8. Using Habitat Data as Indicators of Water Quality

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In the broad sense, physical habitat includes all those structural attributes that influence or provide sustenance to organisms within the waterbody. Physical habitat varies naturally, as do biological characteristics; thus expectations differ even in the absence of anthropogenic disturbance. For example, within a given physiographic region, stream drainage area and overall stream gradient are likely to be strong natural determinants of many aspects of stream habitat, because of their influence on discharge, flood stage, and stream power.

Although habitat quality is recognized as a limiting factor for fisheries and aquatic biota, there is not a consensus on what specific components of physical habitat structure should be assessed. For listing and delisting purposes, the habitat information that is directly linked to pollutants, such as sediments, temperature, and nutrients, will be fundamental. However, identification of impairment related to other physical habitat degradation may be equally important in identifying cost-effective remediation measures and shaping future environmental statutes and regulations.

In developing physical habitat monitoring programs, states should consider several interrelated objectives. Although this guidance is primarily focused onWQS attainment/impairment decisions, physical habitat monitoring programs should address (1) the characterization of physical habitat conditions in reference waterbodies, (2) refinement of aquatic life use classifications in water quality standards (WQS), (3) development and refinement of WQS for specific attributes of physical habitat, and (4) refinement of associated habitat assessment methods.

8.1 How Are Habitat Data Used Within the Context of the States' Water Quality Standards?

Physical habitat assessments are an important part of aquatic life use support determinations for all waterbody types because they (1) facilitate the interpretation of biological data, (2) provide information on nonchemical stressors, and (3) lead to informed decisions regarding problem identification and restoration. For habitat monitoring conducted to assess attainment of the physical, chemical, and biological integrity goals of the Clean Water Act (CWA), the primary purpose is to determine beneficial use support status for WQS, rather than to quantify habitat available for a specific species. In this example from streams, aquatic life use support determination based on habitat assessment data may be categorized as follows:

- *Attaining the WQS and no use is threatened:* Reliable data indicate natural channel morphology, substrate composition, bank/riparian structure, and flow regime of region. Riparian vegetation of natural types and of relatively full standing crop biomass (i.e., minimal grazing or disruptive pressure).

- *Attaining some of the designated uses, no use is threatened:* Modification of habitat slight to moderate, usually due to road crossing, limited riparian zones because of encroaching land use patterns, and some watershed erosion. Channel modification slight to moderate.

- *Impaired or threatened for one or more designated uses:* Moderate to severe habitat alteration by channelization and dredging activities, removal of riparian vegetation, bank failure, heavy watershed erosion, or alteration of flow regime.

Most habitat assessment procedures are designed for streams and rivers; however, guidance for habitat assessment of estuaries, lakes, and wetlands is becoming more readily available (U.S. EPA 2000, 1998, 1997, 1994a, 1994b, Adamus and Brandt 1990). Biological assessment of estuaries and lakes should involve evaluating the habitat as well as the biota of the waterbody. In this type of large waterbody assessment, physical habitat not only is composed of solid structures that serve as shelter but also includes chemical, flow, and hydrography components of the waterbody. Monitoring of wetlands has mainly been done through bioassessment; however, the Hydrogeomorphic (HGM) Approach, developed by the Corps of Engineers, uses geographically calibrated wetland morphology, hydrology, and hydrodynamics to assess wetland conditions (Smith et al. 1995, Brinson 1993, Brinson et al. 1995). Additionally, a series of documents recently published by EPA includes a variety of methods used by states to assess wetland condition (U.S. EPA 2002a-i). Because the methods for habitat assessment of streams and rivers are more established, and data produced using these methods are frequently used in determination of attainment, **this chapter addresses the use of habitat data from rivers and streams**. The aforementioned documents should be consulted for more detailed descriptions of the evaluation of habitat in estuaries, lakes, and wetlands.

8.2 What Habitat Indicators Does the State Use To Evaluate Habitat Quality?

Regardless of the method used for assessing stream habitat, the same components of streams are generally investigated. These characteristics include instream habitat, morphology, and riparian characteristics, each of which includes numerous parameters that are selectively measured depending on the method. This section describes these stream characteristics with their parameters. This is not meant to be an in-depth discussion, but rather an overview and introduction.

EPA identified seven general physical habitat attributes important in influencing stream ecology, each of which is naturally variable and also directly or indirectly influenced by anthropogenic activities (U.S. EPA 1993). These attributes are listed below and discussed in the following paragraphs.

- Stream Size - Channel Dimensions
- Channel Gradient
- Channel Substrate Size and Type
- Habitat Complexity and Cover
- Riparian Vegetation Cover and Structure
- Anthropogenic Alterations
- Channel-Riparian Interactions

8.2.1 Stream Size

Stream size is the main determinant of the quantity of habitat available for aquatic organisms. Natural variation and anthropogenic factors influence channel dimensions, flow patterns, and flooding, all of which affect the quantity and quality of habitat. The physical appearance of a stream is a result of channel adjustments according to the magnitude of flow, erosional debris, and basin relief, along with the history of erosion and sediment deposition (Rosgen 1996). Stream channels need to maintain a channel geometry that provides for water and sediment transport at an equilibrium state that results in a relatively stable channel (Bauer and Ralph 1997). Removal of riparian vegetation reduces the structural stability of the stream channel, with negative impacts to fish productivity (Platts 1990, Platts and Nelson 1989). Frequency of pools and riffles, sinuosity, sediment deposition, stream bank condition, and other channel characteristics are naturally variable in streams, but are also influenced by changes in erosional patterns and flow regimes that are due to human activities.

8.2.2 Channel Gradient

Channel gradient is a major influence of river channel morphology and of associated sediment, hydraulic, and biological functions within a stream network (Rosgen 1996). Stream bed and overall habitat stability are influenced by the stream gradient. The impacts of upstream erosion, sediment introduction, and other anthropogenic influences on stream habitat can be evaluated in detail when gradient interactions with sediment transport are understood.

8.2.3 Channel Substrate

Channel substrate is one of the most important determinants of habitat character for fish and macroinvertebrates in streams. Along with bedform, substrate influences the hydraulic roughness and consequently the range of water velocities in the channel. It also influences the size range of interstices that provide living space and cover for macroinvertebrates, sculpins, and other benthic organisms. Because increased erosion and sediment deposition are common to streams in human-influenced areas, sediment characteristics are often sensitive indicators of the effects of human activities on streams.

Fine sediments in streams either move in suspension in the streamflow or are bounced along the bottom (bedload). The size of the particle and the amount of energy in the stream determine which mode of transport will occur within a stream reach. Large amounts of easily transported bedload will fill in pools, form bars on stream bends, and surround gravel and cobble substrates, resulting in altered channel dimensions and flow patterns, as well as reduced habitat and spawning areas for macroinvertebrates and fish (U.S. EPA 1991).

8.2.4 Habitat Complexity and Cover for Aquatic Fauna

Habitat complexity and cover influence the structure and composition of benthic, fish, and periphyton assemblages in streams (Cummins 1974, Platts et al. 1983). The habitat in which biota reside includes natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna. A wide variety and/or abundance of submerged structures in the stream provides macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases. Riffles and runs are critical for maintaining a variety and abundance of insects in most high-gradient streams and serving as spawning and feeding refugia for certain fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition in high-gradient streams. Riffles and runs offer a diversity of habitat through variety of particle size and, in many small high-gradient streams, will provide the most stable habitat.

Snags and submerged logs are among the most productive habitat structures for macroinvertebrate colonization and fish refugia in low-gradient streams (Benke 1984). Large organic debris is especially important in mountainous regions of the Nation. The amount of large woody debris in streams is related to salmonid abundance and distribution. It also aids in reducing channel erosion and buffering sediment inputs by providing sediment storage in headwater streams (Bauer and Ralph 1997).

Fish abundance is related to the diversity of habitats and number and quality of instream pools in stream environments (Kozel and Hubert 1989, Moore and Gregory 1989). Pool filling and destabilization as a result of sedimentation of the substrate can alter habitat structure. Changes in habitat diversity are often associated with adverse impacts to key salmonid-rearing habitats or pools. Pool quality is largely a function of the amount of cover available in slow-velocity waters (Bauer and Burton 1993).

8.2.5 Riparian Vegetation

Riparian vegetation serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides woody debris that acts as habitat and dissipates energy in the stream (USDI 1995). Additionally, riparian canopy cover over a stream is important in moderating stream temperatures through shading and as an indicator of conditions that control bank stability and the potential for inputs of coarse and fine particulate organic material (Youngblood et al. 1985). Organic inputs from riparian vegetation become food for stream organisms and structure to create and maintain complex channel habitat. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, bare soil, rocks, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and rangeland are the common causes of anthropogenic degradation of the riparian zone. However, the presence of "old field" (i.e., a previously developed field not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone.

8.2.6 Anthropogenic Alterations and Disturbances

Land use, buildings, and other evidence of human activities in the stream channel and its riparian zone may, in themselves, serve as habitat quality indicators; they may also serve as diagnostic indicators of anthropogenic stress. In channels, disturbances include channel revetment, pipes, straightening, bridges, culverts, and accumulation of trash. Near-channel riparian disturbances include buildings, lawns, roads, pastures, orchards, and row crops.

8.3 How Does the State Use Different Types of Habitat Assessment Methods to Assess and Document Data Quality?

As with biological sampling, standardization of habitat assessment methods is important to ensuring data validity and reliability (Barbour et al. 2000). Standard operating procedures (SOPs) that describe in detail the criteria for assessing physical habitat, and a QA/QC plan that identifies accountability throughout the assessment process, should be developed to minimize bias, reduce error, and maintain data integrity. Proper training is also important to ensuring that habitat results, especially those developed through visual assessments, are reliable (Hannaford et al. 1997). The four levels of rigor for habitat assessments (Table 8-1) are associated with different types of documentation because of their purposes in assessments. Documentation follows a similar pattern to that used in the four levels of bioassessment, with the lower levels involving little documentation or training and few QA/QC procedures, and higher levels involving more training, detailed SOPs, and complete QA/QC plans.

The following discussion is limited to those physical habitat assessment methods that are commonly used by State agencies in streams and wadeable rivers. Four levels of rigor have been identified for habitat assessment and are summarized in Table 8-1. The level of effort required to assess and document physical habitat degradation will vary, depending on the extent of degradation. The discussions in each assessment level describe the level of data quality and rigor provided and the relationship between data quality and WQS attainment/impairment decisions. A discussion of the data quality and the use of habitat data in making WQS attainment/impairment decisions should be clearly documented in the state, territory or authorized tribe's assessment and listing methodology.

8.3.1 Level 1: Qualitative Visual Characterization of Habitat

Level 1 represents the most qualitative habitat assessment methods, in which physical habitat features are visually characterized and assessment of quality or condition is more of a cursory examination. These more subjective methods described in Level 1 are best suited for screening and site reconnaissance. This level of effort may be adequate to support listing of impaired waters when habitat impairment is grossly apparent, but may not be adequate to provide the sensitivity needed to identify subtle impairments and support delisting decisions. Photodocumentation is especially important at this level of effort, because of the absence of quantitative measurements and estimates.

8.3.2 Level 2: Visual-Based Habitat Assessment

These methods follow the documented Rapid Bioassessment Protocols (RBPs) (U.S. EPA 1999) or similar techniques developed by the respective state/tribal agency that include a combination of physical structural features of the stream and its flood plain (Ball 1982, Ohio EPA 1987, U.S.

Table 8-1. Hierarchy of habitat assessment approaches for evaluation of aquatic life use attainment

Level of Info[a]	Technical Components	Spatial/Temporal Coverage[b]	Data Quality[c]
1	Visual observation of habitat characteristics; no true assessment; documentation of readily discernible land use characteristics that might alter habitat quality; no reference conditions	Sporadic visits; sites are mostly from road crossings or other easy access	Unknown or low precision and sensitivity; professional scientist (biologist, hydrologist) not required
2	Visual observation of habitat characteristics and simple assessment; use of land use maps for characterizing watershed condition; reference condition pre-established by professional scientist	Limited to annual visits and non-specific to season; generally easy access; limited spatial coverage and/or site-specific studies	Low precision and sensitivity; professional biologist or hydrologist not involved, or only correspondence
3	Visual-based habitat assessment using SOPs; may be supplemented with quantitative measurements of selected parameters; conducted with bioassessment; data on land use compiled and used to supplement assessment; reference condition used as a basis for assessment	Assessment during a single season usually the norm; spatial coverage may be limited or broad and commensurate with biological sampling; assessment may be regional or site-specific	Moderate precision and sensitivity; professional biologist or hydrologist performs survey or provides oversight and training
4	Assessment of habitat based on quantitative measurements of instream parameters, channel morphology, and floodplain characteristics; conducted with bioassessment; data on land use compiled and used to supplement assessment; reference condition used as a basis for assessment	Assessment during 1-2 seasons; spatial coverage usually broad and commensurate with biological sampling; assessment may be regional or site-specific	High precision and sensitivity; professional biologist or hydrologist performs survey and assessment

NOTE: Table is based on use in lotic systems. With some modification, these approaches would apply to other waterbody types.
[a] Level of information refers to rigor of habitat assessment, where 1 = lowest and 4 = highest.
[b] Refers to ability of endpoints to detect impairment or to differentiate along a gradient of environmental conditions.
[c] WBS assessment type codes from Table 1-1.

EPA 1989, Barbour and Stribling 1991, 1994, Rankin 1991, 1995, Raven et al. 1998). The key element to implementing these methods for Level 2 is to adhere to strict protocols and training to reduce subjectivity and investigator bias in the method. *In situ* measurements of temperature, canopy cover, and flow, as well as pebble counts for estimates of substrate typing, may accompany habitat assessment. However, most quantitative measurements are lacking in Level 2. EPA recommends using this level to support listing and delisting decisions when field crews are well trained in using the habitat assessment technique, the judgment criteria are calibrated for the stream classes under study, and periodic quality assurance checks are conducted (U.S. EPA 1999). The level of uncertainty and potential for decision errors may be reduced over time by regionalizing the habitat assessment protocols and criteria to reflect conditions in localized reference waterbodies.

Level 2 in Table 8-1 represents visual assessment methods that score the quality of the habitat feature being evaluated, based on the expertise of trained stream ecologists. In the RBPs, parameters are visually assessed and rated on a numerical scale of 0 to 20 (highest) for each sampling reach (U.S. EPA 1989). The ratings are then totaled and compared to a geographically calibrated reference condition to provide a final habitat ranking. Scores increase as habitat quality increases. To ensure consistency in the evaluation procedure, descriptions of the physical parameters and relative criteria are included in the rating form.

The ability to accurately assess the quality of the physical habitat structure using any visual-based approach depends on several factors (U.S. EPA 1999):

- The parameters selected need to represent the various relevant features of habitat structure.

- A clearly defined continuum of conditions for each parameter must exist and the parameter must be characterized from the optimum for the region or stream type under study to the poorest situation reflecting substantial alteration from anthropogenic activities.

- The judgment criteria for the attributes of each parameter should minimize subjectivity through either quantitative measurements or specific categorical choices.

- The investigators need to be experienced in, or adequately trained for, stream assessments in the region under study.

- Adequate documentation and ongoing training must be maintained to evaluate and correct errors.

In the RBPs, habitat evaluations are made on a combination of instream habitat, channel morphology, bank structural features, and riparian vegetation for a total of 10 parameters that vary according to stream gradient (two categories, high or low gradient).

- Epifaunal substrate/available cover, high and low gradient
- Embeddedness, high gradient
- Pool substrate characterization, low gradient

- Velocity/depth combinations, high gradient
- Pool variability, low gradient
- Sediment deposition, high and low gradient
- Channel flow status, high and low gradient
- Channel alteration, high and low gradient
- Frequency of riffles (or bends), high gradient
- Channel sinuosity, low gradient
- Bank stability, high and low gradient
- Bank vegetative protection, high and low gradient
- Riparian vegetative zone width, high and low gradient

Generally, a single comprehensive assessment is made that incorporates features of the entire sampling reach as well as selected features of the catchment. Additional assessments may be made on neighboring reaches to provide a broader evaluation of habitat quality for the stream ecosystem. The actual habitat assessment process involves rating the 10 parameters as optimal, suboptimal, marginal, or poor based on the criteria included on the Habitat Assessment Field Data Sheets. Some state programs, such as the Florida Department of Environmental Protection (Florida DEP1996) and Mid-Atlantic Coastal Streams Workgroup (MACS) (U.S. EPA 1996), have adapted this approach using somewhat fewer and different parameters.

8.3.3 Level 3: Visual-Based Assessment of Habitat With Quantitative Measurements

Level 3 methods are similar to those described in Level 2 in that they provide a rapid, visual-based habitat assessment approach, designed to describe the overall quality of the physical habitat. However, in addition to the visual-based assessment, Level 3 methods are supplemented with Level 4 quantitative measures of channel dimensions, substrate size and type, habitat characteristics, or riparian features. These quantitative methods are more fully described in Level 4. Of particular importance are measurements of sediment loads and excess water temperatures. As described in Table 8-1, the data produced by Level 3 methods are a more reliable description of the habitat at a site than the data produced by Level 1 or 2 methods.

8.3.4 Level 4: Quantitative Assessment of Habitat

Level 4 contains the most quantitative techniques (Table 8-1) that incorporate measurements of various features of the instream, channel, and bank morphology such as the Environmental Monitoring and Assessment Program (EMAP) of EPA and the National Water Quality Assessment Program (NAWQA) of the U.S. Geological Survey (Meader et al. 1993, U.S. EPA 1994c, 1999). These techniques provide a relatively comprehensive characterization of the physical structure of the stream sampling reach and its surrounding floodplain. Quantitative habitat assessments require detailed measurements of stream components by trained biologists and hydrologists. Because Level 4 methods require a high level of expertise and because measurements are detailed and extensive, the data produced by these methods exhibit high precision and reliability. The components that are measured according to EMAP surface waters physical habitat protocol (U.S. EPA 1999b) include:

- Longitudinal profile
- Large woody debris
- Channel and riparian cross-sections
- Discharge

Assessment of these stream components according to EMAP guidelines requires detailed measurements. For longitudinal profile assessment, aquatic habitat is classified and 11 cross-sectional measurements for soft/small sediment and 11 wetted width cross-sectional measurements are taken. To assess large woody debris, size classes of woody debris are counted. For channel and riparian analyses, within 11 cross-sectional areas, measurements are taken of channel dimensions and channel morphologic characteristics, substrate size and type, habitat complexity, and nearby human disturbances. For discharge calculations, 15-20 measurements of depth and velocity are taken at equally spaced intervals across one appropriately chosen cross-section.

In most quantitative methods, these data are then condensed to stream reach summaries that describe particular aspects of physical habitat. Some of these metrics calculated according to EMAP methods include:

- Channel morphology statistical summaries
- Channel cross-section and bank morphology
- Sinuosity
- Slope
- Residual pool analysis (useful for measuring sediment loadings)
- Substrate size and composition
- Bed substrate stability
- Fish cover
- Large woody debris
- Riparian canopy cover (useful for interpreting excess water temperatures)
- Riparian vegetation structure
- Riparian human disturbances

As with the biological data, reference conditions are established as benchmarks and the habitat metrics for test sites are compared to these reference conditions to assess habitat condition and identify impairments. Level 4 habitat assessments include measurements of sediment loadings and excess temperatures.

8.4 How Does the State Analyze Habitat Data To Determine WQS Attainment?

Habitat quality is a required and integral element of water resource integrity. It is clearly an important limiting factor for aquatic biota. However, the lack of consensus on how to quantify and evaluate habitat has hampered the application of indicators of habitat quality, especially in water resource management. Much of the work on habitat to date has focused on the objective of describing potential fisheries (salmonid) production and limits to this production. This is a narrower objective than describing physical/biological integrity under the CWA.

Any credible and feasible approach for use of habitat indicators should include a clear statement of the use of habitat indicators within the context of the CWA and relevant state laws and if not documented in the WQS, should be documented in the assessment and listing methodology. Habitat may or may not be the sole indicator of WQS attainment in state law, however, how it is used in conjunction with other parts of the appropriate standard should be documented. Application of habitat indicators at an appropriate scale and stratification should be meaningful in comparison to reference conditions, with an emphasis on quantitative measures. Using habitat structure as a direct measure of water resource integrity will improve the linkage to diffuse source activities (Bauer and Ralph 1997). Poff and Ward (1990) address the rationale for using physical habitat as a template for stream biota:

> *In lotic ecosystems, physical habitat structure is of critical importance to the distributions and abundances of organisms. In general, greater spatial heterogeneity at the scale of the organisms results in greater microhabitat and hydraulic diversity and hence in greater biotic diversity.*

Bauer and Ralph (1997) suggest a two-part approach (coarse and fine scale) in the development of habitat indicators. In the first part, habitat indicators should be developed at the coarse ecoregional scale and can serve as default numerical indicators until such time that a finer scale analysis determines they are inappropriate. Habitat quality indicators can be developed from reference condition data in much the same way as biological indicators, and the same limitations will apply to any given approach. The selection of habitat parameters should be evaluated in a manner similar to the selection of biological metrics. The most efficient way to select habitat parameters is to review the existing literature and evaluate existing data for responsiveness of habitat parameters to changes in human influence.

In the second part, indicators should be developed at a finer scale (i.e., from basin to watershed scale). Indicators at a finer scale reduce the problems of resolution associated with larger scale indicators. The two scales of indicators are complementary and should proceed at the same time. Development of indicators at small scales is time-consuming and costly. However, the depth of knowledge that these indicators can provide cannot be replaced by indicators at the larger scale. Because of the importance of stream gradient in categorizing a waterbody (by virtue of its relationship to landform, topography, geological formations, elevation, etc.), the RBPs included different protocols for riffle/run prevalence (high gradient) and glide/pool prevalence (low gradient).

8.4.1 Natural Classification of Waterbodies

Classification helps to evaluate the natural variability in waterbodies and to distinguish natural variability from that of human-induced changes. States should separate the data into different categories so that comparisons and evaluations are made on “like” data. However, too many classification categories can make water resource management cumbersome and difficult to explain to the public. Classification of waterbodies occurs at many scales. First there is the coarsest level, which is merely separating data into waterbody types such as lakes, streams and small rivers, large rivers, wetlands, and estuaries. Next, within any given type, it is usually necessary to further classify waterbodies into homogeneous groups to characterize how ecosystems differ (among the groups) in ecologically important attributes. It would be highly unlikely that any state would be so homogeneous that the physical habitat condition of a particular waterbody type would be uniform throughout the state.

Recent research has suggested that classification consisting of a combination of landscape and physical stream features is an effective approach (Waite et al. 2000, Hawkins et al. 2000). One of the most common landscape classifications is ecoregions. Ecoregions are areas of relative ecosystem homogeneity (or similar quality) defined by similarity of land form, soil, vegetation, hydrology, and general land use. For example, the physical habitat of streams of a given ecoregion are more similar to one another than they will be to streams in another ecoregion. However, ecoregions are not the only method for classifying freshwater ecosystems. Hawkins et al. (2000) point out that the amount of biotic variation related to landscape features is not large, and augmenting classifications based on local habitat features accounts for substantially more variation than the larger scale environmental features. Some states have used other landscape factors such as elevation and rainfall to classify their waterbodies (Spindler 1996).
Stream classification is usually based on a combination of physical features that are used to categorize streams into similar groups. Waite et al. (2000) found that variables such as stream order, stream gradient, or other physical features strengthened classifications based on combinations of ecoregions and catchment. It is likely that classifications will differ regionally in order to obtain the greatest precision and resolution for water quality management. Classifications are improved if collaborations across jurisdictional boundaries are implemented to enhance ecological resolution.

Stream classification is helpful to evaluate the natural variability in streams and distinguish it from human-induced changes (Barbour and Stribling 1991). In the western United States, classification systems are gaining wide use among land managers and other water resource management agencies (Naiman et al. 1992). The two most commonly used systems are those of Montgomery and Buffington (1993) and Rosgen (1985). Montgomery and Buffington (1993) developed a system as part of the State of Washington's Timber, Fish, and Wildlife agreement, and it classifies streams as sediment source, transport, and response (deposition). Rosgen (1985) developed a classification system based on geomorphic and in-channel characteristics. Features of this system include channel gradient, sinuosity, width/depth ratio, bed material, entrenchment, channel confinement, soil erodibility, and bank stability. Rosgen's system is also used to evaluate channel stability. Rosgen's stream-type classification system has been used widely in the west for over ten years (Naiman et al. 1992).

- Level 1 information—no classification of ecosystems done.

- Level 2 information—classification minimal and limited to individual watersheds or basins. May not recognize stream continuum principles where headwaters differ in function from mainstem. In estuaries and lakes, classification may be portions or embayments; however, habitat structure in large ecosystems not well defined.

- Level 3 information—classification done to recognize geographical or other similar organization. Usually based on landscape features and supplemented with instream or other waterbody characteristics.

- Level 4 information—combination of landscape features and physical habitat structure of waterbody type to provide the best classification scheme for assessment.

8.4.2 How Does the State Establish Reference Conditions?

Reference conditions serve as a benchmark for assessing physical habitat condition and establishing water quality goals. The reference condition can be derived from reference sites or some empirical model of expectations that may include knowledge of historical condition or extrapolation from ecological principles. The norm is to use actual sites that represent best attainable conditions of a waterbody, as is done with biological data. In fact, the same reference conditions are often used for habitat and biological data. The discussion of reference conditions in Chapter 5 also applies to those established for assessing physical habitat.

- Level 1 information (See Table 8-1)—no formal reference condition may exist. Professional opinion may be used to support assessment of quality of site and may be unacceptable for listing and delisting if not supported by scientific evidence.

- Level 2 information—reference conditions may be pre-established by professional and based on known physiography of area. Assessments are based on a percentage of reference condition (usually determined by a composite of regional sites) or percentage of maximum score of assessment method.

- Level 3 information—reference condition is regional and/or oriented toward watershed-scale assessments. Regional reference sites are likely developed for the relevant waterbody type and are the basis for habitat assessment and monitoring of changes.

- Level 4 information—regional reference conditions established for each waterbody class and consist of sites and/or other means of establishing regional expectations for assessment of habitat quality.

8.4.3 Data Analysis

Habitat assessment data are important for measuring the attainment of WQS for the protection of aquatic life. The level of effort and approach to data analysis should be commensurate with the specific objectives of the study and level of sampling effort. The lower levels of effort require limited data assessment and, as such, may yield a greater level of uncertainty surrounding WQS attainment decisions. The higher levels of effort, which support the determination of attainment or nonattainment, the development of numeric criteria for physical attributes associated with habitat, and the refinement of assessment methods, may require more rigorous data analyses. The rapid bioassessment protocols describe data assessment and interpretation applicable to the rapid, visual-based methods (U.S. EPA 1999). Procedures for calculating habitat metrics that are useful for making comparisons among sites or against a baseline or reference condition are described in U.S. EPA 1999b.

- Level 1 information—no formal habitat assessment endpoint is established. Assessment may be based on only on the best professional judgment of the investigator.

- Level 2 information—a habitat assessment endpoint is established for specific waterbodies, but may not be calibrated to waterbody classes or statewide application. Watershed monitoring should be conducted where regional reference conditions have not been established.

- Level 3 information—a habitat assessment has been developed and calibrated for use throughout the state or region for the various classes of a given waterbody type. Index is usually relevant to both quantitative and visual-based measures, but may or may not be applicable among several states or tribes.

- Level 4 information—quantitative habitat measurements are used to assess the physical habitat structure. Based on regional and geomorphological expectations, various degrees of impairment are determined.

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