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In Cooperation with Greene County Soil and Water Conservation District and
New York City Department of Environmental Protection

Guidelines for Characterizing Fish Habitat in Wadeable Streams of the Catskill Mountain Region, New York

Open-File Report 02-484

U.S. Department of the Interior
U.S. Geological Survey

Cover photos: (background) Batavia Kill srudy reach before restoration
(foreground) Habitat survey at Warner Creek

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By Christiane I. Mulvihill, Barry P. Baldigo, Anne S. Gallagher, and Phillip Eskeli

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Guidelines for Characterizing Fish Habitat in Wadeable Streams of the Catskill Mountain Region, New York

By Christiane I. Mulvihill, Barry P. Baldigo, Anne S. Gallagher, and Phillip Eskeli[1]

ABSTRACT

Stream-channel stabilization projects are underway in selected streams of the Catskill Mountain region to decrease streambank erosion and the resulting sedimentation of downstream reservoirs that supply drinking water to New York City. This report describes how fish habitats are monitored to document the effects of stream restoration on habitat quality. Emphasis is on describing a habitat-sampling protocol that documents differences in the quality of fish habitats and indices of trout populations and fish-community health. Data-collection forms and an equipment list are included.

INTRODUCTION

Stream-channel erosion in the Catskill Mountains of southeastern New York (fig. 1) results in sedimentation of the downstream reservoirs that provide drinking water to New York City. This sedimentation increases the amount of water treatment required for public use and decreases the streams' ability to support fish communities, especially trout. One approach to slowing the rates of erosion and sedimentation is to stabilize the banks of selected stream reaches; this also is expected to improve the habitat and health of resident fish communities.

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Neither the relations between channel stability and fish habitat, nor the effects of streambank stabilization on fish habitat or fish-community health, have been well documented. The findings of several habitat investigations suggest, however, that the conditions typically found in unstable stream reaches are not conducive to healthy fish communities (Raleigh, 1982). The New York City Department of Environmental Protection (NYCDEP) has a stream-restoration program that entails improving stream-channel stability to decrease the amount of suspended sediment and restore fish habitat and fish-community health within restored reaches (Davis and Miller, 2002). In 2000, the U.S. Geological Survey (USGS), in cooperation with the NYCDEP, began a study to evaluate the effectiveness of NYCDEP stream-restoration projects through a monitoring program that compares selected indicators in three reaches of each stream studied—the restoration reach, an undisturbed control reach, and a stable reference reach that represents target post-restoration conditions (Davis and Miller, 2002). All three reaches are monitored concurrently, and the monitoring includes a geomorphic assessment, an inventory of fish populations, and documentation of the fish-habitat characteristics of each reach.

Objectives

The study will entail characterization of fish-habitat suitability in each stream for at least 1 year before channel stabilization, and for 3 or more years thereafter. Objectives of the USGS data-collection and habitat-assessment effort are to:

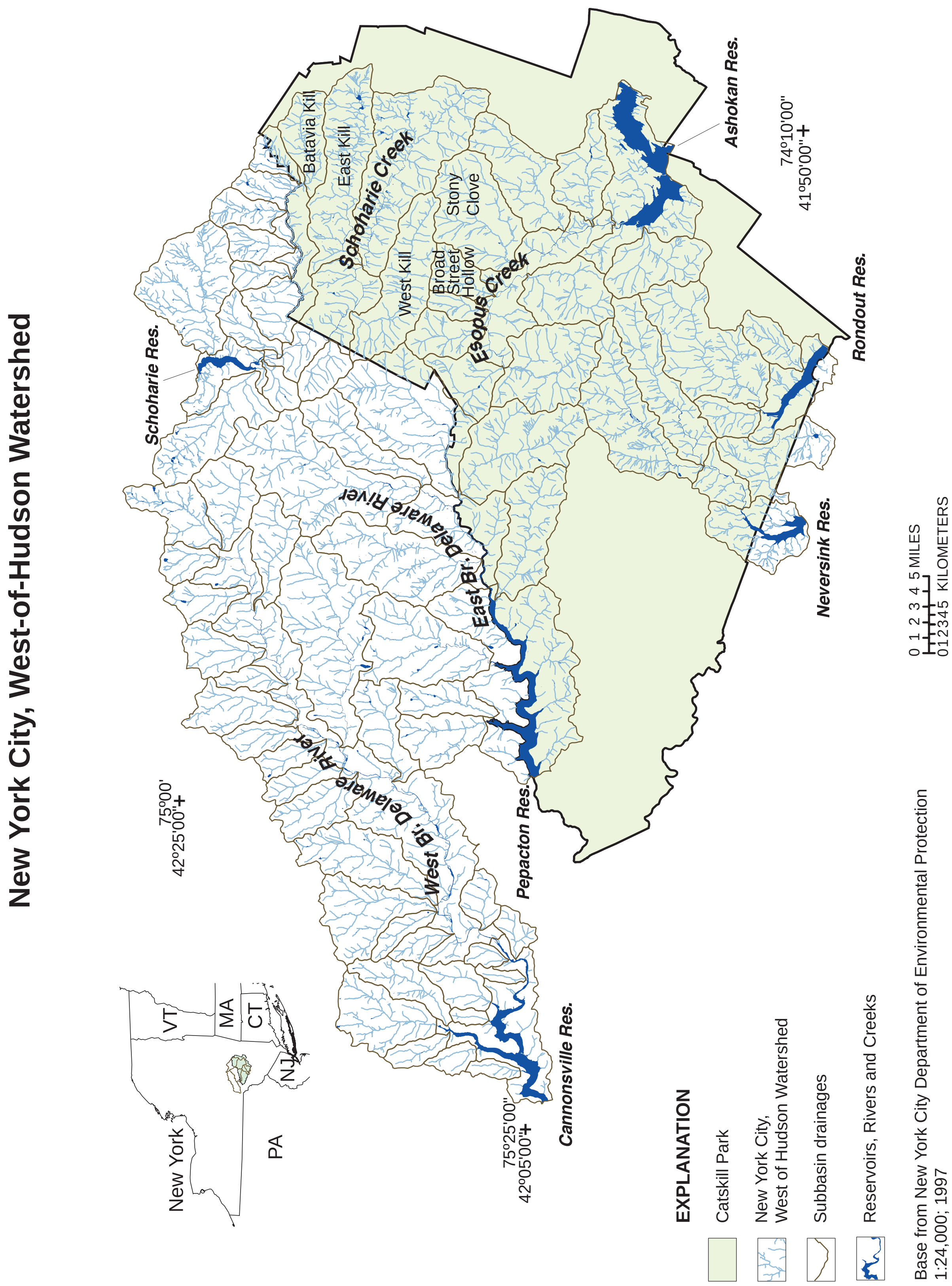

Figure 1. Location of Catskill Mountain region in southeastern New York, and of streams designated for bank-restoration projects.

1. Calculate the trout Habitat Suitability Index (HSI) score of each study reach before restoration to test the hypothesis that reaches with a high HSI score support more trout than those with a low HSI score.
2. Reevaluate the HSI scores of all restoration reaches 1 to 3 years after restoration to test the hypothesis that improved channel stability leads to an increase in the HSI score.
3. Document the extent to which increasing HSI scores can be used as a surrogate for improvements in water quality and channel stability that result from stream restoration.

No habitat-assessment protocols for characterizing stream habitats have been designed to address the effects of extensive channel stabilization on trout populations and fish communities; therefore, the USGS developed the habitat-assessment protocol presented herein specifically for this study.

Approach

The study is designed to provide the data needed to compare the habitat quality of the three types of reaches (restoration reach, undisturbed control reach, and stable reference reach) within every project stream. The undisturbed control reach in each stream will represent the original geomorphic, fish-community, and fish-habitat characteristics of the corresponding restoration reach before stabilization activities begin, and the stable reference reach will represent target conditions for these variables after restoration. The undisturbed control reach will provide a means to distinguish the changes in habitat characteristics that result from normal annual variations in precipitation, air temperature, and stream discharge from those that result from restoration. The geomorphic assessments and fish community inventories will be conducted under a separate program and are not addressed here.

Purpose and Scope

This report presents a protocol for (1) delineating the habitat-study reach within each restoration reach, control reach, and reference reach of each stream, and (2) assessing the variables that affect the quality of fish habitat in each reach. The required field forms and other field-data-handling and quality-assurance guidelines are given at the end of the report.

The protocol describes the step-by-step procedures for collecting data to be entered on the field forms. It closely follows the revised USGS National Water Quality Assessment Program (NAWQA) habitat-sampling methods (Fitzpatrick and others, 1998), with modifications to: (1) characterize stream features that affect trout populations and contribute to trout habitat-suitability indices (HSIs) (Raleigh, 1982; Raleigh and others, 1984; Raleigh and others, 1986), and (2) confine all measurements to predefined stream reaches that will be affected by restoration or that will serve as the undisturbed control or stable reference reaches. It also includes improved methods to characterize habitat features that affect trout species. Additional methods described in Simonson and others (1994b), Bain and Stevenson (1999), and Kaufmann and others (1999) are included where appropriate.

GUIDELINES FOR CHARACTERIZING FISH HABITAT IN WADEABLE STREAMS

This protocol was designed to evaluate specific habitat characteristics and is intended only for use under baseflow or near-baseflow conditions in wadeable trout streams. The procedures described herein are intended to ensure consistency, minimize observer bias, and maximize repeatability in the collection of qualitative and quantitative data on stream channels that provide fish habitat. The qualitative measures require minimal time but may incorporate observer bias and thus lack repeatability (Roper and Scarnecchia, 1995), whereas quantitative measures are more precise but require a greater expense and time commitment. The balance of quantitative and qualitative measures presented here is intended to provide optimal results.

The procedures described herein are primarily based on the USGS NAWQA habitat protocol (Fitzpatrick and others, 1998), which uses a modification of the spatially hierarchical approach proposed by Frissell and others (1986) for describing environmental settings and evaluating stream habitat. This protocol focuses on reach-scale characteristics because the planned channel-restoration activities pertain only to certain reaches. A reach is generally defined as a length of stream that encompasses at least one complete meander wavelength (Leopold and others, 1964). It is typically from 20 to 40 mean channel widths (MCWs) long and contains two or more complete sequences of geomorphic channel units (GCUs), a term used in habitat assessments to refer to flow pattern, channel shape, and scour pattern at a given location (Orth, 1983; Ohio Environmental Protection Agency, 1989). This protocol addresses only two GCUs—pools and riffles—as explained further on.

Types of Variables

The stream-reach variables addressed by the sampling protocol can be grouped into three categories:

1. those that are general to the reach, such as discharge, dissolved oxygen concentration (DO), pH, and water temperature;
2. those that are indicative of stream type, such as pool classification and percentage of reach occupied by each type of GCU; and
3. those that are specific to points in the reach as defined along a series of transects, such as amount of habitat cover, type of substrate, amount of shade, and condition of bank.

Types of data within each of these categories are described in the following paragraphs.

Variables that are General to the Reach

Discharge at each reach will be measured during habitat surveys by standard USGS methods (Rantz 1982).

DO measurements will be made with a field meter near each temperature logger and will be used to develop temperature-to-DO relations from which hourly annual DO records can be estimated.

pH samples will be collected at least quarterly and analyzed at the USGS Watersheds Laboratory in Troy, NY.

Water temperature will be recorded year-round in hourly increments at each reach by a temperature logger.

Variables that are Indicative of Stream Type

These habitat variables will be assessed during the pool-class rating procedure described in the next section. The variables addressed in this study are listed in table 1; the general sampling sequence is summarized in table 2.

Among these variables are the GCUs. This protocol designates only two GCUs—pools and riffles. Two other commonly used GCUs—runs and glides—are treated as pools or riffles in this study. All four are described below.

Pools are areas of the channel with decreased velocity, little surface turbulence, and deeper water than surrounding areas (Fitzpatrick and others, 1998). Pools can form downstream from depositional bars, in backwater areas around boulders or woody debris, or in trenches or chutes. This protocol does not distinguish among the several types of pools but calls

Table 1. Variables that constitute the brook trout habitat-suitability index

[Modified from Raleigh, 1982. DO, dissolved oxygen concentration; mm, millimeters; <, less than]

Variable	Description
1	Mean daily maximum water temperature during low summer flows
2	Mean daily maximum water temperature during fish-embryo-development period
3	Mean daily minimum DO during low summer flows
4	Mean thalweg depth at low summer flows
5	Mean water velocity during embryo-development period
6	Percent in-stream cover during summer low flows
7	Mean size of riffle substrate material with intermediate diameter from 2 to 80 mm
8	Percentage of substrate in reach with diameter of 100 to 400 mm
9	Dominant substrate type in riffles
10	Percentage of reach occupied by pools at low summer flows
11	Percentage of bank that is vegetated by grass, shrub, or trees
12	Percentage of bank with either vegetation or rocky ground cover
13	Annual minimum water pH
14	Percentage of average annual flow represented by mean base flow
15	Pool class rating during low fall flows
16	Percentage of riffles and runs represented by fine material (diameter < 0.063 mm)
17	Percent of stream shaded from 1000 - 1400 hours

Table 2. Habitat-sampling tasks for each study reach
[GCU, geomorphic channel unit].

Step	Definition
1	Locate reach reference features (bridge, gage, and etc.) and note reach conditions (Form 1, item 3 and 11)
2	Locate upper end of reach at GCU transition
3	Measure reach length (Form 1, item 8)
4	Calculate and mark locations of 11 transects (Form 1, items 6-10)
5	Identify class of each pool and calculate total length of each pool class in the reach (Form 2)
6	Sketch and photo-document reach (Form 2)
7	Measure stream discharge or stage at discharge-gaging station
8	Set up tape at first cross section (T1) and mark sampling points (Form 3, items 9-15)
9	Record required physical and water-quality variables at each transect point (Form 3, items 16-24)
10	Measure channel-center characteristics (Form 3, items 25-27)
11	Measure bank characteristics (Form 3, items 28-34)
12	Move downstream to next transect and repeat steps 8-11

for pool-class ratings, explained further on and defined by Raleigh (1982) and Raleigh and others (1984).

Riffles are relatively shallow channel areas where water flows swiftly over completely or partly submerged obstructions to produce surface turbulence (Fitzpatrick and others, 1998). Riffles typically have a coarser substrate than pools and runs and generally occur in straight or constricted reaches.

Runs (not used in this study) are areas with moderate depth and little or no surface turbulence (Fitzpatrick and others, 1998). Substrates in runs generally range from cobble to sand, and velocities can be high or low, but key features are a well-defined thalweg and little apparent surface turbulence. Runs typically are found in the transition zone between riffles and pools and in low-gradient reaches without flow obstructions. In this assessment, all slow-moving runs are considered pools, and all fast-moving runs are classified as riffles, to avoid subjectivity in the field identification of runs (Platts and others, 1983).

Glides (not used in this study). This term has often been applied to runs (Bisson and others, 1982) at the downstream end of a pool where the bed slope becomes positive, water depth decreases, and velocity increases. Glides are difficult to identify without full thalweg profiles and, thus, are grouped with pools in this habitat-assessment protocol.

Variables that are Specific to Points in the Reach

These variables are assessed from point measurements along a series of transects and include items in several categories, including water properties, substrate composition, and bank characteristics. The variables to be measured in these categories are listed as items 16-24 on Form 3.

Field Procedures

This section describes in detail the procedures used to delineate reaches, establish transects and sampling points, and collect the data needed for the HSI.

Establishing Reach Boundaries

A habitat-study reach will be established within each restoration reach, control reach, and stable reference reach of every site selected by the NYCDEP for study. All habitat-study reaches must include the entire fish-sampling reach. Boundaries for each habitat-study reach should be sufficiently far (at least 10 times the MCW) from bridges, dams, waterfalls, and major tributaries to avoid interference. If this is impossible, the condition should be noted, and the relations of the reach to the structure(s) of concern should be sketched on the map on Form 2. General criteria for habitat-study reaches are summarized in table 3.

Permission must be obtained from the local landowner before semipermanent boundary markers are established or habitat data are collected**.** Habitat data should be collected at base flow to standardize and minimize the habitat size and to minimize the fluctuations in habitat variables associated with changing discharge.

Table 3. General criteria for habitat-study reaches

	Reach Requirements
1	Reach is identified as a restoration reach, control reach (without treatment), or stable reference reach
2	Reach lies fully within a predetermined geomorphology-survey study reach (optional)
3	Reach includes the entire reach used for fish-community inventories
4	Reach does not contain major structures or tributaries

Measuring Water Temperature, Dissolved Oxygen Concentration, and pH

Four habitat-suitability variables (1, 2, 3, and 13 in table 1) are associated with water temperature, DO, and pH, and are measured separately from the habitat surveys. Continuous (hourly) temperature loggers are attached to bedrock, concrete, or a boulder at a deep point in the streambed. Temperature data are downloaded at least four times per year. Dissolved oxygen measurements are taken during site visits, at which time water samples are collected for pH measurement. Continuous DO records are estimated from the continuous temperature record and the relation between measured temperatures and DO at each reach. Sample pH is measured at the USGS laboratory in Troy, N.Y., in accordance with standard methods (Lincoln 2002).

General Reach Characterization

Once a reach has been selected, the channel is examined along its length and the locations of 11 transects are established and marked with wire flags. These tasks are summarized in table 4 and explained in the paragraphs that follow.

1. Inspect Reach and Note Site Conditions (Form 1, item 3):

During the first walk-through, indicate the general condition of the reach (evidence of recent floods or storms; manmade alterations; point sources for sediment, contaminants, nutrients; signs of beaver activity; or other features that might affect the reach).

2. Identify Reference Points, Benchmarks, and Locations of Staff or Crest-Stage Gages (Form 1, item 11)

Identify and note any reference points, benchmarks, or staff or crest-stage gages, and install and describe any new reference points if needed. Reference points should be selected at or on a bridge abutment, large boulder, or tree well above bankfull stage.

3. Define Reach Boundaries (Form 1, item 12)

Reach length depends on the stream-channel dimensions and features. If two clearly defined GCU sequences are present, always place the first transect (T1) at a GCU transition upstream from the upper end of the fish-sampling reach. Extend a measuring tape along the REW (right edge of water when looking downstream) for a distance of two complete GCU sequences, or to the first GCU transition below the lower end of the fish-sampling reach, whichever is longer. If only one GCU is present, the length of the habitat assessment reach should be 20 times the MCW (Meador and others, 1993). A length of 450 to 900 ft is sufficient for an adequate habitat characterization in most wadeable streams; however, no habitat-survey reach should be less than 300 ft long or more than 1500 ft long (Meador and others, 1993).

Geomorphologic characteristics (such as degree of incision or slope) and stability can occasionally differ upstream or downstream from the fish-sampling reach; if this is observed, do not extend the habitat-assessment reach into an area atypical of the fish-sampling reach, even if the requirement for minimum reach length must be violated.

4. Establish Transect Locations (Form 1, items 6-10)

Establish 11 transects within each habitat-study reach to collect information on channel,

Table 4. Steps for transect surveys in habitat-study reaches.

Step	Task
1	Position the transect tape
2	Record the type of GCU intersected by the tape
3	Establish sampling points
4	Measure water depth, velocity, and temperature
5	Characterize streambed substrate
6	Describe habitat cover
7	Measure channel-center characteristics
8	Measure bank height and bank angle
9	Measure riparian bank characteristics

bank, and riparian characteristics (Fitzpatrick and others, 1998). Place the transects equidistantly to provide statistical representation of habitat characteristics of the entire reach and eliminate observer bias (Fitzpatrick and others, 1998). Eleven has been found to be the optimum number of transects needed to maintain repeatability and accuracy because it provides about 80-percent accuracy for estimated mean values of habitat characteristics (Simonson and others, 1994b) without excessive time commitment (Kaufmann and Robison, 1994). The locations of the 11 transects are determined by dividing the total reach length by 10 to obtain the distance between transects. Lay as many 300-ft-long tapes as needed in sequence along the REW from transect T1(always at 0 ft) to the lower end of the reach (transect T11), and place a flag along the REW at each transect interval. Label the transect flags T1 through T11.

5. Mark Reach Boundaries with Semi-permanent Markers (Form 1, item 12)

Place upstream and downstream reach-boundary markers as close to T1 and T11 as possible. Each marker consists of a capped rebar driven solidly into the ground, with less than 6 inches extending out of the ground and spray-painted with brightly colored waterproof paint. Use a GPS receiver to obtain the latitude and longitude of each marker and record this information on Form 1. Also note the marker locations relative to the channel and reference markers on the site map (Form 2).

6. Measure Length of Each Pool and Assign Pool Classes and Reach Ratings (Form 2)

Assign these tasks to one field team member to ensure consistency in identifying GCU transitions, pool classes, and reach ratings. A new GCU is assigned when a pool or riffle is at least the length of the MCW (Bisson and Montgomery, 1996). The three pool classes used in this study are summarized below and described in detail in Raleigh (1982). Pools that contain areas representative of more than one class are divided according to the classes. Record the total length of each pool and its class on Form 2.

First-class pools are large enough and deep enough to provide a low-velocity resting area for many adult trout.

- More than 30 percent of the bottom is obscured by deep water and surface turbulence, and by structures such as logs, debris, boulders, overhanging bank, or vegetation that provide shelter in which fish can rest, hide, or feed.
- The greatest pool depth exceeds 4 ft in streams less than 13 ft wide and exceeds 6 ft in streams more than 13 ft wide.

Second-class pools are of intermediate size and depth and provide a low-velocity resting area for a few adult trout.

- From 5 to 30 percent of the bottom is obscured by deep water, surface turbulence, and structures.
- Large eddies behind boulders and moderately deep areas under banks and vegetation are typical.

Third-class pools are small and shallow and provide a low-velocity resting area for one or two adult trout.

- Less than 5 percent of the bottom is obscured by deep water, surface turbulence, or structures.
- Wide, shallow stream areas and small eddies behind boulders are typical.
- All pools that have no cover at all are considered third class.

Reach rating is a designation of A, B, or C to indicate the pool-class distribution throughout the entire reach.

A. More than 30 percent of the reach consists of first-class pools

B. More than 10 percent, but less than 30 percent, of the reach consists of first-class pools, OR more than 50 percent of the reach consists of second-class pools

C. Less than 10 percent of reach consists of first-class pools, AND less than 50 percent of the reach consists of second-class pools.

This rating does not need to be determined in the field.

7. Sketch and Photograph the Reach (Form 2)

Sketch a map of the study reach on Form 2, and then photograph the reach, giving special attention to eroding banks, bars, undercuts, and other features that could affect habitat suitability. Also record on Form 2 the number of each photograph (so it can be identified later) and a brief description. The map of the reach should indicate the approximate length and type of each GCU and the locations of major habitat features, reach boundaries, reference points, transect placements, boundary markers, flood plains, terraces, bars, islands, shelves, and significant large woody debris.

8. Measure Stream Discharge

If a gaging station is near the study reach, record the gage height to estimate discharge from the most recent rating table. If no active USGS gaging station is nearby, measure the stream discharge in accordance with the procedures described in Rantz (1982). Record discharge-measurement notes on a standard USGS Form 9-275-H (a comparable field form is acceptable) or enter the information into an Aquacalc datalogger. A discharge measurement can be done before or after transect sampling, but must be performed before the conclusion of work at the site.

Transect Surveys

Data on channel, bank, and riparian characteristics are collected along each of the 11 transects and recorded on Form 3 using one form for each transect. This information includes data pertaining to channel dimensions, bank features, water depth and velocity, type of substrate material, habitat features, and types of riparian vegetation.

Transects are oriented perpendicular to flow direction. Data are collected at nine evenly spaced points within the wetted channel of each transect to ensure that the amount of data collected is sufficient to encompass the variability of the assessed features. The steps for each transect measurement are summarized in table 4 and outlined in the paragraphs that follow; additional information is given in Fitzpatrick and others (1998).

1. Position the Transect Tape

At the first transect station (T1), extend a measuring tape perpendicular to the direction of flow from the right bank to the left bank, such that the ends pass over the REW, LEW, and transect flag. Secure the ends of the tape with temporary bank pins. The tape must be taut.

2. Record the Type of GCU (Form 3, item 8)

Record the GCU type (riffle or pool) intercepted by most of the tape.

3. Establish Sampling Points (Form 3, items 9-15)

Calculate the wetted channel width (WCW) by subtracting the REW from the LEW (items 9 and 10). Begin and end at the point nearest each shore where any protruding material is not completely surrounded by water, and water sits in pockets (Platts and others, 1983). If no channel features (bars, boulders, islands, or other obstructions) that protrude above the water surface and represent at least 10 percent of the total WCW are present, divide the WCW by 8 to obtain the sampling point interval (item 13) for sampling points P1 through P9. P1 is at the REW, P9 is at the LEW, and P2 through P8 are spaced at equal intervals along the tape between these two points. For example, a stream with a 24-ft WCW would have sampling points at 3-ft intervals, with P1 and P9 at the two edges, and the seven fully wetted sampling points (P2 through P8) would be 3, 6, 9, 12, 15, 18, and 21 ft from the REW, respectively. Sampling-point intervals are rounded to the nearest 0.1 ft.

If one or more channel features are present, account for each one in the table for item 11 as in the following example: suppose this 24 ft transect contained a 3-ft-wide boulder between P2 and P3. The WCW would now be 21 ft, and the sampling-point interval would be 21 ft divided by 8, or 2.6 ft. The sampling-point locations would be adjusted such that none would be on the boulder. The first two sampling points (P1 and P2) would be 0 and 2.6 ft from the REW, and P3 would be equal to the location of the left edge of the boulder (6 ft from the REW) plus the sampling interval (2.6 ft) minus the distance from P2 to the right edge of the boulder (0.4 ft). Thus, P3 would be 8.2 ft from the REW, and the remaining sampling points would be 10.8 ft, 13.4 ft, 16 ft, 18.6 ft, 21.2 ft, and 24-ft from the REW. The distance between the last two points (P8 and P9) may be slightly more or slightly less than the sampling interval as a result of small rounding errors. Record the 9 sampling-point distances in item 15 on Form 3.

4. Measure Temperature, Water Depth, and Velocity (Form 3, items 16-20)

Measure water temperature with a field meter on the streambed at all sampling points on each transect (item 16). Use a wading rod to measure the total water depth to the nearest 0.02 ft at P2 through P8 (item 17).

To measure velocity, count the number of revolutions a pygmy meter makes (item 18) in 20 seconds or more (item 19) and calculate velocity (item 20) from the formula:

V = 0.9604 x (number of revolutions/time in seconds) + 0.0312

If the water is too shallow to obtain a reading from the temperature or velocity meter, or if the sampling point overlies an obstruction (rock, log, etc.), note this as “TS” (too shallow to measure) for items 16 and 18-20 on Form 3. When excessive amounts of aquatic vegetation interfere with the rotation of the pygmy meter cups, note this as “TW” (too weedy to measure) for items 18-20 on Form 3. Record the station distance (item 15) and depth of the thalweg[2] (item 17) on Form 3 for each transect.

5. Characterize Streambed Substrate (Form 3, items 21-23)

Assess the particle-size distribution, degree of embeddedness, and dominant substrate material within a 2-ft^2 PVC frame positioned on the streambed at each sampling point. Note that if the stream is less than 16-ft wide, each framed area will overlap the adjacent ones. Evaluate the particle-size distribution by selecting two particles at random from inside the frame and measure their intermediate axes (item 21). Look away from, not down at, the channel bottom when retrieving bed material to minimize sampling bias. A total of 198 particles will be measured in each reach (2 particles at 9 sampling points per transect, 11 transects per reach). Later, calculate the particle-size distribution for each substrate category as a percentage of the total by dividing the total number of particles collected in each category by 198, then multiplying by 100.

Embeddedness is defined as the extent to which cobbles or larger particles are surrounded or covered by small gravel or smaller particles (< 16 mm) (Platts and others, 1983). Estimate the embeddedness to the nearest 10 percent for one randomly chosen cobble or larger particle at each sampling point and record this value on Form 3 (item 22).

Visually estimate the dominant particle size at each sampling point as the particle-size class that covers the greatest surface area within the PVC frame, and record this information on Form 3 (item 23). A list of the 10 substrate categories (based on Wolman, 1954) is included as footnote c on Form 3.

[2] The thalweg is the part of the channel with the largest amount of flow; it is usually, but not always, the deepest point.

6. Describe Habitat Cover (Form 3, item 24)

Habitat cover includes any mineral or organic matter that provides shelter in which fish can rest, hide, or feed. Natural habitat-cover features include deep pools, large boulders, natural debris piles, undercut banks, aquatic macrophyte beds, and overhanging vegetation; other features may consist of discarded materials such as tires, appliances, or automobile parts. Ten habitat-cover categories are listed as footnote d on Form 3.

Make all habitat-cover measurements inside the 2-ft^2 PVC frame used to characterize streambed substrate. Document only those features that are large enough to shelter at least one 10-inch trout. More than one type of cover may be present at a sampling point, but do not count a specific feature (such as a large boulder that falls within two sample areas) more than once. Later, calculate the abundance of each type of habitat cover within the entire reach as a percentage of total cover by dividing the number of times a specific type of cover is cited in the reach (all transects combined) by the total number of habitat-cover observations made, then multiplying by 100.

7. Measure Center-Channel Characteristics (Form 3, items 25-27)

Characteristics at the center of the channel—the aspect (azimuth) of flow, left and right canopy angles, and the percent shade between 1000 and 1400 hours—are measured or estimated and recorded on Form 3.

Channel aspect (Form 3, item 25) is measured with a compass at the center of each transect (looking downstream) to the nearest degree azimuth from magnetic north.

Left and right canopy angles (Form 3, item 26) are measured from the center of each transect and used to calculate open-canopy angle. Sight the tallest vegetation on each bank along the transect with a clinometer and record the angle with respect to horizontal. Canopies directly overhead have an angle of 90˚. If the canopy from one bank extends beyond the center of the transect, estimate the number of degrees past 90 to which the canopy extends, and add this number to 90 to obtain the canopy angle relative to the bank of interest. The angles for complete canopy closures will be recorded as 90º for both banks.

Percent shade (Form 3, item 27) is estimated by looking along the transect tape and visually estimating the percentage of the transect that would be shaded between 1000 and 1400 hours.

8. Characterize Bank and Riparian Conditions (Form 3, items 28-34)

Bank and riparian-vegetation characteristics that might affect channel stability, water temperature, or the inputs of allochthonous (externally derived) material are measured at both ends of every transect. These characteristics include bank height and bank angle, dominant and subdominant bank material, type of bank vegetation cover, bank stability, amount of rooted vegetation and stable (rocky) ground cover, and degree of riparian canopy closure.

Visually evaluate bank variables along a 2-ft-wide corridor that starts at the left or right edge of water and extends shoreward to the highest point on the bank that shows evidence of being affected by annual flows.

Bank-angle and bank-height measures are relative to the bottom of the active channel. The active channel can be difficult to identify where little deposition or erosion is occurring. For the purposes of this study, the bottom of the active channel is defined as the lowest point in the nonvegetated part of the streambed where the cross-sectional slope first begins to deviate from horizontal. Where the bank extends below the water surface and is almost vertical or is undercut, the bottom of the active channel will be the same as the edge of water at base flow. Specific guidelines for each characteristic follow.

Bank height (Form 3, item 28) is measured from the bottom of the active channel to the top of the bank. For the purposes of this study, the top of the bank is defined as the first point above the bottom of the active channel at which the bank slope shows a significant decrease in steepness. Bank height may approach bankfull stage in unincised channels but can be much greater in incised channels or at actively eroding terraces. A standard survey rod is used to make bank height measures.

Bank angle (Form 3, item 29) is measured as the deviation from horizontal (zero degrees is facing shoreward along the line of the transect) for a line between the bottom of the active channel and the top of the bank. If the bank is undercut and slopes streamward, the angle is added to 90 degrees to obtain the actual angle. Measurements are made by positioning a standard survey rod with one end at the bottom of the active channel and the other end at the top of the bank and measuring the resulting angle with a clinometer.

Bank material (Form 3, item 30). The dominant and subdominant substrate at each bank is visually estimated by the procedure described in step 5 for characterizing the streambed substrate.

Bank vegetation cover (Form 3, item 31). The four types of bank vegetation considered are bare ground, grass, shrubs, and trees. The percentage of each type of vegetation covering the bank is visually estimated so that the sum of all four estimates is 100 percent.

Bank stability (Form 3, item 32). Several variables are normally used to derive the index of bank stability, which is required input for trout habitat-suitability models. A visual estimate of bank stability will serve as a temporary input value for HSI models until additional data from the NYCDEP fluvial geomorphology surveys becomes available. Bank stability will be assigned a score of 1 (0-24% stable), 2 (25-49% stable), 3 (50-74% stable), or 4 (75-100% stable), depending on bank height, substrate, angle, and vegetation type and density (see footnote e on Form 3).

*Average percent rooted vegetation and stable cover (Form 3, item 33)***.** This variable is another surrogate for bank stability and is estimated as the percentage of the bank that is lined or permeated by roots and (or) covered by large cobble, boulder, or bedrock substrate. Roots from trees and shrubs outside the 2-ft-wide observation corridor are included. This estimate should be comparable to bank-stability values, although slight differences are likely because bank stability considers bank height (item 28) and bank angle (item 29), whereas this variable does not. Percent rooted vegetation and stable cover will be assigned a score of 1 (0-24%), 2 (25-49%), 3 (50-74%), or 4 (75-100%) depending on how much stable cover is present (see footnote e on Form 3).

Riparian canopy closure (Form 3, item 34). This variable is measured with a concave spherical densiometer through techniques outlined in Platts and others (1987). The densiometer is modified by applying tape to the mirrored surface to form a “V” such that the mirror reflects only 17 of the possible 37 line intersections. At both ends of each transect, hold the densiometer level, 12 to 15 inches streamward and 12 to 15 inches above the water and facing shoreward. This low position encompasses vegetation directly over the banks as well as any low overhead vegetation (Platts and others, 1987). Use the same relative position for all densiometer measurements to ensure consistency and repeatability of measurements. Count the number of line intersections covered by vegetation for each canopy-closure measurement. Convert the readings to percentage of canopy closure for the reach by summing the readings from all transects, dividing by 374 (2 readings, 17 possible points each, 11 transects), and multiplying by 100.

QUALITY ASSURANCE AND QUALITY CONTROL

Quality-assurance and quality-control procedures focus on training, making duplicate measurements, and having completed field forms inspected by the designated field-team leader as described in Davis and Miller (2002). All field personnel will participate in training session(s) designed to ensure that team members collect data in a uniform fashion. Emphasis will be placed on minimizing bias in subjective estimates such as visual stability, percent shade, and amount of vegetative bank cover. Training coordinators will instruct field personnel in the techniques required for accurate field measurements and visual estimates. All members will practice these techniques using established standards and reference photos (if available). Accuracy of measurements will be assessed by resampling one randomly chosen transect at each reach. Differences in duplicate measures of reach variables will be assessed with initial acceptable control limits of ± 10 percent for quantified variables and ± 20 percent for visually estimated variables.

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Field Forms

1. General reach characterization
2. Pool class rating, site map, and photo log
3. Transect and point characterization

FORM 1. GENERAL REACH CHARACTERIZATION

1. Reach name:____
2. Reach type (circle one): control reference treatment repeat other ______________
3. General condition of reach (evidence of recent floods, manmade alterations, beaver activity, garbage etc.)

____

____

____

4. Date: _____ - ______ - ______ (mm-dd-yy)
5. Team member/task: ____

____

Reach Layout

6. Distance from top of reach through two complete GCUs: __________ ft
7. Mean wetted channel width (WCW) from table below: _______ft

:

Longitudinal station	GCU (circle one)	WCW
	pool riffle	
	pool riffle	
	pool riffle	
	pool riffle	
	pool riffle	

8. Length of reach along REW: _____________ ft (minimum reach length = MCW x 20)
9. Distance between transects: _____________ ft (line 8 ÷ 10)
10. Transect stations (ft):

__0__ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

11. Description of reference point(s):____

____

____

12. Description and location of boundary markers:

TOR boundary/marker: ____

BOR boundary/marker: ____

Habitat-sampling conditions and miscellaneous notes _______________________________

____

____

____

____

____

____

____

Abbreviations:

GCU, geomorphic channel unit
REW, right edge of water
TOR, top of reach
WCW, wetted channel width
MCW, mean channel width
BOR, bottom of reach

FORM 2. POOL CLASS RATING, SITE MAP, AND PHOTO LOG

Reach Name ______________________________ Date ______________

Team member/task: ____

Pool-Class Rating

Longitudinal station distance		Pool-class distances		
From	To	1st	2nd	3rd
Class distance				
Percent of reach*				
Pool class rating =				
Reach length =				

* Percent of reach = (pool-class distance/reach length) x 100

Site Map

Photo Log

No. on map	Description

FORM 3. TRANSECT AND POINT CHARACTERIZATION

1. **Reach name** ____________________________ **2. Reach type** (circle one): control reference treatment other
3. Date (mm-dd-yy): _______ _______ _______ 4. Time (hr: min)_______: ________
5. Transect number (T1-T11) T-________ 6. Transect station (feet downstream from Transect 1) ___________
7. Team member & task:____
8. Transect GCU type (circle one): riffle pool

Computation of sampling-point interval:

9. REW _____ ft LEW _____ ft
10. WCW (LEW minus REW) ______ ft
11. Sum of feature widths (from table at right): ______ ft
12. WCW minus total feature widths (line 10 - line 11): ______ ft
13. Sampling-point interval (line 12 ÷ 8): ______ ft

Transect in-channel features and their width

Feature	Start	End	Width (ft)

Items 14-24. Transect-point measurements (integrate 2-ft^2 area in cover-type and particle-size determinations)

14	15	16	17	18	19	20	21		22	23	24
Point	Sampling-point distance (ft)	Bottom temp. (˚C) [a]	Water depth (ft)	Meter revolutions	Time (seconds)	Water velocity (ft/s) [a, b]	Point substrate particle sizes (mm)		Embedded-ness (%)	Dominant. substrate category [c]	Habitat cover category [d]
P1- REW			na	na	na	na					
P2											
P3											
P4											
P5											
P6											
P7											
P8											
P9 - LEW			na	na	na	na					
Thalweg		na		na	na	na	na	na	na	na	na

Items 25-27 Center-channel characteristics

25. Channel aspect:_______ (az.) 26. Canopy angles: left _____ right _____ 27. Percent of transect in shade:____

Items 28-34. Bank and riparian characteristics (integrate 2-ft width in most determinations)

	28	29	30		31				32	33	34
	Bank height (ft)	Bank angle (degrees)	Bank material [c]		Bank-vegetation cover (total = 100%)				Visual stability [e] (1,2,3,4)	Percent rooted-vegetation and stable cover [e] (1,2,3,4)	Riparian canopy closure [f] (count)
Bank			Dominant	Subdominant	Bare	Grasses	Shrubs	Trees			
Right											
Left											

[a] TS, too shallow to measure [b] TW, too weedy to measure. na, not applicable

[c] **Substrate- and bank-material categories**

1. smooth bedrock or concrete
2. silt, clay, organic detritus (<0.063 mm)
3. sand (0.063 - 2 mm)
4. small gravel (3 -16 mm)
5. medium gravel (17 - 32 mm)
6. large gravel (33 - 64 mm)
7. small cobble (65-128 mm)
8. large cobble (129 - 256 mm)
9. small boulder (257 - 512 mm)
10. large boulder (>512 mm)

[d] **Habitat-cover categories:**

NO - none
BO - boulders/cobble
UB - undercut banks
WD - natural woody debris
MS - manmade objects/structure
TS - too shallow to measure
DP - depth (deep-water pool)
OV - overhanging vegetation
MA - moss or emergent, submergent, and floating macrophytes
OT - other; explain:_________________________________

[e] **Bank stability and percentage of bank consisting of roots, vegetation, rocks:**

1 = 0-24% 2 = 25-49% 3 = 50-74% 4 = 75-100%

[f] Number of intersections out of 17 at point 15 inches streamward and 15 inches above water surface.

Equipment List

300ft tapes (5)
25ft survey rod
clothes pins (27)
bank pins (6)
pygmy velocity meter with top-setting wading rod
stopwatch and headphones or Aquacalc
temperature probe
metric folding ruler (2)
abney level
clinometer
concave densiometer
camera
GPS unit
compass (azimuth)
field forms
wire flags (11)
hammer, rebar, and rebar caps
clipboard with calculator (2)
tape clamps (6)
hand-held laser level
2-ft^2 PVC frame