CHAPTER 9
PHYSICAL HABITAT OF AQUATIC ECOSYSTEMS

Objective

The objective of this chapter is to describe the methods used by the TCEQ for the collection and assessment of physical habitat data in wadeable freshwater streams. In general, the TCEQ will use habitat data collected according to these methods, in conjunction with fish and benthic macroinvertebrate community surveys, to provide a holistic evaluation of the health of biological assemblages and to develop future indices of aquatic life use for these waters. A physical habitat evaluation of a stream is an integral and required part of all biological assessment activities. One of the main functions of a habitat assessment is to characterize the aquatic life potential of a stream. Aquatic habitat quality is an important factor affecting fish and benthic macroinvertebrate community integrity. Characteristics of physical stream habitat such as the presence or absence of instream cover, substrate characteristics, and riparian integrity have important affects on both benthic macroinvertebrate and fish assemblages. Habitat characterization, therefore, is important in interpreting results and determining the cause of decreasing biotic integrity. The data collection protocols outlined below must be followed.

Habitat Assessment Forms

Use the “Stream Physical Characteristics Worksheet–Part I” to record required data in the field. The worksheet is divided into two portions. The upper portion is for general observations made over the entire evaluated reach, while the lower, or boxed, portions are for measurements and observations made at specific transect locations. After field work is complete, data are summarized and averaged from the worksheets to complete the “Summary of Physical Characteristics of Water Body–Part II.” The “Habitat Quality Index (HQI)–Part III” is then scored and calculated based on the values summarized in Part II. Locate transect locations on a USGS topographic quadrangle map and attach to the forms. For RWAs, also locate the existing or proposed discharge point(s) on the map. See Appendix C for Part I, II, and III forms.

Habitat Assessment Requirements for Biological Assessments

Aquatic Life Monitoring, Aquatic Life Assessments, and Use Attainability Analyses

A habitat assessment is a required part of any biological monitoring event. For ALM, ALA, and UAA monitoring, the habitat reach placement requirements are the same and are outlined in Chapter 2, “Biological Monitoring Requirements.” It is very important that the habitat assessment reach covers the areas where fish and benthic macroinvertebrate samples are collected. Effort must be made to ensure the reach is not close to a bridge overpass. Occasionally a bridge crossing is strewn with rip-rap or other debris that forms the only “riffle” in the reach. Sampling from these artificial riffles is discouraged and should only be conducted when all other sampling efforts outlined in Chapter 5, “Methods for Collecting and Assessing Freshwater Benthic Macroinvertebrates” have been exhausted. Once the habitat, fish, and benthic macroinvertebrate sampling crew leaders have agreed where sampling will be conducted, the habitat crew marks the ends of the reach with bright survey flagging. Sampling from areas outside those boundaries is discouraged.

Habitat Assessment Requirements for UAA, ALA, and ALM Monitoring During Second Event in an Index Period

In any one year, most ALMs, ALAs, and UAAs will involve two sampling events conducted within an index period. An HQI score must be part of every biological monitoring data set. A full habitat assessment must be conducted at the *first* biological monitoring event (within the index period) per year. Photographs must be included. A full habitat assessment must be conducted at the *second* biological monitoring event per year, unless it is demonstrated that conditions have not changed appreciably since the first habitat assessment that year. The following evidence must be gathered to demonstrate similar conditions between events:

1. Flow
2. Wetted channel width
3. Photographs of reach
4. Description of bank conditions in relation to first event
5. Description of canopy conditions in relation to first event

If best professional judgment determines that conditions have not changed significantly based on these five pieces of evidence then the HQI from the first event may be used in the second data set. The same lead field staff must conduct habitat assessment at both events. These allowances apply only to two habitat events conducted within one index period.

Receiving Water Assessments

For new permit applications or for WWTPs that have not yet discharged, conduct the habitat assessment beginning at the proposed location of the WWTP outfall and proceed downstream. Once the transect measurements are completed, make general observations over the reach while returning to the point of the proposed outfall.

For amendments or renewals of existing WWTP permits, an assessment upstream of the WWTP outfall is required. Make transect measurements from a point starting approximately 30 m upstream of the outfall and continuing upstream. Once the transect measurements are completed, make general observations over the reach while returning to the discharge point.

Reach Length Determinations

After site selection, the next step in conducting a stream habitat assessment is to determine the length of stream to be evaluated, or the “stream reach.” Determine the stream reach by walking (or boating) the stream for several hundred meters to locate the areas where biological collections will be made. Determine an average stream width during this initial “reconnaissance.” The stream reach encompasses the biological and chemical collection areas and includes as many different geomorphic channel units as possible. Examples of geomorphic units include riffles, runs, glides, and pools.

Wadeable Streams

Streams are considered wadeable if most of the stream channel is accessible by wading during normal flow conditions. Generally, these streams are third order or less. Pool areas or high-flow conditions may cause the stream to be inaccessible to wading in certain places or at certain times; however, the stream would still be considered wadeable when determining reach length. The reach length of a wadeable stream is based on 40 times the average stream width, but not less than 150 m. For most wadeable streams, this will result in a reach length of approximately 200 to 300 m. The maximum reach length for wadeable streams is 500 m.

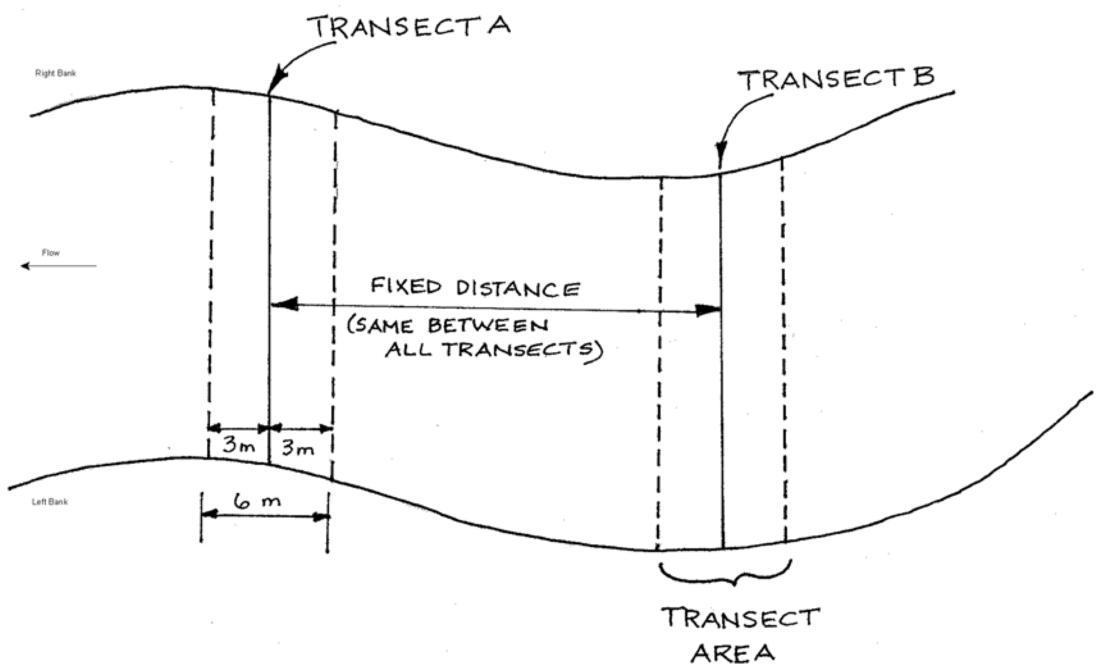
Non-Wadeable Streams

Streams are considered non-wadeable if water depth in the stream channel prohibits wading and requires use of a floatation device (boat or tube) during normal flow conditions. Generally, these are fourth order streams or larger and are usually considered rivers. Riffle areas or low-flow conditions may cause the stream to be accessible to wading in certain places or at certain times; however, the stream would still be considered non-wadeable when determining reach length.

The reach length of a non-wadeable stream should include one full meander of the stream channel, if possible, and should include two examples of at least two types of geomorphic channel units.

The minimum reach length for a non-wadeable stream is 500 m and the maximum length is 1 km. On some rivers, one full meander may be longer than 1 km. In other rivers, the channel may be dominated by only one geomorphic unit, such as a glide. In these cases, limit the reach length to 1 km with as many different types of geomorphic units represented as possible.

Figure 9-1. Transect Placement



Transect Placement

For purposes of transect measurements, left- and right-bank orientation is determined by the investigator facing downstream.

Place transect lines perpendicular to the stream channel at five to 11 evenly-spaced intervals along the reach, as shown in Figure 9-1.

Measurements of some habitat attributes are made along the transect line and in the area 3 m on either side of the transect line defined as the transect area in Figure 9-1. Reach boundaries are included as transects. It is preferable to begin with the transect furthest downstream as this allows the biological sampling to be conducted ahead of the habitat assessment, thereby minimizing disturbance to the biota from the habitat measurement activities. The distance between transects is uniform and this distance must be measured with a measuring tape, hip chain, or range finder. The placement of transects within the reach is as follows:

Wadeable Streams

For reach lengths of 150 to 300 m, place five evenly-spaced transects throughout the length of the reach and include the reach boundaries as transects. The distance between transects is no greater than 75 m.

For reach lengths of 301 to 500 m, place six evenly-spaced transects throughout the length of the reach and include the reach boundaries as transects. The distance between transects is no greater than 100 m.

Non-Wadeable Streams

For reach lengths of 500 m to 1 km, place a minimum of six and a maximum of 11 evenly-spaced transects over the reach length and include the reach boundaries as transects. Select an appropriate number of transects so that transects are no greater than 100 m apart.

Low-Flow or Dry Conditions

A habitat assessment must accompany the collection of biological community samples in rivers and streams. If the stream is dry, do not conduct a stream habitat assessment. If the stream contains standing perennial pools in which aquatic life is found and sampled, conduct a stream habitat assessment in the same manner described in this document with the following modifications.

Determine the reach length in the same manner as stated above using the stream channel width at base flow conditions (as best as can be determined) as the wetted width. If the existing perennial pools cover most (>50 percent) of the reach length, conduct the habitat assessment according to the procedures outlined in this chapter. If a transect crosses a dry part of the channel, record any meaningful data from that transect such as substrate characterization, bank angle under what appears to be normal base flow conditions, riparian information, etc. If the pools cover less than 50 percent of the reach length and pools are separated by exposed channel bed, place transects such that they best characterize the pools and available water.

Record the maximum pool length, depth, and width at each pool measured in the reach. Transect placement must still follow the minimum spacing requirements stated above; however, some transects may be spaced further apart depending on pool location. The overall objective is to characterize the pools where either benthic macroinvertebrates or fish are sampled and to assess the same number of transects that a typical reach of that length would have if there was water in the stream. Characterize only those pools in the reach with a surface area greater than 1 m^2 and deeper than 10 cm.

Part I: Stream Physical Characteristics Worksheet

The Stream Physical Characteristics Worksheet is used to record primary, secondary, and tertiary attributes for each transect or for the entire reach. Instream channel measurements (primary), stream morphology (secondary), and riparian environment (tertiary) information is recorded in the upper portion of the form for attributes describing the entire reach and in the lower boxes for each transect.

Primary Attributes—Instream Channel Characteristics

Primary attributes of a stream's aquatic habitat are the in-channel aspects of habitat type, substrate quality, food, and cover availability for fish and benthic macroinvertebrates. Basically, primary attributes characterize the shelter and food quality for aquatic organisms. Kaufmann and Robison (1998) provide the basis for many of the measurement protocols in this chapter.

Habitat Type (Geomorphic Units)

Identify the habitat type in the area where the transect falls. In order to be considered a discrete habitat type, the width of the geomorphic unit (riffle, run, glide, pool) must be greater than 50 percent of the width of the stream and the length of the geomorphic unit must be ≥ the average stream width. If the transect falls in a transition area or on the border between two habitat types, identify both in the box marked "Habitat Type."

Riffle: A shallow portion of a stream extending across a stream bed characterized by relatively fast-moving turbulent water with a broken water surface. The water column in a riffle is usually constricted and water velocity is fast due to a change in surface gradient. The channel profile in a riffle is usually straight to convex.

Run: A relatively shallow portion of a stream characterized by relatively fast-moving, bank-to-bank, non-turbulent flow. A run is usually too deep to be considered a riffle, but the water velocity is too fast to be a glide. The channel profile under a run is usually a uniform flat plane.

Glide: A portion of a stream where the flow is characterized by slow-moving laminar flow, similar to that found in a shallow canal. Water surface gradient over a glide is nearly zero, so velocity is slow, but flow is uniform across the channel without eddy development. A glide is too shallow to be a pool but the water velocity is too slow to be a run. The channel profile under a glide is usually a uniform flat plane.

Pool: A portion of a stream in which water velocity is slow and the depth is greater than the riffle, run, or glide. Pools often contain eddies with varying directions of flow compared to riffles, runs, and glides where flow is almost exclusively downstream. The water surface gradient of pools is close to zero and their channel profile is usually concave.

Number of Riffles
Count the number of riffles in the habitat assessment reach. Riffles are considered discrete if they are separated by a run, glide, or pool that is at least as long as the average stream width. Otherwise, count it as one riffle.

Dominant Substrate Type
The channel substrate is the mineral or organic material that forms the bottom of the stream. Substrate materials are usually classified by particle size. Identify the dominant substrate type that characterizes the stream bottom along and 3 m on either side of each transect according to the following guidelines,

- Bedrock —
- Large Boulders > 45 cm
- Boulders > 25 to 45 cm
- Cobble > 6 to 25 cm
- Gravel > 2 to 60 mm
- Sand 0.06 to 2 mm
- Mud and Silt < 0.06 mm

The size composition can be assessed visually or by obtaining one or more small samples by hand or grab.

Percent Gravel or Larger
Estimate the percentage of the substrate that is > 2 mm in size along and 3 m on either side of the transect. The size composition can be assessed visually or by obtaining a small sample by hand.

Algae and Macrophytes
Determine if algae and macrophytes are present along and 3 m on either side of the transect. Visually estimate whether algae and macrophytes are abundant, common, rare, or absent. If only algae or only macrophytes are present, circle either algae or macrophyte on the form and estimate abundance.

Instream Cover Types
Instream cover refers to physical structures which provide shelter for fish and benthic macroinvertebrates. It includes, but is not limited to, logs, tree stumps, woody debris, root wads, leaf packs, gravel or larger-sized substrates, boulders, artificial cover (for example: tires, cement slabs), undercut banks, macrophyte beds, and overhanging vegetation.

Percent Instream Cover

Visually estimate percentage instream cover along and 3 m on either side of the transect. This percentage represents an evaluation of the area of the stream bottom described above, as well as the water column and area immediately above the water surface along the stream banks. The cover must be at a water depth suitable for use by aquatic organisms. For example, if leaf packs and logs are in 2 cm of water on a sand bar, they are not suitable for use by fish or most benthic macroinvertebrates and must not be counted.

Percent instream cover must be evaluated with a gradient of percentages from the lowest percentage for bare bedrock or concrete to the highest percentage for a highly heterogeneous mix of several categories, such as gravel, cobble, logs, macrophytes, and overhanging vegetation. Additional dimensions contribute to higher percentages, such as cover that extends from the substrate up though the water column and above the stream surface.

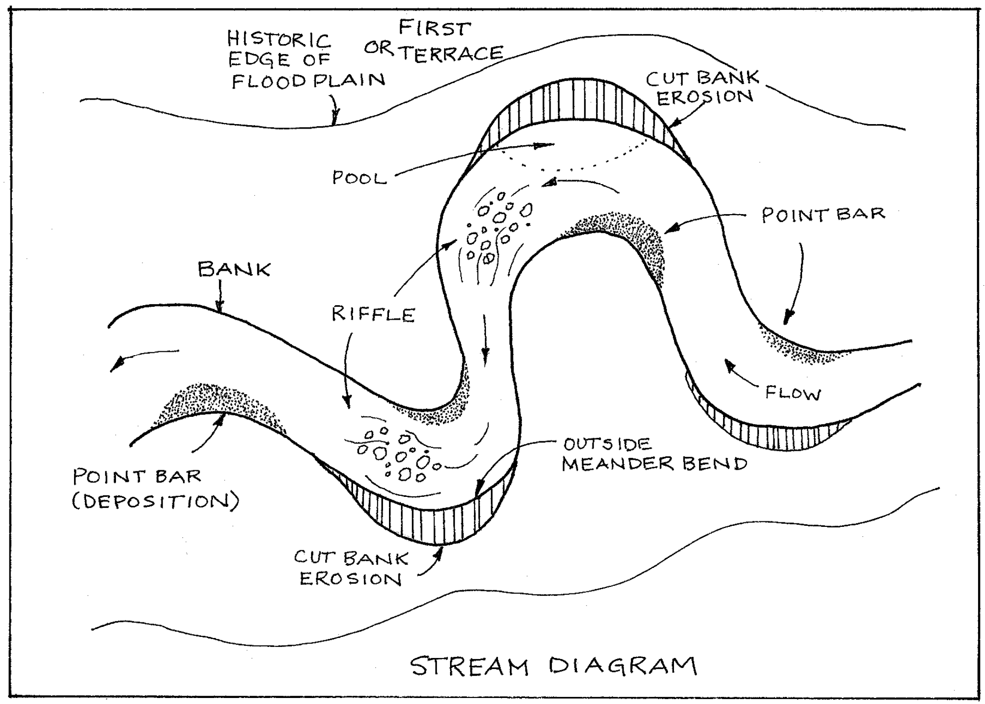


Figure 9-2. Stream Morphology

Secondary Attributes—Stream Morphology

Secondary attributes of a stream's aquatic habitat are characterized by the structure of the stream channel over the entire reach where the primary attributes are located. It is a broader look at the channel itself and the morphological characteristics that influence the quality of the primary attributes. Figure 9-2 depicts a typical stream channel with a well developed stream pattern.

Stream Bends

Count the number of stream bends and determine their definition (well, moderate, poor). Figure 9-3 illustrates stream-bend classifications.

A high degree of sinuosity produces diverse habitat and fauna, and the stream is better able to handle surges during storm fluctuations. The absorption of this energy by bends protects the stream from excessive erosion and flooding and provides shelter for benthic macroinvertebrates and fish.

A well defined bend will usually have a point bar at the inside of the bend and a cut bank on the outside of the bend with flow directed toward the cut bank side. Eddy currents are usually found in these bends. Moderately defined stream bends have somewhat less sinuosity and the bends and

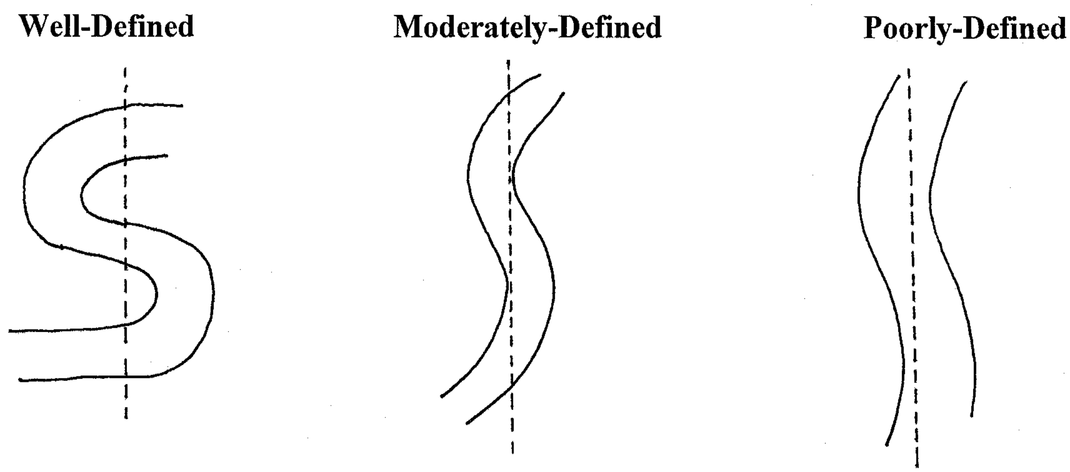


Figure 9-3. Stream Bends

point bars are not as well developed. Poorly defined bends have almost no sinuosity or are straight as in channelized streams. In some situations stream-bend development can be evaluated from viewing topographical maps.

The speed of water flow depends on several factors, including the angle of the bed slope, the roughness of the bed, the depth of the water, and the type of geologic materials the stream flows through. For example, streams flowing through soft soils tend to meander more and have less velocity than streams flowing through hard erosion-resistant rock. Generally, if the stream meanders a great deal, the stream's gradient is probably low.

Channel Obstructions or Modifications

Indicate observed channel obstructions such as fences, log jams, culverts, and low water bridges. Also indicate any channel modifications such as channelization, levees, concrete lining, or rip-rap within the reach; note whether these modifications are natural or man-induced.

Channel Flow Status

Channel flow status is the degree to which water covers the entire available channel substrate, from bank to bank. It is not to be confused with "flow severity" referred to in the TCEQ's *Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue*, RG-415 (TCEQ 2003). Flow severity is a visual assessment of the amount of flowing water in the channel relative to base flow or "normal" flow conditions. Look for the percentage of substrate that is covered with water throughout the reach, or conversely, the percentage of substrate that is exposed in the channel. This attribute is a measure of how much of the potential habitat is available to aquatic organisms based on the amount of water present in the channel at the time of assessment. When water does not cover much of the stream bed, the amount of substrate available for aquatic organisms is limited relative to times when flow is higher. For example, if the true channel is 20 m wide and water only fills 10 m of the channel, the channel flow status would be reported as "low" with water filling 25 to 75 percent of the available channel. This observation is especially useful for interpreting biological information under low-flow conditions.

Estimate the percentage of water in the available channel and the amount of substrate exposed as:

High: Water reaches the base of both banks. Very little (less than 5 percent), if any, of the channel substrate is exposed.

Moderate: Water fills greater than 75 percent of the available channel or less than 25 percent of channel substrate is exposed.

Low: Water fills 25 to 75 percent of the available channel and riffle substrates are mostly exposed.

No flow: Very little water in the channel; mostly present as standing pools or stream is dry.

Stream Width

Stream width is the horizontal distance along the transect line from water's edge to water's edge along the existing water surface. It is also referred to as the wetted width.

Measure the width of the water in the stream channel from water's edge to water's edge at a transect. Water's edge can be defined as the point where stream materials, such as rocks, are no longer surrounded by water. Record this width in meters.

It is important to remember that stream width is only the wetted width, whereas channel flow status looks at the entire available channel, bank to bank.

Stream Depths at Points Across the Transect

Stream depth is the vertical height of the water column from the existing water surface level to the channel bottom.

Measure the water depth in meters at 11 equally spaced points across each transect for wadeable streams, beginning and ending with the depth at the water's edge. For streams less than 1.5 m wide or greater than 11 m wide, measure as many depths as will adequately profile the channel substrate. Also locate the thalweg, or deepest portion of the channel, and measure its depth. Indicate the thalweg depth as a separate depth measurement in the area labeled "Thalweg Depth" on Part I.

For non-wadeable streams, measure the water depth at 11 or more equally spaced points across each transect. Locate and measure the depth of the thalweg as for wadeable streams. In non-wadeable streams, best profession judgement will be required to determine how many depth measurements to make; the number chosen must adequately profile the stream channel bottom at that transect. The number of depth measurements must increase as the stream bottom becomes more irregular.

Tertiary Attributes—The Riparian Environment

The riparian environment is defined as follows.

Riparian Zone

The riparian zone can be defined in many ways, but it is generally considered to be the area from the stream bank out onto the flood plain. The limit of the zone depends on many factors including plant community, soil moisture, and distance from the stream. It also depends on the limit of interaction between land and stream processes. The riparian zone is periodically inundated by flood waters from the stream. Interaction between this terrestrial zone and the stream is vital for the health of the stream.

Natural Vegetative Buffer

The natural vegetative buffer refers to an area of either natural or native vegetation that buffers the water body from terrestrial runoff and the activities of man. In natural areas, it may be much greater than the riparian zone width. In man-altered settings, the natural vegetative buffer limit would be at the point of man's influence in the riparian zone, such as a road, parking lot, pasture, or crop field. It is the width of this buffer that the TCEQ is most interested in measuring for purposes of qualifying potential stream disturbances.

Aesthetics

Circle the descriptor that most adequately describes the reach as a whole. Make only one selection. The descriptors are defined as follows:

Wilderness (1): The surrounding landscape has outstanding natural beauty. Usually wooded or unpastured areas typical of what would be found in a wilderness area such as in a national forest or preserve. There is no evidence of man-made alterations to landscape. Water clarity may be exceptional.

Natural area (2): Trees and/or native vegetation are common. Some development or alteration to the landscape by man may be evident, but is usually minimal, such as fields, pastures, or rural dwellings. Water may be discolored or slightly turbid.

Common setting (3): Landscape and stream are fairly altered by man, but the alteration is not offensive. This category could include an urban park setting. Water clarity is often colored or turbid.

Offensive (4): Stream does not enhance the aesthetics of the landscape. Stream is littered with trash, highly developed, or is a dumping area. Water may be discolored or very turbid.

Riparian Vegetation (percent)

Indicate the percentage of riparian vegetation types on each bank located in the riparian zone. If no plants exist in the riparian zone, indicate this by recording 100 percent in “other”.

Bank Slope (Bank Angle)

Measure the slope of each bank at the transect with a clinometer and a survey rod or pole. Place one end of the survey rod at the water’s edge and lay it on the ground perpendicular to the stream channel along the bank pointed toward the top of the first main terrace. Lay the clinometer on top of the survey rod and record the angle reading. Refer to Figure 9-4 for bank angle measurements. The clinometer can only measure angles less than 90°.

During low flow conditions, the water’s edge may recede from the true bank, revealing part of the stream bottom as the “bank.” In these instances, measure the slope of this “bank” from the water’s edge.

A *vertical bank* has a bank angle of 90°. If the vertical portion of the bank is $\geq$ 0.3 m, record only the vertical measurement. If the vertical portion of the bank is < 0.3 m, measure the vertical portion of the bank as well as the angle at the top of the vertical section and average the readings. Record the average as the bank angle.

A *gently sloping bank* has a bank angle of < 90° and can be read directly off the clinometer.

For banks greater than 90°—*undercut banks*—place a survey rod flush up against the roof of the undercut bank and in as far as possible. Turn the clinometer over and take the reading and subtract it from 180°.

If the bank is very irregular in shape or has many small, intermediate terraces, take several bank angle readings at each elevation break and average the readings, or, if the irregularities are fairly small, lay the survey rod across the irregularities and take one average bank angle reading. Record the average as the bank angle.

Measure both left and right banks and record these angles separately.

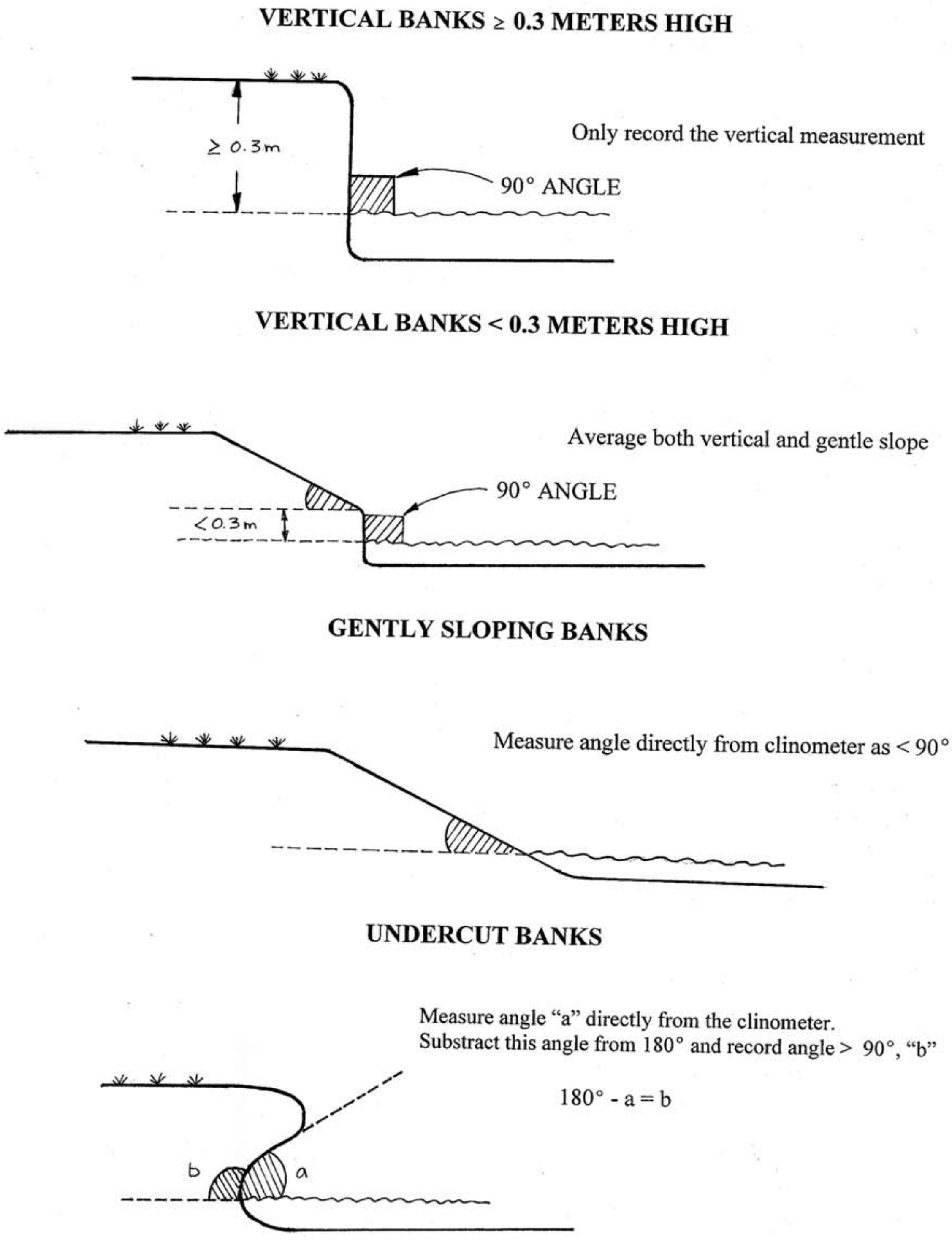


Figure 9-4. Bank Angle Measurements

Bank Erosion

Estimate the percentage of the areas of the stream bank which shows evidence of or potential for erosion. Assess each bank separately, up to the first terrace within the transect area (along and 3 m on either side of the transect). Record an estimate for each bank on the form. The range is as follows:

- 100 percent: totally bare, unconsolidated soil not stabilized by roots
- 0 percent: totally covered by thick vegetation or hard rock, such as a canyon wall

Tree Canopy

Tree canopy is the uppermost spreading, branching layer of stream-side trees that shades the water surface. Tree canopy is reported as percent cover and is measured with a densiometer. Tree canopy is an indicator measurement of stream corridor health and level of disturbance. Possible measurement range is from 0 percent (totally open) to 100 percent (totally closed canopy cover). See Figure 9-5, Densiometer Diagram.

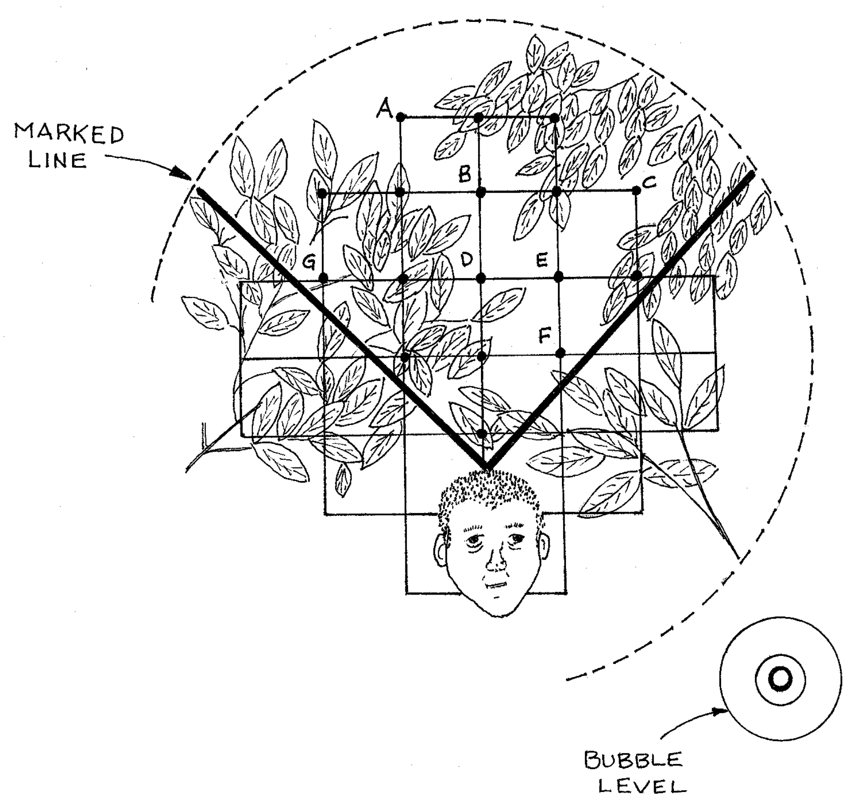


Figure 9-5. Convex Spherical Densiometer Diagram, (From Mulvey et al., 1992)

Measure the amount of tree canopy cover with a convex spherical densiometer along the transect line at mid-channel, once facing the left bank and once facing the right bank. Make two additional measurements along the transect line at the water's edge, once facing the left bank and once facingthe right bank.

<u>Note</u>: This is a change from previous procedures that specified a concave densiometer and only two measurements in mid-channel.

Use the following method for marking and reading a convex densiometer:

- With a black permanent fine-tipped marker, mark the densiometer, as shown in Figure 9-5, so that 17 grid intersections are located above the marked lines. Measure canopy cover by holding the densiometer level 0.3 m above the surface of the water.

Note: This is a change in procedure from the one that specified holding the densiometer at waist level.

- The observer's face must be kept from reflecting in the grids of the mirror. While concentrating on the 17 points of intersection, the observer then counts the number of intersections that are covered by reflected canopy cover. In this example, the densiometer reading would be 10.
- Two densiometer readings are taken at mid-stream, one facing the left bank and one facing the right bank. Two additional readings are taken at the water's edge, one facing the left bank and one facing the right bank. The four readings are averaged and the percentage calculated. For example, if the average of the four densiometer readings is 9, the reported percent tree canopy would be:

$$9 \div 17 = 0.53 \text{ or } 53 \text{ percent}$$

- Range: no trees, totally open = 0 percent
  large trees providing total shading = 100 percent

Dominant Types of Riparian Vegetation

Indicate the types of riparian vegetation observed within 3 m either side of the transect (oak trees, sunflowers, Bermuda grass) for each bank. Record this information for each bank separately. If a bank contains no riparian vegetation, indicate this by describing the conditions, such as a paved parking lot up to edge of stream bank.

Width of Natural Buffer Vegetation

Measure the width in meters of the natural vegetative buffer on each bank. This can be performed with a hip chain, a measuring tape, or an optical range finder. If the buffer is greater than 20 m, simply indicate >20 m on the form.

General Observations

After finishing the transect measurements, complete the general observation portion of the worksheet. Count the number of riffles throughout the evaluated reach. Record the width and maximum depth, in meters, of the largest pool in the reach, if applicable. Also note the number and quality of bends in the reach.

At an appropriate location within the stream reach, measure stream flow. See Chapter 3 of the SWQM Procedure, Volume 1 for details on measuring flow.

Take photographs of the stream reach from mid-channel, facing upstream and downstream. Ideally, photographs are taken at each transect from mid-channel facing left bank, right bank, upstream, and downstream.

Part II—Summary of Physical Characteristics of Water Body

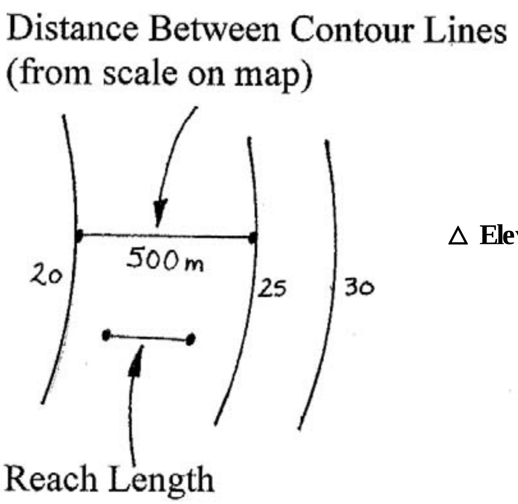
Once the field worksheet (Part I) has been completed, summarize the measurements on the summary sheet (Part II) in preparation for calculating the habitat metrics. Use information from all transects and measurements in Part I, as well as from other sources, to complete this form. This summary is used primarily to calculate the habitat metrics but is also used in other areas of biological assessment, such as determining appropriate ALUs. The parameter codes for each habitat descriptor is listed in parentheses after each descriptor heading.

Streambed Slope (72051)

Using a USGS topographic map of the reach, measure the *change in elevation* between the first contour line crossing the stream upstream of the upstream reach boundary and the first contour line crossing the stream downstream of the downstream reach boundary. Convert to meters. Divide this by the *length of the stream reach* in meters from Part I. Multiply by 1000 to get m/km.

Example: 10 ft/250 m = 3.048 m/250 m x 1000 = 12.192 (1 ft = 0.3048 m)

For low-gradient streams or for short reach lengths, the reach may fall between two contour lines (See Figure 9-6). In these instances, determine the slope over the entire interval between the two contour lines that encompass the reach and assign that slope to the reach.



△ Elevation ÷ Distance Between Contour Lines x 1000 = Slope

5 meters ÷ 500 meters x 1000 = 10

Figure 9-6. Stream Slope

Drainage Area (89859)

Using either a USGS topographic map, a quarter-scale county highway map and a planimeter, or GIS, determine the drainage area upstream of the furthest downstream transect. Record this area in square kilometers.

Stream Order (84161)

Using a USGS topographic map with a scale of 1:24,000, determine the stream order classification. The smallest, unbranched tributaries of a drainage basin (intermittent or perennial on the map) are designated first order streams. Where two first order streams join, a second order stream is formed; and where two second order streams join, a third order stream is formed, and so on. Figure 9-7 depicts a typical stream order pattern.

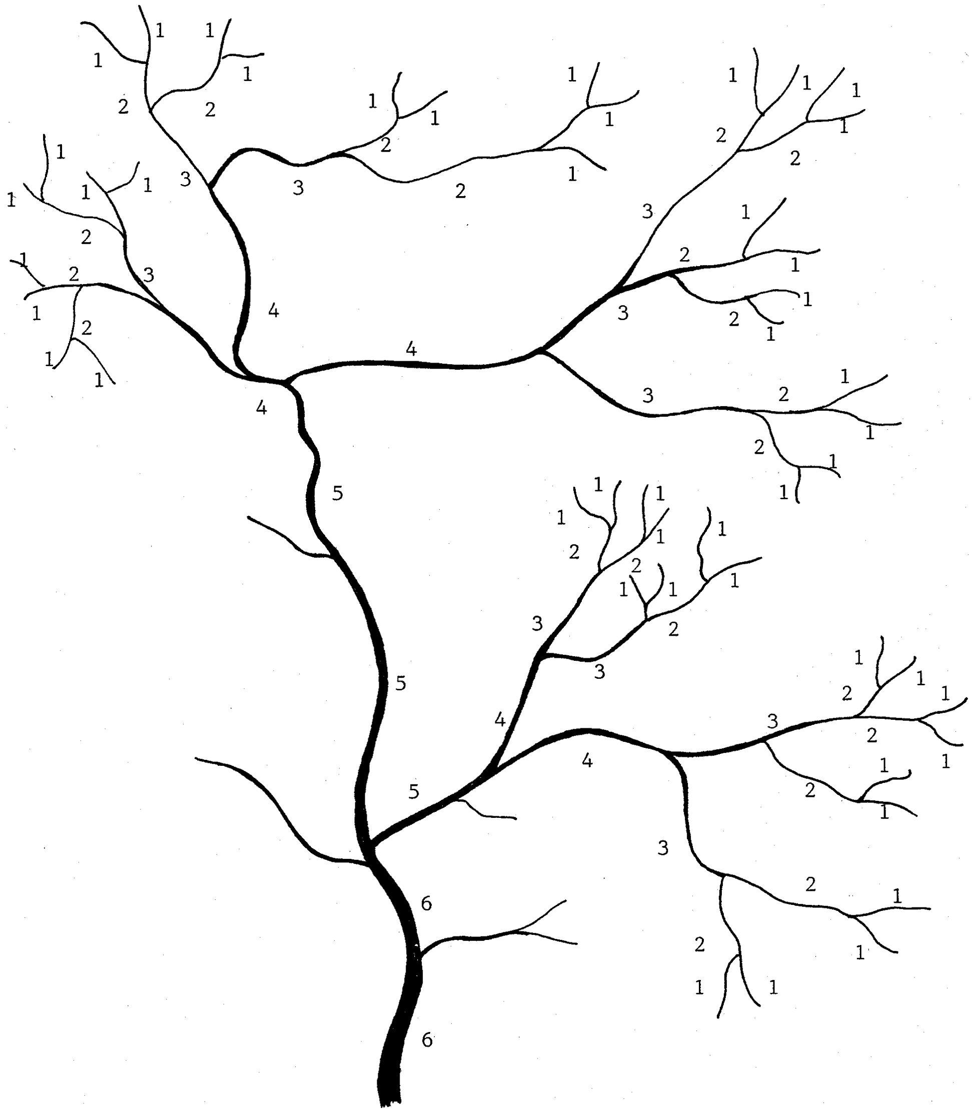


Figure 9-7. Stream Order

Length of Stream Evaluated (89860)

From Part I. Record in meters.

Number of Lateral Transects Made (89832)

Record number of transects measured in the stream reach. There will be anywhere from five to 11 transects depending on the length of the reach.

Average Stream Width (89861)

Average the stream width measurements from all transects. Record in meters.

Average Stream Depth (89862)

Average the individual stream depth measurements from all transects. For example, if there were five transects, with 10 depth measurements made at each transect, the average is calculated from all 50 individual depth measurements. Record in meters.

Instantaneous Stream Flow (00061)

Record the measured stream flow in the reach on the same day the transect measurements are made. It is preferable to measure flow in the field even if there is a USGS stream flow gauge nearby. Record in ft^3/sec.

Flow Measurement Method (89835)

Indicate the type of equipment used to measure flow.

Channel Flow Status (89848)

Record high, moderate, low, or no flow from Part I.

Maximum Pool Width (89864)

Record the maximum width of the largest pool encountered in the reach. This is usually done when making "General Observations" on the walk back after performing the last transect measurement. Record in meters.

Maximum Pool Depth (89865)

Record the maximum depth of the largest pool encountered in the reach. This is usually done when making "General Observations" on the walk back after performing the last transect measurement. Record in meters.

Total Number of Bends (89839)

Record the sum of the following three sub-categories from Part I: well defined, moderately defined, poorly defined. These are usually tallied during the "General Observations" portion of the assessment. Additionally, record the number of bends in each bend category:

- Well defined bends (89840)
- Moderately defined bends (89841)
- Poorly defined bends (89842)

Total Number of Riffles (89843)

Record number of riffles from Part I. These are usually tallied during the "General Observations" portion of the assessment.

Dominant Substrate Type (89844)

Record the dominant substrate type from all transects in the reach. For example, if six transects were measured and four listed "sand" as the dominant substrate type and two listed "gravel" as the dominant substrate type, then "sand" would be recorded as the dominant type for the reach on Part II. If there is an even number of two types, use professional judgment to determine the most prevalent type.

Average Percent of Substrate Gravel-size or Larger (89845)

Average all percent gravel numbers recorded for each transect from Part I. Record as a percentage.

Average Percent Instream Cover (84159)

Average all percent instream cover numbers recorded for each transect from Part I. Record as a percentage.

Average Percent Stream Bank Erosion (89846)

Average the individual percent stream bank erosion determinations from all transects. For example, if five transects were made, and a left and right bank percent erosion was determined at each transect, the average is calculated from all 10 individual percent stream bank erosion numbers. Record as a percentage.

Average Stream Bank Angle (89847)

Average the individual stream bank angle measurements from all transects. For example, if five transects were made, and a left and right bank angle measurement was made at each transect, the average is calculated from all 10 individual bank angle measurements. Record in degrees.

Average Width of Natural Buffer Vegetation (89866)

First determine the minimum natural buffer vegetation width at each transect. Next, average the minimum widths for all transects in the reach.

Average Riparian Vegetation Percent Composition

Average the left and right bank determinations made in Part I for each category of vegetation type. For example, if the percent trees was 65 percent on the left bank and 40 percent on the right bank, record 52 percent for total percent trees. The total of all vegetation types equals 100 percent. Record average percent vegetation type as follows:

- Average percent trees as riparian vegetation (89849)
- Average percent shrubs as riparian vegetation (89850)
- Average percent grasses as riparian vegetation (89851)
- Average percent cultivated fields as riparian vegetation (89852)
- Average percent other as riparian vegetation (89853)

Average Percent Tree Canopy Coverage (89854)

Average the individual percent tree canopy coverage measurements from all transects and record this value.

Overall Aesthetic Appraisal of the Stream (89867)

Record your assessment from Part I.

Part III—Habitat Quality Index

After completing the summary of physical characteristics of water body form (Part II), complete the HQI form (Part III) and calculate a total habitat score for the stream. Use the values from Part II and any field notes to score each metric. For example, if the average percent instream cover from Part II was 50 percent, the available instream cover metric would score a "three as common". Once all metrics are scored individually, calculate the total score by adding all individual scores. The assigned habitat assessment category based on the HQI is as follows:

26 - 31	**Exceptional**
20 - 25	**High**
14 - 19	**Intermediate**
$\leq$ 13	**Limited**

Assessing the Habitat of Lakes and Reservoirs

At this time there is limited guidance on assessing the physical habitat of lakes and reservoirs for regulatory purposes. The HQI is designed for freshwater streams. Some of the HQI metrics would not be applicable for lakes and reservoirs. As habitat assessments become an important part of assessing biological integrity, there will be a need to develop a uniform approach to assessing the habitat of lakes and reservoirs.

Preliminary work has begun to determine what habitat attributes are important for reservoirs. Some of the attributes that are being studied include: aquatic macrophyte coverage, shoreline habitat, human disturbance, and volumetric surveys. The USEPA has a field operation manual for environmental monitoring and assessment for lakes (USEPA 1997) and a guidance document for lake and reservoir bioassessment and biocriteria (USEPA 1998) that may provide guidance on how to conduct habitat assessment for Texas reservoirs.

Assessing the Habitat of Tidal Streams and Estuaries

There are no standardized guidelines for evaluating habitat in Texas tidal streams and estuaries. A recommended resource for habitat evaluation in larger (non-wadeable) tidal streams is Section 6 of the USEPA EMAP protocol for non-wadeable streams (USEPA 2000).