one channel width. This distance is generally sufficient to determine the mean slope of the reach (Emmett, 1975). The water-surface profile can be determined simultaneously by having the rodman record the water depth at each location and add this value to the channel-bed elevation. Profiles of the flood plain along both banks also are conducted. In nonwadeable reaches, longitudinal profiles of the channel bed are determined using a hydroacoustic depth meter, and water-surface elevations are determined along one bank or both banks.

At a minimum of three locations (both reach boundaries and a location that includes a prominent geomorphic feature), leveled cross-sectional surveys are conducted from left flood plain to right flood plain. Each cross-sectional survey is plotted, with elevation recorded on the ordinate axis and distance in meters along the abscissa. All surveys are conducted in relation to the reference location. A map of the reach is constructed, indicating the locations of the longitudinal profiles and the cross-sectional surveys. Cross-sectional surveys of nonwadeable reaches include as much information as can possibly be recorded.

In addition to an analysis of channel geometry, a quantitative analysis of channel substrate particle size is conducted. Pebble counts (Wolman, 1954) are conducted to determine bed material particle-size distribution in wadeable reaches. At the three surveyed cross sections, a pebble-count transect is established, and the pebble count is conducted in the following method:

(1) Begin the count at each transect at bankfull elevation on the left bank and proceed to bankfull elevation on the right bank.
(2) Proceed one step at a time, with each step constituting a sampling point.
(3) At each step, reach down to the tip of your boot and, with your finger extended, pick up the first pebble-size particle touched by the extended finger.
(4) To reduce sampling bias, look across and not down at the channel bottom when taking steps or retrieving bed material.
(5) As you retrieve each particle, measure the intermediate axis. If the intermediate axis cannot be determined easily, measure the long diameter and the short diameter of the particle, and determine the average of the two numbers.

Thus, the size distribution of particles is determined and expressed in percentage by number of particles. A count of 100 particles is recommended; however, to determine percentages of particle sizes, 50 or 25 particles can be measured. To obtain a quantitative determination of finer grained bed material, three samples of the bed material are collected along each transect and composited. In addition, samples of the bank substrate material can be collected from one bank or both banks. These samples are returned to the laboratory for sieve analysis.

Permanent plot vegetation analysis is also suggested as a component of the second-level reach characterization. To construct a permanent vegetation plot, select an area at the end of each of the surveyed cross sections. A 20- by 20-m plot is identified by using a tape measure to determine the appropriate distance and a compass to establish 90-degree angles at the corners of the plot. The corners are then marked with semipermanent boundary markers. The edge of the plot nearest the bank edge should be at least several meters from the bank. Sample the vegetation by determining the diameter and species of all trees and shrubs within the plot. Record only living trees and shrubs. If the riparian zone is narrow such that a 20- by 20-m plot cannot be established, then two or more smaller plots are established so that the total area sampled equals 400 m^2. Where herbaceous vegetation is clearly dominant, then a 10- by 10-m square plot is established. At herbaceous vegetation plots, the aerial coverage of up to five species is measured, and the percent coverage of these species within the plot is calculated.

Mapping of all geomorphic channel units and habitat features can also provide critical information needed to evaluate temporal trends in habitat. Though the diagrammatic stream map should indicate the presence of these units and features to approximate scale, the first-level reach characterization does not attempt to quantify the occurrence of all features throughout the reach. In the second-level reach characterization, the two-dimensional area of all significant geomorphic channel units and habitat features is determined.

Other instream and riparian features that can provide meaningful information on temporal changes in stream habitat should be considered as a part of the second-level reach characterization at all fixed sites. The procedures and techniques used in collecting any additional habitat data must be documented to facilitate future data collection.

Synoptic sites

Synoptic sites usually number more than 15 per study unit and are not sampled continuously over time. Also, synoptic sites are generally designed to address various specific questions. Therefore, the approach used to collect habitat data at synoptic sites must be (1) flexible to accommodate the variety of questions being addressed at a synoptic site, (2) relatively rapid to facilitate data collection at a large number of sites, yet (3) capable of providing an adequate description of stream habitat at one point in time.

Habitat variables evaluated at synoptic sites are locally and regionally important. Therefore, the reach characterization conducted at synoptic sites should be locally designed with consideration of regional issues. The reach characterization conducted at synoptic sites, at a minimum, should consist of a subset of the first-level reach characterization conducted at fixed sites. Consistent data collection based on the techniques and procedures defined for the first-level reach characterization allows for data evaluation that includes information from fixed and synoptic sites. The use of techniques or procedures other than those described for the first- level reach characterization limits the ability to conduct such analyses.

Microhabitat Characterization

Microhabitat consists of the localized set of conditions that describe where aquatic organisms live. Specifically, microhabitat is considered to be relatively homogeneous patches of such stream habitat features as macrophytes or woody debris, or a bed substrate type within a geomorphic channel unit. Studies have revealed that analyzing patterns in relations between aquatic organisms and habitat at the microhabitat scale can provide insight to patterns of relations between biota and habitat at larger scales (Hawkins, 1985; Biggs and others, 1990).

Collection of microhabitat data is essential for an understanding of the relations among benthic invertebrate and algal communities and physical, chemical, and biological factors. Invertebrate and algal samples are collected at specific locations within geomorphic channel units in a reach. Conversely, fish community samples are collected throughout the reach and are not associated with specific microhabitat data. Procedures for collecting microhabitat data are described in documents detailing the collection of invertebrate (Cuffney and others, 1993) and algal (Porter and others, 1993) samples, and are not within the scope of this report.

SUMMARY

The NAWQA Program is designed to assess the status of and trends in the Nation's water quality and to develop an understanding of the major factors that affect observed water-quality conditions and trends. Stream habitat is characterized as part of an integrated physical, chemical, and biological assessment of the Nation's water quality. The goal of stream habitat characterization as part of NAWQA is to relate habitat to other physical, chemical, and biological factors to describe water-quality conditions. To accomplish this goal, environmental settings are described at sites selected for water-quality assessment. In addition, spatial and temporal patterns in habitat are examined at local, regional, and national levels. Evaluating stream habitat as part of the NAWQA Program is based on a spatially hierarchical framework for habitat characterization that incorporates habitat data at basin, segment, reach, and microhabitat scales. This framework provides a basis for national consistency in collection techniques while allowing flexibility in habitat assessment within individual study units.

The GIS data bases are a primary component of basin characterization. Two levels of data-base coverage, national and local, are required for basin characterization to ensure the use of the most complete basin-level information at the greatest resolution for individual study units, as well as to allow comparisons of basin characterizations among study units. GIS data bases that are incorporated into basin characterization include data bases on land use, ecoregion, physiographic province, potential natural vegetation, soil type, and wetlands.

The stream segment is defined as that part of a stream bounded by tributary junctions or discontinuities, such as major waterfalls, landform features, significant changes in gradient, or point-source discharges. A segment should be a distinct stream unit that is relatively homogeneous with respect to physical, chemical, and biological properties. Data at the segment scale are collected using GIS data bases and(or) 7.5' maps. Segment characteristics include gradient, sinuosity, stream order, downstream link number, and the presence of water management features such as dams, canals, lakes, or point-source discharges.

The length of a segment often prohibits effective field collection of habitat data. Therefore, the stream reach is chosen as the sampling unit to collect data on habitat. The reach is defined on the basis of the type and distribution of geomorphic channel units (pools, riffles, and runs) that are present in a segment. If the stream is composed of only one geomorphic channel unit (for example, a run), the length of the sampling reach is 20 times the channel width. Regardless of the geomorphic channel units present or the channel width, minimum and maximum length criteria are used. Minimum reach lengths of 150 m in wadeable reaches and 500 m in nonwadeable reaches are recommended. In most wadeable reaches, a maximum reach length of 300 m is sufficient for adequately characterizing habitat and providing representative samples of biological communities. However, in relatively wide (greater than about 30 m) wadeable streams, a maximum reach length of 500 m should be considered. A maximum reach length criterion of 1,000 m should be considered for nonwadeable reaches.

The type of reach characterization conducted depends on the type of site--fixed or synoptic. At fixed sites, two levels of reach characterization are considered: a first-level reach characterization that provides for relatively rapid, consistent data collection within and among study units; and a second-level reach characterization that provides a balance between detailed descriptions of stream habitat and study unit flexibility in data-collection efforts.

The first-level reach characterization consists of field collection of instream and riparian habitat data based on six transects established perpendicular to streamflow. The second-level reach characterization consists of an analysis of channel geometry, plus additional quantitative evaluations of channel and riparian characteristics that are selected locally to enhance the understanding of temporal changes in the environmental setting and stream habitat at fixed sites.

At synoptic sites, the approach used to collect habitat data must be (1) flexible to accommodate the variety of questions being addressed at a synoptic site, (2) relatively rapid to facilitate data collection at a large number of sites, yet (3) capable of providing an adequate description of stream habitat at one point in time. The reach characterization conducted at synoptic sites, at a minimum, should consist of a subset of the first-level reach characterization conducted at fixed sites.

Microhabitat characterization is an evaluation of the local set of conditions that describe the location of benthic invertebrate and algal communities. Procedures for collecting microhabitat data are described in documents detailing the collection of invertebrate and algal samples, and are not within the scope of this report.

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