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DIVISION OF ENVIRONMENTAL QUALITY
ENVIRONMENTAL SERVICES PROGRAM
Project Procedure

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Table of Contents

1.0 Introduction 4
2.0 Stream Reach Considerations 6
3.0 Riffle/Pool Prevalence 6
3.1 Epifaunal Substrate/Available Cover 6
3.2 Embeddedness 7
3.3 Velocity/Depth Regime 9
3.4 Sediment Deposition 9
3.5 Channel Flow Status 10
3.6 Channel Alteration 11
3.7 Riffle Quality 11
3.8 Bank Stability 12
3.9 Bank Vegetative Protection 13
3.10 Riparian Vegetative Zone Width 14
4.0 Glide/Pool Prevalence 15
4.1 Epifaunal Substrate/Available Cover 15
4.2 Pool Substrate Characterization 16
4.3 Pool Variability 16
4.4 Sediment Deposition 16
4.5 Channel Flow Status 17
4.6 Channel Alteration 17
4.7 Channel Sinuosity 18
4.8 Bank Stability 18
4.9 Bank Vegetative Protection 19
4.10 Riparian Vegetative Zone Width 20
5.0 Physical Characterization/Water Quality 21
5.1 General Information 21
5.1.1 Date 21
5.1.2 Time 21
5.1.3 Locational Data 21
5.1.4 USGS#/Reach# 21
5.1.5 Water Body Identification Number (WBID) 21
5.1.6 Legal Coordinates 21
5.2 Physical Features 21
5.2.1 Drainage Area 21
5.2.2 Gradient 22
5.2.3 Velocity and Discharge 22
5.2.4 Stream Order 22
5.3 Water Quality 22
5.3.1 Temperature 22
5.3.2 Dissolved Oxygen 22
5.3.3 pH 22
5.3.4 Conductivity 23
5.3.5 Alkalinity 23
5.3.6 Hardness 23
6.0 Literature Cited 24

Uncontrolled Document

List of Appendices

Appendix A - Riffle/Pool Habitat Assessment Form 29
Appendix B - Glide/Pool Habitat Assessment Form 32
Appendix C - Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms 35
Appendix D - Physical Characterization/Water Quality Data Form 38

List of Figures and Tables

Figure 1 – Habitat vs. Biological Condition (Plafkin et al. 1989) 5
Table 1 – Epifaunal Substrate/Available Cover Scoring Criteria 7
Table 2 – Embeddedness Scoring Criteria 7
Figure 2 – Example of Embeddedness 8
Table 3 – Velocity/Depth Regime Scoring Criteria 9
Table 4 – Sediment Deposition Scoring Criteria 10
Table 5 – Channel Flow Status Scoring Criteria 10
Figure 3 – Upper and Lower Bank 11
Table 6 – Channel Alteration Scoring Criteria 11
Table 7 – Riffle Quality Scoring Criteria 12
Table 8 – Bank Stability Scoring Criteria 13
Table 9 – Vegetative Protection Scoring Criteria 14
Table 10 – Riparian Vegetative Zone Width Scoring Criteria 14
Table 11 – Epifaunal Substrate/Available Cover Scoring Criteria 15
Table 12 – Pool Substrate Characterization Scoring Criteria 16
Table 13 – Pool Variability Scoring Criteria 16
Table 14 – Sediment Deposition Scoring Criteria 17
Table 15 – Channel Flow Status Scoring Criteria 17
Table 16 – Channel Alteration Scoring Criteria 18
Table 17 – Channel Sinuosity Scoring Criteria 18
Table 18 – Bank Stability Scoring Criteria 19
Table 19 – Vegetative Protection Scoring Criteria 20
Table 20 – Riparian Vegetative Zone Width Scoring Criteria 20

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1.0 Introduction

This procedure is designed to support the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (MDNR 2012a) by providing a standardized manner of assessing physical habitat quality in the permanent wadeable streams of Missouri. The assessment of stream habitat supports understanding of the relationship between habitat quality and the biological community. Such assessments identify obvious constraints on the attainable biological potential of the site, assist in the selection of appropriate sampling stations, and provide basic information for interpreting biological survey results.

The act of estimating or determining the significance, importance, or worth of an item on a scale of values is the definition of an assessment. The basis of stream habitat assessment lies in the measurement of quantitative and qualitative features that are recorded on the Physical Characterization/Water Quality Data Form (Appendix D) and the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms (Appendix C). The information collected is then used to score a number of habitat parameters on the Riffle/Pool Habitat Assessment Form (Appendix A) or the Glide/Pool Habitat Assessment Form (Appendix B).

During macroinvertebrate surveys, the physical habitat of a study location is compared to the physical habitat of other locations that have as little disturbance as possible (reference sites). These reference sites may be selected from a nearby reference stream or from reference streams [Table I in the Missouri Water Quality Standards (MDNR 2014) in the same ecoregion. When selecting reference sites, the investigator must make a decision whether the habitat quality of a study site is comparable to the habitat quality of a reference site. The total score from the physical habitat assessment of the study sites is expected to be from 75% to 100% similar to the total score of the reference site in order to fully support a comparable biological community.

Habitat assessment categories are as follows:

1) Comparable to Reference	≥90%
2) Supporting	75-89%
3) Partially Supporting	60-74%
4) Non-supporting	<59%

If the investigator has a concern that very similar total scores between sites were derived from several widely different individual parameters, a percent parameter similarity can be calculated from the Riffle/Pool or Glide/Pool Habitat Assessment Forms. The first step in determining percent parameter similarity is to convert all 10 parameter scores on each habitat assessment form to percent of the total. The lowest percent score from each parameter is selected and the 10 scores are added together. The percent parameter similarity will total between 0 and 100 percent. Percent parameter similarity is to be used only as secondary support of total score comparability.

Assuming that water quality and quantity remains constant over time, the theoretical relationship between physical habitat quality and biological condition is somewhat linear, as illustrated in Figure 1 (Plafkin et al. 1989). On the horizontal axis, habitat is shown to vary from poor to optimal, relative to reference conditions. The quality of the habitat can range from 0% to 100% of the reference, and can be categorized as non-supporting, partially supporting, supporting, or

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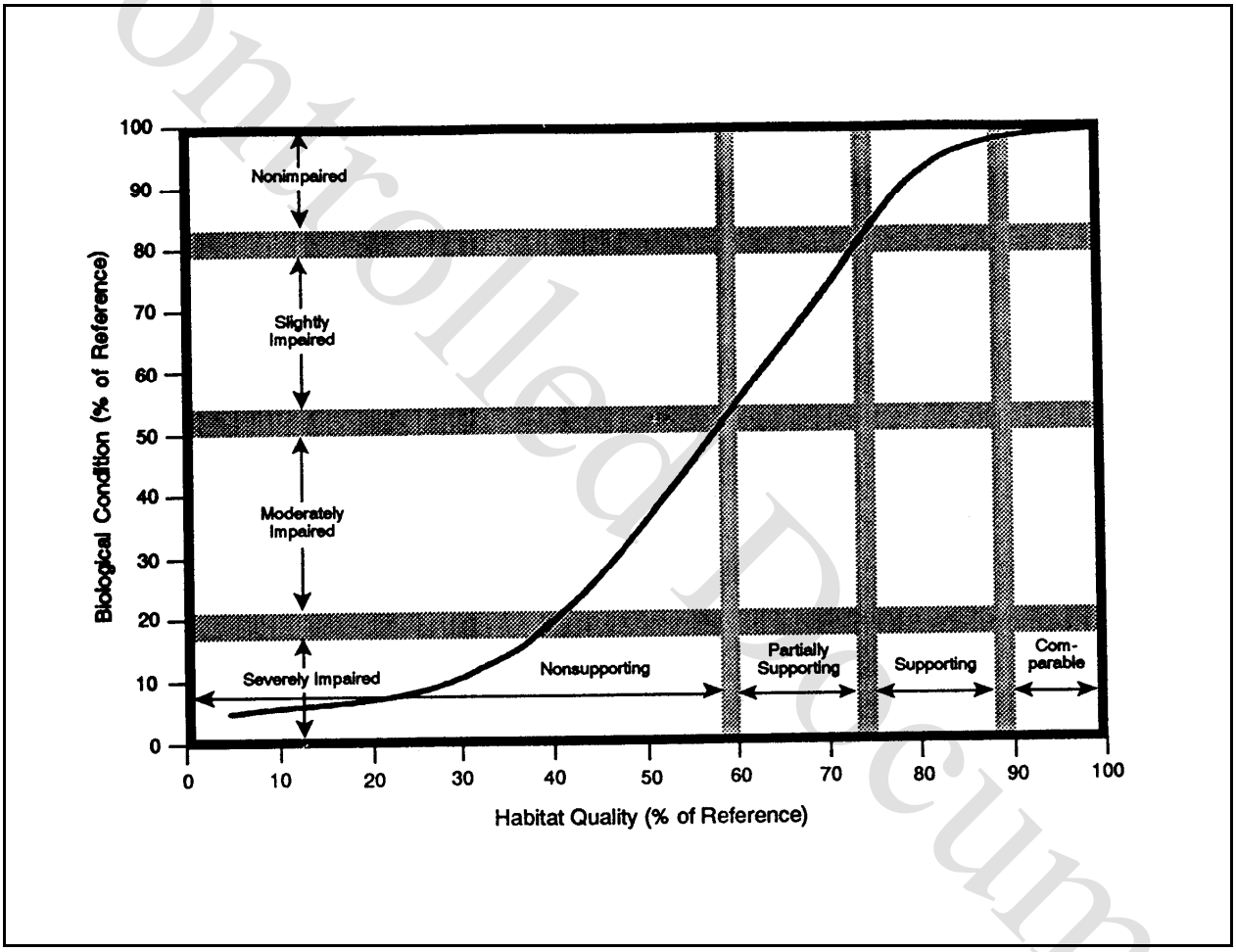
comparable. On the vertical axis, biological condition is also shown to vary from poor to optimal, relative to reference conditions. The quality of the biological community can range from 0% to 100% percent of the reference, and can be categorized as severely impaired, moderately impaired, slightly impaired, or non-impaired (Barbour and Stribling 1991).

The actual orientation of the relationship line between habitat quality and biological condition is not fixed and in different ecological regions of Missouri may differ in the degree of linearity, slope, and y-intercept.

Figure 1
Habitat vs. Biological Condition (Plafkin et al. 1989)



This habitat assessment procedure is a modified version of the High Gradient and Low Gradient Habitat Assessment found in the Rapid Bioassessment Protocols (Barbour et al. 1999). The Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program (MDNR, DEQ, ESP) has modified the assessment devices to increase the precision and to reflect the conditions in Missouri.

Minimum qualifications of individuals who perform assessments as described in this procedure should be a Bachelor of Science in a biological field along with at least one year of training under

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a senior aquatic biologist. Assessments should be done only when flow and depth conditions do not impair the ability of the investigator to efficiently or safely work in the stream.

2.0 Stream Reach Considerations

The length of stream evaluated for habitat is equal to a distance of approximately 20 times the average width of the stream. The average width of a stream is determined by randomly selecting five cross section transects along the survey reach. At each transect, the width of the stream at the top of the lower bank is measured. See Section 3.5 (Figure 3) for an example of the lower bank. After the average width is calculated, the study reach is defined by measuring and marking 10 sections of stream, each equal to two average stream widths.

3.0 Riffle/Pool Prevalence

Riffle/pool habitat assessment is appropriate for wadeable streams having a high gradient and a prevalence of riffles and runs, such as streams found in the Ozarks aquatic region (Missouri Resource Assessment Partnership 2000). Further explanation of each parameter is provided in the following sections. Data gathered for some parameters are recorded on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms (Appendix C) and later converted to a numeric score on the Riffle/Pool Habitat Assessment Form (Appendix A). For consistency it is helpful if all study team members are involved in the scoring process.

3.1 Epifaunal Substrate/Available Cover: Bottom substrate/instream cover refers to the availability of adequate habitat for a variety of aquatic benthic macroinvertebrates. Good habitat is provided by substrate that is stable and/or substrate with adequate interstitial space. The presence of cobble and coarse gravel incorporated into a heterogeneous mixture with small gravel is considered to be optimal for creating good interstitial space. Wentworth's (1922) substrate particle size classification system is used to define cobble as 6-26 cm (2.5-10 inches) and coarse gravel as 3-6 cm (1.25-2.5 inches). Instream materials such as boulders, large woody debris, snags, tree roots, submerged and emergent vegetation, and undercut banks provide stable habitat on which a diverse assemblage of macroinvertebrates can also be found.

This parameter is scored by estimating the percent area of each of the 10 stream sections that has stable substrate and/or a cobble/large gravel mixture. Each estimate is recorded on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms (Appendix C). After all 10 sections are completed, the numbers are summed to arrive at a number between 1 and 1,000. This sum is multiplied by 0.1 to convert to the percentage of the total stream reach, and an appropriate score is assigned to the Riffle/Pool Habitat Assessment Form using criteria from Table 1.

Selected References: Wesche et al. 1985, Pearsons et al. 1992, Gorman 1988, Rankin 1991, Barbour and Stribling 1991, Plafkin et al. 1989, Platts et al. 1983, Osborne et al. 1991, Benke et al. 1984, Wallace et al. 1996, Barbour et al. 1999.

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Table 1 - Epifaunal Substrate/Available Cover Scoring Criteria

Percent of stream with stable substrate and/or cobble/large gravel substrate	Score
>50%	16-20
50%-30.1%	15-11
30%-10.1%	10-6
10%-0%	5-0

3.2 Embeddedness: Embeddedness refers to how much of the surface area of large substrate particles is surrounded by fine sediment or sand. Higher levels of sediment are thought to be correlated with lower biotic productivity. Platts et al. (1983) first used the term embeddedness to rate the degree that large channel or riffle particles (boulder, cobble, and large gravel) were surrounded or covered by fine sediments. They initiated the use of a five point rating system to assess embeddedness based upon how much surface area of the larger particles was covered by fine sediments. A modified version of measuring embeddedness (Huggins and Moffett 1988) is to estimate the cross section area that is embedded. Often the embedded portion of the large particles is distinct due to the lack of periphyton growth or color differences resulting from conditions associated with the fine sediment.

This parameter is scored by randomly selecting 16 pieces of surface cobble or large gravel from at least two riffle areas. Each piece is evaluated by picking it up, viewing it from the side, and estimating the percent of the cross section that was embedded (see the example in Figure 2). The percentage embeddedness is recorded on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms, then each is assigned to one of four general categories. After all 16 pieces have been evaluated, the predominant category is selected and an appropriate score is assigned to the Riffle/Pool Habitat Assessment Form using criteria from Table 2.

Selected References: Ball 1982, Osborne et al. 1991, Barbour and Stribling 1991, Platts et al. 1983, MacDonald et al. 1991, Rankin 1991, Reice 1980, Clements 1987, Benke et al. 1984, Hawkins et al. 1982, Burton and Harvey 1990, Barbour et al. 1999.

Table 2 - Embeddedness Scoring Criteria

Predominant Category	Percent	Score
I	0-25%	20-16
II	25.1-50%	15-11
III	50.1-75%	10-6
IV	>75%	5-0

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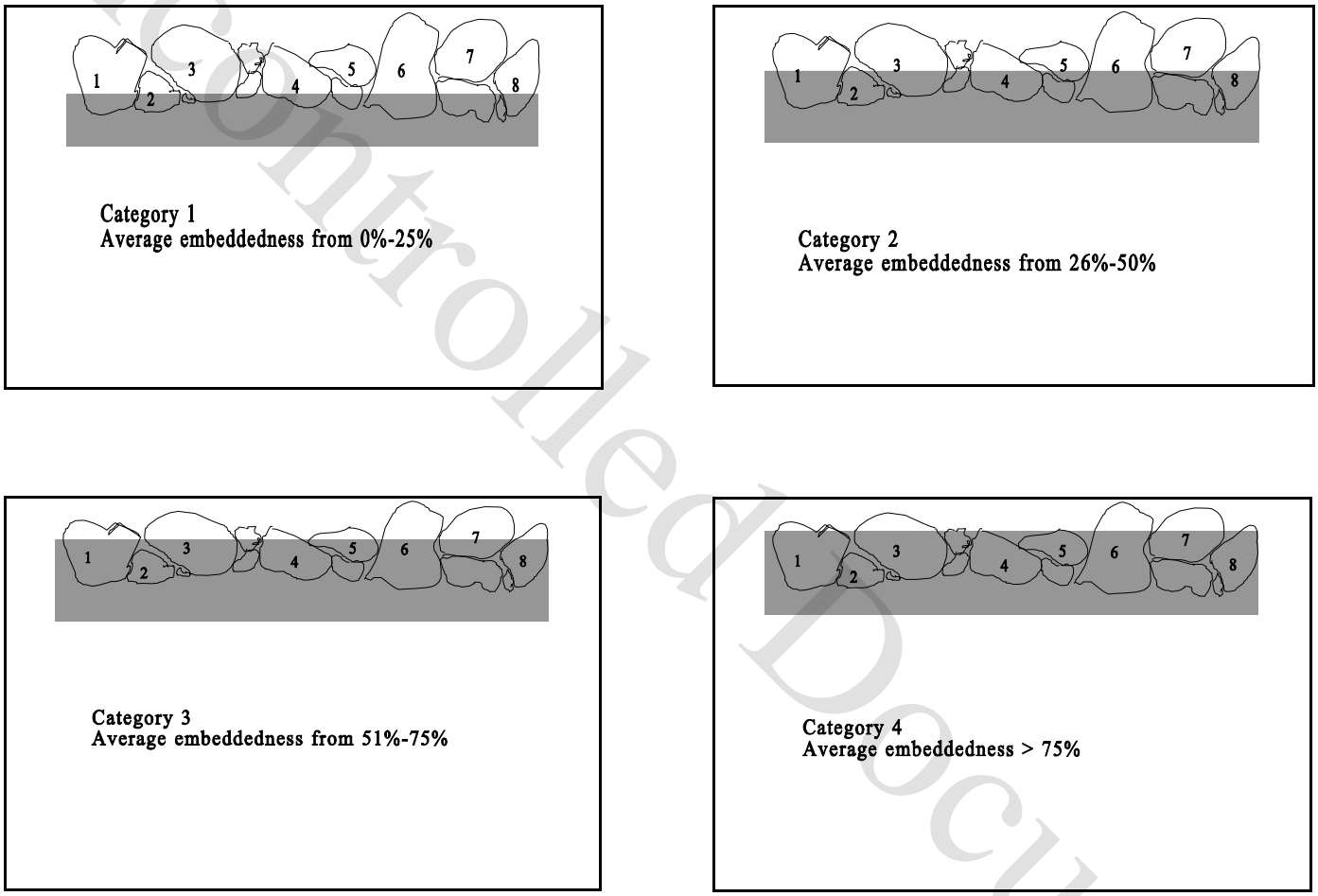
Figure 2 – Example of Embeddedness

The following figures demonstrate the categories of embeddedness. Examination of eight surface-occurring cobble-sized stones reveals that individual stones may vary in embeddedness. The predominant level of embeddedness determines the score in this example.



Example (Category 2): Examination of eight, surface-occurring, cobble-sized stones reveal that individual stones may vary in embeddedness, but the predominant level of embeddedness in this example equals Category 2 (26%-50%)

Individual Cobble	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Estimate of % Embeddedness	50	80	35	60	30	40	10	50
Category	2	4	2	3	2	2	1	2

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3.3 Velocity/Depth Regime: The size of a stream is known to influence the structure and function of its aquatic communities. This parameter rates the quality of stream flow with respect to: 1) the amount of water in small streams; and 2) the variety of velocity-depth regimes in larger streams and rivers. The presence of four general regimes of velocity and depth are optimal for benthic and fish communities: 1) slow, shallow; 2) slow, deep; 3) fast, shallow; 4) fast, deep. Definitions of velocity and depth categories are: Slow, <1 f/s; fast, >1 f/s; shallow, <1.6 ft.; and deep, >1.6 ft. Habitat quality is reduced in the absence of one or more of these categories. Characteristics of water current largely determine substrate quality and, by implication, the structure and composition of benthic communities (Minshall 1984). See MDNR-ESP-113, *Flow Measurement in Open Channels* (MDNR 2013), for information on measurement of stream velocity. Streams are scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 3.

Selected References: Hupp and Simon 1991, Ball 1982, Brown and Brussock 1991, Brussock and Brown 1991, Platts et al. 1983, Rankin 1991, Rosgen 1985, 1994, 1996, Osborne and Hendricks 1983, Hughes and Omernik 1983, Cushman 1985, Gore and Judy 1981, Bain and Boltz 1989, Gislason 1985, Hawkins et al. 1982, Oswood and Barber 1982, Statzner et al. 1988, Barbour et al. 1999.

Table 3 - Velocity/Depth Regime Scoring Criteria

Velocity/Depth Regime	Score
Slow-deep; slow-shallow; fast-deep and; fast-shallow	20-16
Three of the four regimes	15-11
Two of the four regimes	10-6
Dominated by one regime	5-0

3.4 Sediment Deposition: The character of above-water sediment deposits is an indication of the severity of watershed and bank erosion, and allows a rough estimation of stream stability. Deposits are generally found on the downstream side of rocks and logs, on the inside of bends, below channel constrictions, and where stream gradient flattens out. These deposits tend to grow in depth and length with continued watershed disturbance. An actively growing deposit can generally be recognized by lack of vegetation and the loose consistency of the depositional materials. An evaluation of bottom deposition based on an estimate of the percentage of riffle and pool substrate affected within the transect also should be included. This parameter is estimated along the entire stream reach, recorded on the worksheet, and scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 4.

Selected References: MacDonald et al. 1991, Platts et al. 1983, Ball 1982, Armour et al. 1991, Barbour and Stribling 1991, Rosgen 1985, Barbour et al. 1999.

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Table 4 - Sediment Deposition Scoring Criteria

Condition of island or point bar	Score
Little or no enlargement of island or point bars, <5% of bottom affected by sediment deposition.	20-16
Some new increase in bar formation, mostly from coarse gravel, 5-30% of bottom affected by sediment deposition.	15-11
Moderate deposition of new gravel and coarse sand on old and new bars, 30.1-50% of bottom affected by sediment deposition.	10-6
Heavy deposits of fine material, increased bar development, >50% of bottom affected by sediment deposition.	5-0

3.5 Channel Flow Status: Stream forms in Missouri vary from wide and shallow to narrow and deep. The lower bank is the intermittently submerged portion of the stream cross-section from the normal high-water line to the channel bottom and is commonly unvegetated. Within the lower bank, the water depth can exhibit a variety of width to depth ratios. The important component of stream integrity is the maintenance of a channel in which most of the available substrate is in the wetted channel. Figure 3 is a diagram that demonstrates the lower and upper banks. This parameter is scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 5.

Selected References: Rankin 1991, Rosgen 1985, Hupp and Simon 1986, MacDonald et al. 1991, Ball 1982, Hicks et al. 1991, Barbour et al. 1999.

Table 5 - Channel Flow Status Scoring Criteria

Wetted channel	Score
100% between lower banks	20-16
99.9-75% between lower banks	15-11
74.9 –25%	10-6
<25%	5-0

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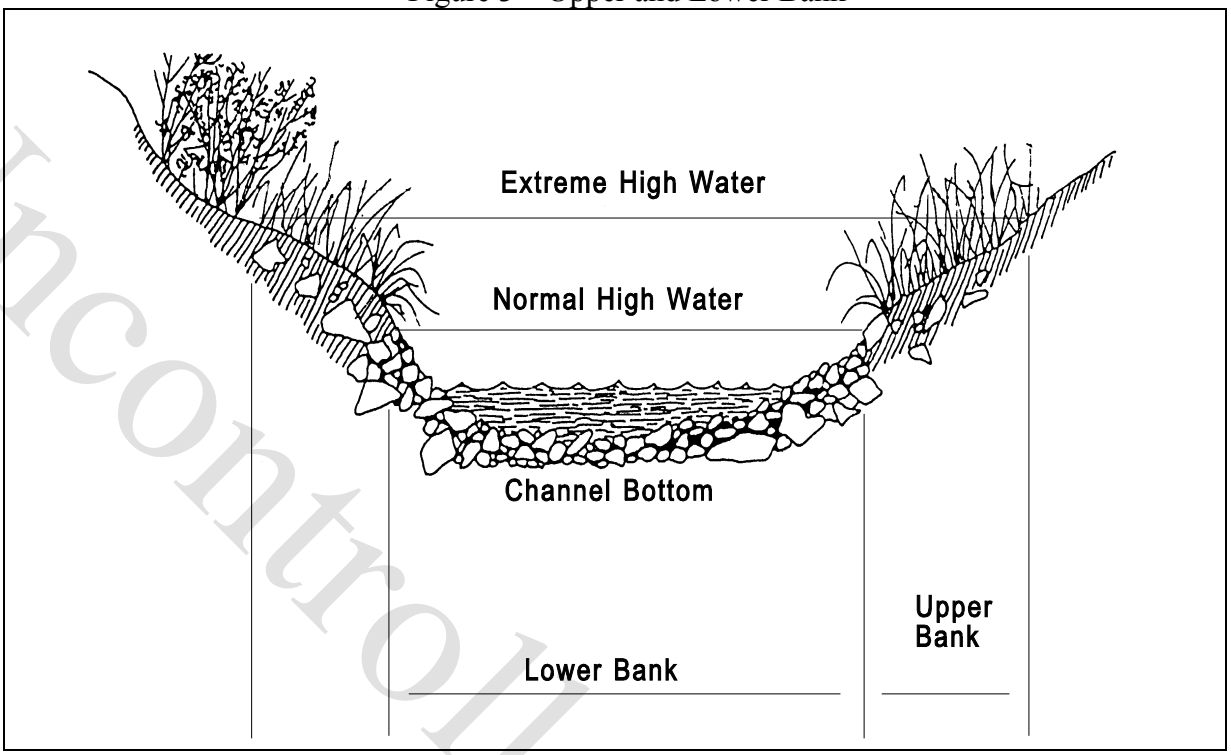
Figure 3 – Upper and Lower Bank



3.6 Channel Alteration: Channel altering activities are performed for a variety of reasons ranging from channel straightening, dredging around bridges, and the mining of gravel. All of these activities disturb the stability of the benthic substrate and the stream channel. Extreme situations can have a great effect on the upstream channel and bank stability. These processes can be ongoing or may have happened many years ago. This parameter is scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 6.

Selected References: Barbour and Stribling 1991, Simon 1989, Simon and Hupp 1987, Hupp and Simon 1986, Hupp 1992, Rosgen 1985, Rankin 1991, MacDonald et al. 1991, Barbour et al. 1999.

Table 6 - Channel Alteration Scoring Criteria

Percentage of stream reach with channel altering activity	Score
<5%	20-16
5-39.9%	15-11
40-80%	10-6
>80%	5-0

3.7 Riffle Quality: Riffle quality is essentially the microhabitat diversity of hard substrates (i.e., cobble and gravel) available for macroinvertebrates. Riffles and runs are critical for maintaining a variety and abundance of insects in most high-gradient streams and serve as spawning and

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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. This parameter is scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 7.

Selected References: Ball 1982, Osborne et al. 1991, Barbour and Stribling 1991, Platts et al. 1983, MacDonald et al. 1991, Rankin 991, Reice 1980, Clements 1987, Hawkins et al. 1982, Barbour et al. 1999.

Table 7 - Riffle Quality Scoring Criteria

Riffle condition	Score
Riffle as wide as stream and length extends two times the width of stream; abundance of cobble.	20-16
Riffle as wide as stream but length is less than two times width, abundance of cobble; gravel common.	15-11
Run area may be lacking, riffle is wide as stream and its length is less than two times the stream width; gravel or bedrock prevalent, some cobble present.	10-6
Riffles or runs virtually nonexistent; bedrock prevalent; cobble lacking.	5-0

3.8 Bank Stability: The upper bank (Figure 3) is the land area from the break in the general slope of the surrounding land to the top of the lower bank. It is normally vegetated and is covered by water in only extreme high water periods. The likelihood of erosion is usually increased with the steepness of the upper bank, since such banks often will not support vegetation. Streams with poor banks will often have poor instream habitat. Minor adjustments can be made in areas where clay composition, riprapping, or other human activities reduce erosion potential.

This parameter is evaluated by assigning both banks on each of the 10 stream sections to one of four categories on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. After all 10 sections are assigned, the predominant category is selected and scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 8.

Selected References: Ball 1982, MacDonald et al. 1991, Armour et al. 1991, Barbour and Stribling 1991, Hupp and Simon 1986, Simon 1989, Hupp 1992, Hicks et al. 1991, Osbourne et al. 1991, Rosgen 1994, 1996, Barbour et al. 1999.

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Table 8 - Bank Stability Scoring Criteria

Predominant Category	Bank condition	Right Bank Score	Left Bank Score
I	Upper banks stable and vegetated; <5% evidence of erosion or bank failure; little potential for future problems.	10-9	10-9
II	Upper bank moderately stable with small infrequent areas of erosion mostly healed over; 5-29.9% evidence of erosion or bank failure; slight erosion potential in extreme floods.	8-6	8-6
III	Upper bank unstable with moderate frequency and size of erosion areas; 30-59.9% evidence of erosion or bank failure; high erosion potential in extreme floods.	5-3	5-3
IV	Upper bank unstable with many eroded areas; "raw" areas frequent along straight sections and bends; 60-100% evidence of erosion or bank failure.	2-0	2-0

3.9 Bank Vegetative Protection: The primary concern addressed by this parameter is increased erosion due to reduced vegetation. Bank soil is generally held in place by plant root systems, although boulder, cobble, or gravel material may also provide erosional protection. Areas of higher vegetative cover receive higher ratings.

This parameter is scored by estimating the percentage of upper bank covered by vegetation in each of the 10 stream sections and recording the observation on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. When the percent vegetation for all 10 sections of each bank is completed, they are summed to arrive at a number between 1 and 1,000. This sum is multiplied by 0.1 to convert to the percentage of the total stream reach. An appropriate score for each bank is assigned to the Riffle/Pool Habitat Assessment Form using criteria from Table 9.

Selected References: Platts et al. 1983, Hupp and Simon 1986, 1991, Simon and Hupp 1987, Ball 1982, Osborne et al. 1991, Rankin 1991, Barbour and Stribling 1991, MacDonald et al. 1991, Armour et al. 1991, Myers and Swanson 1991, Barbour et al. 1999.

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Table 9 - Vegetative Protection Scoring Criteria

Vegetation	Left Bank Score	Right Bank Score
>90%	10-9	10-9
90-70%	8-6	8-6
69.9-50%	5-3	5-3
<50%	2-0	2-0

3.10 Riparian Vegetative Zone Width: The riparian vegetative zone width rates the entire riparian buffer zone on both sides of the stream. Decreasing buffer zone width is negatively correlated with shade (Lafferty 1987; Bartholow 1989), thus demonstrating its effect on water temperature, photosynthetic activity, and other temperature-dependent enzyme-mediated biological processes. Buffer strips can also slow runoff and filter organic material and sediment from entering the stream channel.

This parameter is scored by assigning each of the 10 stream sections to one of four categories and recording them on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. After all 10 sections for each bank have been recorded, the predominant category is selected and scored on the Riffle/Pool Habitat Assessment Form using criteria from Table 10.

Selected References: Barton et al. 1985, Naiman et al. 1993, Hupp 1992, Gregory et al. 1991, Platts et al. 1983, Rankin 1991, Barbour and Stribling 1991, Barbour et al. 1999.

Table 10 - Riparian Vegetative Zone Width Scoring Criteria

Predominant Category	Riparian Vegetative Condition	Left Bank Score	Right Bank Score
I	Riparian zone >18 meters	10-9	10-9
II	Riparian zone 17.9-12 meters	8-6	8-6
III	Riparian zone 11.9-6 meters	5-3	5-3
IV	Riparian zone <6 meters	2-0	2-0

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4.0 Glide/Pool Prevalence

Many of the parameters for Glide/Pool Prevalence are identical to those presented for assessment of Riffle/Pool Prevalence, except for two primary parameters and one secondary parameter. This habitat assessment is used when evaluating low gradient streams such as those found in the Mississippi Alluvial Plains and Prairie aquatic regions of Missouri (Missouri Resource Assessment Partnership 2000). Information that is ascertained from most parameters is recorded on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms and later converted to a numeric score on the Glide/Pool Habitat Assessment Form (Appendix B). For consistency, it is helpful if all study team members are involved in the scoring process.

4.1 Epifaunal Substrate/Available Cover: Bottom substrate/instream cover refers to the availability of adequate habitat for a variety of aquatic benthic macroinvertebrates. Good habitat is provided by substrate that is stable and/or substrate with adequate interstitial space. The presence of cobble and coarse gravel incorporated into a heterogeneous mixture with small gravel is considered to be optimal for creating good interstitial space. Wentworth's (1922) substrate particle size classification system is used to define cobble as 2.5-10 inches (6-26 cm) and coarse gravel as 1.25-2.5 inches (3-6 cm). Instream materials such as boulders, large woody debris, snags, tree roots, submerged and emergent vegetation, and undercut banks provide stable habitat on which a diverse assemblage of macroinvertebrates can be also found.

This parameter is scored by estimating the percent area of each of the 10 stream sections that has stable substrate and/or a cobble/large gravel mixture. Each estimate is recorded on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. After all 10 sections are completed, the numbers are summed to arrive at a number between 1 and 1,000. This sum is multiplied by 0.1 to convert to the percentage of the total stream reach, and an appropriate score is assigned to the Glide/Pool Habitat Assessment Form using criteria from Table 11.

Selected References: Wesche et al. 1985, Pearsons et al. 1992, Gorman 1988, Rankin 1991, Barbour and Stribling 1991, Plafkin et al. 1989, Platts et al. 1983, Osborne et al. 1991, Benke et al. 1984, Wallace et al. 1996, Barbour et al. 1999.

Table 11 - Epifaunal Substrate/Available Cover Scoring Criteria

Percent of stream with stable substrate and/or cobble/large gravel substrate	Score
>50%	20-16
50-30.1%	15-11
30-10.1%	10-6
10-0%	5-0

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4.2 Pool Substrate Characterization: Pools with a diverse mixture of substrates are rated higher than those with a uniform substrate. This parameter is scored on the Glide/Pool Habitat Assessment Form using criteria from Table 12.

Selected References: Beschta and Platts 1986, U.S. EPA 1983, Barbour et al. 1999.

Table 12 - Pool Substrate Characterization Scoring Criteria

Pool substrate	Score
Mixture of substrate materials with gravel and firm sand prevalent; rootmats, snags or submerged vegetation common.	20-16
Mixture of soft sand, mud, or clay; mud may be dominant; some root mats, snags, or submerged vegetation.	15-11
All mud or clay or channelized with sand bottom; little or no root mat, snags, or submerged vegetation.	10-6
Hardpan clay or bedrock; no root mat, snags, or submerged vegetation.	5-0

4.3 Pool Variability: Pool variability rates the mixture of pool sizes within a stream reach. This variability is essential in providing the habitat to support healthy aquatic communities (Platts et al. 1983). Colonization by benthic communities is in response to available habitat. A variety of pool types will allow for a diversity of benthic macroinvertebrates, representing different sensitivities and preferences. This parameter is scored on the Glide/Pool Habitat Assessment Form using criteria from Table 13.

Selected References: Beschta and Platts 1986, U.S. EPA 1983, Barbour et al. 1999.

Table 13 - Pool Variability Scoring Criteria

Pool variability	Score
Even mixture of deep, shallow, large, and small pools present.	20-16
Majority of pools large and deep; very few shallow pools.	15-11
Shallow pools much more prevalent than deep pools.	10-6
Majority of pools small and shallow.	5-0

4.4 Sediment Deposition: The character of above-water sediment deposits is an indication of the severity of watershed and bank erosion and allows a rough estimation of stream stability. Deposits are generally found on the downstream side of rocks and logs, on the inside of bends, below channel constrictions, and where stream gradient flattens out. These deposits tend to grow in depth and length with continued watershed disturbance. An actively growing deposit can generally be recognized by lack of vegetation and the loose consistency of the depositional materials. An evaluation of bottom deposition based on an estimate of the percentage of riffle

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and pool substrate affected within the transect also should be included. This parameter is estimated along the entire stream reach, recorded on the worksheet, and scored on the Glide/Pool Habitat Assessment Form using criteria from Table 14.

Selected References: MacDonald et al. 1991, Platts et al. 1983, Ball 1982, Armour et al. 1991, Barbour and Stribling 1991, Rosgen 1985, Barbour et al. 1999.

Table 14 - Sediment Deposition Scoring Criteria

Condition of island or point bar	Score
Little or no enlargement of island or point bars, <20% of bottom affected by sediment deposition.	20-16
Some new increase in bar formation, mostly from coarse gravel, 20.1-50% of bottom affected by sediment deposition.	15-11
Moderate deposition of new gravel and coarse sand on old and new bars, 50.1– 80% of bottom affected by sediment deposition.	10-6
Heavy deposits of fine material, increased bar development, >80% affected by sediment deposition.	5-0

4.5 Channel Flow Status: Stream forms in Missouri vary from wide and shallow to narrow and deep. The lower bank is the intermittently submerged portion of the stream cross-section from the normal high-water line to the channel bottom and is commonly unvegetated. Within the lower bank, the water depth can exhibit a variety of width to depth ratios. The important component of stream integrity is the maintenance of a channel in which most of the available substrate is in the wetted channel. Figure 3 is a diagram that demonstrates the lower and upper banks. This parameter is scored on the Glide/Pool Habitat Assessment Form using criteria from Table 15.

Selected References: Rankin 1991, Rosgen 1985, Hupp and Simon 1986, MacDonald et al. 1991, Ball 1982, Hicks et al. 1991, Barbour et al. 1999.

Table 15 - Channel Flow Status Scoring Criteria

Wetted channel	Score
100% between lower banks	20-16
99.9-75% between lower banks	15-11
74.9-25%	10-6
<25%	5-0

4.6 Channel Alteration: Channel altering activities are performed for a variety of reasons ranging from channel straightening, dredging around bridges, and the mining of gravel. All of these

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activities disturb the stability of the benthic substrate and the stream channel. Extreme situations can have a great effect on the upstream channel and bank stability. These processes can be ongoing or may have happened many years ago. This parameter is scored on the Glide/Pool Habitat Assessment Form using criteria from Table 16.

Selected References: Barbour and Stribling 1991, Simon 1989, Simon and Hupp 1987, Hupp and Simon 1986, Hupp 1992, Rosgen 1985, Rankin 1991, MacDonald et al. 1991, Barbour et al. 1999.

Table 16 - Channel Alteration Scoring Criteria

Percentage of stream reach channel alterations	Score
<5%	20-16
5-39.9%	15-11
40-80%	10-6
>80%	5-0

4.7 Channel Sinuosity: Channel sinuosity is defined as the ratio of channel length between two points of a channel compared to the straight-line distance between the same two points. In general, low sinuosity suggests steeper channel gradient, fairly uniform cross section, limited undercut banks, and limited pools. High sinuosity is associated with lower gradients, asymmetrical cross sections, undercut banks, and bank pools on the outside of bends. This parameter is scored on the Glide/Pool Habitat Assessment Form using criteria from Table 17.

Selected References: Hupp and Simon 1991, Ball 1982, Brown and Brussock 1991, Brussock and Brown 1991, Platts et al. 1983, Rankin 1991, Rosgen 1985, 1994, 1996, Osborne and Hendricks 1983, Hughes and Omernik 1983, Cushman 1985, Gore and Judy 1981, Bain and Boltz 1989, Gislason 1985, Hawkins et al. 1982, Oswood and Barber 1982, Statzner et al. 1988, Barbour et al. 1999.

Table 17 - Channel Sinuosity Scoring Criteria

Channel Sinuosity	Score
Instream channel length 4-3.1 times a straight line.	20-16
Instream channel length 3-2.1 times a straight line.	15-11
Instream channel length 2-1.1 times a straight line.	10-6
Channel straight or channelized.	5-0

4.8 Bank Stability: The upper bank (Figure 3) is the land area from the break in the general slope of the surrounding land to the top of the lower bank. It is normally vegetated and is covered by water in only extreme high water periods. The likelihood of erosion is usually increased with the

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steepness of the upper bank, since such banks often will not support vegetation. Streams with poor banks will often have poor instream habitat. Minor adjustments can be made in areas where clay composition, riprapping, or other human activities reduce erosion potential.

This parameter is evaluated by assigning each of the 10 stream sections to one of four categories on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. After all 10 sections are assigned, the predominant category is selected and scored on the Glide/Pool Habitat Assessment Form using criteria from Table 18.

Selected References: Ball 1982, MacDonald et al. 1991, Armour et al. 1991, Barbour and Stribling 1991, Hupp and Simon 1986, Simon 1989, Hupp 1992, Hicks et al. 1991, Osbourne et al. 1991, Rosgen 1994, 1996, Barbour et al. 1999.

Table 18 - Bank Stability Scoring Criteria

Predominant Category	Bank condition	Right Bank Score	Left Bank Score
I	Upper banks stable and vegetated; <5% evidence of erosion or bank failure; little potential for future problems.	10-9	10-9
II	Upper bank moderately stable with small infrequent areas of erosion mostly healed over; 5-29.9% evidence of erosion or bank failure; slight erosion potential in extreme floods.	8-6	8-6
III	Upper bank unstable with moderate frequency and size of erosion areas; 30-59.9% evidence of erosion or bank failure; high erosion potential in extreme floods.	5-3	5-3
IV	Upper bank unstable with many eroded areas; "raw" areas frequent along straight sections and bends; 60-100% evidence of erosion or bank failure.	2-0	2-0

4.9 Bank Vegetative Protection: The primary concern addressed by this parameter is increased erosion due to reduced vegetation. Bank soil is generally held in place by plant root systems, although boulder, cobble, or gravel material may also provide erosional protection. Areas of higher vegetative cover receive higher ratings.

This parameter is scored by estimating the percentage of upper bank covered by vegetation in each of the 10 stream sections and recording the observation on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. When percent vegetation for all 10 sections of each bank is completed, they are summed to arrive at a number between 1 and 1,000. This sum is multiplied by 0.1 to convert to the percentage of the total stream reach. An appropriate score for

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each bank is assigned to the Glide/Pool Habitat Assessment Form using criteria from Table 19.

Selected References: Platts et al. 1983, Hupp and Simon 1986, 1991, Simon and Hupp 1987, Ball 1982, Osborne et al. 1991, Rankin 1991, Barbour and Stribling 1991, MacDonald et al. 1991, Armour et al. 1991, Myers and Swanson 1991, Barbour et al. 1999.

Table 19 - Vegetative Protection Scoring Criteria

Vegetation	Left Bank Score	Right Bank Score
>90%	10-9	10-9
90-70%	8-6	8-6
69.9-50%	5-3	5-3
<50%	2-0	2-0

4.10 Riparian Vegetative Zone Width: The riparian vegetative zone width rates the entire riparian buffer zone on both sides of the stream. Decreasing buffer zone width is negatively correlated with shade (Lafferty 1987; Barthalow 1989), thus demonstrating its effect on water temperature, photosynthetic activity, and other temperature-dependent enzyme-mediated biological processes. Buffer strips can also slow runoff and filter organic material and sediment from entering the stream channel.

This parameter is scored by assigning each of the 10 stream sections to one of four categories and recording them on the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. After all 10 sections for each bank have been recorded, the predominant category is selected and scored on the Glide/Pool Habitat Assessment Form using criteria from Table 20.

Selected References: Barton et al. 1985, Naiman et al. 1993, Hupp 1992, Gregory et al. 1991, Platts et al. 1983, Rankin 1991, Barbour and Stribling 1991, Barbour et al. 1999.

Table 20 - Riparian Vegetative Zone Width Scoring Criteria

Predominant Category	Riparian Vegetative Condition	Left Bank Score	Right Bank Score
I	Riparian zone >18 meters	10-9	10-9
II	Riparian zone 17.9-12 meters	8-6	8-6
III	Riparian zone 11.9-6 meters	5-3	5-3
IV	Riparian zone <6 meters	2-0	2-0

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5.0 Physical Characterization/Water Quality

As part of the habitat assessment, a Physical Characterization/Water Quality Data Form (Appendix D) should be completed at all sites. This form has sections for recording general information, physical features, sediment quality, substrate types, water quality, periphyton characteristics, macrophyte characteristics, and photography/sketch information. Further explanation is provided for the general information, physical features, and water quality parameters.

5.1 General Information

5.1.1 Date: The date format is Day/Month/Year (example: 15 September 1995).

5.1.2 Time: The time format is HH/MM (example: 14:05).

5.1.3 Locational Data: Locational data will be collected at each study site using Geographic Positioning System equipment and will be done in accordance with current MDNR protocols.

5.1.4 USGS #/Reach #: When there is a need to refer to a stream segment that may be of interest, the USGS Reach # can be used to identify the stream section. The USGS Reach # is an eight digit number (USGS #) followed by a six digit number (Reach #). The six-digit reach number will always have zeros in the first and fourth places. These numbers are used by MDNR in the National Pollutant Discharge Elimination System (NPDES) permitting process and for location of data collected from the stream section.

5.1.5 Water Body Identification Number (WBID): The WBID is an MDNR number that corresponds to each section of stream listed in the Missouri Water Quality Standards (MDNR 2012e). In many cases the WBID represents a smaller stream section than the USGS Reach #. The WBID is a four digit number ranging from 0001 through 7358.

5.1.6 Legal Coordinates: Legal coordinates will be determined from the appropriate 1:24,000 topographic maps. They will be reported in the standard format of Section/Township/Range (example: NW1/4 NW1/4 Sec. 24, T24N, R5W).

5.2 Physical Features

5.2.1 Drainage Area: The drainage area can be closely approximated from a 1:24,000 topographic map. The drainage area can be traced on an acetate overlay by carefully outlining the highest elevation surrounding the watershed of interest. A one square mile grid can then be superimposed over the watershed area from which grids can be counted. Partial estimates can be made at the 3/4, ½, and 1/4 square mile levels. The total area is rounded off and expressed to the nearest square mile.

Alternatively, drainage area may be calculated using Geographic Information Systems (GIS) software such as ArcMap®. Because of the complexity of this operation, consultation with a GIS specialist may be required.

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5.2.2 Gradient: Gradient will be estimated using a 1:24,000 topographic map. The measurement starting point is the first intersection of the stream and a contour line upstream from the sampling site, and the endpoint is the first intersection of the stream and a contour line downstream from the sampling point. Following the course of the stream, the distance between the two contour lines is measured using a planimeter and converted to miles. The change in elevation between start and endpoint is divided by the segment length. The results are expressed as the number of feet per mile change in stream elevation. As with drainage area calculations, GIS software may be used to calculate gradient.

5.2.3 Velocity and Discharge: See the Standard Operating Procedure, *Flow Measurement in Open Channels* (MDNR 2013) for information on the determination of velocity and discharge.

5.2.4 Stream Order: Stream Order is to be determined through the use of 1:24,000 topographic maps. The first headwater stream shown is considered a first order stream. Thereafter, order is sequentially increased when two streams of the same size join (example: two first order streams joining equals a second order stream; two second order streams joining equals a third order stream; etc.). Stream orders range from one through six for permanent wadeable Missouri streams, with orders three through five being most common.

5.3 Water Quality

5.3.1 Temperature: Normal temperature measurements may be made with any good quality Celsius thermometer that is subject to regular quality control procedures. At a minimum, the thermometer should have a scale marked for every 1.0°C. Make the readings with the thermometer immersed in water long enough to complete equilibration and report the results to the nearest 0.5°C. See Standard Operating Procedure, *Field Measurement of Water Temperature* (MDNR 2010a) for more information.

5.3.2 Dissolved Oxygen: The ability of a body of water to support life is dependent on the level of dissolved oxygen (DO) contained within it. The level of DO in natural water depends on the physical, chemical, and biochemical activities in the body of water. The minimum level of DO to support aquatic life is 5.0 mg/L for cool-warm waters (6.0 mg/L for cold waters). Accurate DO levels can be determined with relative ease through the use of a membrane electrode or optical sensor meter. The manufacturer's directions for maintenance and use of the meter must be followed. See Standard Operating Procedure *Sample Collection and Field Analysis for Dissolved Oxygen Using A YSI Membrane Electrode Meter, Hach HQ40d LDO Probe, or YSI Pro Probe* (MDNR 2012b) for more information.

5.3.3 pH: The pH value of a solution represents hydrogen ion activity. Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic because of the presence of bicarbonates and carbonates of the alkali and alkaline earth metals. The most accurate field measurement is done by potentiometric measurement using a glass electrode and reference electrode, although a pH pen may be used for habitat assessment purposes. The manufacturer's directions for use and maintenance of the pH meter must be followed. See Standard Operating Procedure *Field Analysis of Water for pH* (MDNR 2012c) for more information.

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5.3.4 Conductivity: Conductivity is a numerical expression of the ability of an aqueous solution to carry an electrical current. This ability depends upon the presence of ions, their total concentration, mobility, valence, relative concentrations, and the temperature of measurement. Solutions of most inorganic acids, bases, and salts are relatively good conductors. Freshly distilled water, a poor conductor, has a conductivity of 0.5 to 2 µmhos/cm. The conductivity of potable waters in the United States generally ranges from 50 to 1500 µmhos/cm (Standard Methods for the Examination of Water and Wastewater 2005). The manufacturer's directions for the use and maintenance of the selected conductivity meter or pen must be followed. See Standard Operating Procedure *Field Analysis of Specific Conductance* (MDNR 2010b) for more information.

5.3.5 Alkalinity: Alkalinity of water is its acid-neutralizing capacity. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate, and hydroxide content, it is taken as an indicator of the concentration of these constituents. The measured value also may include contributions from borates, phosphates, silicates, or other bases if these are present. Accurate levels may be determined with relative ease through the use of compact titrimetric test kits which are based upon the procedures used in Standard Methods for the Examination of Water and Wastewater. Test kits are available from many scientific supply companies.

5.3.6 Hardness: Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter. When numerical hardness is greater than the sum of carbonate and bicarbonate alkalinity, the amount of hardness equivalent to total alkalinity is called "carbonate hardness" and the amount of hardness in excess of this is called "noncarbonate hardness." When the numerical hardness is equal to or less than the sum of carbonate and bicarbonate alkalinity, all hardness is carbonate hardness and non-carbonate hardness is absent. Approximate levels of hardness can be determined through the use of EDTA titration test kits available from many scientific supply companies.

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APPENDIX A

Riffle/Pool Habitat Assessment Form

Missouri Department of Natural Resources
Stream Habitat Assessment Procedure
Riffle/Pool Habitat Assessment Form

Date:	Analyst:	Station #: Sample #:	Location:

Habitat Parameter	Optimal	Suboptimal	Marginal	Poor
A. Epifaunal substrate/ available cover	Greater than 50% mix of cobble, large gravel, submerged logs, undercut banks, or other stable habitat. 20-16 _____	A 50-30.1% mix of cobble, large gravel, or other stable habitat. Habitat adequate for maintenance of populations. 15-11 _____	A 30-10.1% mix of cobble, large gravel, or other stable habitat. Habitat less than desirable. Substrate frequently disturbed or removed. 10-6 _____	Less than 10% mix of cobble, large gravel, or other stable habitat. Lack of habitat is obvious. Substrate unstable or lacking. 5-0 _____
B. Embeddedness	Gravel, cobble, or boulders are between 0-25% surrounded by fine sediment or sand. 20-16 _____	Gravel, cobble, or boulders are between 25.1-50% surrounded by fine sediment or sand. 15-11 _____	Gravel, cobble, or boulders are between 50.1-75% surrounded by fine sediment or sand. 10-6 _____	Gravel, cobble, or boulders are over 75% surrounded by fine sediment or sand. 5-0 _____
C Velocity/ depth regime	All four velocity/depth regimes present. Slow (<0.3 m/s) - deep (>0.5 m); slow - shallow (<0.5 m); fast (>0.3 m/s) - deep; fast-shallow. 20-16 _____	Only 3 of the 4 regimes present (if fast-shallow is missing score lower than if missing other regimes). 15-11 _____	Only 2 of the 4 regimes present (if fast-shallow or slow-shallow are missing receive lower score). 10-6 _____	Dominated by one velocity/depth regime (usually slow-deep). 5-0 _____
D. Sediment deposition	Little or no enlargement of islands or point bar and less than 5% of bottom affected by sediment deposition. 20-16 _____	Some new increase in bar formation, mostly from coarse gravel, sand or fine sediment From 5-30% of bottom affected by sediment deposits. Slight sediment deposition in pools. 15-11 _____	Moderate deposition of new gravel, sand, or sediment on old and new bars; pools partially filled with silt. From 30.1-50% of bottom affected. Deposits at obstructions, constrictions, and bends. Moderate deposition of pools prevalent 10-6 _____	Heavy deposits of fine material, increased bar development. More than 50% of the bottom changing frequently. Pools almost absent due to substantial deposition. 5-0 _____
E. Channel flow status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed 20-16 _____	Water fills 99.9-75% of the available channel; or <25% of channel substrate exposed. 15-11 _____	Water fills 74.9-25% of the available channel, and/or riffle substrates are mostly exposed 10-6 _____	Very little water in channel (<25%) and mostly present as standing pools 5-0 _____
F. Channel alteration	Channelization or dredging absent or minimal (<5%) stream with normal pattern 20-16 _____	Some channelization present (5-39.9%), usually in areas of bridge abutments; evidence of past channelization, i.e., dredging (greater than 20 years) may be present, but recent channelization is not present. 15-11 _____	Channelization may be extensive; embankments or shoring structures present on both banks; and 40-80% of stream reach channelizes or disrupted. 10-6 _____	Banks shored with gabion or cement; over 80% of the stream reach channelized or disrupted. Instream habitat greatly altered or removed entirely 5-0 _____

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G. Riffle Quality	Well developed riffle and run; riffle is as wide as stream and length extends two times the width of stream; abundance of cobble. 20-16 _____	Riffle is as wide as stream but length is less than two times width; abundance of cobble; gravel common. 15-11 _____	Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; gravel or bedrock prevalent; some cobble present. 10-6 _____	Riffles or runs virtually nonexistent; bedrock prevalent; cobble lacking. 5-0 _____
H. Bank stability - Score each bank Left Bank Right Bank	Bank stable; evidence of erosion or bank failure absent or minimal; little potential for future problems; <5% of bank affected. 10-9 _____ 10-9 _____	Moderately stable; infrequent, small areas of erosion, mostly healed over; 5-29.9% of bank in reach has areas of erosion. 8-6 _____ 8-6 _____	Moderate unstable; 30-59.9% of bank in reach has areas of erosion; high erosion potential during floods. 5-3 _____ 5-3 _____	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60- 100% of bank has erosion scars. 2-0 _____ 2-0 _____
I. Vegetative protection – Score each bank Left Bank Right Bank	More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory, or herbaceous growth; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally. 10-9 _____ 10-9 _____	90-70% of the stream bank surface covered by native vegetation; but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining. 8-6 _____ 8-6 _____	69.9-50% of the stream bank surface covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining. 5-3 _____ 5-3 _____	Less than 50% of the stream bank surface covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height. 2-0 _____ 2-0 _____
J. Riparian vegetative zone width - Score each bank Left Bank Right Bank	Width of riparian zones >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone. 10-9 _____ 10-9 _____	Width of riparian zones 17.9-12 meters; human activities have impacted zone minimally. 8-6 _____ 8-6 _____	Width of riparian zones 11.9-6 meters; human activities have impacted zone a great deal. 3-5 _____ 3-5 _____	Width of riparian zones <6 meters; little or no riparian vegetation due to human activities. 2-0 _____ 2-0 _____

Total _____

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APPENDIX B

Glide/Pool Habitat Assessment Form

Missouri Department of Natural Resources
Stream Habitat Assessment Procedure
Glide/Pool Habitat Assessment Form

Date:	Analyst:	Station #: Sample #:	Location:

Habitat Parameter	Optimal	Suboptimal	Marginal	Poor
A. Epifaunal substrate/ available cover	Greater than 50% mix of cobble, gravel, submerged logs, undercut banks, or other stable habitat. 20-16 _____	A 50-30.1% mix of cobble, gravel, or other stable habitat. Adequate habitat for maintenance of population. 15-11 _____	A 30-10.1% mix of cobble, gravel, or other stable habitat; habitat availability less than desirable. 10-6 _____	Less than 10% cobble, gravel, or other stable habitat; lack of habitat is obvious; substrate unstable or lacking. 5-0 _____
B. Pool substrate characterization	Mixture of substrate materials with gravel and firm sand prevalent; root mats, snags or submerged vegetation common. 20-16 _____	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats, snags or submerged vegetation. 15-11 _____	All mud or clay or channelized with sand bottom; little or no root mat, snags or submerged vegetation. 10-6 _____	Hardpan clay or bedrock; no root mat, snags or submerged vegetation. 5-0 _____
C. Pool variability	Even mix of large-deep, large- shallow, small-shallow, and small-deep pools present. 20-16 _____	Majority of pools large-deep; very few shallow pools. 15-11 _____	Shallow pools much more prevalent than deep pools. 10-6 _____	Majority of pools small-shallow or pools absent. 5-0 _____
D. Sediment deposition	Little or no enlargement of islands or point bars and less than 20% of bottom affected by sediment deposition. 20-16 _____	Some new increase in bar formation, mostly from gravel sand or fine sediment; 20.1-50 % of bottom affected; slight deposition in pools. 15-11 _____	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50.1-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools. 10-6 _____	Heavy deposits of fine material, increased bar development; more than 80% of bottom affected; changing frequently, pools almost absent due to substantial sediment deposition. 5-0 _____
E. Channel flow status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed 20-16 _____	Water fills 99.9-75% of the available channel; or <25% of channel substrate exposed. 15-11 _____	Water fills 74.9-25% of the available channel, and/or riffle substrates are mostly exposed 10-6 _____	Very little water in channel (<25%) and mostly present as standing pools 5-0 _____
F. Channel alteration	Channelization or dredging absent or minimal (<5%) stream with normal pattern 20-16 _____	Some channelization present (5-39.9%), usually in areas of bridge abutments; evidence of past channelization, i.e., dredging (greater than 20 years) may be present, but recent channelization is not present. 15-11 _____	Channelization may be extensive; embankments or shoring structures present on both banks; and 40- 80% of stream reach channelizes or disrupted. 10-6 _____	Banks shored with gabion or cement; over 80% of the stream reach channelized or disrupted. Instream habitat greatly altered or removed entirely 5-0 _____

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G. Channel sinuosity	The bends in the stream increase the stream length 4-3.1 longer than if it was a straight line. 20-16 _____	The bends in the stream increase the stream length 3-2.1 times longer than if it was a straight line. 15-11 _____	The bends in the stream increase the stream length 2-1.1 times longer than if it was a straight line. 10-6 _____	Channel straight; waterway has been channelized for a long distance. 5-0 _____
H. Bank stability - Score each bank	Bank stable; evidence of erosion or bank failure absent or minimal; little potential for future problems; <5% of bank affected.	Moderately stable; infrequent, small areas of erosion, mostly healed over; 5-29.9% of bank in reach has areas of erosion.	Moderate unstable; 30-59.9% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60- 100% of bank has erosion scars.
Left Bank	10-9 _____	8-6 _____	5-3 _____	2-0 _____
Right Bank	10-9 _____	8-6 _____	5-3 _____	2-0 _____
I. Vegetative protection - Score each bank	More than 90% of the stream bank surfaces and immediate riparian zone covered by native vegetation, including trees, understory, or herbaceous growth; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	90-70% of the stream bank surface covered by native vegetation; but one class of plants is not well represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	69.9-50% of the stream bank surface covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the stream bank surface covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Left Bank	10-9 _____	8-6 _____	5-3 _____	2-0 _____
Right Bank	10-9 _____	8-6 _____	5-3 _____	2-0 _____
J. Riparian vegetative zone width - Score each bank	Width of riparian zones >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zones 17.9-12 meters; human activities have impacted zone minimally.	Width of riparian zones 11.9-6 meters; human activities have impacted zone a great deal.	Width of riparian zones <6 meters; little or no riparian vegetation due to human activities.
Left Bank	10-9 _____	8-6 _____	3-5 _____	2-0 _____
Right Bank	10-9 _____	8-6 _____	3-5 _____	2-0 _____

Total _____

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APPENDIX C

Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms

Missouri Department of Natural Resources
Stream Habitat Assessment Procedure
Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms

Date:	**Analyst:**	**Station #:** **Sample #:**	**Location:**

A. Epifaunal Substrate\Available Cover

Section	1	2	3	4	5	6	7	8	9	10
%										

Total _____ (Sections 1-10) x .1 = Total Stream Reach Percentage

B. Embeddedness

Cobble	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
% Emb																
Cat.																

Category I = 0-25% Embedded
Category II = 25.1-50% Embedded
Category III = 50.1-75% Embedded
Category IV = >75% Embedded

Predominant Category

D. Sediment Deposition

Section	1	2	3	4	5	6	7	8	9	10
%										

Total _____ Sections (1-10) x .1 = Total Stream Reach Percentage

H. Bank Stability

LB Section	1	2	3	4	5	6	7	8	9	10
Category										
RB Section	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Category										

Category I = Stable. <5% bank affected.
Category II = Moderately stable. 5-29.9% of bank reach has erosion.
Category III = Moderately unstable. 30-59.9% of bank reach has erosion.
Category IV = Unstable. Many eroded areas; 60-100% of bank reach has erosion.

LB Predominant Category
RB Predominant Category

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I. Vegetative Protection

LB Section	1	2	3	4	5	6	7	8	9	10
%										
RB Section	1	2	3	4	5	6	7	8	9	10
%										

LB Total _____ Sections (1-10) x 0.1 = LB Stream Reach Percentage
RB Total _____ Sections (1-10) x 0.1 = RB Stream Reach Percentage

J. Riparian Vegetative Zone Width

LB Section	1	2	3	4	5	6	7	8	9	10
Category										
RB Section	1	2	3	4	5	6	7	8	9	10
Category										

Category I = >18 meters
Category II = 17.9-12 meters
Category III = 11.9-6 meters
Category IV = <6 meters

LB Predominant Category
RB Predominant Category

Lower bank width measurements are used to figure the 20X width sampling reach and the 10 transect segments for the Riffle/Pool or Glide/Pool worksheet. Five well-spaced measurements are taken within a stream segment.

Transect	1	2	3	4	5
Lower Bank Width					

Average Width =
Average width x 20 = _____ sampling reach length
Average width x 2 = _____ transect segment length

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APPENDIX D

Physical Characterization/Water Quality Data Form

Missouri Department of Natural Resources
Stream Habitat Assessment Procedure
Physical Characterization / Water Quality Data Form

General Information

Waterbody Name:	Station #: Investigators:
Date: Time:	Latitude: Longitude:

USGS#: Reach #:	MDNR Reach #:	Legal Coordinates:

Physical Features

Drainage Area (sq. mi.):	Gradient (ft./mi.):	Velocity (ft./sec.)	Discharge (cu. ft./sec.)

Average Riffle Width (ft.):	Average Run Width (ft.):	Average Pool Width (ft.):
Average Riffle Depth (ft.):	Average Run Width (ft.):	Average Pool Depth (ft.):

High Water Mark (ft.):	Stream Order:

Predominant Land Use: ☐ Forest ☐ Hayfield ☐ Row Crop ☐ Pasture ☐ Animal Confinement

☐ Urban Commercial ☐ Urban Industrial ☐ Suburban Residential ☐ Suburban Commercial

Other:

Human Disturbance: ☐ Access Roads ☐ Footpaths ☐ Trash ☐ Livestock Watering ☐ RV Tracks

☐ Gravel Mining ☐ Camping Sites Other:

Local Watershed Erosion:	Canopy Cover:	Estimated Water Level:	Stream Bank Vegetation:
☐ None	☐ Open	☐ Low Flow	☐ Raw ☐ Bare Areas
☐ Moderate	☐ Partly Shaded	☐ Within Lower Bank	☐ Grasses and Forbes
☐ Heavy	☐ Shaded	☐ Over Lower Bank	☐ Large Trees ☐ Trees and Shrubs

Major Habitats Present: ☐ Flow Coarse Substrate ☐ Non-flow over Deposition ☐ Snags/Woody Debris
☐ Flow Fine Substrate ☐ Leaf Packs ☐ Root Mats

Channel: ☐ Dam Present ☐ Dam Absent ☐ Channelized ☐ Natural

Point Source Pollution: ☐ Discharge ☐ No Discharge Estimated Flow:
Type of Discharge:

Non-point Source Pollution (excluding erosion): ☐ Obvious ☐ Potential ☐ No Observable
Type of NPS Pollution: Source of NPS Pollution:

Sediment

Sediment Deposits: ☐ No Deposits ☐ Sewage Sludge ☐ Silt ☐ Sand ☐ Gravel
Other Types of Deposits: Deposit thickness: Deposit Area:

Sediment Odors: ☐ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic
Other:

Sediment Odor Severity: ☐ Not Offensive ☐ Moderately Offensive ☐ Grossly Offensive

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Substrate			
Type	Approximate % of Area	Type	Approximate % of Area
Bedrock:		Woody Debris (<6 inch in diameter and 36 inches long):	
Boulder (>10 inch diameter):			
Cobble (2.5 - 10 inch diameter):		Snags (>6 inches in diameter and 36 inches in length):	
Gravel (0.1 – 2.5 inch diameter):			
Sand (<0.1 inch diameter, gritty):		Muck (Black with very fine organic matter):	
Silt:			
Compact Clay:		Total:	100%

Water Quality			
Temperature (C):	Dissolved Oxygen (mg/L):	pH:	Conductivity (µmos/L):
Alkalinity (mg/L):	Hardness (mg/L):	Other:	

Water Odors: ☐ No Odor ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Other

Water Surface Oils: ☐ No oils ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks

Turbidity: ☐ Clear ☐ Slightly Turbid ☐ Moderately Turbid ☐ Opaque | Water Color:

Periphyton

Substrate: ☐ Detached ☐ Epilithic (on rocks) ☐ Epipelic (on mud) ☐ Epiphitic (on plants)

Growth Form: ☐ Prostrate ☐ Strands Less Than 2 Inches ☐ Strands From 2 – 12 Inches ☐ Strands >12 Inches

Density: ☐ Low Density (<25% of Substrate) ☐ Moderate Density (25-75% of Substrate) ☐ High Density (>75%)

Taxa: ☐ Green Filamentous ☐ Diatoms ☐ Blue-green

Macrophytes

Growth Form: ☐ Floating ☐ Submerged ☐ Emergent ☐ No Macrophytes

Density: ☐ Rare (<10% of Area) ☐ Common (10-50% of Area) ☐ Abundant (>50% of Area)

Length of Bank Having Emergent Vegetation: | Taxa:

Photography/Sketches

☐ Photos Taken	☐ Photos Recorded in Data Log	☐ Frame Numbers:	☐ Sketch Drawn

Subject:
Direction:

Miscellaneous Information:

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