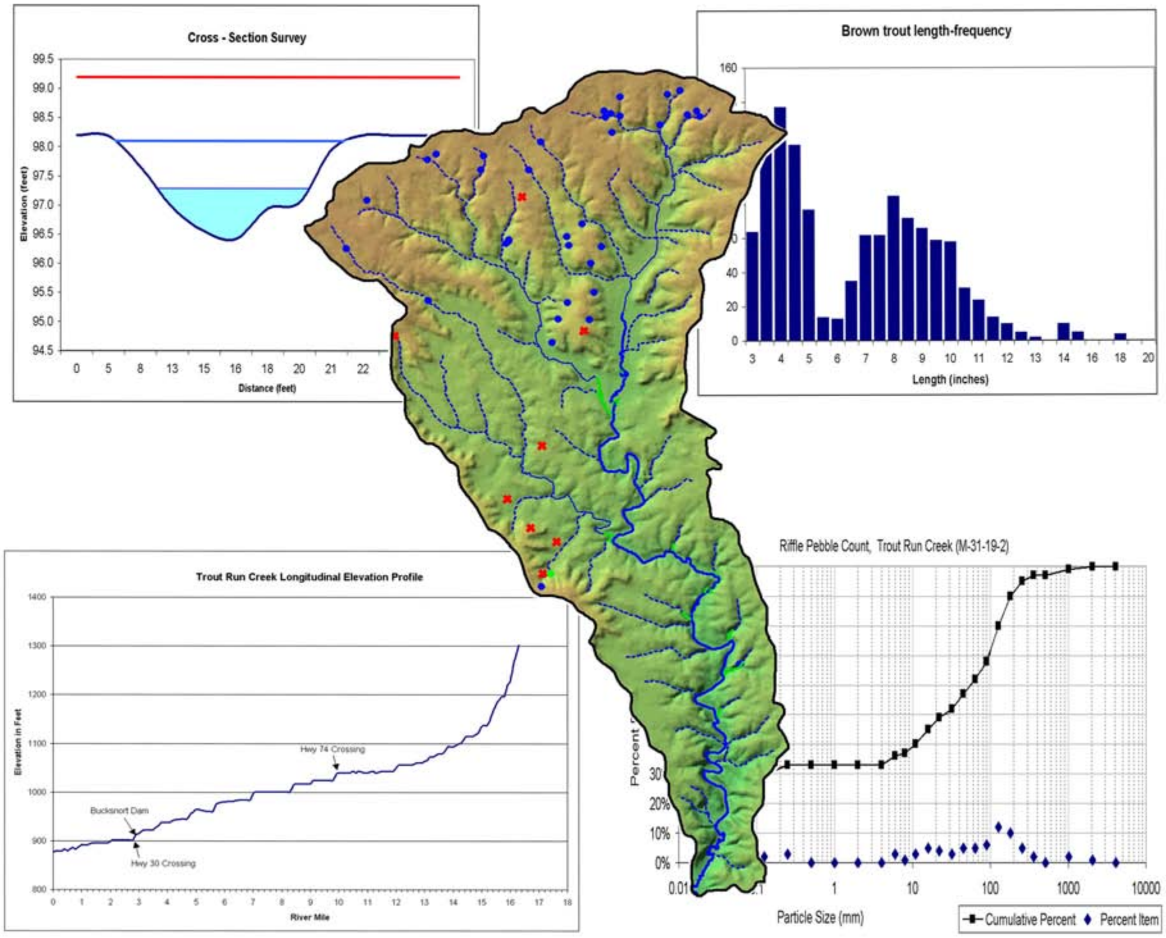
Fisheries Stream Survey Manual

Stream Survey Methods



Minnesota Department of Natural Resources
Division of Fish and Wildlife
Section of Fisheries

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Minnesota Department of Natural Resources
Division of Fish and Wildlife
St. Paul, Minnesota

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STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

March 31, 2007

To: DNR Fisheries Employees

Re: Revised Stream Survey Manual

There are an estimated 69,200 miles of streams and rivers and 21,200 miles of drainage ditches across Minnesota. This vast array of aquatic ecosystems represents some of the most diverse fish communities, important recreational fisheries, and greatest management challenges. To help meet these challenges, the Section of Fisheries Management assigned a statewide committee the task of revising and updating our stream survey manual. The charge for the group was to develop a manual that includes: 1) science-based, standard methods to understand stream ecosystems and inform management actions; 2) minimum data requirements for all stream surveys; and 3) flexibility to accommodate variability in resources.

This manual provides an organizing framework that describes the fundamental components of stream ecosystems and a logical process for collecting and analyzing information. Perhaps most important, this manual provides an iterative process for understanding streams and evaluating management actions. The iterative process starts with an initial survey, which provides fundamental building blocks by examining streams in the context of their watershed, including elements of hydrology, water quality, and connectivity in ecosystem functions. Completion of a full survey provides a more comprehensive examination of reach specific components, such as geomorphology, fish habitat, and biological communities. Finally, supplemental surveys, which are targeted sampling efforts, help address special needs or maintain long-term data sets.

The methods described herein provide the scientific rigor and repeatability to meet current challenges and anticipated future needs in fisheries management. This manual represents a necessary increase in the scope and intensity of our work in streams, while it also sets an ambitious course for a broader and more comprehensive stream management program in Minnesota. As we begin this new course in stream management, I would especially like to thank the committee members for their insight, passion, and commitment to developing a tool that helps us meet our mission.

Sincerely,

Ronald D. Payer, Chief
Fisheries Management Section

Organization of the Manual

This manual is organized into seven primary sections:

1. **Introduction** – describes some fundamental principles for planning stream surveys, such as information needs and the importance of temporal and spatial scales. The introduction includes a Quick Reference Guide and a sample timeline to help schedule office and field work.

2. **Initial Survey** – includes a phased approach to completing an initial survey, along with checklists for each of the methods, examples of maps, and completed field forms.

3. **Full Survey** – describes the methods required for a full survey, and includes checklists for each of the methods, examples of maps, and completed field forms. An initial survey must be completed before a full survey is undertaken.

4. **Supplemental Surveys** – describes how individual survey components may be used to supplement existing survey data. Supplemental surveys are not intended to replace initial and full surveys.

5. **Literature Cited**

6. **Appendices** – contains blank field forms for all of the procedures described in the manual; USGS Hydrologic Unit Code / MDNR Major Watershed conversion table; Minnesota Stream Identification System (Kittle Number); and Guidelines for the Selection and Safe Use of Electrofishing Gear.

7. **Electronic Appendices** – included on the accompanying CD to minimize the use of paper. These appendices are not essential, but may be useful references.

The manual committee highly recommends you read the introduction and skim the initial survey section to help plan your work. We also highly recommend you read the Stream Survey Manual Reference Document as a guide when planning surveys and potentially again when interpreting data and writing reports.

Some of the information needed may already be available for streams with existing surveys. Use of this information can reduce the amount of time and effort needed for completing a new survey. However, each piece of data should be reviewed to determine the likelihood of significant changes.

Table of Contents

Letter to Employees i
Organization of the Manual ii
Table of Contents iii
List of Figures vi
List of Tables x

Introduction 1
- Spatial Scales 4
  - Global Scale 4
  - Watershed Scale 6
  - Macrohabitat Scale 6
  - Mesohabitat Scale 8
  - Microhabitat Scale 8
  - Temporal Scales 8
- Sampling Fish in Streams 9
- Quick Reference Guide 11

Initial Survey 13
- Initial Survey Checklist 14
- Field Forms 15
- Hydrology 16
  - Identifying Watersheds, Watercourses and Reaches 16
  - Generating Maps 24
  - Basic Watershed Measures 34
  - Precipitation 38
  - Stream flow 38
  - Springs, seeps, sinkholes, stream sinks, discharges 39
- Geomorphology 46
  - Geomorphology Checklist 46
  - Stream and Valley Morphology 46
  - Minnesota Stream Habitat Assessment (MSHA) Methods 50
- Water Quality 65
  - Water Quality Checklist 65
  - Water Quality Methods 65
- Biology 69
  - Biology Checklist 69
  - Biology Methods 69
- Connectivity 70
  - Connectivity Checklist 70
  - Connectivity Methods 70
  - Stream crossing evaluation 72

Full Survey 73
Full Survey Checklist 73
Hydrology 74
Hydrology Checklist 74
Stream Discharge 74
Using a Flowmeter 75
Springs, seeps, sinkholes, stream sinks, discharges 78
Geomorphology and Fish Habitat 79
Geomorphology and Fish Habitat Checklist 79
Channel Geometry Measurements 81
Longitudinal Profile Survey 84
Channel Cross-Section Survey 91
Channel substrate measurements 99
Cover for Larger Fish Measurements 100
Predicting Stream Bank Erosion Rates 103
Bank Erosion Hazard Index (BEHI) 103
Near Bank Shear Stress (NBS) 107
Stream Classification 114
Assessment of Stream Condition 114
Additional Required Data 124
Water Quality 125
Water Quality Checklist 125
Water Sampling Instructions 125
Longitudinal Temperature Profile 126
Laboratory Water Quality Parameters 127
Biology 133
Biology Checklist 133
Biology Survey Methods 133
Riparian Vegetation Survey 134
Aquatic Plant Survey 138
Aquatic Invertebrate Survey 140
Fish Community Survey 144

Supplemental Surveys 155
Water Quality 155
Biology 156
Riparian Vegetation 156
Fish Aging 160
Fish Sampling 162

Literature Cited 164

Appendices 174

Contents of Appendices 174

Appendix 1. Blank Field Forms 175

Appendix 2. Table for Translating USGS Hydrologic Units and Minnesota DNR Major Watershed Numbers..............230

Appendix 3. MN Stream Identification System (Kittle number) 234

Appendix 4. Guidelines for the Selection and Safe Use of Electrofishing Gear..242

Electronic Appendices (on accompanying CD)

Appendix 5. Stream Reach Inventory and Channel Stability Evaluation: A Watershed Management Procedure (Pfankuch 1975).

Appendix 6. Stream Channel Reference Sites: An Illustrated Guide to Field Technique (Harrelson et. al. 1994).

Appendix 7. Introduction to Common Fish Diseases.

Appendix 8. Trot Line Use.

Appendix 9. Key to Fishes of Wisconsin (Becker 1983).

Appendix 10. Artificial Key to the Families of Fishes in Minnesota (Eddy and Underhill (1974).

List of Figures

1. The five components of river systems 2
2. River scale is a nested hierarchy 5
3. The Snake River system. 7
4. Riverine components function over a range of scales 10
5. Quick reference guide 11
6. Example timeline for completing a full stream survey 12
7. The four phases of completing an initial stream survey 13
8. Minnesota’s four major drainages. 17
9. Minnesota’s 81 major watersheds 18
10. Example watershed illustrating Kittle Number linkages 21
11. Example of DNR stream similar reaches 23
12. Example watershed map (Map 1) with shaded relief 25
13. Example watershed map (Map 2) with Kittle numbers and roads 26

14a. Example watershed map (Map 3a) showing soil texture and DNR 24K stream layer 27

14b. Example watershed map (Map 3b) showing soil classification and DNR 24K stream layer 28

15. Example watershed map (Map 4) showing geomorphic sedimentary associations, karst features, and designated trout streams 29
16. Example watershed map (Map 5) showing land cover information........ 30
17. Example watershed map (Map 6) showing USGS 24-minute quadrangle and Mn/DOT road layers. 31
18. Example watershed map (Map 7) showing 2003 aerial photography, Mn/DOT road layers, and DNR 24K stream layer 32

List of Figures (continued)

19. Example map (Map 8) of Strahler stream order assigned 33

20. Strahler stream order system 36

21. Strahler stream orders assigned for the Whitewater River 37

22. Example plot of mean monthly precipitation 40

23. Statewide variation in normal annual precipitation 41

24. Comparison of precipitation at International Falls and Lanesboro 42

25. Total annual precipitation for Lanesboro, 1885–2005 42

26. Mean monthly stream discharge for the Root River near Lanesboro. 43

27. Example plots of daily discharge for the Root River. 43

28. Annual peak flow over time for the Root River, 1910–1990. 44

29. Example field form for documenting springs, seeps, and discharges 45

30. Example longitudinal elevation profile with stream crossings and barriers, Trout Run Creek, Minnesota. 47

31. Guidelines for stream classification. 48

32. Example map (Map 9) of similar reach identification 49

33. Minnesota Stream Habitat Assessment (MSHA) form (1 of 2) 52

34. Minnesota Stream Habitat Assessment (MSHA) form, (2 of 2) 53

35. Example map (Map 10) of watershed boundaries and dams, road crossings, barriers, and culverts 71

36. Cross-section of a stream showing sampling locations for water depth and velocity. 75

37. Measuring water velocity with a flowmeter and wading rod. 76

38. Example Discharge Measurement Form 77

List of Figures (continued)

39. Channel geometry measurements (Pattern) 81

40. Example stream map (field sketch)... 83

41. Longitudinal profile showing bed features, elevations........................... 84

42a. Longitudinal Recording Sheet (1 of 4) 85
42b. Longitudinal Recording Sheet (2 of 4) 86
42c. Longitudinal Recording Sheet (3 of 4)... 87
42d. Longitudinal Recording Sheet (4 of 4) 88

43. Example Longitudinal Profile, Trout Run Creek 90

44. Conducting a stream channel cross-section survey............................... 93

45. Example stream cross-section recording field sheet 94

46. Particle axes. 95

47. Example pebble count recording field sheet 96

48. Stream Morphological Description Summary Sheet 98

49. Example particle size distribution plot 99

50. Example Cover for Larger Fishes field form 102

51. Streambank cross-section illustrating some of the variables
surveyed to estimate Bank Erosion Hazard Index (BEHI) 104

52. Example Bank Erosion Hazard Index (BEHI) field form....................... 105

53. Streambank erodibility criteria used for the BEHI rating 106

54. Prediction of Annual Streambank Erosion Rates using Colorado
data for streams found in sedimentary and/or
metamorphic geology 109

55. Prediction of Annual Streambank Erosion Rates using Yellowstone
data for streams found in alpine glaciation and/or
volcanism areas 110

List of Figures (continued)

56. Example Near Bank Shear Stress (NBS) field form 111

57. Example BEHI and NBS field sketch map 112

58. Example summary form for estimating annual streambank erosion 113

59a. Example Stream Condition Assessment form (1 of 2) 117
59b. Example Stream Condition Assessment form (2 of 2) 118

60. Stream channel stability evaluation field form.................................... 119

61. Example photo documentation photos 122

62. Example photo documentation cover sheet 123

63. Mean daily water temperature graph for Blackhoof River.................. 129

64. Example Longitudinal Water Temperature Profile field sheet............. 130

65. Example continuous temperature logger output table........................ 131

66. Example Water Quality Laboratory Analysis field form 132

67. Example Riparian Area/Aquatic Invertebrate field sheet..................... 136

68. Example aquatic plants field sheet.. 139

69. Example Fishes data field cover sheet.. 146

70. Example Fishes Field Measurements field form 148

List of Tables

1. Minnesota’s 81 major watersheds..19

2. Example watershed metrics for Trout Run Creek 35

3. Plan-view groups of river patterns (Rosgen 1996) 47

4. Minnesota Stream Habitat Assessment (MSHA) metrics..........................51

5. Conversion of channel stability scores to sample site condition by stream type...120

6. Pfankuch form codes scoring sheet for adjusting channel stability scores 121

7. Qualitative riparian land use/land cover types 137

8. Example aquatic invertebrate sample results table................................143

9. Status of IBI development in the major river basins of Minnesota 152

10. Example fish community data for Clearwater River 153

11. Scoring criteria for the 10 metrics used to calculate IBI score................154

12. Summary categories used to describe riparian vegetation patterns.........157

13. Summary of riparian zone characteristics for Trout Run Creek 158

14. Summary of aquatic plant survey for Trout Run Creek 159

15. Recommended hard body part structures to use for aging selected fishes 160

Introduction

Fisheries managers are faced with increasingly complex challenges when managing fish populations in streams and rivers. Fish populations need suitable habitat for each life stage and for the organisms on which they depend. River ecosystems can be defined by processes generally categorized into five components: hydrology, geomorphology, biology, water quality, and energy pathways/connectivity (Figure 1). Threats to fish habitat can originate in any of these five components and thereby affect the populations we are managing.

The resource work is only part of management. Subsequent management prescriptions often demand additional public involvement and institutional work, and potential legal changes if controversy is encountered or a change in policy is involved. Each of these steps can be incredibly involved; to effectively manage stream resources and negotiate the management process today, fisheries managers must access relevant data that encompass the breadth of the underlying problems.

Stream surveys form the basis for understanding the systems we manage. In addition, stream surveys and management plans are used as a basis for planning and management efforts by local, state, and federal governments. These challenges and potential influence of our management plans demand a thorough understanding of all factors affecting the resource and their interrelationships.

The notion of managing a fish population in isolation of all the watershed forces acting on a river is no longer viable. Running waters are enormously diverse. They range from small streams, such as Heartbreak Creek (Lake Superior drainage), to large rivers, such as the Mississippi, and occur under widely differing conditions of climate, vegetation, topography, and geology. The free play of a stream’s hydrodynamic forces creates a rich diversity of habitats for aquatic life. Habitat diversity results from variation in stream depth, width, water velocity, and substrate throughout the channel. Diverse habitats support a high degree of biological diversity. Alteration of aquatic habitats associated with streams and rivers is extensive in North America, largely as a consequence of the rapid increase in human population and the associated consumption of aquatic resources and production of waste (Gleick 1993; Naiman et al. 1995; Naiman and Bilby 1998). To make sense of biological findings from such disparate settings, it is important to have a comprehensive framework that reflects the study system (Allen 1995). For rivers, such a framework must include consideration of all five basic components.

The intent of this manual is to:

1) Provide an overarching framework for conducting stream surveys that includes the fundamental factors contributing to healthy stream ecosystems.

2) Provide a basis for documenting the status and condition of stream systems.

3) Provide a logical basis for management decisions that effectively target core problems and solutions.

The methods contained here are applicable to most Minnesota streams. Large rivers are beyond the scope of this manual.

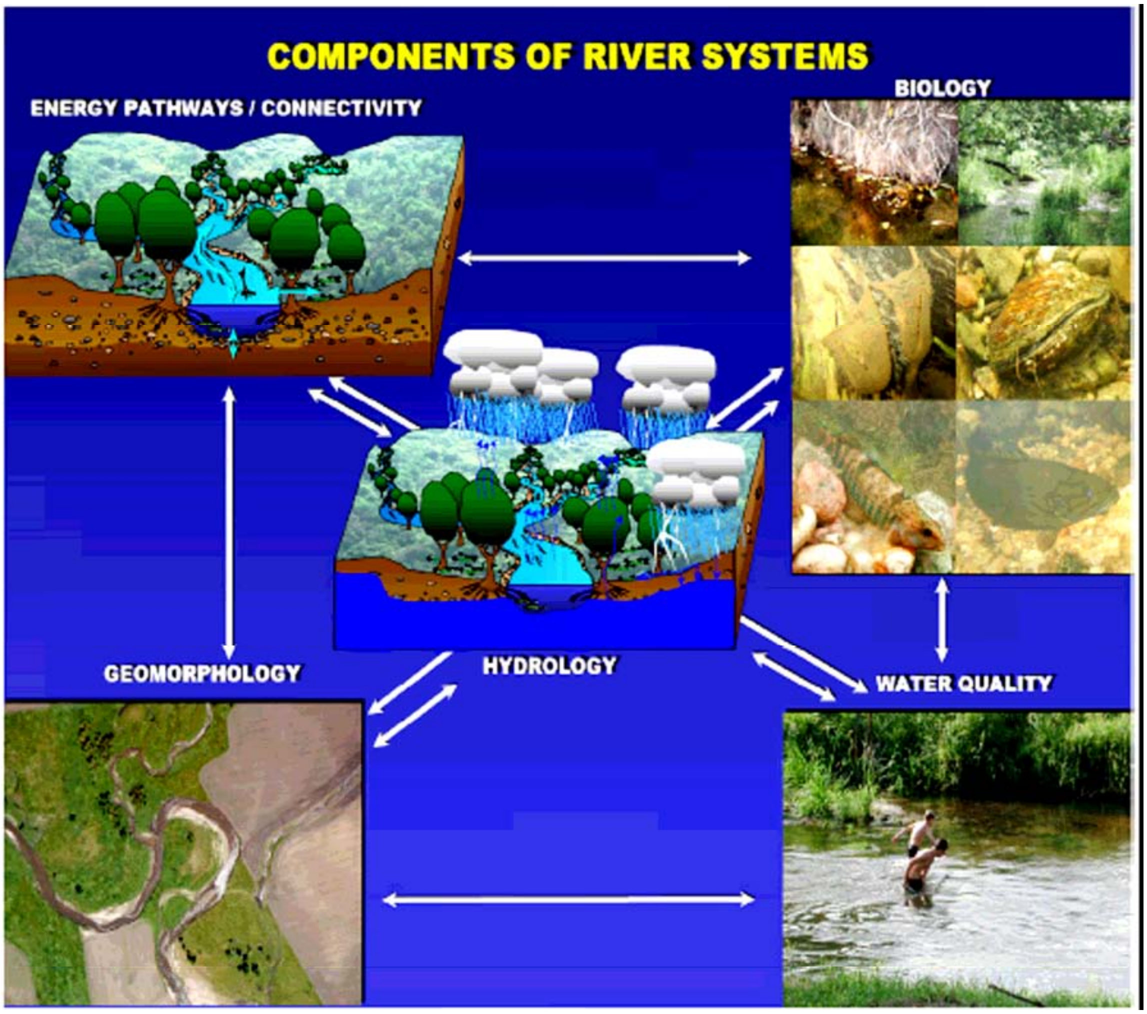


Figure 1. The five components of river systems: hydrology, geomorphology, biology, water quality, and energy pathways/connectivity.

This comprehensive framework with detailed techniques for sampling within each of the five basic components provides the necessary scientific rigor to meet current challenges. It also provides guidelines for when to sample, and at what level and frequency. The results of sampling with this approach will be enhanced repeatability and comparability among streams and regions.

This manual represents a necessary increase in the scope and intensity of our work in streams; it also provides flexibility in study design based on assumptions and documented information needs. Data collection using this manual is intended to be an iterative process. Each iteration should be used to refine the stream management plan and further clarify additional information needs. Subsequent data collection should address specific questions or identify management actions to be implemented, and may require intensifying sampling of specific components. During this process, data collection will shift to emphasize monitoring, evaluating management actions, and revising subsequent management plans. Viewed in this manner, data collection provides an essential feedback loop to stream management planning. It's up to the area supervisor to evaluate the initial questions, such as:

1) What are my priorities? Do I have basic information for stream X?

2) What trends in the stream resources are occurring? What do I think is causing these trends? What information is necessary to verify trends?

3) What are the limiting factors for my stream resources? What data are needed to support this?

4) What are the potential future constraints? What data will be needed to address them?

5) Do I have the necessary resources to address my priorities? How will I address resource shortfalls?

The variables described in this manual will contribute to a broader understanding of stream systems throughout Minnesota and allow comparisons across regions and over time. The various quantitative measures will be useful in understanding and managing stream ecosystems.

Surveying Minnesota streams, identifying management goals, and developing management plans can no longer be handled by single disciplines within the Minnesota Department of Natural Resources (DNR), or even within DNR. Citizens and local, state, and federal agencies all have a stake in Minnesota stream management. Expertise from DNR Fisheries, DNR Division of Ecological Services, DNR Division of Waters, and other sources will often be needed to complete stream surveys and management plans. For example, regional geographic information system (GIS) specialists could be contacted for watershed information and other available data layers. Area and regional hydrologists can assist with stream-flow and ground-water data. Other county and state resources will sometimes need to be tapped for information on current stream and watershed status. The complexity and volume of information needing synthesis may result in fewer stream surveys overall, but the compilation of more detailed information should result in higher quality surveys available to resource decision makers.

The five riverine components help resource managers address the whole ecosystem when making stream management prescriptions. Assessment methods and sampling designs must be matched to appropriate spatial and temporal scales in order to meet survey objectives, and develop and evaluate management plans.

Spatial Scales

A study reach is the part of a stream system where stream surveys and management occur. It is the point of reference for geographic scale discussion. Spatial scales range from global to micro. River scale is a nested hierarchy; the smaller spatial scales, including micro-, meso-, and macrohabitats, are nested within larger landscape features, such as reach, stream segment, stream, watershed, and major drainage. The relative importance of controlling factors changes with the spatial scale, as does a manager’s ability to uniquely influence those factors; however, to be effective, managers must be aware of regional and global trends (Figure 2).

Global Scale

For migratory fish—whether white sturgeon (*Acipenser transmontanus*), American eel (*Anguilla rostrata*), American shad (*Alosa sapidissima*), Chinook salmon (*Oncorhynchus tshawytscha*), or another species, including those with less extensive migration areas—a spatial scale larger than the watershed should be considered. Fish species previously considered relatively sedentary (e.g., nonanadromous stream salmonids, cyprinids) have been shown to move more than previously thought (Crook 2004). Even fish that spend their entire lives in a single pool can in some way be affected by global changes. Hydrology, water temperature, and aquatic ecosystem functions can all be influenced by climate change (Jager et al. 1999). For example, Kling et al. (2003) project global climate changes will impact the Great Lakes region substantially within the next century. A warmer, drier climate will alter hydrology by causing earlier ice-out dates, low water levels, diminished ground water recharge, and more frequent flooding due to land use changes and increases in heavy rainfalls. River water temperatures are projected to increase, while the amount of habitat available to aquatic organisms is projected to diminish due to the shrinking of aquatic refugia in streams and wetlands. Distribution of fish is likely to change with the northward expansion of cool- and warm-water species, while cold-water species' northern distribution limits will retreat. Localized populations of stream salmonids may shrink or be lost.

Because global changes can have local impacts, even resource agencies that have little ability to influence global-scale phenomena should consider global trends when making management decisions. Important questions to ask are whether stream management prescriptions will be adequate to meet objectives if climate changes the timing or magnitude of flows in the system, and if water will maintain an acceptable temperature if the air temperature increases.

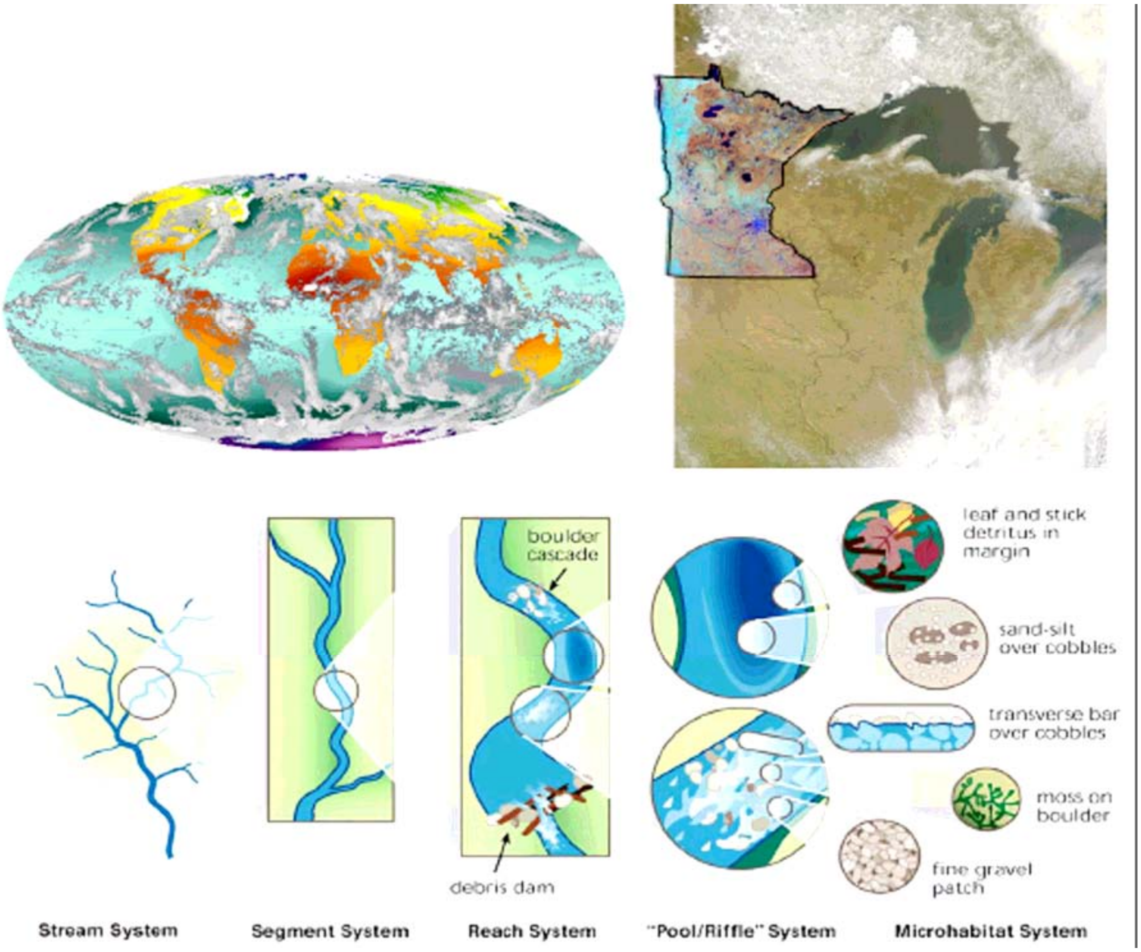


Figure 2. River scale is a nested hierarchy: The smaller spatial scales are nested within larger landscape features, such as reach, stream segment, stream, watershed, region, and, ultimately, the globe (adapted from Frissell et al. 1986).

Watershed Scale

Watershed or river basin refers to a scale at which state and federal agencies have more management control. For major watersheds, it may be more practical to address issues on a subbasin scale, because river management decisions generally influence a subbasin scale watershed more directly and information at this scale is more easily understood. For example, the Snake River watershed in east-central Minnesota is large, encompassing 1,008 square miles (Figure 3). Complex management issues can be identified more easily at the subbasin scale (in this case, 75 subbasins).

Conditions of a watershed directly affect the channel form and the timing and magnitude of flow in the management reach (Hill et al. 1991). The watershed interacts with climate, topography, and geology to influence vegetation, stream channel, groundwater, and stream flow. Vegetation influences the channel through erosion and deposition patterns and rates. The effects of fire illustrate the connection of watershed, stream, and fish populations (Gresswell 1999). That connection is evident in the way land-use activities—such as urban or suburban development, road building, agriculture, and forestry—modify vegetation, erosion, and sedimentation, as well as the temporal relationship between precipitation and stream flow. Watershed conditions such as migration barriers may limit movement of fish into or out of a management reach. Watersheds that contain lakes and wetlands modify hydrology and store and release water somewhat more gradually than do watersheds without lakes (Leopold 1994).

Macrohabitat Scale

Geomorphologists have coined the term “hydraulic biotope” to describe the flow-dependent abiotic environment of a community or species assemblage (Wadeson and Rowntree 1998). Hydraulic biotopes occur at different levels, such as macro- meso-, and microhabitat. Macrohabitat includes many reach-scale and larger phenomena, primarily dealing with abiotic habitat conditions (e.g., channel morphology and chemical or physical properties of water) that control the longitudinal distribution of aquatic organisms. The mix of mesohabitats (see below), such as the ratio of pools to riffles, is determined by macrohabitat. Macrohabitat is determined by long-term geological setting, climate interaction with geology, vegetation, and the shorter-term influence of land use superimposed on the preceding processes. It includes such factors as net rate of sediment transport and type of sediments transported, as well as abundance and distribution of sediment, large woody debris, and boulders. Infrequent high flows also have a major influence on macrohabitat. Flows that form channels, flood plains, and valleys were discussed by Hill et al. (1991) and Whiting (1998).

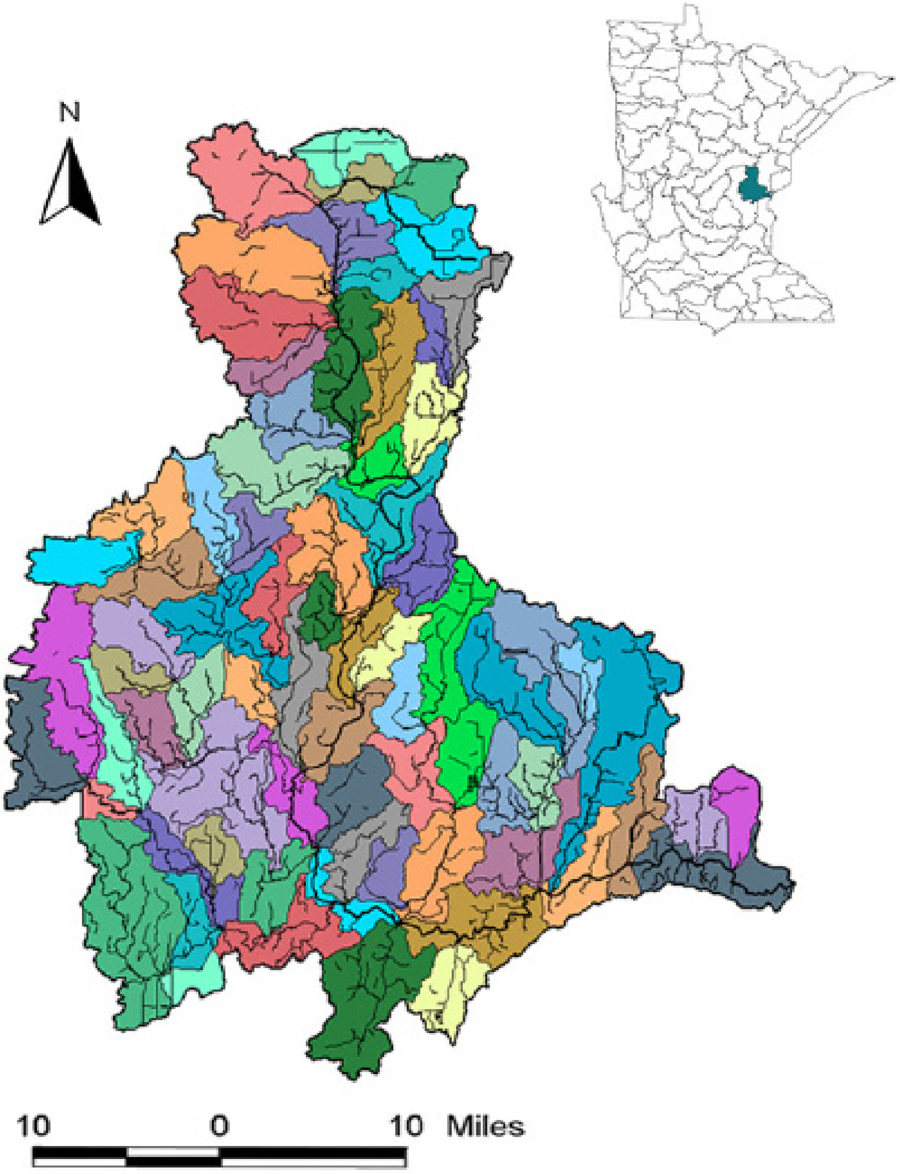


Figure 3. Managing large, complex stream systems requires data analysis and remedies at the proper scale. For example, the Snake River system in east-central Minnesota, which encompasses 1,008 square miles, is managed as 75 sub-basins.

Mesohabitat Scale

Mesohabitat refers to a combination of pools, riffles, runs, cascades, waterfalls, and off-channel habitats within a reach (Bisson et al. 1988; Kershner and Snider 1992; Hawkins et al. 1993; Vadas and Orth 1998). At least at low flows, certain combinations and ranges of depth and velocity are associated with different mesohabitats (Vadas and Orth 1998). Relative proportions of different mesohabitats appear to vary with flow as depth and velocity distributions change (Vadas and Orth 1998; Hildebrand et al. 1999). However, work by others (Rowntree and Wadeson 1998; Wadeson and Rowntree 1998) suggested that geomorphic-defined units do not change with discharge (when the stream and its watershed are in “dynamic equilibrium”). Certain life stages of certain fish species are associated with particular mesohabitats (Bisson et al. 1988).

The connectivity among mesohabitats is often flow dependent. A connection among habitats at certain times is critical to the life history of some fishes. Passage through or around migration barriers—such as shallow riffles, cascades, waterfalls—and access to the flood plain depends on flow (Smith 1973; Powers and Osborn 1985).

Microhabitat Scale

Microhabitat refers to the hydraulic features determined by the unique combination of depth, velocity, substrate, and cover at specific points in a stream (Bovee 1982). Many commonly used in-stream flow methods focus on the hydraulics of microhabitat. One commonly used tool is the PHABSIM component of the IFIM, which allows analysis of the distribution of hydraulic habitat at different flows (Bovee and Milhous 1978; Bovee 1982; Bovee et al. 1998). The microhabitat variables provide a reasonable within-reach description of hydraulic features selected and avoided by fish at different flows within a reach (Orth and Maughan 1982; Beecher et al. 1993, 1995; Shuler and Nehring 1993; Thomas and Bovee 1993; Shuler et al. 1994; Gallagher and Gard 1999).

Although PHABSIM results are useful for identifying how the hydraulic features of microhabitat vary with flow, units of microhabitat must be sufficiently large or contiguous to support the species and life stages of interest (Gallagher and Gard 1999).

Temporal Scales

Streams are dynamic systems, changing over time. Yet a fundamental problem in the development of a general model of system response to river alteration is the failure to consider changes within an appropriate time scale (Petts 1984). When data collection and analysis take months or even years, the channel form must be described anew if and when its geometric characteristics change significantly. Seasonal and flow-related changes impact fish community composition (Matthews and Hill 1980); fish communities have even been found to vary by the time of day (Starret 1950).

The present status of a watershed reflects its history, as expressed in the volume, stratification, and slope of deposits—all of which affect the present dynamics of the channel. Moreover, as climate, discharge, and sediment change, the geomorphic characteristic of a river also changes (Amoros et al. 1987) and different components of the system respond at different rates (Petts 1987). In watersheds undisturbed by human activity, all these factors usually operate in a dynamic equilibrium. Human actions can change process rates by several orders of magnitude, disrupting the equilibrium. The minimum time required for system adjustment to a new set of conditions depends on those variables that require the longest time to achieve a stable structure. The relative importance of these factors change with the spatial scale, which is inversely related to the time scale of potential persistence. Microhabitats may change daily; mesohabitats may change annually; stream reaches may change with the occurrence of landslides, log inputs or washouts, dam building, and the like; and the watershed may change through tectonic uplift, subsidence, glaciation, or climate shifts (Frissell et al. 1986; Figure 4).

Sampling Fish in Streams

Stream fish communities are composed of species that vary substantially in population size, both spatially and temporally, resulting in high natural variability. Fish management in streams benefits from understanding natural variation due to seasonal, annual, and longer-time-scale variation as compared to variation attributed to changes in biotic and abiotic factors including sedimentation, water quality, hydrology, in-stream habitat, and watershed impacts associated with human activities. Sampling methods must account for the high natural variability of the stream environment and associated fish communities through the use of stratified sampling and increased size and frequency of samples where required.

Fish community sampling methods must be matched closely to objectives. As objectives move from basic to more complex (e.g., from fish presence-absence to relative abundance; from catch per unit effort to estimated population density; and finally to trends in population metrics over time), methods must be adjusted. Small sample sizes with little quantitative gear can yield basic information on fish presence-absence. Documenting spatial and temporal distribution requires sampling more representative reaches more often. Various mesohabitats (riffles, pools, undercut banks, runs) must also be representatively sampled.

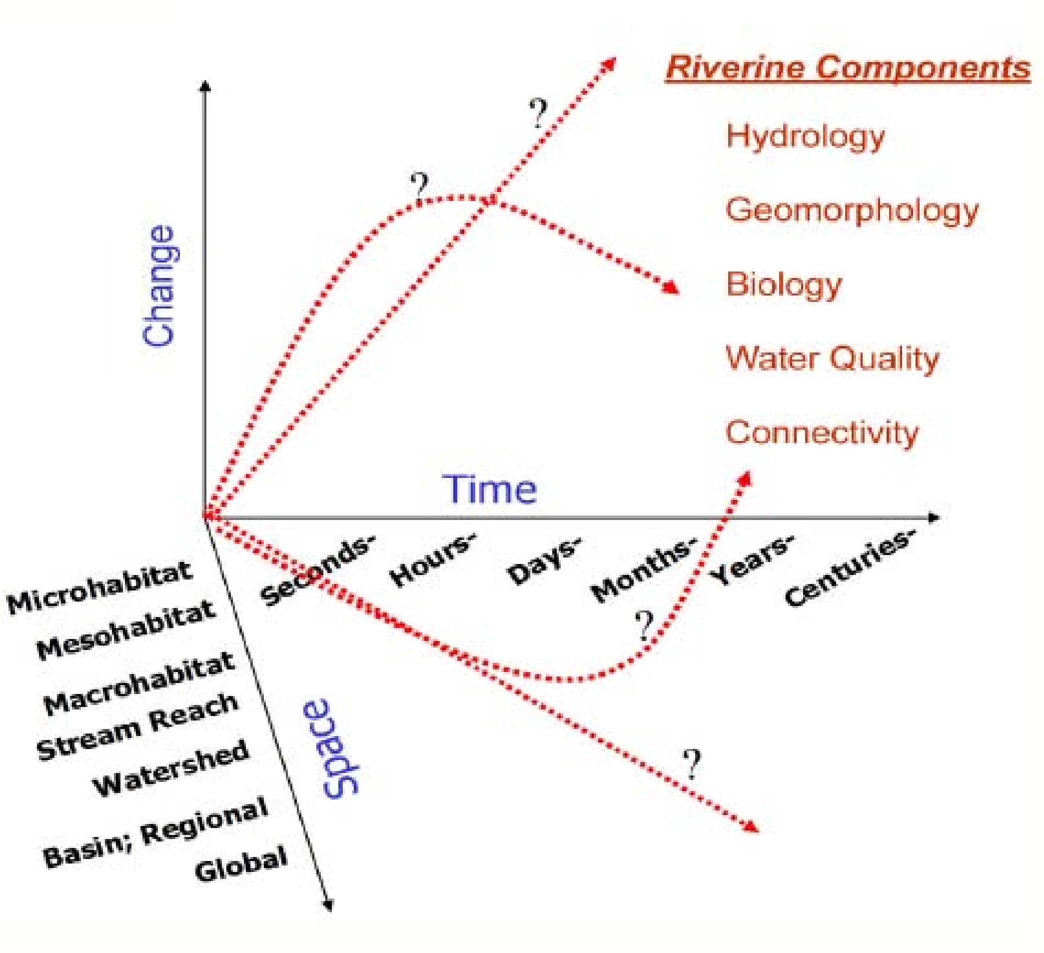


Figure 4. Each riverine component functions over the full range of temporal and spatial scales (e.g. microhabitat to global and seconds to centuries and beyond). The riverine components respond to natural and human induced perturbations at different rates. Those system variables that require the longest time to reach equilibrium determine the time of adjustment (adapted from Frissell et al. 1986).

Time-series information can be used to document the persistence of a species of fish (whether it remains in specific areas or habitats over time). In long-term sampling where species disappear, often one or more anthropogenic effects can be linked to the declines (Burr and Burr 1991). Presence-absence data can document a change in the number of species, but cannot document changes in relative abundance.

Long-term data sets are needed to document changes in fish communities that can then be used as a potential gauge of future changes that may be associated with anthropogenic effects. In measuring the stability of fish populations, it is important to have more quantitative data, such as estimates of numbers and biomass of target species, along with associated estimates of variation.

Quick Reference Guide

A quick reference guide describes the basic steps for completing a stream survey (Figure 5). An example timeline for planning stream survey activities in an area fisheries office provides a checklist for stream survey and management planning activities (Figure 6).

The procedures are organized by survey type (initial or full) and survey component consistent with the reference document provided along with this manual. Examples of maps and procedures are provided along with field forms for recording data.

Quick Reference Guide

Step 1. Develop stream survey planning priority list for area (office).

Step 2. Develop stream survey plan / federal aid proposal for coming year (office).

Step 3. Complete an initial survey (see checklist on page 14), including:
a. Prepare watershed and base maps (office)
b. Complete drainage basin analysis (office)
c. Describe precipitation and runoff patterns (office)
d. Identify similar reaches and stations (office)
e. Verify and mark survey stations (field)
f. Complete water quality measurements (field)
g. Complete fish sampling (field)
h. Complete MN Stream Habitat Assessment (MSHA: field)

Step 4. Write initial stream survey report (office).

Step 5. Complete full stream survey field measures at each station for each of the following components (see checklist on page 73):
a. Hydrology
b. Geomorphology and fish habitat
c. Water quality
d. Fish community
e. Riparian vegetation community
f. Aquatic plant community
g. Aquatic invertebrate community

Step 6. Analyze full survey field measurements (office)

Step 7. Write full stream survey report (office).

Figure 5. A quick reference guide for completing a stream survey.

Stream survey and management planning activity:	Month of the Year											
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1. Develop stream survey planning priority list for area (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
2. Submit stream survey plan / federal aid plan for coming year to region (office	🟦											🟦
3. Complete initial stream survey (office and field)												
a. Prepare watershed and base maps (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
b. Complete drainage basin analysis (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
c. Describe precipitation and runoff patterns (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
d. Identify similar reaches and stations (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
e. Verify and marking survey stations (field)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
f. Complete water quality and temperature measurements (field)				🟧	🟧	🟧	🟧	🟧	🟧			
g. Complete fish sampling (field)							🟧	🟧	🟧			
h. Complete MN Stream Habitat Assessment (MSHA, field)				🟧	🟧	🟧	🟧	🟧	🟧			
4. Write initial stream survey report (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
5. Complete full stream survey data collection (field)												
Complete field measurements at each station for the following components:												
a. Hydrology (field)				🟧	🟧	🟧	🟧	🟧	🟧	🟧		
b. Geomorphology and fish habitat (field)				🟧	🟧	🟧	🟧	🟧	🟧	🟧		
c. Water quality (field)				🟧	🟧	🟧	🟧	🟧	🟧	🟧		
d. Fish community components (field)							🟧	🟧	🟧	🟧		
e. Riparian vegetation community (field)				🟧	🟧	🟧	🟧	🟧	🟧	🟧		
f. Aquatic plant community (field)				🟧	🟧	🟧	🟧	🟧	🟧	🟧		
g. Aquatic invertebrates (field)				🟧	🟧	🟧	🟧	🟧	🟧	🟧		
6. Analyze full survey field measurements (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
7. Write full stream survey report (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
8. Write new or revise existing stream management plan (office)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
9. Implement stream management plans	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

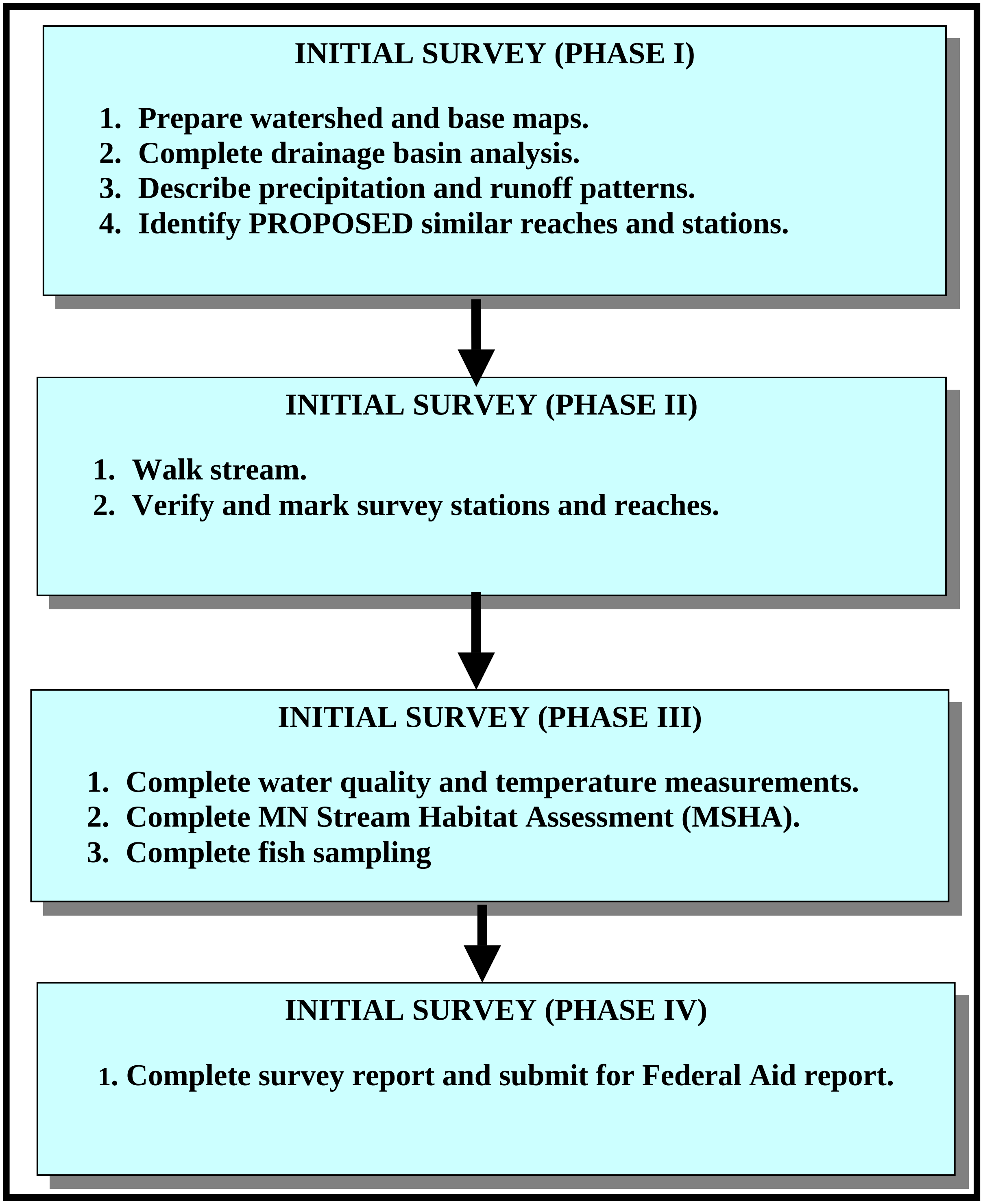
🟦 = office activities

🟧 = field activities

Figure 6. Example timeline for planning stream survey and management planning activities in an area fisheries office.

Initial Survey

An initial survey is comprised of four sequential phases (Figure 7).



INITIAL SURVEY (PHASE I)

1. **Prepare watershed and base maps.**
2. **Complete drainage basin analysis.**
3. **Describe precipitation and runoff patterns.**
4. **Identify PROPOSED similar reaches and stations.**

INITIAL SURVEY (PHASE II)

1. **Walk stream.**
2. **Verify and mark survey stations and reaches.**

INITIAL SURVEY (PHASE III)

1. **Complete water quality and temperature measurements.**
2. **Complete MN Stream Habitat Assessment (MSHA).**
3. **Complete fish sampling**

INITIAL SURVEY (PHASE IV)

1. **Complete survey report and submit for Federal Aid report.**

Figure 7. Phase I – IV describes the sequential process for completing an initial stream survey.

Initial Survey Checklist

Hydrology

1. ____ Watershed map with shaded relief and 24K stream network (Map 1, Figure 12; page 24)
2. ____ Map of known springs, seeps, sinkholes, stream sinks, discharges with stream designations (Map 2, Figure 13; page 24)
3. ____ Map of soil types with 24K stream network (Map 3, Figure 14; page 24)
4. ____ Map of bedrock geology (Map 4, Figure 15; page 24)
5. ____ Land cover/land use map (Map 5, Figure 16; page 24)
6. ____ Topographic quad map with USGS 1:24,000 quad view (Map 6, Figure 17; page 24)
7. ____ Aerial photography map of watershed (Map 7, Figure 18; page 24)
8. ____ Map of Strahler stream order (Map 8, Figure 19; page 24)
9. ____ Basic watershed or drainage basin measures (pages 34-35; Table 2)
10. ____ Precipitation and runoff patterns (page 38; Figures 22-25)
11. ____ Peak flow analysis (gauged stations only) (page 38; Figures 26–28)

Geomorphology

12. ____ Stream and valley morphology (sinuosity and channel cross-section morphology, channel plan-view morphology, page 46; Table 3)
13. ____ Longitudinal elevation profile (page 47, Figure 30)
14. ____ Similar reach and station boundaries (pages 22, 47; Figure 11; Map 9, Figure 32)
15. ____ Field verification of similar reaches and survey stations
16. ____ Minnesota Stream Habitat Assessment (MSHA; pages 50–64; Figures 33-34, Table 4)

Water Quality

17. ____ Air temperature (page 65)
18. ____ Water temperature (pages 65–67)
19. ____ pH (page 67)
20. ____ Dissolved oxygen (pages 67–68)
21. ____ Conductivity (page 68)
22. ____ Transparency (page 68)

Biology

23. ____ Fish community (page 69, 144-154)

Connectivity

24. ____ Map showing public land and easements (pages 70-71; Map 10, Figure 35)
25. ____ Locate and map dams, channelized reaches, and road crossings (page 70; Map 10, Figure 35)
26. ____ Identify and evaluate fish barriers (page 70; Map 10, Figure 35)
27. ____ Identify and evaluate point source discharges (page 70; Map 10, Figure 35)

Field Forms

Blank field forms are located in Appendix 1. Examples of completed field forms are provided throughout this manual. Nearly all field forms have a header with common data fields for describing and delineating sampling stations:

Stream Name. Use the common stream name, usually that given on the USGS quadrangle map. If no name is given, use the commonly accepted local name.

Kittle Number. This is the MSIS or Kittle code developed by DNR Fisheries in the 1970s (MNDNR 1978).

Survey Date. Sample date or date range, in month-day-year format (e.g., 07-01-2006).

Recorder or Crew Name(s) of the field crew, including the person recording the field data.

Station Name. If the station has a common name, record it here.

Station ID Code or Number. Number stations starting at the mouth and progressing upstream. If historical station numbers already exist, use these.

River Mile. The river mile of the downstream end of the sampling station.

Station Length. Length of the station in feet measured along the thalweg.

Station Coordinates (UTM Easting and UTM Northing). Universal Transverse Mercator, Zone 15, GPS coordinates for the downstream and upstream ends of the station.

Coordinate Source. List the source of your station coordinates, whether they are field GPS readings from a GPS unit or from a GIS computer source such as Landview.

Sample Time. Time of day (range) in military time that sampling was completed (e.g., 0900–1430).

Hydrology

Identifying Watersheds, Watercourses, and Reaches

Any stream survey and monitoring program must account for the unique identification of watersheds, watercourses, and reaches. The development of future information systems will rely on unique identifiers for each of these parameters. Multiple standards and terminology have resulted in confusion in the past. The Hydrography Committee for the Minnesota Governor's Council on Geographic Information has developed identification and naming standards for Minnesota governmental agencies to promote data integration across state lines and with national data sets.

Watershed Identification

Minnesota has four major drainages: Mississippi River, Hudson Bay (Red and Rainy Rivers), Lake Superior, and Iowa Sioux River (Figure 8). Management at this scale is complex, involving five other states and the province of Ontario, Canada. River management is more feasible on a watershed level (basin or sub-basin). Minnesota's four drainage basins can be further subdivided into 81 major watersheds or basins (Figure 9, Table 1).

Minnesota law defines watersheds in terms of the State of Minnesota Watershed Boundaries 1979 Mapping Project. This DNR project represented a major effort to develop official, systematic, detailed height-of-land boundary maps for all watersheds of the state. The project identified and delineated what has become known as the 81 DNR major watersheds and approximately 5,600 DNR minor watersheds.

In 1995, the DNR Division of Waters developed GIS coverages for both major and minor watersheds from the original U.S. Geological Survey (USGS) 7½-minute quadrangles, based on 5- to 20-foot contours. The DNR major watersheds were designed to be consistent with federal watershed standards for hydrologic units (HU).

An update of the watershed boundaries now underway as part of the DNR's Minnesota Lake Watershed Delineation (Lakeshed) Project retains the intent of the original DNR watershed mapping project while making modifications to the delineation procedures to make Minnesota watersheds more consistent with the new federal Watershed Boundary Dataset standard. The current efforts are also delineating even smaller watersheds that will be aggregated to create national watershed boundary dataset hydrologic units. Delineation, naming, and numbering of these hydrologic units is described in Federal Standards for

Delineation of Hydrologic Unit Boundaries Version 2.0 – October 1, 2004, proposed by the Federal Geographic Data Committee (FGDC).

Figure 8. Minnesota has four major drainages: Mississippi River, Hudson Bay, St. Lawrence (Great Lakes), and the Iowa drainage.

The Minnesota Governor's Council on Geographic Information Hydrography Committee exists to promote consistent development of hydrography data and enable data exchange through coordination, cooperation, and standard development. The Lakeshed Project is developing data using state and federal standards that will be certified for inclusion in the national Watershed Boundary Dataset (WBD). A translation table has been developed to bridge USGS HUs and Minnesota major watersheds (Appendix 2).

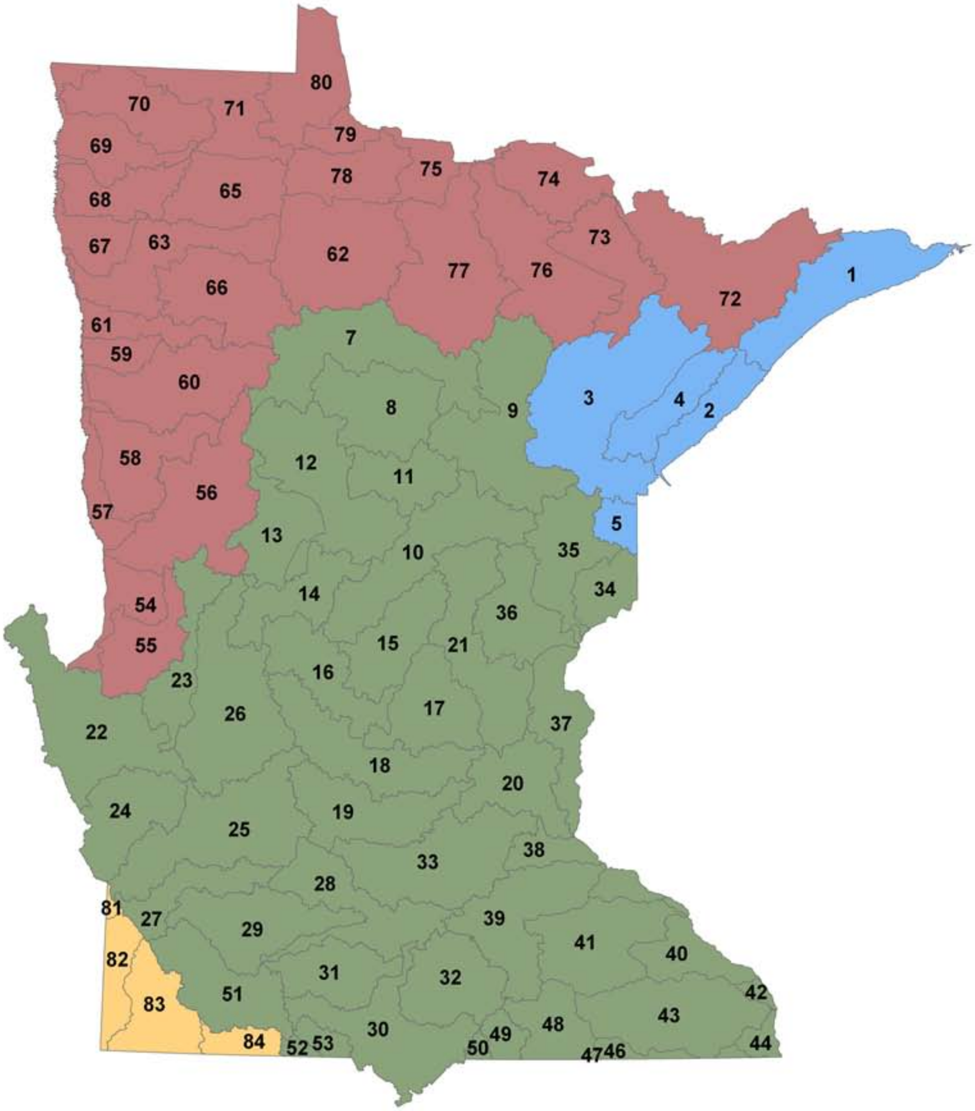


Figure 9. Minnesota's four major drainages are divided into 81 major watersheds (see Table 1 for key to numbers).

Table 1. Minnesota’s 81 major watersheds.

MAJOR	MAJOR NAME	MAJOR	MAJOR NAME
1	Lake Superior - North	41	Zumbro River
2	Lake Superior-South	42	Miss R-La Crescent
3	St. Louis River	43	Root River
4	Cloquet River	44	Miss R-Reno
5	Nemadji River	46	Upper Iowa River
7	Miss R-Headwaters	47	Wapsipinican River
8	Leech Lake River	48	Cedar River
9	Miss R-Grand Rapids	49	Shell Rock River
10	Miss R-Brainerd	50	Winnebago River
11	Pine River	51	W Fork Des Moines-Head
12	Crow Wing River	52	W Fork Des Moines-Lower
13	Redeye River	53	E Fork Des Moines
14	Long Prairie River	54	Bois De Sioux River
15	Miss R-Sartell	55	Mustinka River
16	Sauk River	56	Otter Tail River
17	Miss R-St. Cloud	57	Red River of North
18	North Fork Crow R	58	Buffalo River
19	South Fork Crow R	59	Marsh River
20	Mississippi River	60	Wild Rice River
21	Rum River	61	Sandhill River
22	Minn R-Headwaters	62	Upper/Lower Red Lake
23	Pomme de Terre River	63	Red Lake River
24	Lac Qui Parle River	65	Thief River
25	Minn R-Granite Falls	66	Clearwater River
26	Chippewa River	67	Grand Marais Creek
27	Redwood River	68	Snake River
28	Minn R-Mankato	69	Tamarac River
29	Cottonwood River	70	Two Rivers
30	Blue Earth River	71	Roseau River
31	Watonwan River	72	Rainy R-Headwaters
32	Le Sueur River	73	Vermilion River
33	Minn R-Shakopee	74	Rainy R-Rainy Lake
34	St. Croix R-Upper	75	Rainy River-Manitou
35	Kettle River	76	Little Fork River
36	Snake River	77	Big Fork River
37	St. Croix R-Stillwater	78	Rapid River
38	Miss R & L Pepin	79	Rainy R-Baudette
39	Cannon River	80	Lake of the Woods
40	Miss R-Winona	81	Big Sioux-Medary Creek
		82	Big Sioux-Pipestone
		83	Rock River
		84	Little Sioux River

Stream (Watercourse) Identification

The Minnesota Stream Identification System (MSIS), or Kittle number, was developed by the DNR Section of Fisheries in the 1970s (MNDNR 1978) and adopted by the DNR in 1979 as part of the Minnesota Watershed Mapping Project (MNDNR Office of Planning 1981). The Minnesota Governor's Council on Geographic Information Hydrography Committee has adopted the MSIS as Minnesota's standard for state watercourse identification (see Appendix 3).

Numbers assigned by the MSIS are commonly referred to as "Kittle numbers" or "tributary numbers." Kittle numbers are based on the concept of a watercourse, which in this context defined a named flow path of a stream drainage, usually from source to mouth. A watercourse can be composed of multiple stream segments or reaches.

A Kittle number is a compound identifier consisting of up to 10 parts, each designating another level of tributary. All stream numbers begin with a letter prefix indicating the main drainage basin into which they flow:

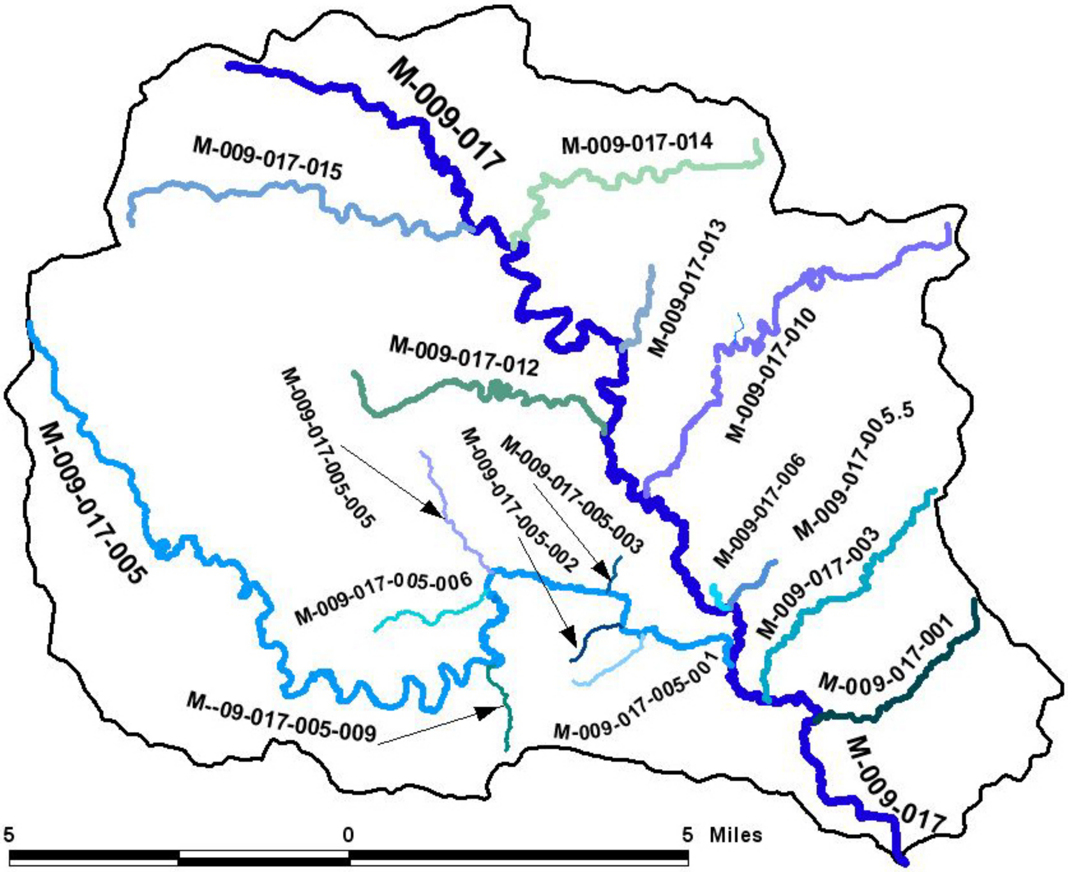
M = Mississippi River
S = St. Lawrence (Great Lakes)
H = Hudson Bay (Red & Rainy Rivers)
I = Iowa

Within each of these major drainages rivers are numbered, with each upstream tributary represented as an additional number separated by a dash. For example, Minnesota tributaries to the Mississippi River are numbered from the south boundary of the state upstream.

Example:

River Name	*Kittle number*
Mississippi River	*M*
Minnesota River	*M-055*
Blue Earth River	*M-055-076*
Watonwan River	*M-055-076-003*

The Kittle number thus contains information about upstream/downstream relationships between watercourses (Figure 10). For standards to assign Kittle numbers, refer to MNDNR (1978) and Appendix 3.



Rush Creek Watershed

Winona, Fillmore, Houston Counties

Key to Kittle Numbers

Stream Name	Kittle Number
Root River	M-009
Rush Creek	M-009-017
Schueler Creek	M-009-017-001
Unnamed Creek	M-009-017-003
Pine Creek	M-009-017-005
Unnamed Creek	M-009-017-005.5
Unnamed Creek	M-009-017-005-001
Unnamed Creek	M-009-017-005-002
Unnamed Creek	M-009-017-005-003
Coolridge Creek	M-009-017-005-005
Hemmingway Creek	M-009-017-005-006
Unnamed Creek	M-009-017-005-007
Voelker Brook	M-009-017-005-009
Borson Spring	M-009-017-006
Ahrensfeld Creek	M-009-017-010
Unnamed Creek	M-009-017-010-003
Ferguson Creek	M-009-017-012
Unnamed Creek	M-009-017-013
Unnamed Creek	M-009-017-014
Unnamed Creek	M-009-017-015

Figure 10. The Minnesota Stream Identification System (MSIS), or Kittle number, preserves stream connectivity information through its hierarchal numbering system. The Rush Creek watershed (above), tributary to the Root River system (M-009) in southeastern Minnesota, illustrates these linkages. (Note that some small tributaries do not appear on the map).

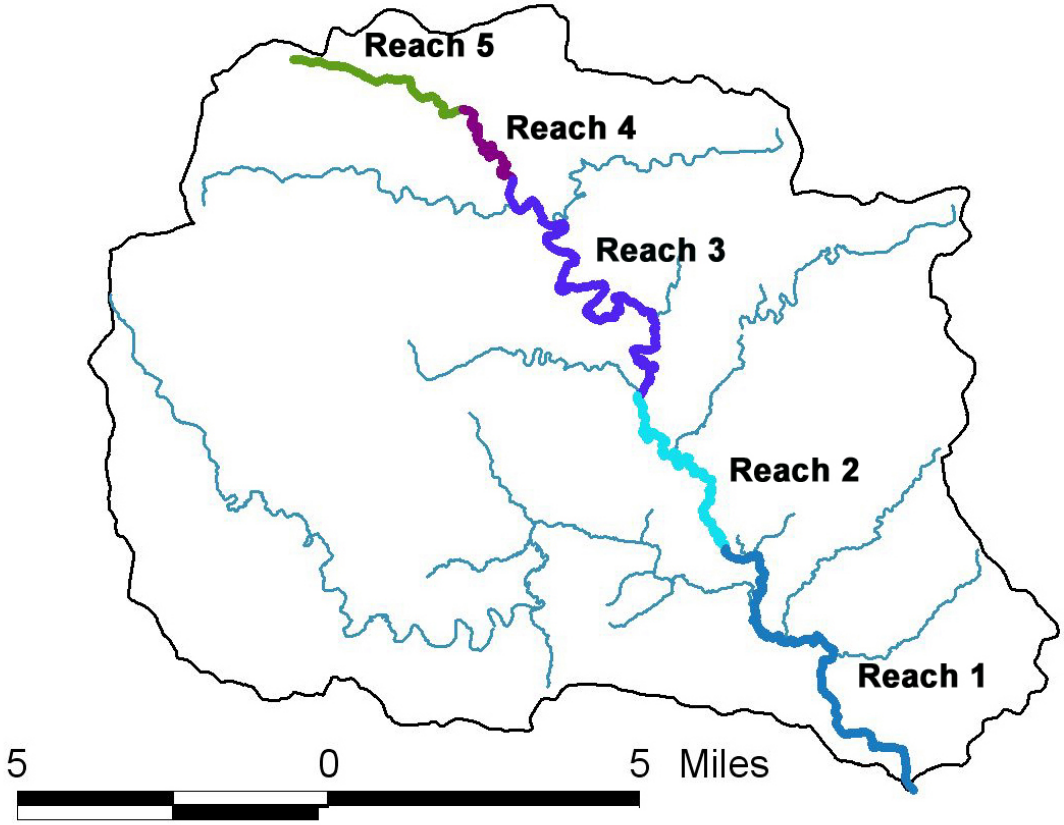
Reach Identification

A stream reach is a segment of a stream, river, or ditch, generally defined from confluence to confluence or by some other distinguishing hydrologic feature. Reach is often used interchangeably with segment, although the term segment is better used to describe a longitudinal section of stream bounded by any downstream and upstream point; it usually doesn't carry any hydrologic significance unless stated. Reaches and segments have been commonly defined based on river miles or distance from a confluence (e.g., 3.3 to 6.4 miles from mouth). While river miles have been useful references in the past, and they still retain usefulness in quick references to stream locations, Global Positioning System (GPS) coordinates are needed for stream data to retain geographic meaning as channels (and thus river mile references) change.

DNR Fisheries Similar Reach

DNR Fisheries has used a reach designator, the similar reach, as a basis for stream management. The term similar reach (sometimes used synonymously with sector) refers to a defined stream segment used as a functional unit of stream for planning and management (Figure 11). While no formal definition was documented, MNDNR (1978) used two characteristics, gradient and sinuosity, to delineate similar reaches on a watercourse. Since no formal methodology for defining similar reaches was defined, the designation of similar reaches is subjective and may vary with the designee's tendency to lump or split and to incorporate other variables, including riparian corridor condition, disconnectivity (dams, dredging, etc.), and major changes in water quality (tributaries and major springs). While some past similar reach designations have involved subjectivity, most appear to have been based on both hydrologic and biological criteria. This is evident in the ecological classification of stream similar reaches based on the suitability of conditions for a fish species or combination of species. With these limitations, the use of similar reach designations has been helpful to stream planning and management for DNR fisheries, and is expected to continue.

Defining stream reaches or segments based on management objectives or other needs are not limited to similar reach. Any segment of stream bounded by upstream and downstream boundaries can be defined with current mapping and GIS technologies. Examples include stream habitat improvement projects, special fishing regulations, political boundaries (counties, watershed districts), and management units.



KITTLE_NO	REACH	RIVERMILE_LOWER	RIVERMILE_UPPER
M-009-017	1	0	7.363
M-009-017	2	7.363	12.325
M-009-017	3	12.325	21.163
M-009-017	4	21.163	23.524
M-009-017	5	23.524	26.769

Figure 11. Example of Minnesota DNR stream similar reaches (Rush Creek, M-009-017, Winona and Fillmore counties, tributary to the Root River, M-009)

Generating Maps

The maps listed below should be included in the initial survey. These maps are easily generated using readily available GIS data layers found in the tools within ArcView. Several of these maps will be used for subsequent watershed analyses as described below, and become the basis for identifying similar reach and station boundaries.

1. **Watershed Map** (Map 1, Figure 12)
2. **Map of Known Springs, Seeps, Sinkholes, Stream Sinks, Discharges** (Map 2, Figure 13)
3. **Map of Soil Types** (Map 3a, 3b, Figures 14a, 14b)
4. **Map of Bedrock Geology** (Map 4, Figure 15)
5. **Land Cover/Land Use Map** (Map 5, Figure 16)
6. **Topographic/Quad Map** (Map 6, Figure 17)
7. **Aerial Photography Map** (Map 7, Figure 18)
8. **Map of Strahler Stream Order** (Map 8, Figure 19)
9. **Map of DNR Fisheries Similar Reaches** (Map 9, Figure 32). Methods for this map are found in the Geomorphology Section on page 47.
10. **Map of dams, channelized reaches, road crossings, culverts, and other barriers to fish movement** (Map 10, Figure 35). Methods for this map are found in the Connectivity Section on pages 70-72.

The DNR's Intranet site for DNR Fisheries GIS users contains valuable, timesaving tip sheets for working with ArcView and various tools that were developed specifically for DNR Fisheries use. Note: the page serves as the centralized storage location for all DNR Fisheries–related GIS tip sheets.

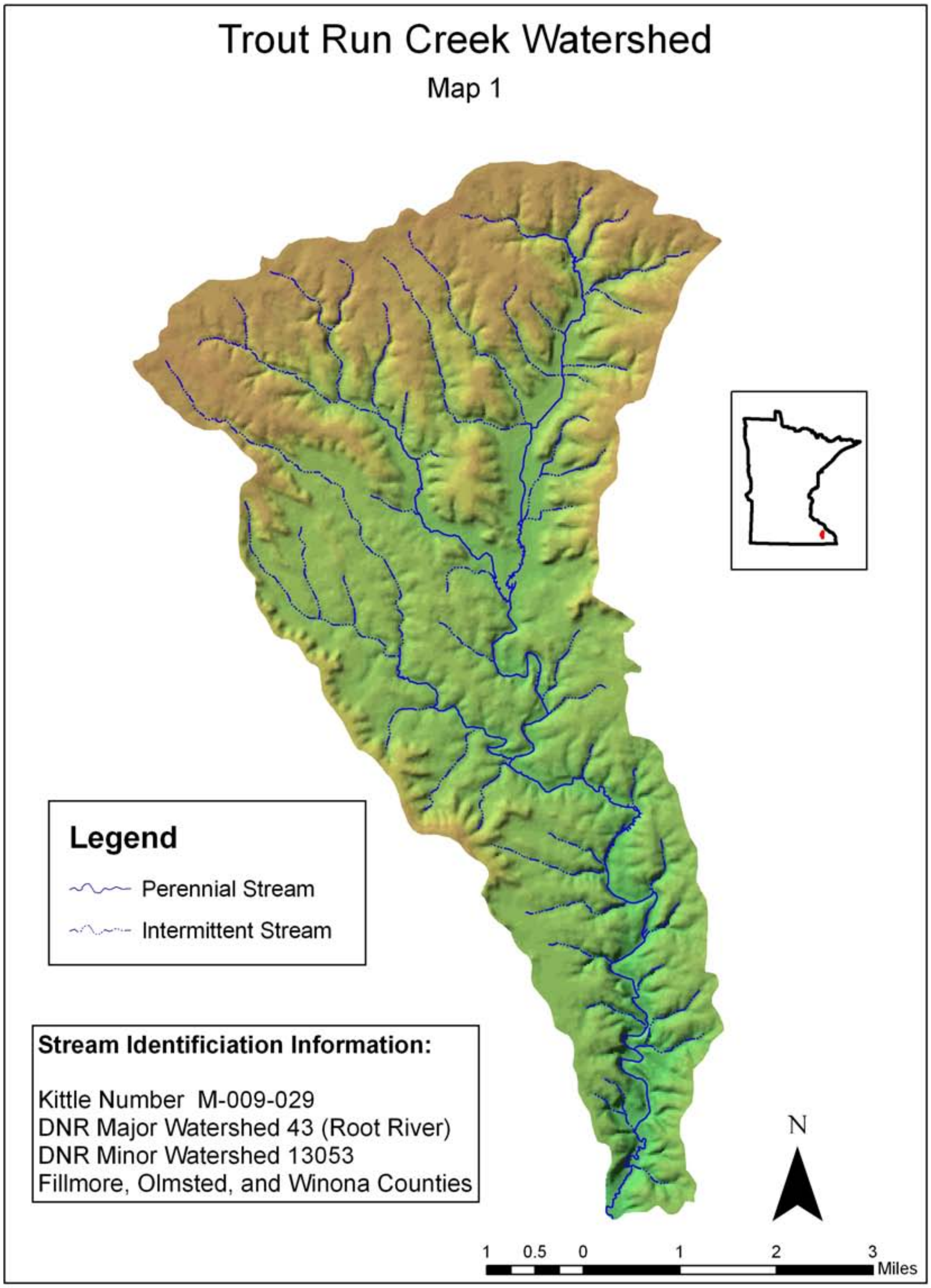


Figure 12. Example watershed map (Map 1) showing shaded relief and DNR 24K rivers and streams, DNR minor watershed, Trout Run Creek (M-009-029, Fillmore County).

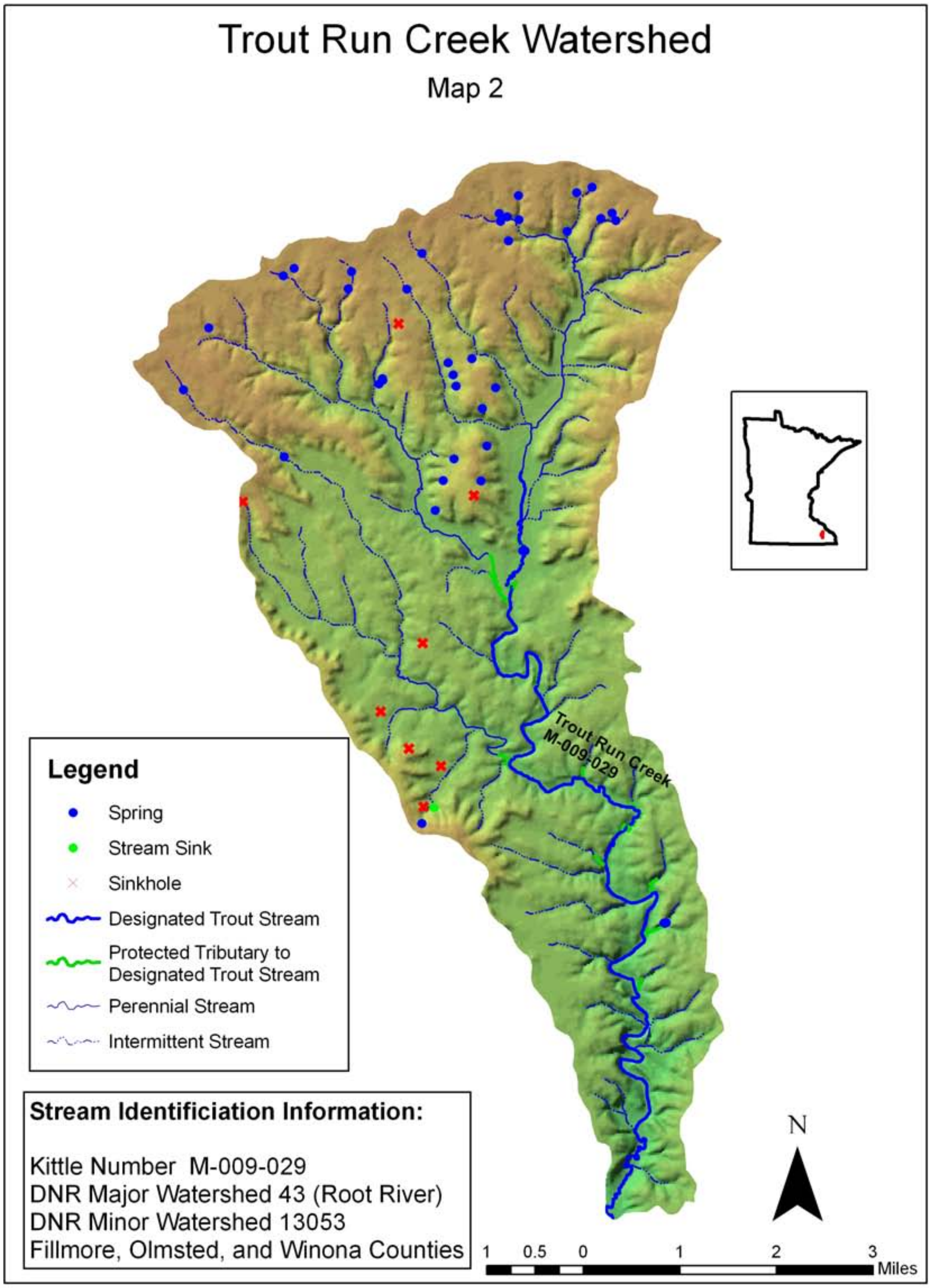


Figure 13. Example watershed map (Map 2) showing assigned Kittle number and trout streams, springs, stream sinks, and sinkholes, Trout Run Creek (M-009-029, Fillmore County).

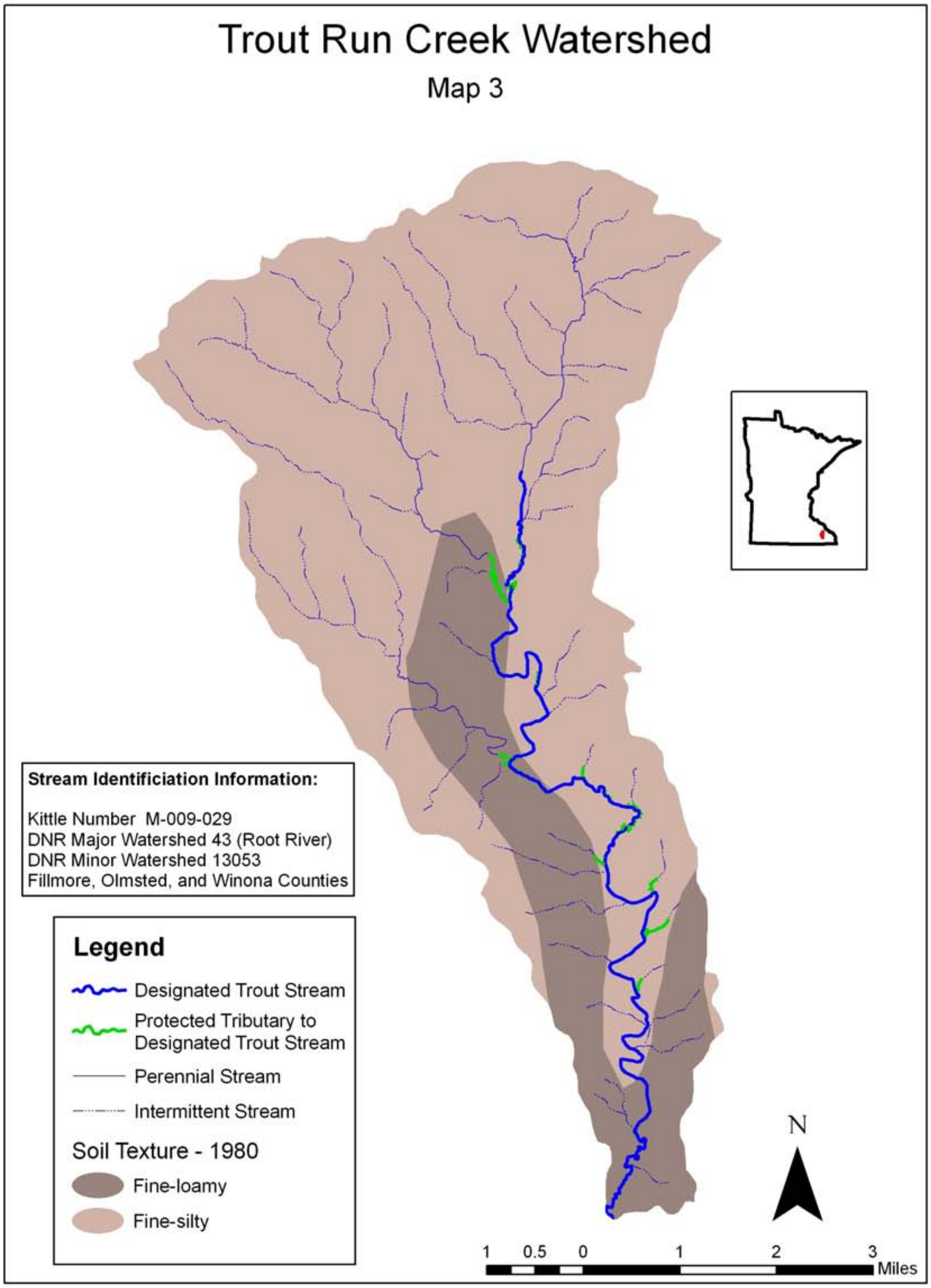


Figure 14a. Example watershed map (Map 3a) showing soil texture and DNR 24K stream layer, Trout Run Creek (M-009-029, Fillmore County).

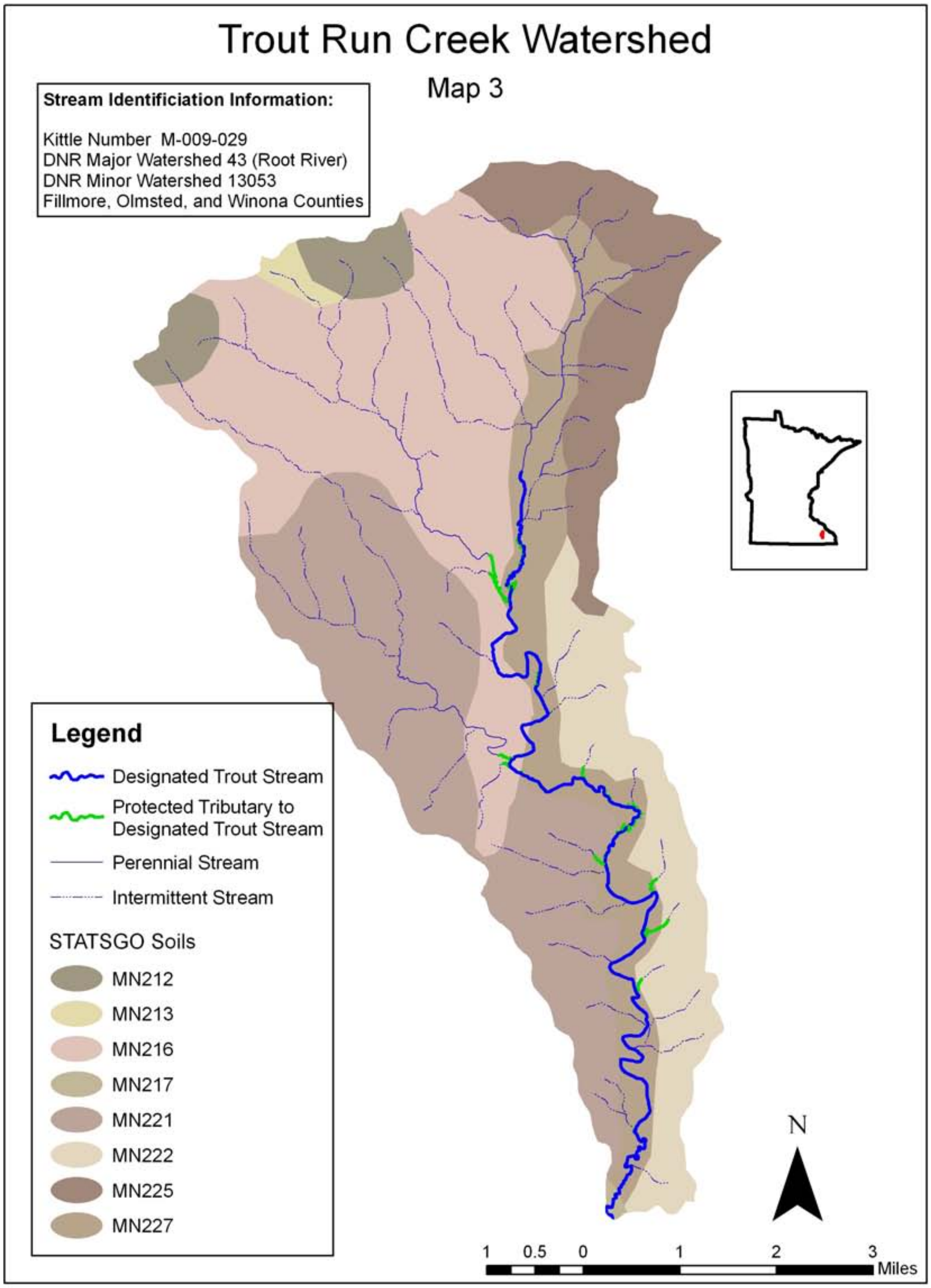


Figure 14b. Example watershed map (Map 3b) showing soil classification and DNR 24K stream layer, Trout Run Creek (M-009-029, Fillmore County).

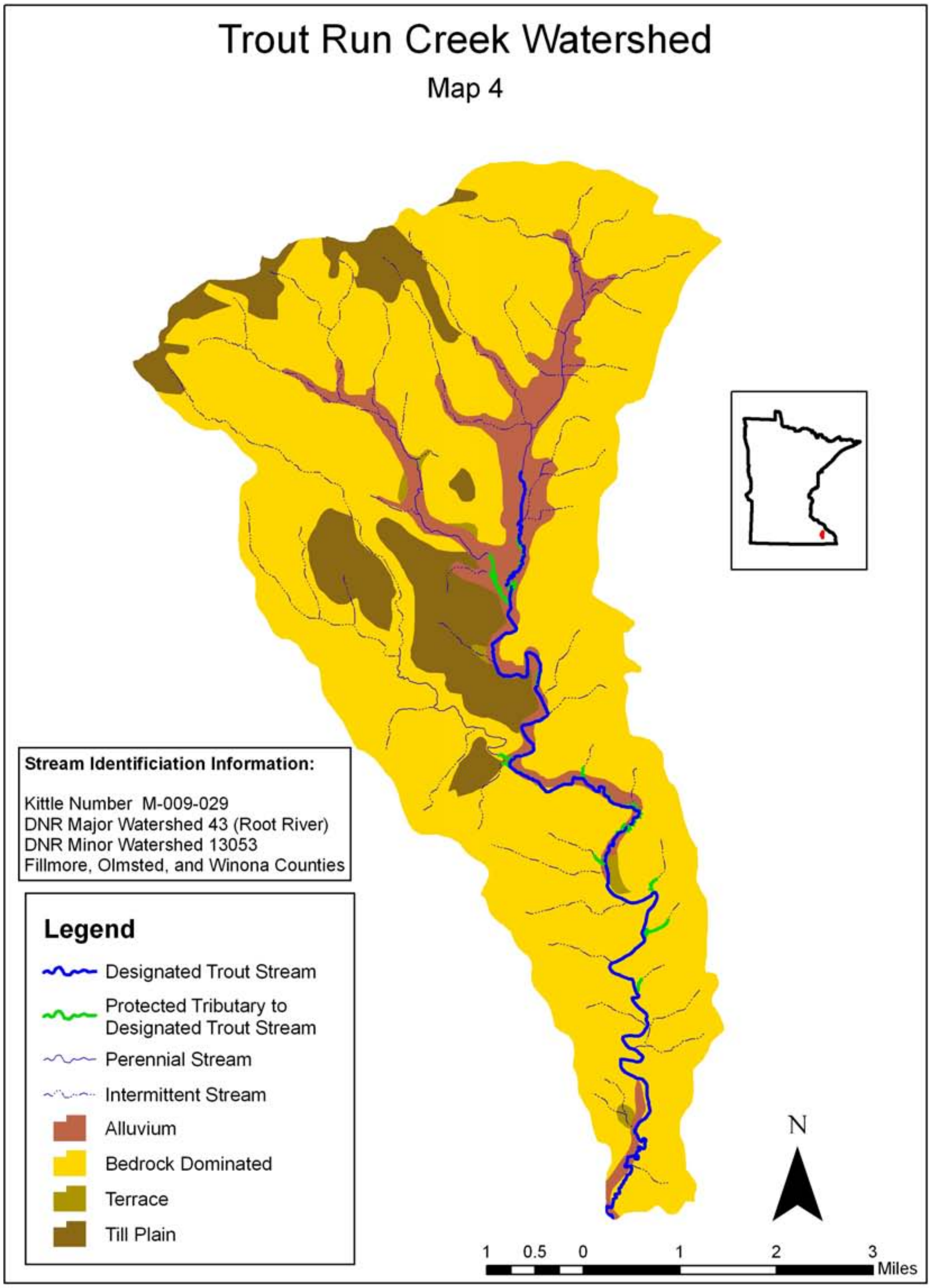


Figure 15. Example watershed map (Map 4) showing geomorphic sedimentary associations, Trout Run Creek (M-009-029, Fillmore County).

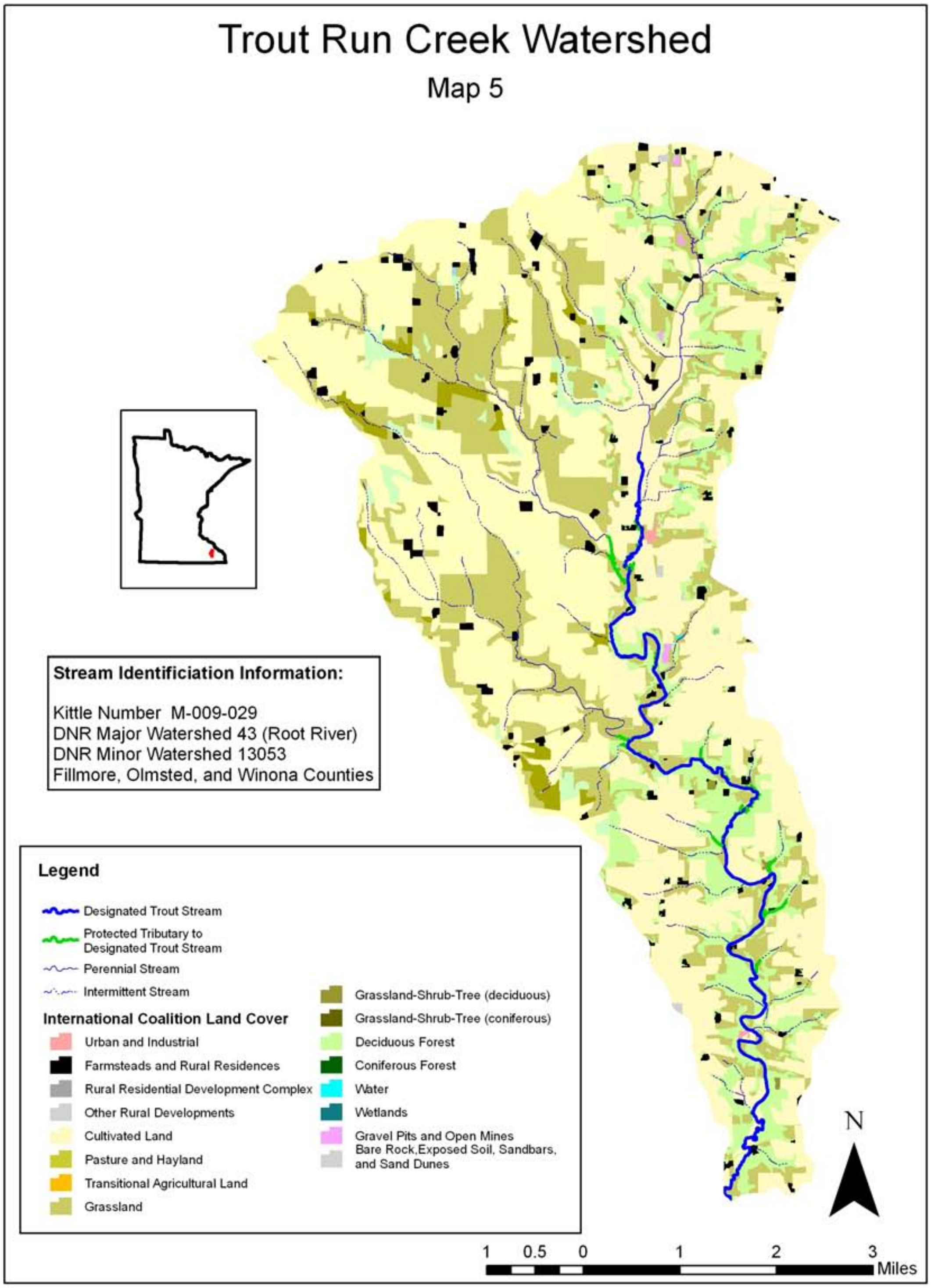


Figure 16. Example watershed map (Map 5) showing land cover information from 1992 satellite imagery, Trout Run Creek (M-009-029, Fillmore County).

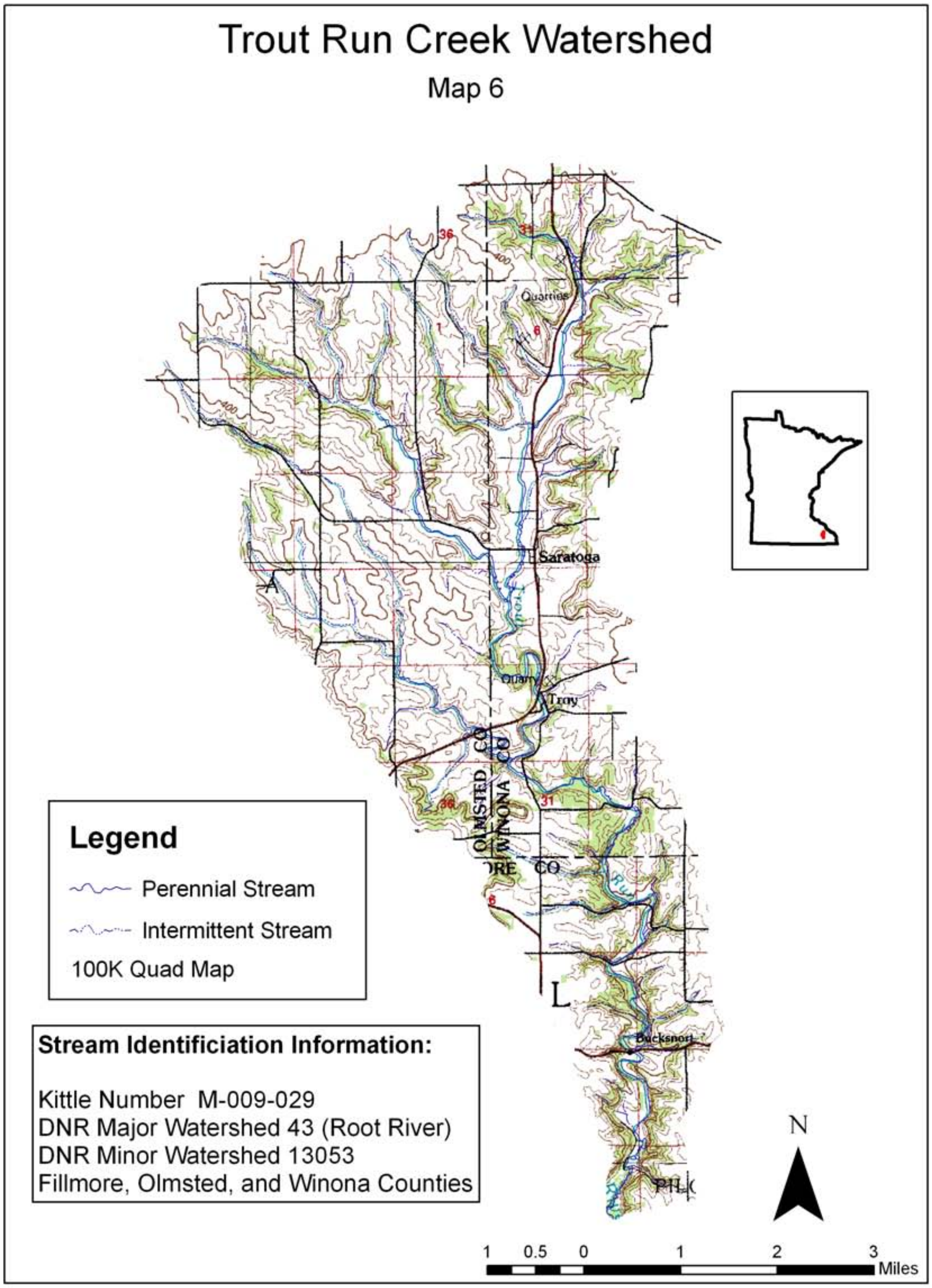


Figure 17. Example watershed map (Map 6) showing USGS 24-minute quadrangle, Trout Run Creek (M-009-029, Fillmore County).

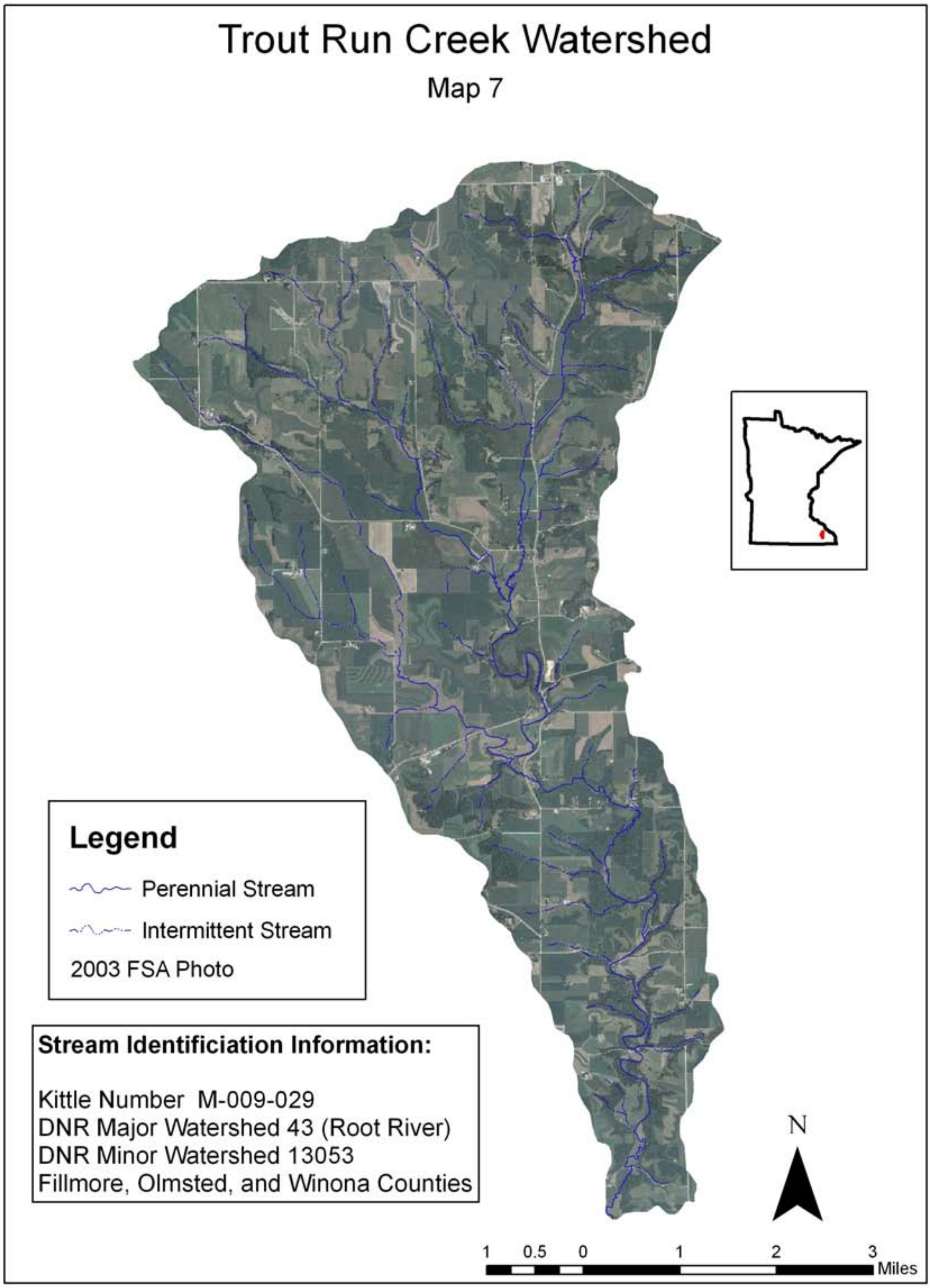


Figure 18. Example watershed map (Map 7) showing 2003 aerial photography and DNR 24K stream layer, Trout Run Creek (M-009-029, Fillmore County).

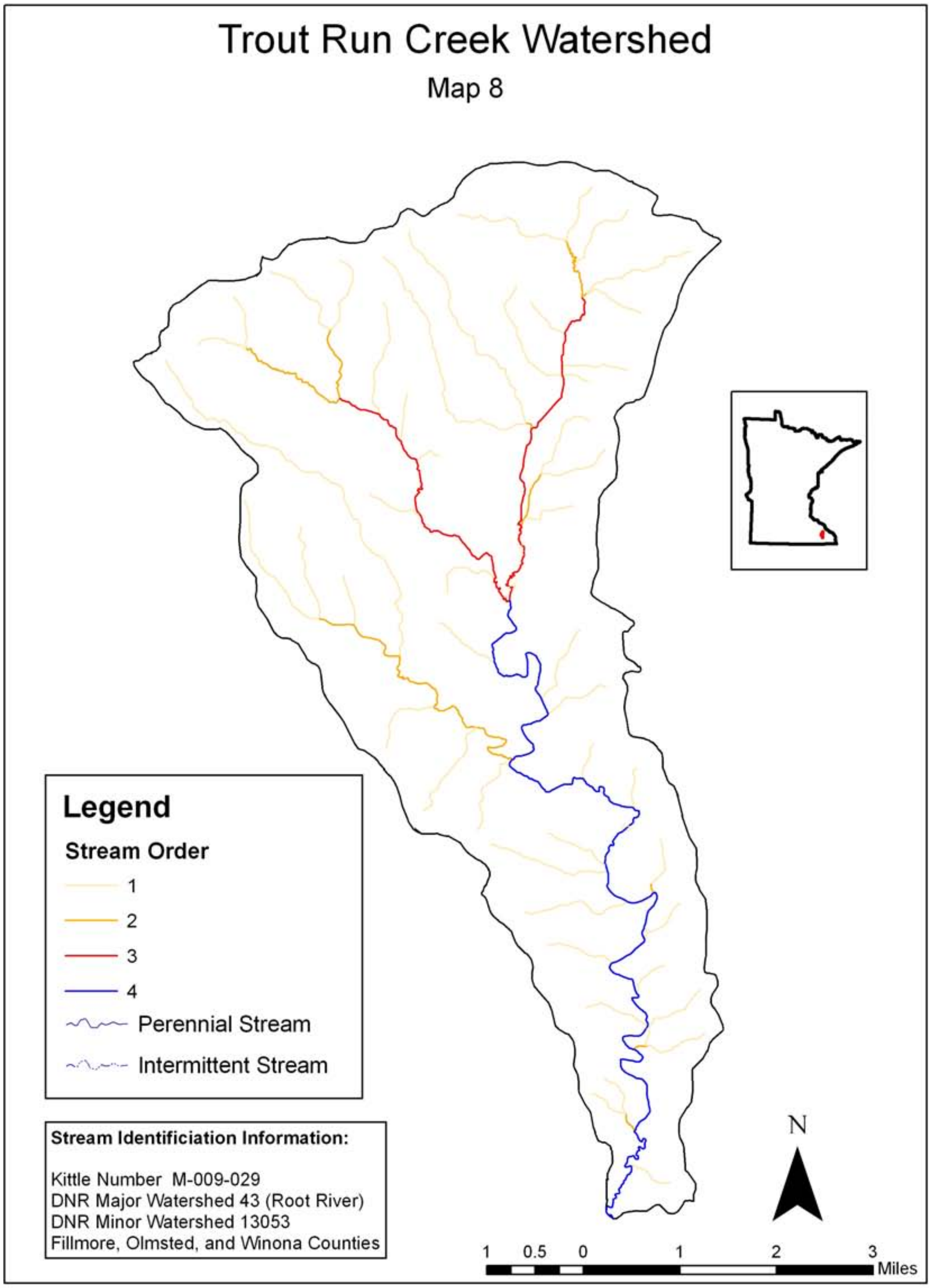


Figure 19. Example map (Map 8) of Strahler stream order assigned, Trout Run Creek (M-009-029, Fillmore County).

Basic Watershed Measures

Calculate and record the basic watershed measures listed below (see Table 2 for an example).

1. **Watershed or Basin Area "A"**. Measure the basin area in square miles or acres.

2. **Basin Length "L"**. Measure the length of the watershed in feet or miles from the farthest point to the mouth.

3. **Basin Relief**. Use a topographic map to determine the difference between the highest and lowest elevation in the basin.

4. **Basin Relief Ratio "R_r"**. Determine the difference between the highest and lowest elevation in the basin and divide by basin length, or use a topographic map to determine the difference between the highest and lowest elevation in the basin and divide by basin length.

5. **Basin Shape (Elongation ratio R_e)**. Calculate the elongation ratio, R_e (Schumm 1956): R_e=diameter of a circle with the same area as that of the basin divided by basin length. To find the diameter, divide the area (in square units) by p (approximately 3.14159), then take the square root of the result. This is the radius. Now double the radius to get diameter.

   Example: 303,000/3.14159 = 96447.98, the square root of the result = 310.56. Double this = 621.12. Now divide by the length of the basin.

6. **Stream Order (Strahler)**. Assign Strahler stream order (Strahler 1952), where a stream with no tributaries is considered a first-order stream (use DNR 24K Rivers and Streams as the base map), a segment downstream of the confluence of two first-order streams is a second-order stream, etc. (see Figures 19, 20, and 21).

7. **Main Stem Stream Length.** Select the stream segments with the Kittle number desired as far as categorized as a perennial stream, and use map tools / statistics to measure the length of the main channel in feet or miles.

8. **Mean Stream (Channel) Slope, "Sc".** Use a topographic map to determine the highest and lowest elevation for the main stream. Subtract the lowest stream elevation from the highest and divide by stream length.

9. **Drainage Density.** Divide total channel length by drainage basin area. (miles/square miles or feet/square feet).

10. **Land Use and Land Cover**. Use GIS tools with the latest available land cover maps to calculate the total area by land use and land cover, then calculate percent total by land use/cover type.

Table 2. Example watershed metrics for Trout Run Creek (M-009-029, Fillmore County, MN).

Basic Watershed Measures	
1) Watershed Area	A = 32 mi^2 (20,4070 acres)
2) Basin Length	L = 58,124.75 ft
3) Basin Relief	445 ft
4) Basin Relief Ratio	R_r = 0.0076
5) Basin Shape	R_e = 0.58
6) Stream Order	4 (see Map 8, Figure 19)
7) Main Stem Stream Length	89,903 ft (17.0 mi)
8) Total Channel Length	38423,5 ft (72.7 mi)
9) Mean Stream Slope	S_c = 0.0048
10) Drainage Density	2.28 mi/mi^2
11) Land Use / Land Cover	See Map 5, Figure 16

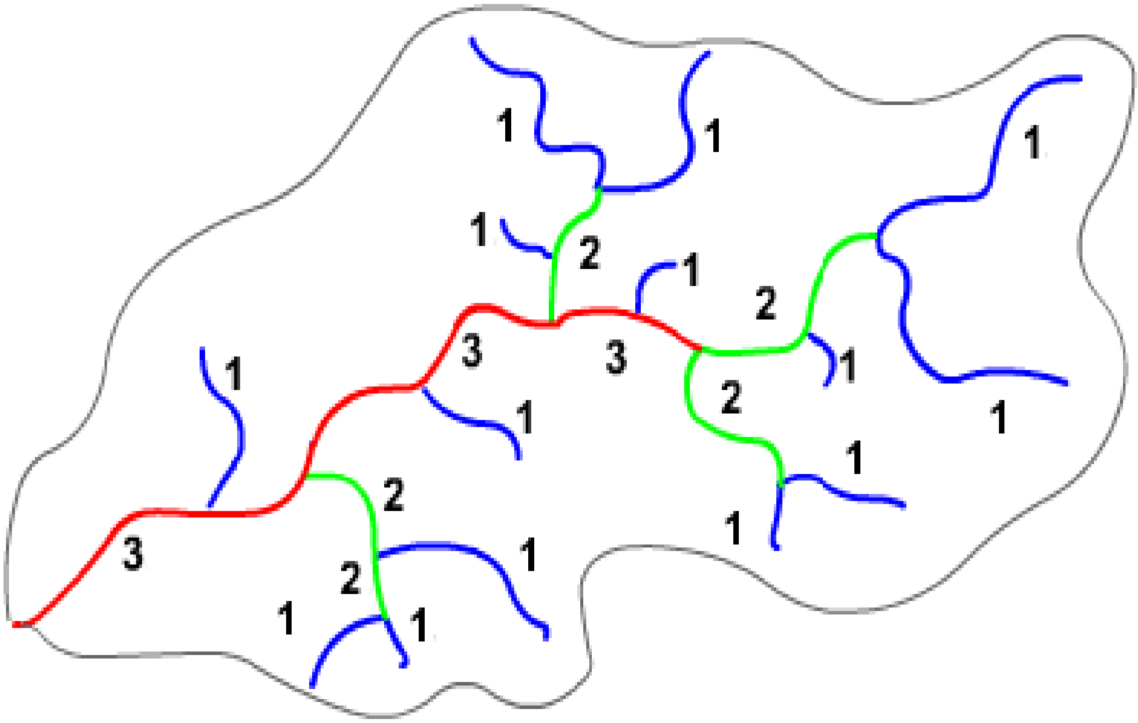


Figure 20. Strahler's (1952) stream order system is a simple method of classifying stream segments based on the number of tributaries upstream. A stream with no tributaries (headwater stream) is considered a first-order stream. A segment downstream of the confluence of two first order streams is a second order stream. Thus, an n^{th} - order stream is always located downstream of the confluence of two $(n-1)^{th}$ - order streams.

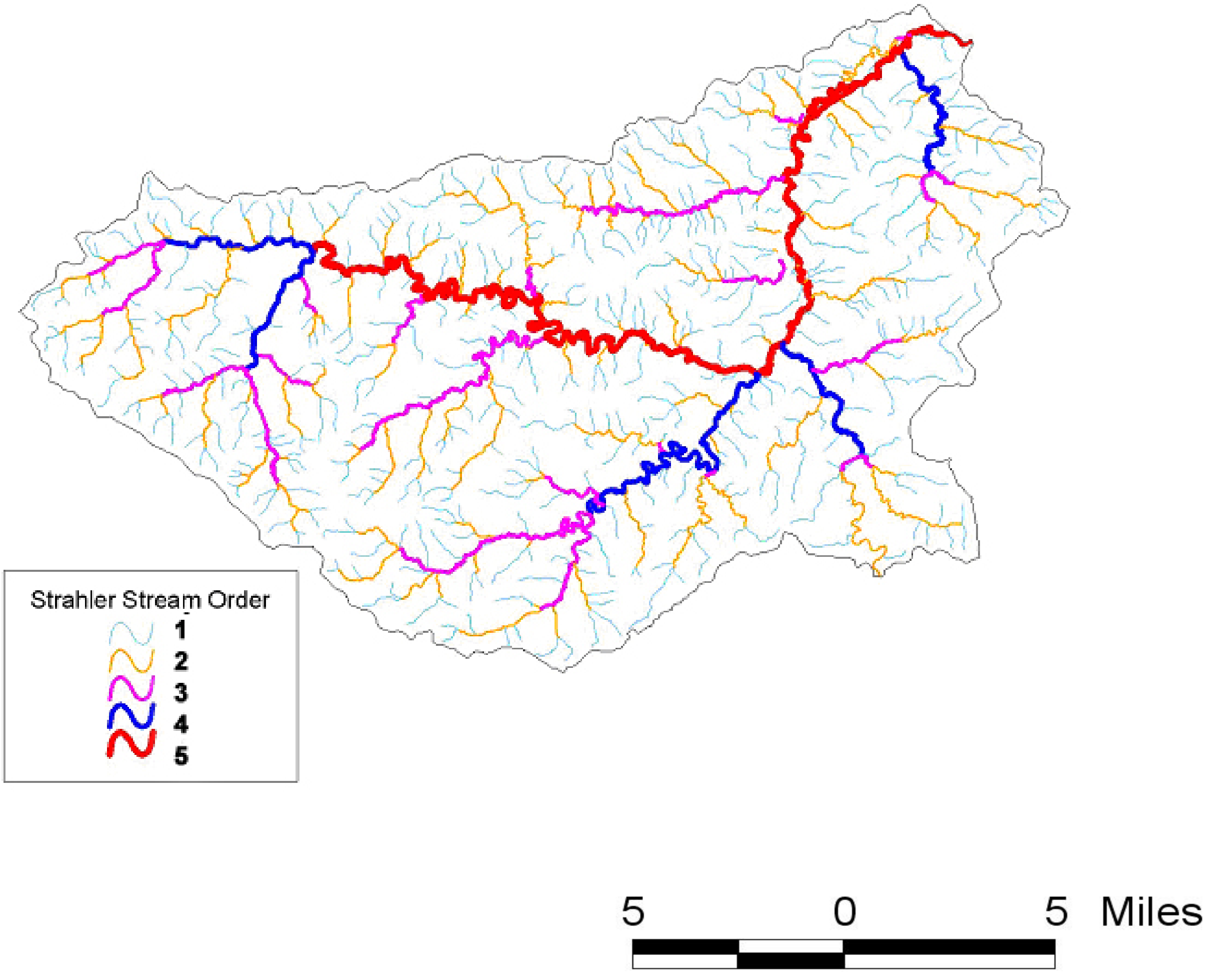


Figure 21. Strahler stream orders assigned, first through fifth order, for Whitewater River (M-031, Olmsted, Winona, and Wabasha counties, southeastern Minnesota).

Precipitation

Precipitation includes all forms of water falling from the atmosphere to the earth's surface. The characteristics of the precipitation at a location in a given storm, in terms of intensity, duration, and areal extent, are determined by the source of the water vapor in the atmosphere and the lifting mechanism, which causes precipitation. In particular, convective rainfall typically has higher intensities for shorter durations, and affects a smaller area, than cyclonic or frontal rainfall. Variations in these characteristics, and whether the precipitation falls as rain or snow, have a profound effect on the nature and extent of subsequent hydrological processes on and below the land surface. Spatial variability in precipitation, especially rainfall, can dramatically affect the amount and timing of runoff contributed by various parts of the drainage network (a.k.a. variable source concept).

Regional precipitation data are readily available from the State Climatology Office (http://climate.umn.edu/doc/historical.htm) or the National Weather Service. A wealth of climate data is available. Examine precipitation patterns to help understand how they may influence a stream's daily or annual hydrograph. Long-term trends in annual precipitation may be indicators of changes in stream flow regimes.

Obtain monthly and annual data from the State Climatology Office Web site, and create the following plots for the area of interest:

1. Seasonal precipitation patterns (e.g., percent contribution from snow and rain; use Figure 22 to show statewide variation and seasonability).

2. Mean annual precipitation (Figure 23).

3. Trends or departures from normal; may be evident by examining discrete time periods (examples, Figures 24 and 25).

Stream Flow

1. Seasonal patterns and variability (mean monthly discharge, Figure 26).

2. Plots of mean daily (Figure 27), monthly, and annual (Figure 28) flow over time.

Springs, Seeps, Sinkholes, Stream Sinks, Discharges

A spring is any natural discharge of water from rock or overlying soil onto the surface of the land or into a body of surface water. Springs are an important source of flow for some streams, especially in karst geologic features. The intimate connection between ground water and surface water in some areas (e.g., southeast Minnesota) gives rise to large number of coldwater streams where trout and other important species thrive (Runkel et. al. 2003).

Karst is an efficiently drained landscape that forms on soluble rock. Karst is characterized by caves, sinkholes, a lack of surface drainage and other climatically controlled features, and is mainly, but not exclusively, formed on limestone. Karst features arise when rain falls and infiltrates the soil, where the availability of carbon dioxide causes the formation of weak carbonic acid, dissolving soluble carbonic rocks.

Dissolution of the rock is focused where water flow and surface area are greatest, and this is usually along areas of pre-existing fractures, and partings or bedding planes. These features easily conduct the water, and are gradually widened by dissolution, sometimes widening greatly until they become caves or a collapse feature (e.g. sinkholes) occurs at the surface. Surface streams that run into holes in the ground can completely cease flowing on the surface. A disappearing stream may re-emerge at a spring.

Since the early 1980s, the Minnesota Geological Survey and Department of Geology and Geophysics at the University of Minnesota have been mapping karst features and publishing various versions of their results. A karst feature database of Minnesota has been developed that allows springs, sinkholes and other feature distributions to be displayed and analyzed in a GIS environment.

As part of an initial stream survey, the location of known springs, seeps, sinkholes, stream sinks, and discharges should be documented on a map (see Map 2, Figure 13. Check the DNR website for the status and availability of GIS data and tools to map spring locations.

If you encounter any undocumented springs during stream survey field activities, fill out a Spring Data Sheet (example form in Figure 29, blank form in appendix 1) and mail a copy to:

Groundwater Hydrologist
DNR Waters
2300 Silver Creek Road
Rochester, MN 55906
(jeff.green@dnr.state.mn.us)

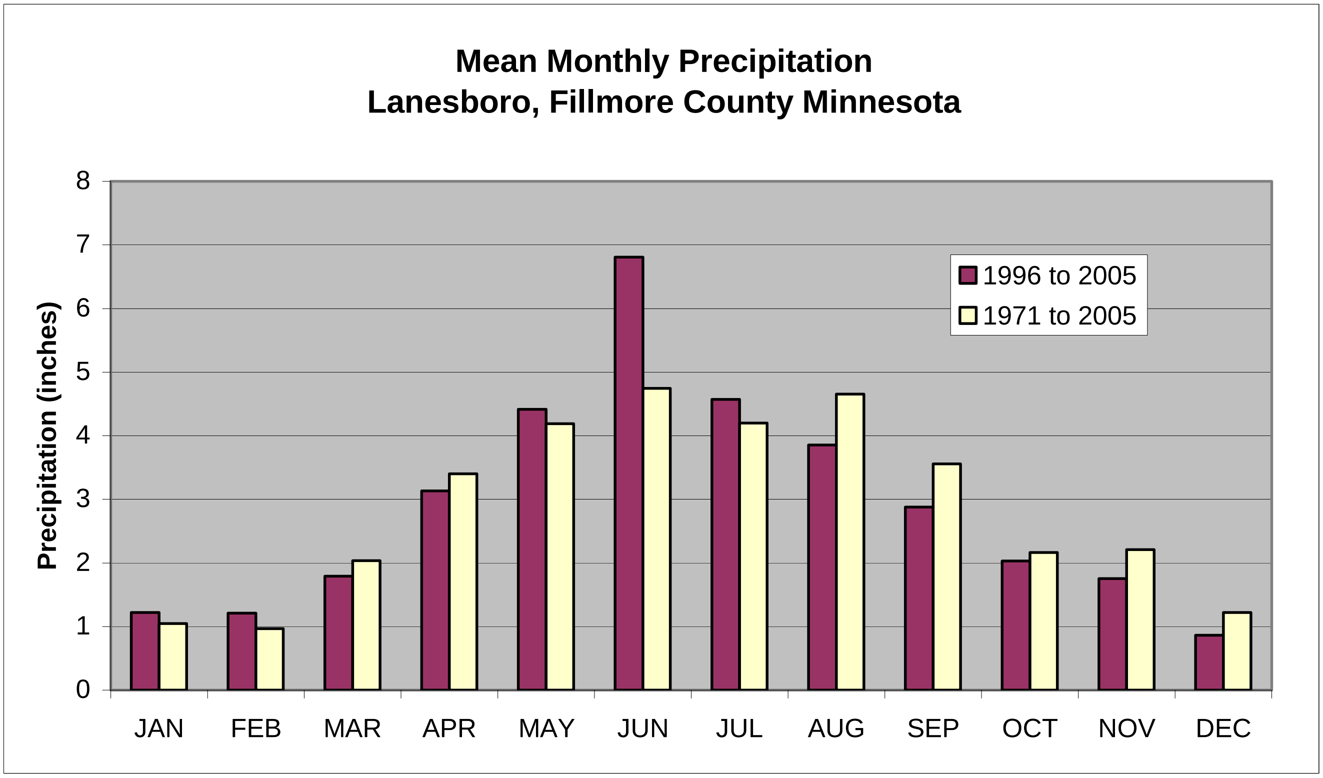


Figure 22. Example plot of mean monthly precipitation pattern for Lanesboro, Minn. (station nearest to the Trout Run Creek watershed). The past 10 years suggest increased precipitation in June and less precipitation during August through December, compared to 35-year means.

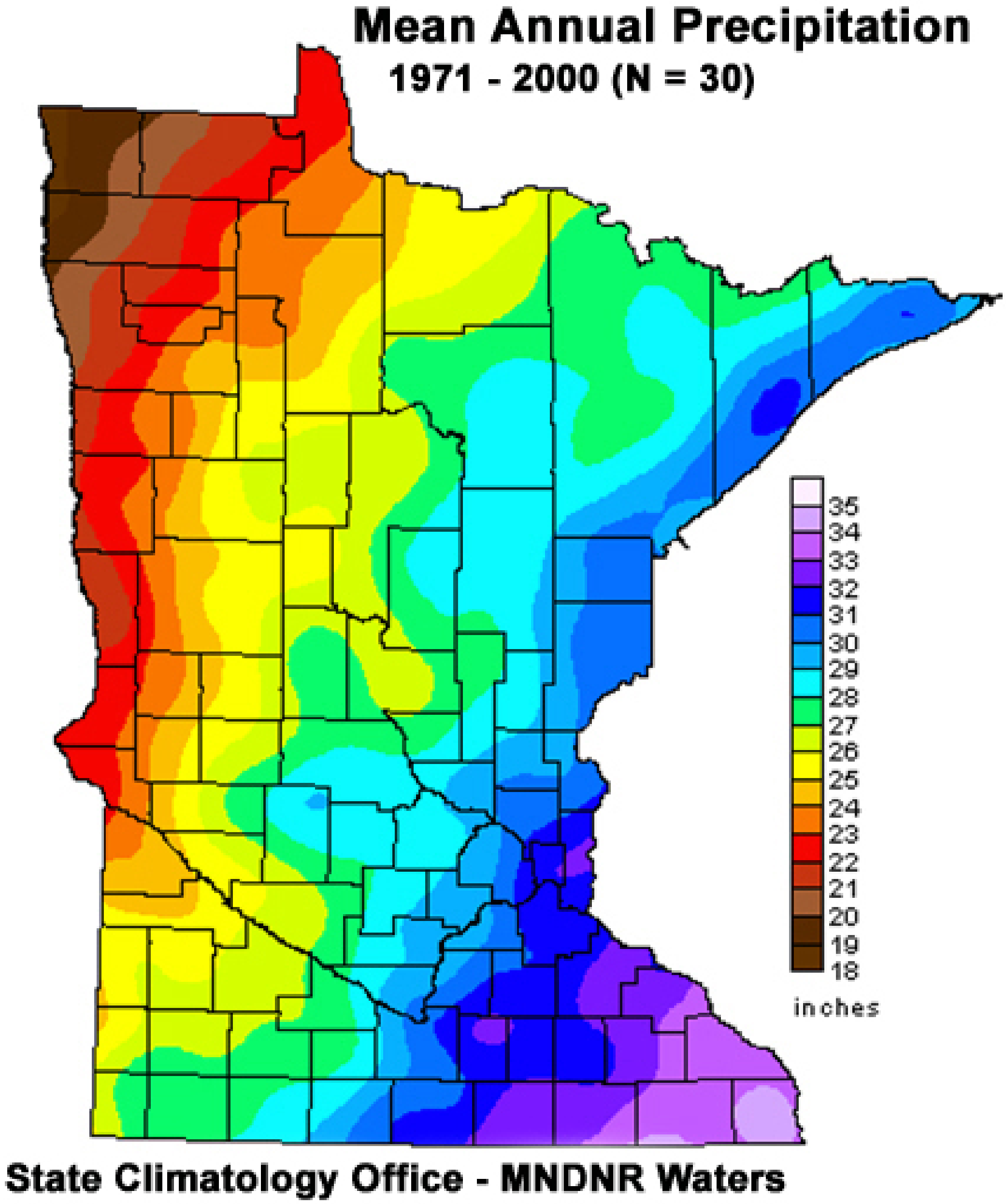


Figure 23. Statewide variation in mean annual precipitation for Minnesota, 1971-2000 (source: Minnesota State Climatology Office, MNDNR Waters, calculated July 2003).

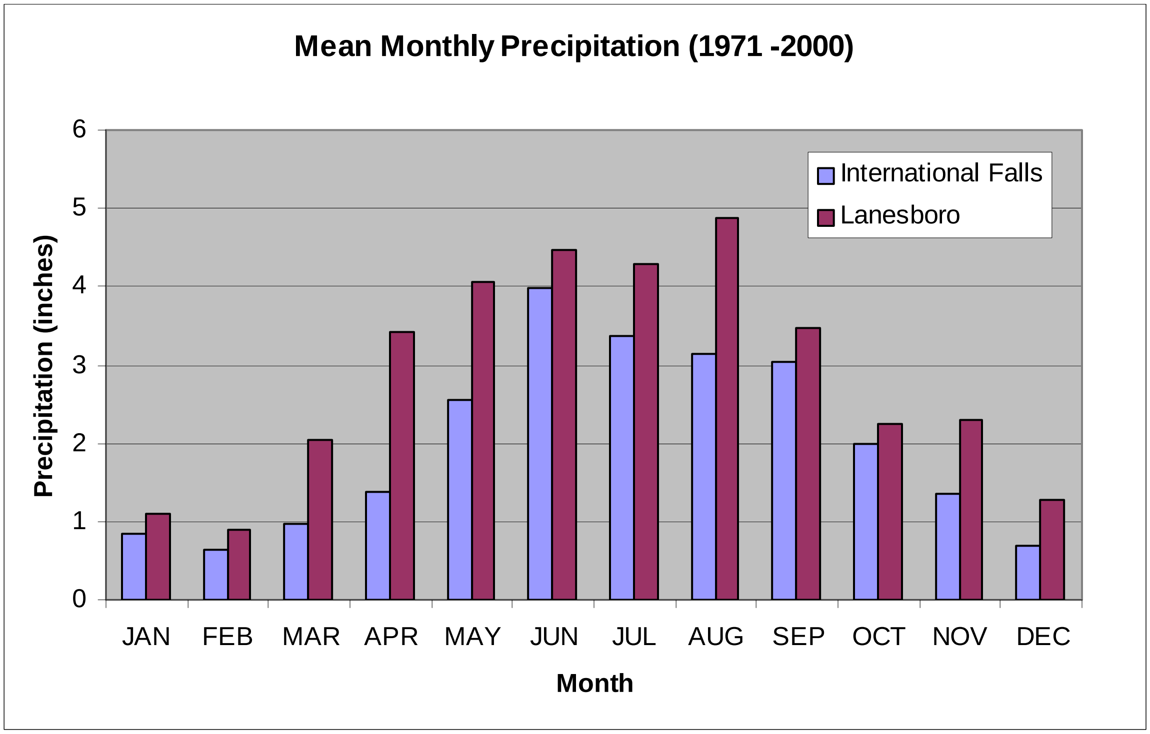


Figure 24. Comparison of mean monthly precipitation at International Falls, Minn. and Lanesboro, Minn., illustrating seasonal and geographic variation (1971-2000, N=30).

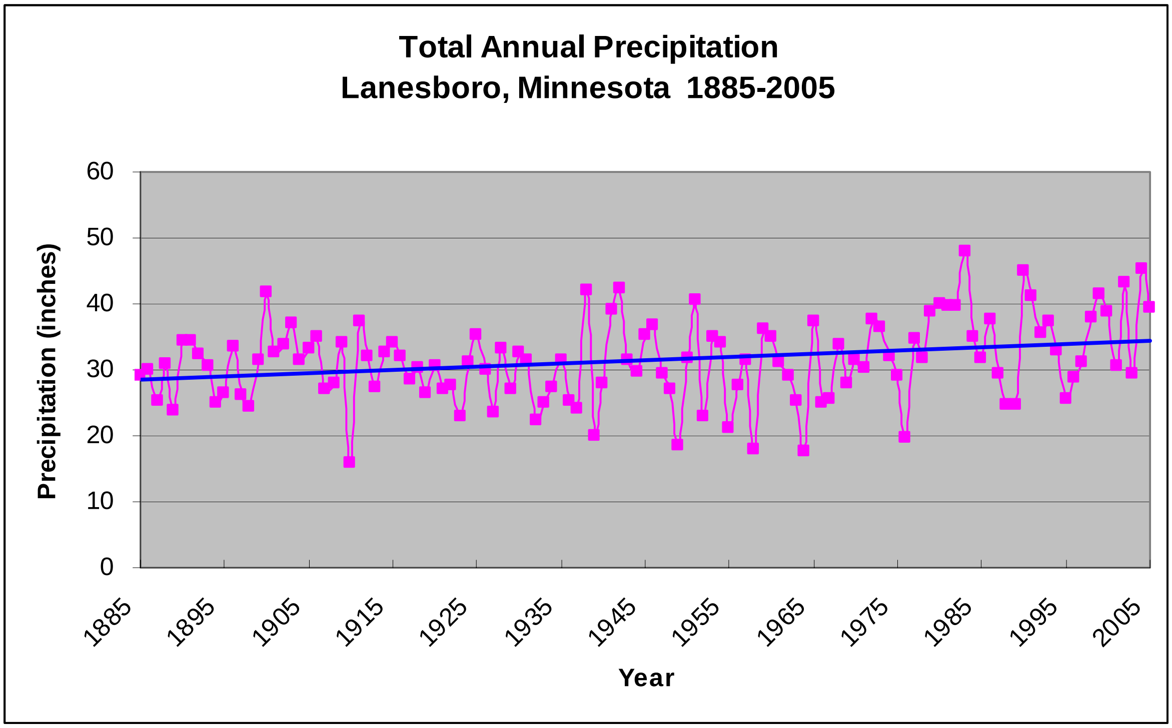


Figure 25. Total annual precipitation for Lanesboro, Minn., (Root River watershed, M-009), 1885–2005. Annual precipitation data from monthly precipitation sums from the National Weather Service (N=12), Carrolton Township, T.103N., R.10W., S.2.

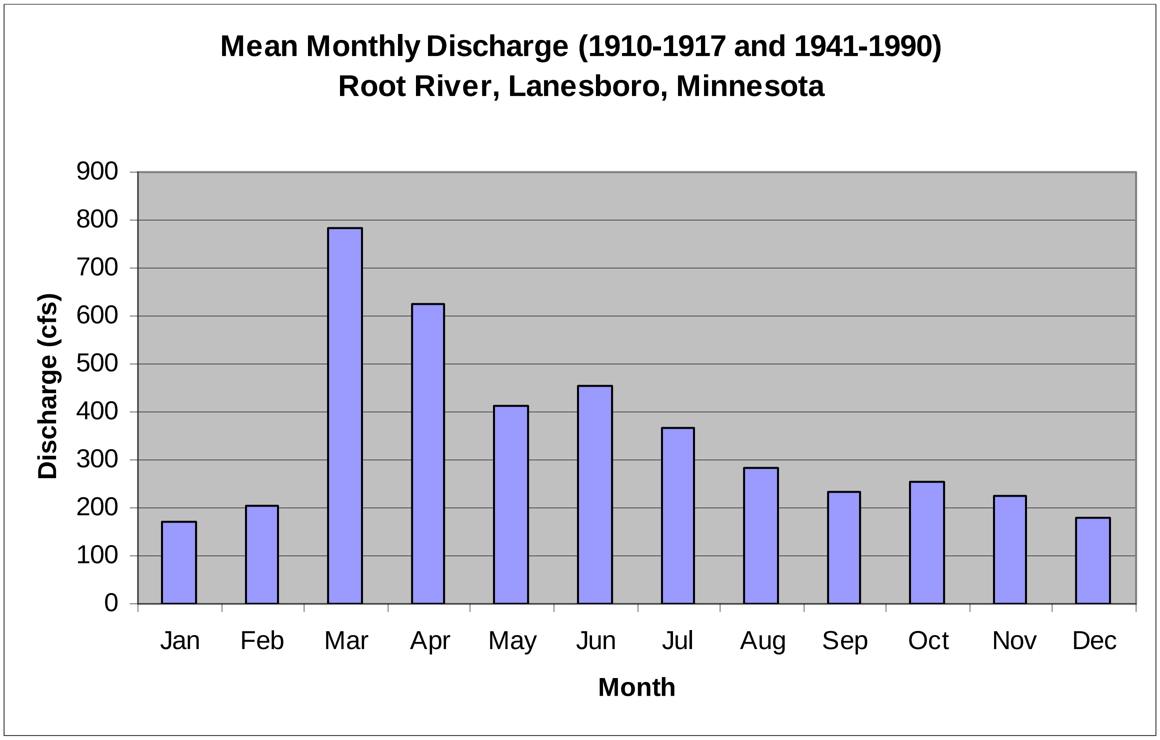


Figure 26. Mean monthly stream discharge for the Root River near Lanesboro, Minn.

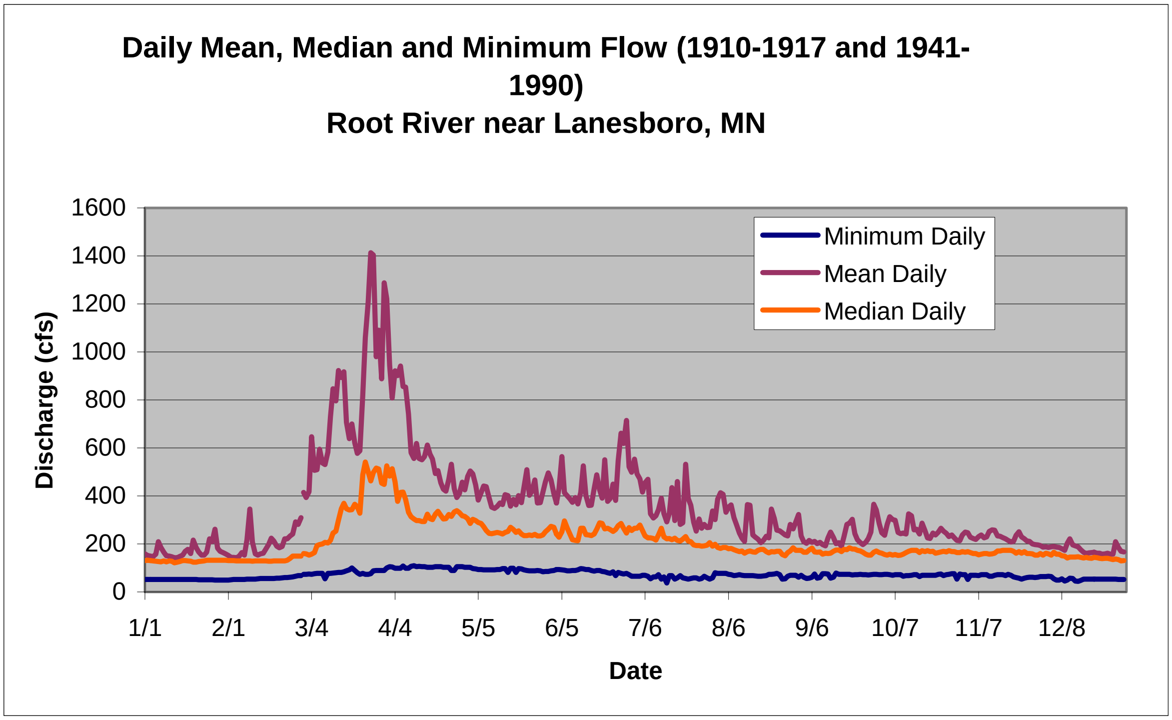


Figure 27. Example plots of daily discharge for the period of record for the Root River near Lanesboro, MN. This graph depicts the seasonality of stream discharge, with higher flows associated with spring snowmelt and early summer rain.

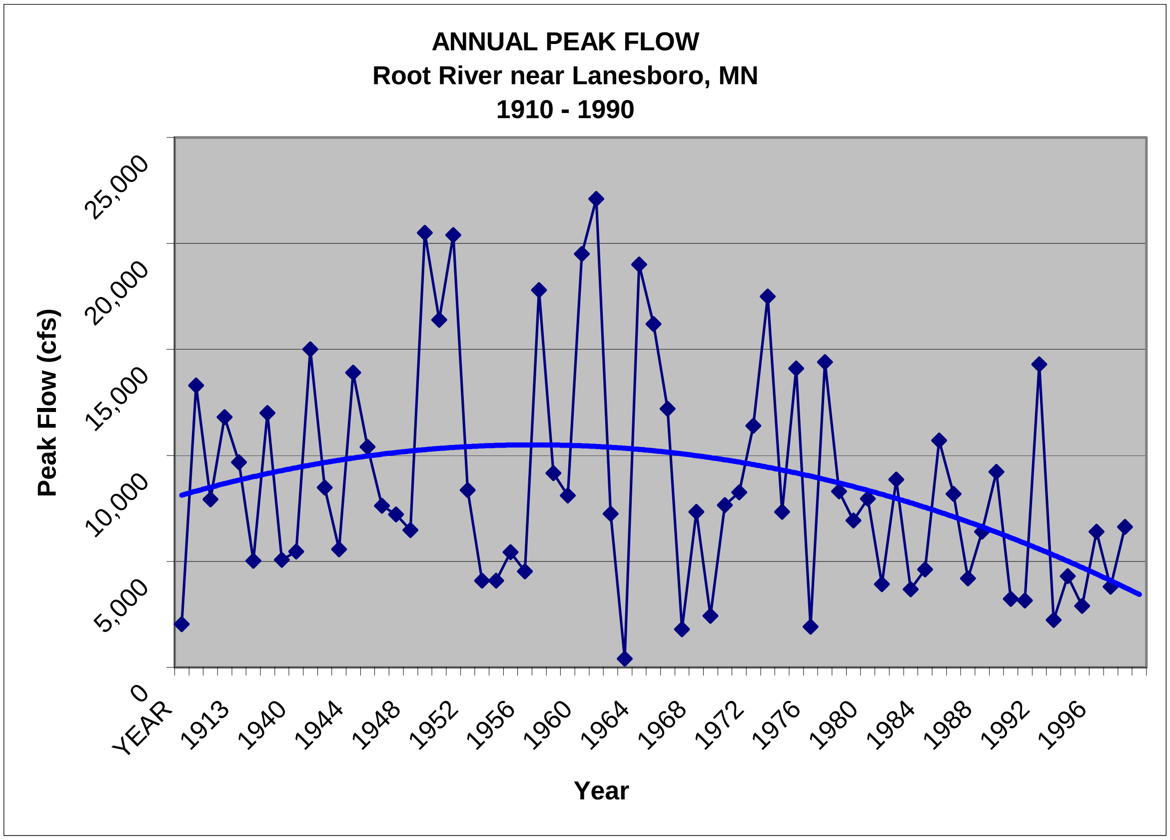


Figure 28. Annual peak flow over time for the Root River near Lanesboro, MN, 1910–1990 (N=67).

STREAM SURVEY:

SPRING DATA FIELD SHEET

Stream Name:	**Kittle Number:**	**Survey Date:**
Crew Names:	Area Office:	

Spring Location Information

Spring Name:		County
Sample Date:		Distance from stream (ft.):
GPS Coordinates (UTM, Zone 15)	X:	Y:
Coordinate Source:		Legal Description (T-R-S):
Landowner information (Name, address, telephone number):		

Spring Physical and Chemical Parameters

Elevation (ft. above sea level):	pH:
Spring Water Temperature (^{o}F):	Dissolved Oxygen (ppm):
Air Temperature (^{o}F):	Turbudity:
Spring flow (c.f.s):	Flow methodology:

Spring Description, additional field information (attach digital photographs if possible).

Mail a copy to:

Groundwater Hydrologist
DNR Waters
2300 Silver Creek Road
Rochester, MN 55906
(jeff.green@dnr.state.mn.us)

Figure 29. Example spring field sheet.

Geomorphology

Geomorphology Checklist

1. ____ Stream and valley morphology (sinuosity and channel cross-section morphology, channel plan-view morphology, page 46; Table 3)
2. ____ Longitudinal elevation profile (page 47, Figure 30)
3. ____ Similar reach and station boundaries (pages 22, 47; Figure 11; Map 9, Figure 32)
4. ____ Field verification of similar reaches and survey stations
5. ____ Minnesota Stream Habitat Assessment (MSHA; pages 50–64; Figures 33-34, Table 4)

The following techniques and procedures are used to describe the geomorphic characteristics of a stream and its watershed. Use these characteristics, along with information collected in other survey components, to define similar reaches and survey stations. Following the methods described below, use Figure 31 to determine the general stream type for each stream reach of interest For the purpose of this report, a reach is defined as a segment of stream with relatively consistent morphological characteristics (e.g., gradient, sinuosity, cross-section morphology) and in-stream habitat is assumed to be similar throughout a delineated reach. Reach numbering begins with the farthest downstream reach and progresses sequentially upstream. On a stream with previously completed surveys, verify that stations and reach boundaries are still valid.

Stream and Valley Morphology

Refer to map 3 (soils; Figure 14a and 14b), map 4 (bedrock geology; Figure 15), and map 6 (topography; Figure 17) as described in the initial survey for hydrology.

Channel Sinuosity. Sinuosity (K) is estimated as the ratio of stream channel length to the valley length, or the valley slope to the channel slope. Digital ortho photographs provide the most accurate channel length and should be used for estimating channel sinuosity. However, the DNR 24K streams layer may be used when stream channels cannot be seen on the digital ortho photos. Sinuosity should be determined for each individual similar reach.

Channel Cross-section Morphology. Estimate channel cross-section morphology. The interpretation of channel cross-section shapes at this level should be adequate to distinguish between narrow, deep streams and wide, shallow streams. Characteristics important for this interpretation include flood plain extent, position of terraces, structural control features, degree of channel confinement and entrenchment, and overall valley versus channel macro-dimensions.

Channel Plan-view Morphology. Determine channel plan-view morphology as described in Table 3.

Table 3. Plan-view groups of river patterns (adapted from Rosgen 1996).

Plan-view groups	**Stream Type Association**
Relatively straight	A
Low sinuosity	B
Meandering	C and F
Tortuously meandering	E
Complex stream patterns (multiple channels, braided or anastomosed)	D and DA

Longitudinal Elevation Profile. Create a longitudinal elevation profile (Figure 30). Refer to the MNDNR Fisheries web site for instructions on using GIS tools to complete this profile.

Similar Reach Map. Create a similar reach map (Map 9, Figure 32), identifying proposed similar reach boundaries, stream types of reaches (Bain and Stephenson 1999, adapted from Rosgen 1996; Figure 31), and reach specific sinuosity.

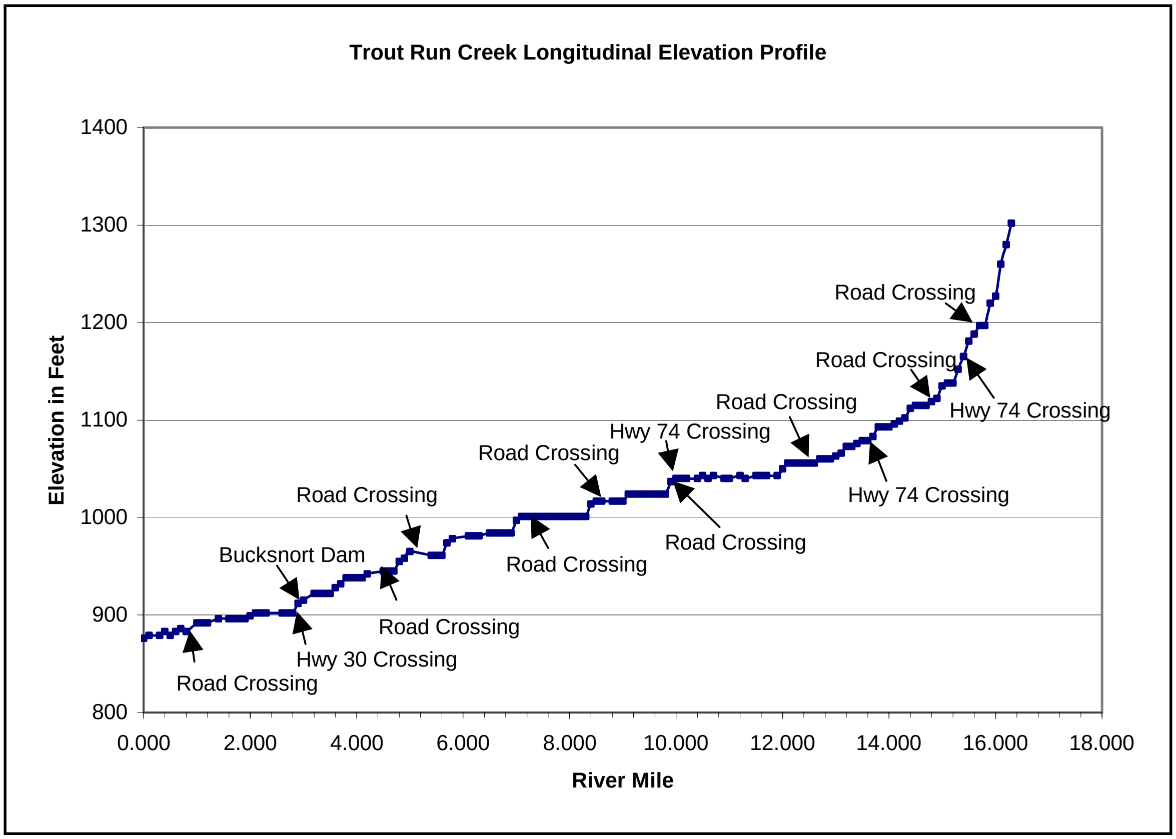


Figure 30. Example longitudinal elevation profile with stream crossings and barriers, Trout Run Creek, Fillmore County, MN.

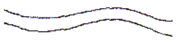
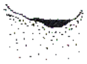
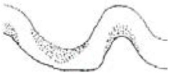
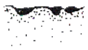
Stream Type	General Description	Longitudinal Profile (slope)	Cross Section	Plan view Morphology	Landform, soils, features
Aa+	Very steep; deeply entrenched; debris transport; torrent	>0.10	 ER <1.4 W:D<12	 Sinuosity 1.0-1.1	Very high relief; erosional, bedrock, or depositional features; debris flow potential; deeply entrenched; vertical steps with deep scour pools; waterfalls
A	Steep, entrenched, cascading, step-pool; high energy and debris transport, depositional soils; very stable if bedrock or boulder dominated	0.04-0.10	 ER<1.4 W:D<12	 Sinuosity 1.0-1.2	High relief; erosional or depositional and bedrock forms; entrenched and confined; cascading reaches; frequently spaced, deep pools; step-pool bed morphology
B	Moderately entrenched, moderate gradient; riffle dominated; infrequently spaced pools; very stable plan and profile; stable banks	0.02-0.039	 ER 1.4-2.2 W:D>12	 Sinuosity >1.2	Moderate relief, colluvial deposition, and structural; moderate entrenchment and W:D ratio; narrow, gently sloping valleys; rapids predominate with scour pools
C	Low gradient; meandering riffle-pool; alluvial; broad, well-defined flood plains	<0.02	 ER>1.2 W:D>12	 Sinuosity>1.4	Broad valleys with terraces in association with flood plains; alluvial soils; slightly entrenched; well-defined meandering; riffle-pool bed morphology
D	Braided; longitudinal and transverse bars; very wide; eroding banks	<0.04	 ER n/a W:D>40	 Sinuosity n/a	Broad valleys; alluvium, steeper fans; glacial debris and depositional features; active lateral adjustment; abundance of sediment supply; convergence or divergence bed features; aggradational processes; high bedload and bank erosion
DA	Anastomosing; narrow, deep; extensive, well-vegetated flood plains and associated wetlands; gentle relief; highly variable sinuosities and W:D ratios; very stable banks	<0.005	 ER>2.2 W:D highly variable	 Sinuosity highly variable	Valleys broad, low gradient with fine alluvium or lacustrine soils; anastomosed; fine deposition; well-vegetated bars are laterally stable; broad wetland floodplains; very low bedload; high wash load sediment
E	Low gradient; meandering; riffle-pool; low W:D ratio; little deposition; very efficient and stable; high meander width ratio	<0.02	 ER>2.2 W:D<12	 Sinuosity >1.5	Broad valley or meadows; alluvial materials with flood plains; highly sinuous; stable, well-vegetated banks; riffle-pool morphology; very low W:D ratios
F	Entrenched; meandering; riffle-pool; low gradient; high W:D ratio	<0.02	 ER<1. 4 W:D>12	 Sinuosity>1.4	Entrenched in highly weathered material; gentle gradients; high W:D ratio; meandering; laterally unstable with high bank erosion rates; riffle-pool morphology
G	Entrenched "gully"; step pool; low W:D ratio; moderate gradients	0.02-0.039	 ER<1.4 W:D<12	 Sinuosity >1.2	Gullies; step-pool morphology; moderate slopes; low W:D ratio; narrow valleys or deeply incised in alluvial or colluvial materials; unstable with grade control problems and high bank erosion rates

Figure 31. Guidelines for stream classification (from Bain and Stevenson 1999, adapted from Rosgen 1994). ER = entrenchment ration and W:D = width/depth ratio.

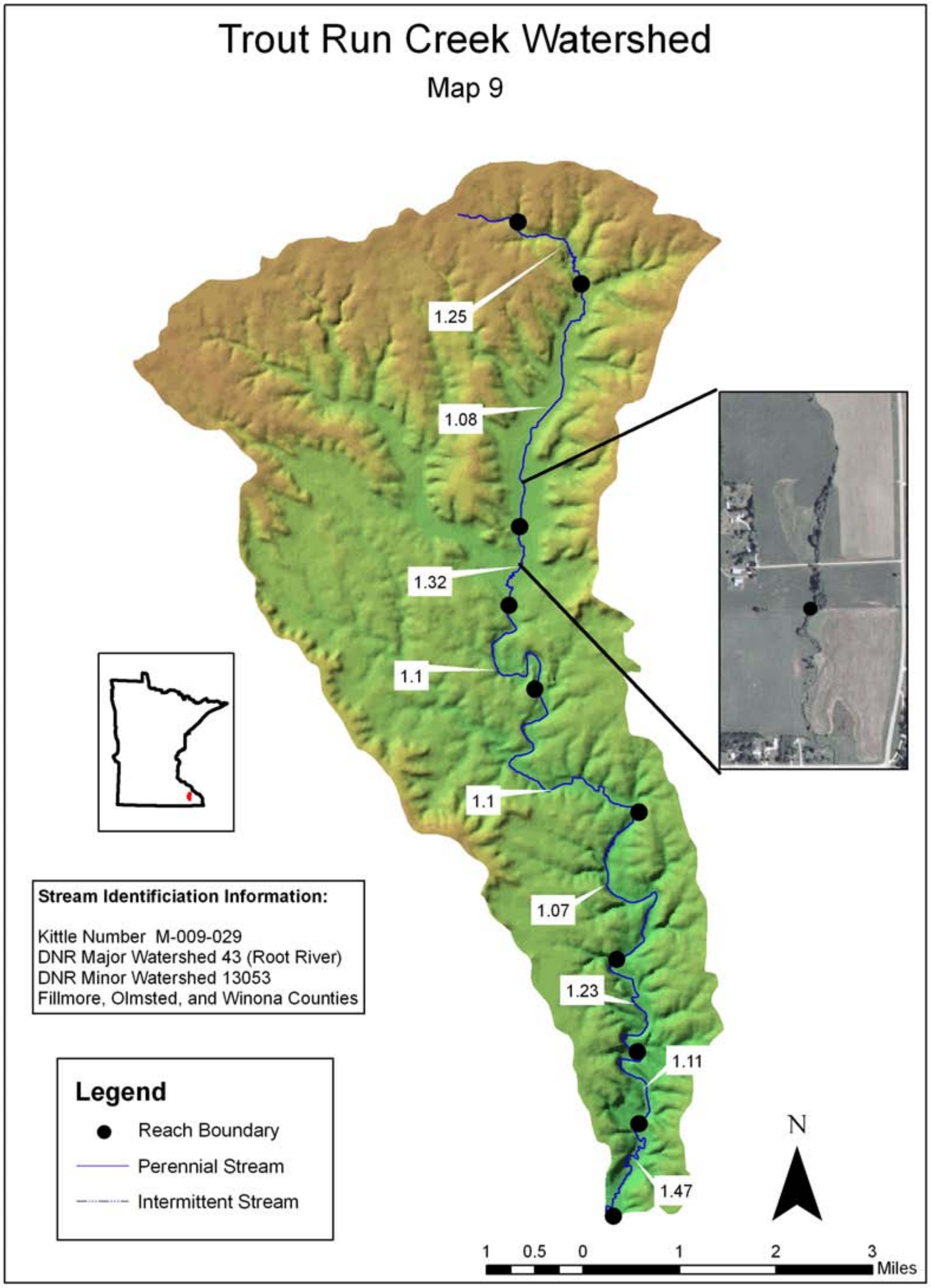


Figure 32. Example of similar reach identification (Map 9), showing proposed boundaries, reach specific sinuosity, and shaded relief. Valley and bedrock features discussed in sidebars. Trout Run Creek (M-009-029), Fillmore County, Minn.

Minnesota Stream Habitat Assessment (MSHA)

The presence and abundance of stream fishes is strongly related to the physical and chemical characteristics of a stream. With changes in stream size, nutrients and habitat, obvious shifts in fish community structure and function may occur.

Physical habitat in streams has been measured and quantified by a multitude of methods. Often, these methods are time consuming and costly (e.g., Habitat Suitability Indices, Habitat Quality Index, Index of Biotic Integrity). The Ohio Environmental Protection Agency has developed a methodology termed the Qualitative Habitat Evaluation Index or QHEI (Rankin 1989, Ohio Environmental Protection Agency 1989, 2006). This index is designed to provide a measure of macrohabitat quality that generally corresponds to physical factors that affect fish communities and are generally important to other aquatic life such as invertebrates. The QHEI is composed of an array of metrics describing attributes of physical habitat that may be important in explaining species presence and absence and composition of fish communities in a stream, without employing the more labor-intensive methods of various Habitat Suitability Indices developed for specific fish species in the fish community.

The Minnesota Pollution Control Agency (MPCA) has developed a stream habitat assessment worksheet derived from the Ohio QHEI methodology, herein referred to as the “Minnesota Stream Habitat Assessment” or MSHA. A comparison of the two assessments indicates a very strong similarity; however, the MSHA methodology is believed to be a better reflection of important factors influencing Minnesota streams. DNR Fisheries is adopting the MSHA methodology, which will facilitate exchange of data between agencies.

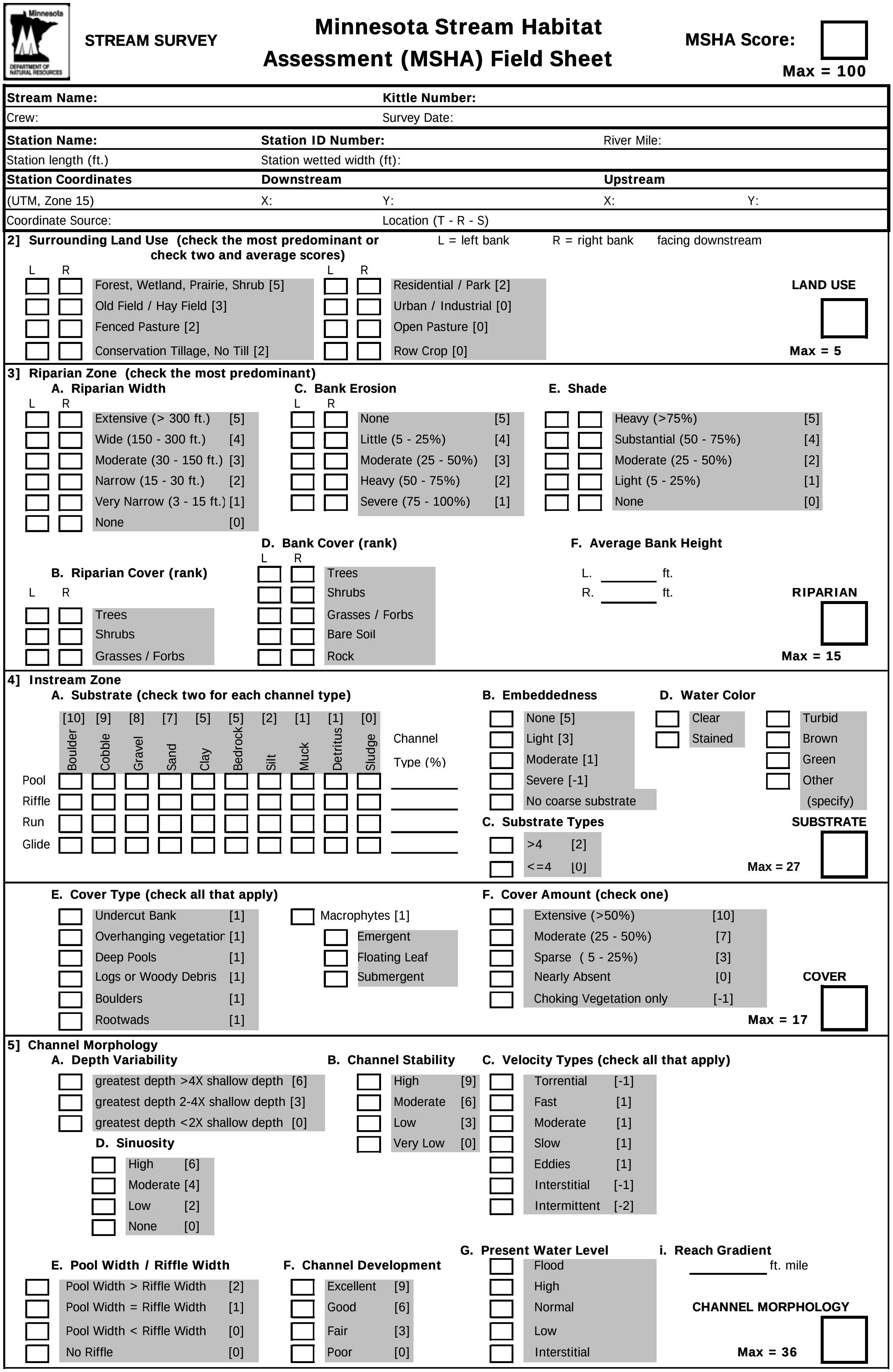
The Ohio QHEI is composed of six principal metrics, while the MSHA includes four metrics (see Table 4). The maximum MSHA site score is 100. Each of the metrics is scored individually on a standard field sheet (Figure 33) and then summed to provide the total MSHA site score. The back of the field sheet (Figure 34) can be used as a worksheet to document and score individual metrics.

Standardized definitions for pool, run, and riffle habitats are essential for accurately using the MSHA. Refer to the definitions for various channel types on pages 56-57.

Table 4. Minnesota Stream Habitat Assessment (MSHA) metrics, metric components, scoring range, and maximum scores by component.

QHEI Scoring (Maximum = 100)

	QHEI Metric		Metric Component	Component Scoring Range	Maximum Component Score
1.	Stream Documentation				No Score
2.	Surrounding Land Use	a)	Type	0 to 5	5
			Subtotal Metric 2		**5**
3.	Riparian Zone	a)	Riparian Width	0 to 5	5
		b)	Riparian Cover	Rank	-
		c)	Bank Erosion	0 to 5	5
		d)	Bank Cover	Rank	-
		e)	Shade	0 to 5	5
		f)	Average Bank Height	Data in ft.	-
			Subtotal Metric 3		**15**
4.	Instream Zone	a)	Substrate Type	0 to 10	20
		b)	Embeddedness	-1 to 5	5
		c)	No. of Substrate Types	0 to 2	2
		d)	Water Color	Color	-
		e)	Water Clarity	Depth in cm.	-
		f)	Cover Type	1 to 1	7
		g)	Cover Amount	-1 to 10	10
			Subtotal Metric 4		**44**
5.	Channel Morphology	a)	Depth Variability	0 to 6	6
		b)	Channel Stability	0 to 9	9
		c)	Velocity Types	-2 to 1	4
		d)	Sinuosity	0 to 6	6
		e)	Pool Width/Riffle Width	0 to 2	2
		f)	Channel Development	0 to 9	9
		g)	Present Water Level	-	-
		i)	Reach Gradient	ft./mile	-
			Subtotal Metric 5		**36**
	TOTAL		**Maximum Score**		**100**



STREAM SURVEY

Minnesota Stream Habitat Assessment (MSHA) Field Sheet

MSHA Score: ☐
Max = 100

Stream Name:
Kittle Number:
Crew:
Survey Date:

Station Name:
Station ID Number:
River Mile:
Station length (ft.)
Station wetted width (ft):

Station Coordinates	**Downstream**		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:

Coordinate Source:
Location (T - R - S)

2] Surrounding Land Use (check the most predominant or check two and average scores) L = left bank R = right bank facing downstream

L	R		L	R	
☐	☐	Forest, Wetland, Prairie, Shrub [5]	☐	☐	Residential / Park [2]
☐	☐	Old Field / Hay Field [3]	☐	☐	Urban / Industrial [0]
☐	☐	Fenced Pasture [2]	☐	☐	Open Pasture [0]
☐	☐	Conservation Tillage, No Till [2]	☐	☐	Row Crop [0]

LAND USE ☐ **Max = 5**

3] Riparian Zone (check the most predominant)

A. Riparian Width

L	R		
☐	☐	Extensive (> 300 ft.)	[5]
☐	☐	Wide (150 - 300 ft.)	[4]
☐	☐	Moderate (30 - 150 ft.)	[3]
☐	☐	Narrow (15 - 30 ft.)	[2]
☐	☐	Very Narrow (3 - 15 ft.)	[1]
☐	☐	None	[0]

C. Bank Erosion

L	R		
☐	☐	None	[5]
☐	☐	Little (5 - 25%)	[4]
☐	☐	Moderate (25 - 50%)	[3]
☐	☐	Heavy (50 - 75%)	[2]
☐	☐	Severe (75 - 100%)	[1]

E. Shade

☐	☐	Heavy (>75%)	[5]
☐	☐	Substantial (50 - 75%)	[4]
☐	☐	Moderate (25 - 50%)	[2]
☐	☐	Light (5 - 25%)	[1]
☐	☐	None	[0]

B. Riparian Cover (rank)

L	R	
☐	☐	Trees
☐	☐	Shrubs
☐	☐	Grasses / Forbs

D. Bank Cover (rank)

L	R	
☐	☐	Trees
☐	☐	Shrubs
☐	☐	Grasses / Forbs
☐	☐	Bare Soil
☐	☐	Rock

F. Average Bank Height

L. ________ ft.
R. ________ ft.

RIPARIAN ☐ **Max = 15**

4] Instream Zone

A. Substrate (check two for each channel type)

	[10] Boulder	[9] Cobble	[8] Gravel	[7] Sand	[5] Clay	[5] Bedrock	[2] Silt	[1] Muck	[1] Detritus	[0] Sludge	Channel Type (%)
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________

B. Embeddedness

- ☐ None [5]
- ☐ Light [3]
- ☐ Moderate [1]
- ☐ Severe [-1]
- ☐ No coarse substrate

C. Substrate Types

- ☐ >4 [2]
- ☐ <=4 [0]

D. Water Color

- ☐ Clear
- ☐ Stained
- ☐ Turbid
- ☐ Brown
- ☐ Green
- ☐ Other (specify)

SUBSTRATE ☐ **Max = 27**

E. Cover Type (check all that apply)

☐	Undercut Bank	[1]
☐	Overhanging vegetatior	[1]
☐	Deep Pools	[1]
☐	Logs or Woody Debris	[1]
☐	Boulders	[1]
☐	Rootwads	[1]

☐ Macrophytes [1]
- ☐ Emergent
- ☐ Floating Leaf
- ☐ Submergent

F. Cover Amount (check one)

☐	Extensive (>50%)	[10]
☐	Moderate (25 - 50%)	[7]
☐	Sparse (5 - 25%)	[3]
☐	Nearly Absent	[0]
☐	Choking Vegetation only	[-1]

COVER ☐ **Max = 17**

5] Channel Morphology

A. Depth Variability

☐	greatest depth >4X shallow depth	[6]
☐	greatest depth 2-4X shallow depth	[3]
☐	greatest depth <2X shallow depth	[0]

B. Channel Stability

☐	High	[9]
☐	Moderate	[6]
☐	Low	[3]
☐	Very Low	[0]

C. Velocity Types (check all that apply)

☐	Torrential	[-1]
☐	Fast	[1]
☐	Moderate	[1]
☐	Slow	[1]
☐	Eddies	[1]
☐	Interstitial	[-1]
☐	Intermittent	[-2]

D. Sinuosity

☐	High	[6]
☐	Moderate	[4]
☐	Low	[2]
☐	None	[0]

E. Pool Width / Riffle Width

☐	Pool Width > Riffle Width	[2]
☐	Pool Width = Riffle Width	[1]
☐	Pool Width < Riffle Width	[0]
☐	No Riffle	[0]

F. Channel Development

☐	Excellent	[9]
☐	Good	[6]
☐	Fair	[3]
☐	Poor	[0]

G. Present Water Level

- ☐ Flood
- ☐ High
- ☐ Normal
- ☐ Low
- ☐ Interstitial

i. Reach Gradient

________ ft. mile

CHANNEL MORPHOLOGY ☐ **Max = 36**

Figure 33. Example MSHA field form, page 1.

NEARSTREAM OBSERVATIONS

Riparian width		Riparian cover		Shade	Bank height		Bank cover		Bank erosion	
L (ft)	R	L	R		L (ft)	R	L	R	L	R

INSTREAM OBSERVATIONS

Channel Type	Length (ft.)	Width (ft.)	Depth max/avg (ft.)	Substrate	Embed.	Cover type	Cover amount	Velocity type

	Total length (ft.)	Total width (ft.)	Total depth max/avg (ft.)
POOLS			
RIFFLES			
RUNS			
TOTAL			
AVERAGE			
Water Clarity (ft.)			

6] Sources of Pollution Observed at Site

L	R	
☐	☐	**Feedlots**
☐	☐	**Livestock Grazing**
☐	☐	**Dump (type)**
☐	☐	**Tiling Outfalls**
☐	☐	**Storm Sewer Outfalls**
☐	☐	**Gully Erosion**
☐	☐	**Sheet Erosion**
☐	☐	**Other (specify)**
☐	☐	**Other (specify)**
☐	☐	**None**

7] Flow Restrictions

8] Evidence of High Water:

9] Photographs

Number	Location	Number	Location

Figure 34. Example MSHA field form, page 2.

Completing the MSHA Field Sheet

Record MSHA results on the MSHA field sheet (example in Figure 33 and Figure 34, field quality copy in Appendix 1) as follows:

1] Stream Documentation

Stream Name. The name of the stream as shown on the most recent USGS 7.5” topographic map. Include all parts of the name (e.g., “North Branch,” “Creek,” “River,” “Ditch”).

Kittle Number. This is the Minnesota Stream Identification System (MSIS) or Kittle Code, which was originally developed by the DNR Section of Fisheries in the 1970’s (MNDNR 1978) and adopted by the Minnesota DNR in 1979 as part of the Minnesota Watershed Mapping Project (MN Planning 1981). Assign the Kittle Number as described earlier in this manual (page 20; also refer to Appendix 3).

Crew. Name(s) of the field crew, including the person recording the field data (circle the name of the data recorder).

Survey Date. Sample date or date range, in month-day-year format (e.g., 07–01–2006).

Station Name. If the station has a common name, record it here.

Station ID Code. Stations should be numbered starting at the mouth and progressing upstream. If historical station numbers already exist, use these.

River Mile. The river mile of the downstream end of the sampling station.

Station Length. Length of sampling station in feet measured along the thalwag.

Station Coordinates (UTM Easting and UTM Northing). Universal Transverse Mercator, Zone 15, GPS coordinates for the downstream and upstream ends of the sampling station location. Record to the nearest 0.1 unit.

Coordinate Source. List the source of your station coordinates, whether they are field GPS readings from a GPS unit or from a GIS computer source such as Landview. For Garmin and Trimble GPS unit setup, see the DNR website.

Location (T-R-S). The location of the downstream end of the station in common Township, Range, and Section off the latest USGS quadrangle map.

2] Surrounding Land Use. Record the predominant land use on each bank within approximately 2 to 3 square miles, not just the area surrounding the site. The emphasis should be on upstream land use. Check either the most predominant land use, or choose two and average the scores. A land use or aerial map can be used for this assessment if available. Land use categories are as follows:

Forest, Wetland, Prairie, Shrub: Land that is dominated by trees, low-lying areas saturated with water, grasses and forbs, or woody vegetation less than 3 meters in height.

Old Field/Hay Field: Land that is used for agricultural purposes other than row crops or pasture.

Fenced Pasture: Land that is regularly grazed by livestock, but is fenced to prevent livestock from entering streams.

Conservation Tillage, No Till: Land that is currently in agricultural production, but retains the vegetative material from the previous year’s crop to protect the soil.

Residential/Park: Land that has been modified for residential use (i.e. backyards, city parks).

Urban/Industrial: Land that has been modified for commercial or industrial use (i.e. parking lots, malls).

Open Pasture: Land that is regularly grazed by livestock, but is not fenced to prevent livestock from entering streams.

Row Crop: Land that is currently in agricultural production, and doesn’t use any conservation tactics.

These land use category definitions may be subject to change as GIS tools and technology improve. Staff should periodically check the DNR website for the status of land use categories and definitions.

3] Riparian Zone.

A. Riparian Width. Estimate the width of the undisturbed vegetative zone adjacent to the stream. Beneficial vegetation types include stable grasses, trees, and shrubs with low runoff potential. Disturbed vegetation is not included in the riparian width (i.e. mowed grass).

***B. Bank Erosion*.** – Estimate the percentage of the stream bank that has changed from optimal condition and is receiving stress. To be considered as erosion, the banks must be actively eroding through break down, soil sloughing, or false banks. False banks are natural banks that have been cut back, usually by livestock trampling.

C. Shade. Estimate the percentage of overhead canopy cover that is shading the stream channel. Professional judgment may be required to rate stream shading characteristics in larger streams and rivers as 100% shade cover would not be expected in these systems even in the absence of disturbance. The general intent of the rating is to evaluate the condition of stream canopy characteristics.

4] Instream Zone.

A. Substrate. Document the two predominant substrate types for each channel type present within the reach. In instances where only one substrate type predominates (> 80% of the channel type), one substrate type can be recorded. For each channel type present within the reach, estimate the percent of the stream channel represented by that channel type. The percentages should add up to 100. For example, if the majority of your reach was a run, with a few pools and one riffle, the percentage could be 75% run, 20% pool, and 5% riffle. The definitions for each channel and substrate type are as follows:

Channel Types

Pool: Water is slow and generally deeper than a riffle or run. Water surface is smooth, no turbulence. A general rule that can be used to distinguish a pool is if two or more of the following conditions apply; the stream channel is wider, deeper, or slower than average.

Riffle: Higher gradient areas where the water is fast and turbulent, water depths are relatively shallow, and substrates are typically coarse. Water surface is visibly broken.

Run: The water may be moderately fast to slow but the water surface typically appears smooth with little or no surface turbulence. Generally, runs are deeper than a riffle and shallower than a pool.

Glide: Similar to a run, but where there is no visible flow and the channel is too shallow for a pool. Examples include a channelized stream with a uniform depth and flow. This term should not be used in conjunction with pools, riffles, and runs in a natural stream setting.

Substrate types

Boulder: Large rocks ranging from 250 mm to 4,000 mm in diameter (basketball to car size).

Cobble: Rocks ranging in diameter from 64 mm to 250 mm (tennis ball to basketball).

Gravel: Rocks varying in diameter from 2 mm to 64 mm (BB to tennis ball).

Sand: Inorganic material that is visible as particles and feels gritty between the fingers. Particles are 0.06 to 2.0 mm in diameter.

Clay: Very fine inorganic material. Individual particles are not visible or are barely visible to the naked eye. Will support a person's weight and retains its shape when compacted.

Bedrock: A solid slab of rock, >4,000 mm in length (larger than a car).

Silt: Fine inorganic material that is typically dark brown in color. Feels greasy between fingers and does not retain its shape when compacted into a ball. A person's weight will not be supported if the stream bottom consists of silt.

Muck: A fine layer of black completely decomposed vegetative organic matter.

Detritus: Decaying organic material such as macrophytes, leaves, finer woody debris, etc. that may appear similar to silt when very fine.

Sludge: A thick layer of organic matter of animal or human origin, often originating from wastewater.

B. Embeddedness: Embeddedness is the degree that cobble, gravel, and boulder substrates are surrounded, impacted in, or covered by fine materials (sand and silt). Substrates should be considered embedded if >50% of surface of the substrates are embedded in fine material. Embedded substrates cannot be easily dislodged. This also includes substrates that are concreted or “armor-plated”. Naturally sandy streams are not considered embedded; however, a sand predominated stream that is the result of anthropogenic activities that have buried the natural coarse substrates is considered embedded. In this metric we are estimating pervasiveness of embedded conditions throughout a station. Boxes are checked for extensiveness (i.e., pervasiveness throughout the area of the sampling zone) of the embedded substrates as follows: Severe->75% of site area; Moderate- 50-75%; Light- 25-50%; None-<25%.

C. Substrate Types: Check the number of substrate types present at the station, either less than 4, or equal to or greater than 4.

D. Water Color: Record the predominant color of the water by checking the appropriate category. Definitions are as follows:

Clear: Water is transparent, and objects are clearly visible underwater.

Stained: Water is colored due to minerals in the water, but objects are still visible.

Turbid: Water is colored and not transparent; brown due to silt, green due to algae, or other.

E. Cover Type: Indicate the types of cover available to fish within the reach (check all that apply). Cover for fish consists of objects or features dense enough to provide complete or partial shelter from the stream current or concealment from predators or prey. In order to be considered cover, the water depth must be at least 10 cm where the cover type occurs. Definitions are as follows:

Undercut Banks: Stream banks where the stream channel has cut underneath the bank. The bank could overhang the water surface when water levels are low. The undercut bank must overhang (horizontally) the wetted stream channel a minimum of 15 cm and the bottom of the bank must be no more than 15 cm above the water level in order to be considered cover for fish.

Overhanging Vegetation: Terrestrial vegetation overhanging the wetted stream channel. Vegetation must be no more than 15 cm above the water level to be considered cover for fish.

Deep Pools: Area where the channel is particularly deep, often near a bend.

Logs or Woody Debris: Logs, branches, or aggregations of smaller pieces of wood in contact with or submerged in water.

Boulders: Large rocks as described under Substrate Types.

Rootwads: Aggregation of tree roots that extend into a stream.

Emergent Macrophytes: Vascular plants that typically have a significant portion of their biomass above the water surface. Examples include *Typha*, *Scirpus*, and *Zizania*.

Floating Leaf Macrophytes: Vascular plants with a significant amount of their biomass floating on the water in the form of leaves and flowers. Examples include duckweed and water lily.

Submergent Macrophytes: Vascular plants that have all of their biomass (except flowers) at or below the surface of the water. Examples include *Vallisneria, Elodea, Potamogeton, Nymphaea* and *Ceratophyllum*.

F. Cover Amount: The percentage of total fish cover along the reach. If the channel is completely filled with aquatic vegetation, mark the “choking vegetation only” option.

5] Channel Morphology. (Check the most appropriate category for each).

A. Depth Variability: The difference in thalweg depth between the shallowest stream cross-section and the deepest stream cross-section. The thalweg depth is the deepest point along a stream cross-section. Indicate the degree to which the thalweg depths vary within the stream reach.

B. Channel Stability: The ability of a stream channel to maintain its bed and banks, without eroding or moving particles downstream. A riffle that forms diagonally across the channel and has a high amount of fine substrates that change location is indicative of an unstable stream bed. Channelized streams often have high bank stability but low bed stability as the substrate is typically comprised of fine materials that are susceptible to moving downstream. Ratings are as follows:

High: Channel with stable banks and substrates, little or no erosion of the banks, and little or no bedload within the stream. Artificial channels (i.e. concrete) exhibit a high degree of stability even though they typically have a negative effect on biological communities.

Moderate/High: Channel has the ability to maintain stable riffle, run, and pool characteristics. A minor amount of bank erosion and/or bedload is present.

Moderate: Channel that exhibits some instability, characterized by erosion, bedload, or shows the effects of wide fluctuations in water level.

Low: Channels that have a high degree of bedload and severely eroding banks. A homogenous stream bed characterized by shifting sand substrates has low stability.

C. Velocity Types: Indicate which flow types are present within the reach (check all that apply). The definitions are as follows:

Torrential: Extremely turbulent and fast flow, water surface is broken; usually limited to gorges and dam spillways.

Fast: Mostly non-turbulent flow with small standing waves in riffle-run areas; water surface may be partially broken.

Moderate: Non-turbulent flow that is detectable (i.e. floating objects are visibly moved downstream).

Slow: Water flow is detectable, but barely perceptible.

Eddies: Areas of circular current motion within the current, usually formed in pools immediately downstream of riffles/runs.

Interstitial: Water flow that infiltrates a streambed, and moves through gravel substrates in riffle-run areas.

Intermittent: No flow is present, with standing pools separated by dry reaches.

D. Sinuosity: Indicate the degree to which the stream meanders. Sinuosity is defined as the ratio of stream channel distance to straight-line distance between two points on a stream. For wide streams or rivers it may be necessary to consider a longer stream reach, as the true meander cycle is often not adequately represented in these systems within the sampling reach. Ratings are as follows:

Excellent: Streams exhibiting a high degree of meandering. Presence of 2 or more well defined bends (deep areas outside and shallow areas on the inside of the bend).

Good: Stream with more than 2 bends, with at least one well-defined bend.

Fair: Channel with 1 or 2 poorly defined outside bends, or slight meandering within a modified reach.

Poor: Straight channel with no bends in the reach. Channelized streams or ditches are often rated as poor.

E. Pool Width/Riffle Width: Indicate the ratio of pool width to riffle width within the reach. If there is no riffle at the site select “no riffle”.

F. Channel Development: Indicate the complexity of the stream channel or the degree to which the stream has developed different channel types, creating sequences of riffles, runs, and pools. In small streams, riffles, runs, and pools must occur more than once within the sampling reach. The ratings of channel development are as follows:

Excellent: Well-defined riffles present with gravel, cobble, or boulder substrates; pools vary in depth, and there is a clear transition of runs between pools, riffles, and runs. Multiple sequences of riffles, runs, and pools are present within the reach.

Good: Riffles, runs, and pools are all present, but with less frequency, and are less distinct. Riffles have large substrates (gravel, rubble, or boulder), and pools have variation in depth.

Fair: Riffles are absent or poorly developed (shallow with sand and fine gravel substrates). Some deeper pools may exist, but transitions are generally not abrupt.

Poor: Riffles are absent; pools if present are shallow or lack variation in depth. Channelized streams generally have poor channel development.

G. Present Water Level: An estimation of water level as it relates to summer base flow expectations. In most streams, the "normal" water level can be determined with relative ease by observing channel characteristics.

Additional Information

Record additional information about the site on the reverse side of the MSHA site field sheet (Figure 33), and is described as follows (the reverse side of the field sheet is illustrated in Figure 34):

Nearstream Observations**.** Use this section as a note-taking aid to record instream observations through the sample location. These observations will then be used to complete the previous sections 1 through 4. Riparian Zone on the front of the sheet (riparian width, riparian cover, shade, bank height, bank cover, and bank erosion) for both left (L) and right (R) banks (facing downstream).

Instream Observations. Use this section as a note-taking aid to record instream observations through the sample location. These observations will then be used to complete the previous sections 1 through 4.

6] Sources of Pollution Observed at Site. Check left (L) or right (R) bank (facing downstream) for each of the pollution sources listed. If not listed, check "Other" and specify the source.

7] Flow Restrictions. List beaver dams, culverts, artificial dams, and any other natural or constructed restrictions to water flow.

8] Evidence of High Water. List high-water marks and any evidence of water levels higher (or lower) than present levels.

9] Photographs. Record the number and briefly describe the subject of each photograph taken.

Stream Map. Attach a blank sheet of paper with the entire sampling zone sketched. Note important physical features on the map using standard symbols where possible. Describe the sampling path taken and provide any other relevant information. For full surveys, include location of benchmarks, longitudinal profile and cross-section(s).

Scoring the MSHA

Following are instructions on how to score the completed MSHA form. The maximum score is 100. MSHA scores cannot exceed the maximum listed in Table 4.

2] Surrounding Land Use: Average the scores of the two banks. For example, if residential/park was the land use selected on the left bank, and forest, wetland, prairie, shrub was selected on the right bank, then the land use score would be (2+5)/2=3.5. In the case of two land uses selected for one bank, the two scores are averaged together, and then averaged with the score of the other bank. The maximum land use score is 5.

3] Riparian Zone: Average the scores of the two banks for Riparian Width, Bank Erosion, and Shade; then add the three scores. For example, if moderate riparian width (3) was chosen for the left bank and very narrow (1) on the right bank; little bank erosion (4) on the left bank, and moderate (3) on the right bank; heavy shade (5) on the left bank, and substantial (4) on the right bank; the riparian zone score would be: [(3+1)/2] + [(4+3)/2] + [(5+4)/2] = 10. The maximum riparian score is 15.

4] Instream Zone

A) Substrate, Embeddedness, and Substrate Types – Add the scores of substrate, embeddedness, and substrate type. The substrate score is calculated by adding the two substrate scores for each channel type, multiplying by the percentage of the channel type, and adding the scores for each channel type present. If only one substrate type is chosen because it makes up more than 80% of the channel type, multiply the one substrate score by 2 before multiplying it by the percentage of the channel type. The maximum substrate score is 27.

B) Cover Type and Cover Amount – Add the scores of cover type and cover amount. The cover score can range from 1 to 8. The highest macrophyte score is 1, even if all three macrophyte types are present. The maximum cover score is 17.

5] Channel Morphology: Add the scores of Depth Variability, Channel Stability, Velocity Types, Sinuosity, Pool Width/Riffle Width, and Channel Development. The maximum channel morphology score is 36.

Total Score: Add the Surrounding Land Use, Riparian Zone, Instream Zone, and Channel Morphology scores together to get the total MSHA score for the site.

Water Quality

Water Quality Checklist

1. ____ Air temperature (page 65)
2. ____ Water temperature (pages 65–67)
3. ____ pH (page 67)
4. ____ Dissolved oxygen (pages 67–68)
5. ____ Conductivity (page 68)
6. ____ Transparency (page 68)

Water Quality Methods

Determine each of the core water quality parameters at each station at least once during an initial survey. The scope of parameters tested can be expanded to fit individual stream needs. Data is recorded on the Water Quality Analysis form.

Air Temperature. If only point sampling (not continuous) is used for water temperature, take a point air temperature sample in the shade along the stream bank. When using continuous recorders for water temperature, use air temperature data from the closest monitoring station (National Weather Service: see http://www.nws.noaa.gov/ for currently available stations) if available. If those data are not available, you can use a continuous temperature-sampling logger set as close as possible to the stream and about 1 meter off the ground. Shade the air temperature logger from sunlight and concealed it as much as practical.

Water Temperature. Temperature in a stream will vary with width and depth as well as sun and shade. If it is safe to do so, take temperature measurements at varying depths and across the surface of the stream to obtain vertical and horizontal temperature profiles. This can be done at each site at least once to determine the necessity of collecting a profile during each sampling visit. Measure temperature at the same place every time. Temperature in the stream is measured with a thermometer or a meter. Alcohol-filled thermometers are preferred over mercury-filled thermometers because they are less hazardous if broken. Armored thermometers for field use can withstand more abuse than unprotected glass thermometers and are worth the additional expense. Meters for other tests, such as pH (acidity) or dissolved oxygen, also measure temperature and can be used instead of a thermometer.

Point Samples. In general, sample away from the stream bank in the main current. The outside curve of the stream is often a good place to sample, since the main current tends to hug this bank. In shallow stretches, wade into the center current carefully to measure temperature. If wading is not possible, tape your thermometer to an extension pole or use a boat. Reach out from the shore or boat as far as safely possible. If you use an extension pole, read the temperature quickly before it changes to the air temperature. If you are doing a horizontal or vertical temperature profile, make sure you can safely reach all the points where a measurement is required before beginning. To measure temperature:

1. Place the thermometer or meter probe in the water at least 4 inches below the surface or halfway to the bottom if in a shallow stream.

2. If using a thermometer, allow enough time for it to reach a stable temperature (at least 1 minute). If using a meter, allow the temperature reading to stabilize at a constant temperature reading.

3. If possible, try to read the temperature with the thermometer bulb beneath the water surface. If not, quickly remove the thermometer and read the temperature.

4. Record the temperature on the field data sheet.

Continuous Monitors. Use of continuously recording water temperature loggers is required for full stream surveys and recommended on an initial stream survey. A minimum of two units will be deployed per stream for each full survey. The focus for deployment is during summer with a recording period from June 1 through September 30. Managers can deploy temperature loggers during any period if specialized temperature investigations are needed (e.g., brook trout spawning season). Although deployment is only required for one season, managers are encouraged to acquire continuous temperature data over multiple years. Managers may also use temperature loggers during other investigations when the loggers are not required.

Program the temperature loggers for a delayed start and set to record point measurements at least once per hour. Turn off the logger high, low, and multiple sampling features to extend battery life. The delayed start time for the temperature loggers may be set for the first planned deployment time of the season or based on daily or weekly needs.

During deployment record all field data, including station number, station name, temperature logger ID numbers, and air and water temperature measurements obtained with a thermometer or thermistor thermometer on the

Continuous Temperature Station Survey Form (blank form in Appendix 1). Include a sketch, digital photograph, GPS coordinates, and description of the logger location that notes a landmark reference point such as a unique rock, log, root, or tree.

Deployment generally follows the procedures described in Schuett-Hames et al. (1999). In small streams, install loggers as close to the thalweg as possible and within 15 centimeters of the bottom. In large streams, avoid areas of potential temperature stratification (resulting from eddies, ground water, and tributaries). A 0.5 to 0.75 meter deep location downstream or alongside a landmark rock or stream bed feature improves the chance of the logger staying submerged during deployment and being located for retrieval.

pH. Field analysis is recommended because pH changes with temperature and carbon dioxide concentration of ambient air. Measure pH at the same approximate time of day for each reach being surveyed, and consistent with the sampling time from past surveys. Mid-day sampling is recommended. If a high degree of accuracy and precision in pH results is required, measure pH with a laboratory-quality pH meter and electrode. Color comparators and pH "pocket pals" are suitable for most other purposes.

If using an electronic meter and a probe, follow the manufacturer’s instructions for proper maintenance, operation, and calibration. Once the meter is turned on and calibrated, wade into the pool and place the probe below the surface of the water. Record the pH following the instructions for the particular meter.

pH pocket pals are electronic hand-held “pens” that are dipped in the water and provide a digital readout of the pH. They can be calibrated to one pH buffer. Lab meters, on the other hand, can be calibrated to two or more buffer solutions and thus are more accurate over a wide range of pH measurements.

Dissolved Oxygen. Measure dissolved oxygen at approximately the same time of day for each reach being surveyed, and consistent with the sampling time from past surveys. Midday sampling is recommended.

The desired mesohabitat location for measuring dissolved oxygen is in a pool that is representative of the sampling reach. Measurement of dissolved oxygen is required at one site per sampling reach, but sampling at additional sites is encouraged if special concerns are noted.

Dissolved oxygen concentrations are measured using an electronic meter and a probe. Follow the manufacturer’s instructions for proper maintenance, operation, and calibration of the meter. When the meter is warmed up and calibrated, wade into the pool and place the probe below the surface of the water. Record the dissolved oxygen concentration (ppm or mg/L), following the instructions for the particular meter.

Conductivity. Conductivity is a measure of water's ability to conduct an electric current, and is dependent on the concentration and type of dissolved ions and the water temperature. Conductivity is reported as microSiemens per centimeter (µmS/cm) (formerly mmhos/cm). Most modern meters automatically correct for temperature, and standardize the readings to 25°C. This will be the standard for reporting conductivity.

Follow the manufacturer's directions to prepare your conductivity meter for use. Most conductivity meters must be calibrated using a standard solution for the range you will be measuring.

The desired mesohabitat location for measuring dissolved conductivity is in a pool that is representative of the sampling reach. Measurement of conductivity is required at one site per sampling reach, but sampling at additional sites is encouraged if special concerns are noted.

Once the meter is warmed up and calibrated, wade into the pool, approaching the site from downstream. Place the probe below the surface of the water (or collect the sample for analysis on shore or back at the lab). Record the conductivity to at least the nearest 10 µS/cm, following the instructions for your particular meter.

Transparency. Transparency is a measure of water clarity, expressed in centimeters, that serves as an indirect measure of the amount of dissolved and suspended materials. Transparency is measured using a 60 cm transparency tube.

In general, collect water samples in the main current away from the riverbank. It is especially important that the sample be collected from undisturbed water. Consider impacts of inflows, such as tributaries, springs, seeps, or irrigation return flows, when selecting sampling sites. Sample where the water is well mixed. Try to step upstream, lean, and reach into the current to collect the sample.

Either collect a representative water sample in a separate container and then fill the transparency tube with water, or fill the tube directly with water from the stream. Then, while looking directly down into the tube, release water through the valve until the black-and-white symbol at the bottom of the tube is visible. Record the depth of water (cm) when the symbol just becomes visible. If the symbol is visible when the tube is full of water, record the transparency reading as ">60cm."

Biology

Biology Checklist

1. ____ Fish community (page 69, 144–154)

Biology Methods

The only biological measurement to be conducted in an initial survey is a fish community assessment using the Index of Biotic Integrity. At least one fish community assessment should be completed for the stream; but additional community assessments may be completed (e.g., one in each similar reach) if desired. A community assessment can only be completed in each similar reach if the similar reaches have already been defined in previous or the current survey. Specific methods for completing a fish community assessment are presented in the full survey methods section (pages 144–154).

Connectivity

Connectivity Checklist

1. ____ Map showing public land and easements (pages 70-71; Map 10, Figure 35)
2. ____ Locate and map dams, channelized reaches, and road crossings (page 70; Map 10, Figure 35)
3. ____ Identify and evaluate fish barriers (page 70; Map 10, Figure 35)
4. ____ Identify and evaluate point source discharges (page 70; Map 10, Figure 35)

Connectivity Methods

Assessing Connectivity on Streams. When developing river management prescriptions, practitioners must account for the presence of physical, chemical, and biological barriers to connectivity. Examples include an assessment of dams, including their position in the watershed; dam operation (hydrology); effects on water quality (e.g., DO, mercury methylization); sediment and thermal regimes; natural history of fishes in the area; and effect on aquatic communities (e.g., lacustrine or exotic species, predator concentrations). On smaller streams and in headwater reaches, improperly designed and misplaced culverts can degrade stream health and restrict fish passage (Verry et al. 2000). Even without dams and culverts, flow reduction through water withdrawal can affect connectivity by rendering riffles too shallow for passage of migratory fish.

Fragmentation of an ecosystem in any of its dimensions disrupts the individual components and natural processes of the system as a whole. Examples of disruption include physical (e.g., dams), biological (e.g., exotic species introductions or extinction of native biota), hydrological (e.g., dewatering of aquifers), and water quality (e.g., endocrine disruption, or thermal, chemical, or sediment pollution). Vaughan (2002) suggested that culverts and other barriers in stream channels can have negative effects on the upstream movement of some invertebrates.

Dams, channelized reaches, road crossings, culverts, and other potential barriers to fish movement should be documented and placed on a map for inclusion in the initial survey report (Map 10, Figure 35). Identify public land and easements, point source discharges and include on Map 10.

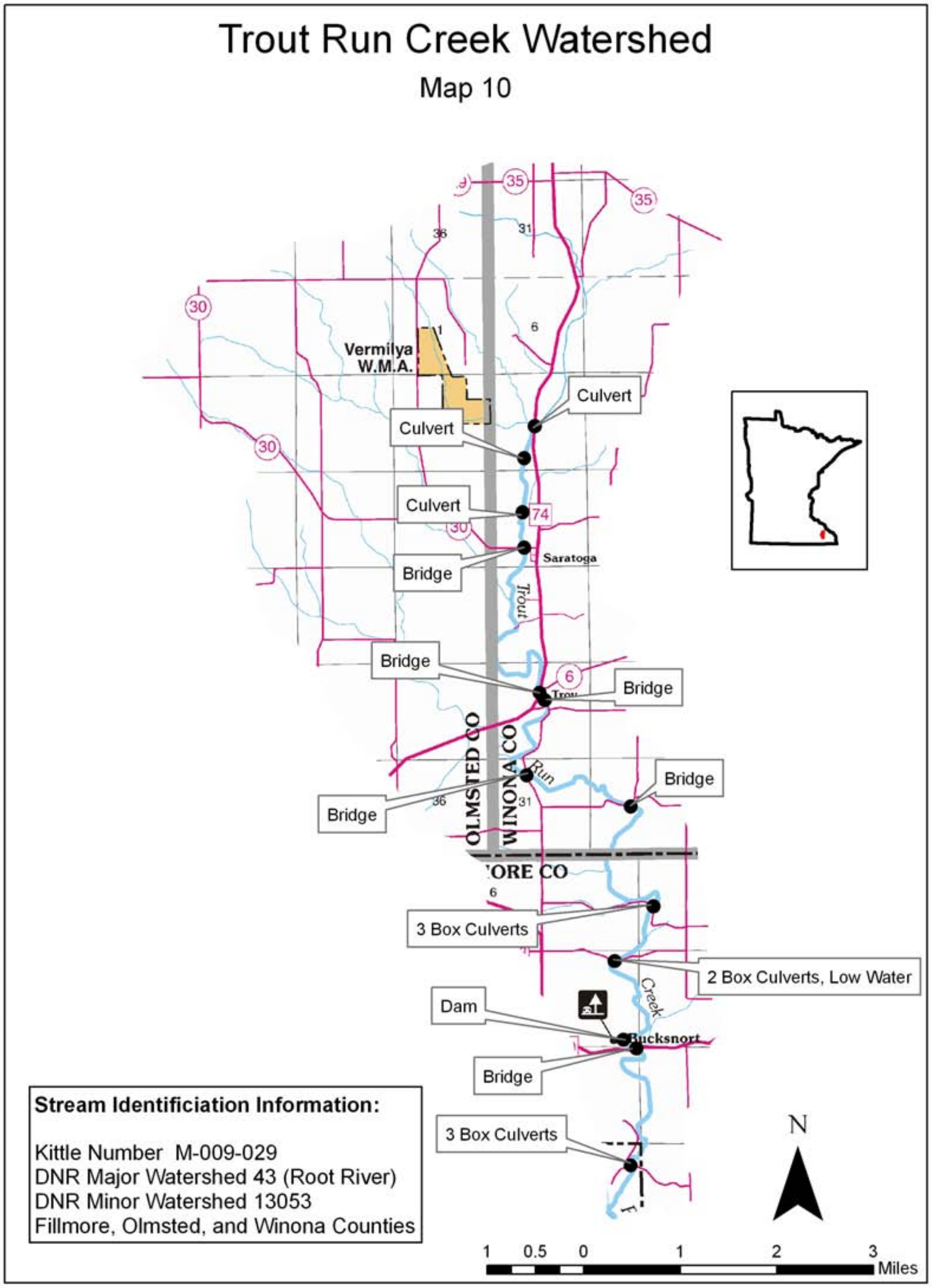


Figure 35. Example watershed map (Map 10) showing dams, channelized reaches, culverts, road crossings and other barriers to fish movement. Map 10 also shows the location of public land and easements, and point source discharges. Trout Run Creek (M-009-029, Fillmore County, MN).

Stream Crossing Evaluation. Improperly designed, sized, or installed stream crossings can negatively impact the hydrology, connectivity, and geomorphology, and, therefore, biology, of a stream. Perched culverts block fish migration. Undersized culverts increase exit velocities and result in backing up of water upstream, preventing fish migration and causing scouring (degradation) below culverts and aggradation upstream as well as increasing the likelihood of road failure. Additionally, sediment washing off gravel and dirt roads increases the stream's sediment load, filling pools. These impacts can be localized or extend for long ways downstream or upstream from the crossing.

The U.S. Forest Service surveyed 387 stream crossings on the Superior National Forest and found that 10% to 13% exhibited obvious organism passage issues (perching) and about 30% exhibited obvious geomorphic impacts from the crossing. The geomorphic impacts often extended ¼ to ½ mile upstream and downstream of the site. An inventory of improperly designed culverts is one way to ensure that culvert concerns are addressed in the future as they are replaced and will identify culverts that need immediate replacement. Proper installation of culverts requires a design that mimics the bankfull stream channel to allow sediment and fish passage. Ideally a bridge or bottomless culvert is used and flood plain culverts are installed to pass flood flows. To evaluate the quality of a culvert installation, check its compliance with the "MESBOA" principle (Verry 2000):

Match culvert width to bankfull width.
Extend culvert beyond toe of slope (to reduce erosion of embankment).
Slope the culvert at the same slope as the channel. (Use thalweg riffle slope to define bottom.)
Bury the culvert 1/6th of its diameter (up to 2 feet, to allow bedload passage and a natural stream bottom in culvert).
Offset multiple culverts, so the thalweg culvert is buried and others are on the stream bottom (to allow fish passage at low flows).
Align the culvert with the stream channel alignment.

Additionally, look for other signs of degradation such as channelization, sedimentation from roadbed or embankment erosion, and extensive beaver dams.

Full Survey

Full Survey Checklist

Hydrology

1. ____ Stream discharge (pages 74-77)
2. ____ Location of springs, seeps and discharges (page 78)

Geomorphology and Fish Habitat

3. ____ Channel geometry measurements (pages 81-83)
4. ____ Longitudinal profile survey (pages 84–90)
5. ____ Channel cross-section survey (pages 91–97)
6. ____ Channel substrate measurements (page 99)
7. ____ Larger fishes cover measurements (pages 100–102)
8. ____ Bank Erosion Height Index BEHI (pages 103-106)
9. ____ Near Bank Stress NBS (pages 107-113)
10. ____ Stream classification (page 114)
11. ____ Stream condition assessment (pages 114–121)
12. ____ Minnesota Stream Habitat Assessment (MSHA; pages 50–64)
13. ____ Additional required data (page 124)

Water Quality

14. ____ Air temperature (page 65)
15. ____ Water temperature (pages 65–67)
16. ____ pH (page 67)
17. ____ Dissolved oxygen (pages 67–68)
18. ____ Conductivity (page 68)
19. ____ Transparency (page 68)
20. ____ Longitudinal temperature profile (pages 126-127)
21. ____ Laboratory water quality parameters (pages 127–128)

Biology Checklist

22. ____ Riparian vegetation survey (pages 134–137)
23. ____ Aquatic plant survey (pages 138–139)
24. ____ Aquatic invertebrate survey (pages 140–143)
25. ____ Fish community survey (pages 144–154)

Connectivity

Typically not sampled at a station level

Hydrology

Hydrology Checklist

1. ____ Stream discharge (pages 74-77)
2. ____ Location of springs, seeps and discharges (page 78)

Stream Discharge

Stream flow or discharge is the volume of water passing through a stream per unit time. A simple way to estimate discharge is to multiply a cross-sectional area by the average velocity of the water. Stream velocity (recorded in ft/s) and the cross-sectional area (ft^2) produce volume per unit time (ft^3/s). However, water in a channel flows at different speeds depending on its location. It is therefore necessary to divide a stream cross-section into subsections and determine the discharge of each subsection. The total of all the section discharges equals the total stream discharge.

Preparation. Before you begin, assemble a tape measure or metal tag line, stakes, and a water velocity meter. Calibrate or test the water flowmeter using the instructions specific to the device.

Procedure. Unless discharge across a pool is specifically needed, it is best to measure discharge across a section of smoothly moving water, such as a run. Stretch a tape measure (small streams) or metal tag line (marked wire line) across the stream, perpendicular to stream flow. Anchor between two stakes, keeping level and taut. Measure the width of the stream, from water's edge to water's edge. Divide this distance by 20 or 25 to set the approximate measurement interval.

Interval widths do not have to be consistent; use shorter intervals for deeper or swifter parts of the channel or where there is a change in topography, and larger intervals in shallow areas or where the depth and flow variability are relatively low. No subsection should contain more than 5% of the total discharge.

Starting at the left bank (looking downstream), record the following for each subsection (see Figure 36, also Figure 38 example field form):

1. distance from the left bank along the tape measure.
2. water depth, recorded from a wading rod or flowmeter rod (zero at ends of the transect).
3. water velocity is measured as outlined below.

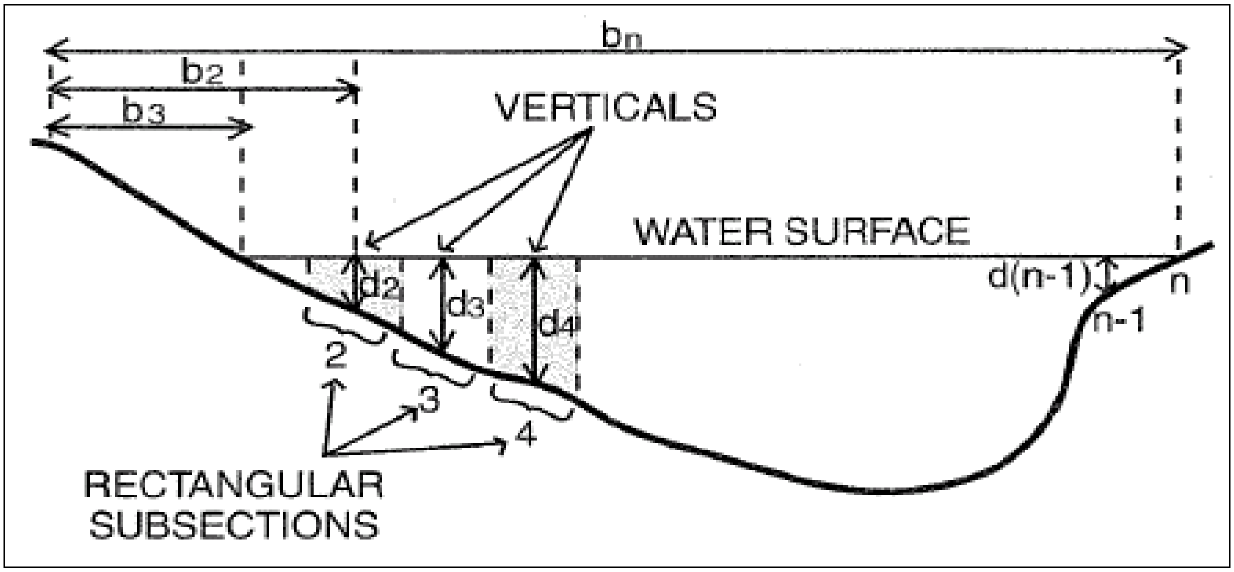


Figure 36. Cross-section of a stream showing sampling locations for water depth (d) and velocity. Note that the interval represented is half the distance between adjacent measurement points except the first and last interval to the water edge.

Once velocity measurements have been made, calculate the total stream discharge for each subsection according to the equation below, or use the field form as a computation worksheet.

$$Q_n = d_n \bullet \left(\frac{b_{n+1} - b_{n-1}}{2} \right) \bullet v_n$$

Q_n = discharge for subsection n,
d_n = depth at halfway point across subsection n,
b_n = distance along the tape measure from the initial point on the left bank to point n,
v_n = mean velocity of subsection n

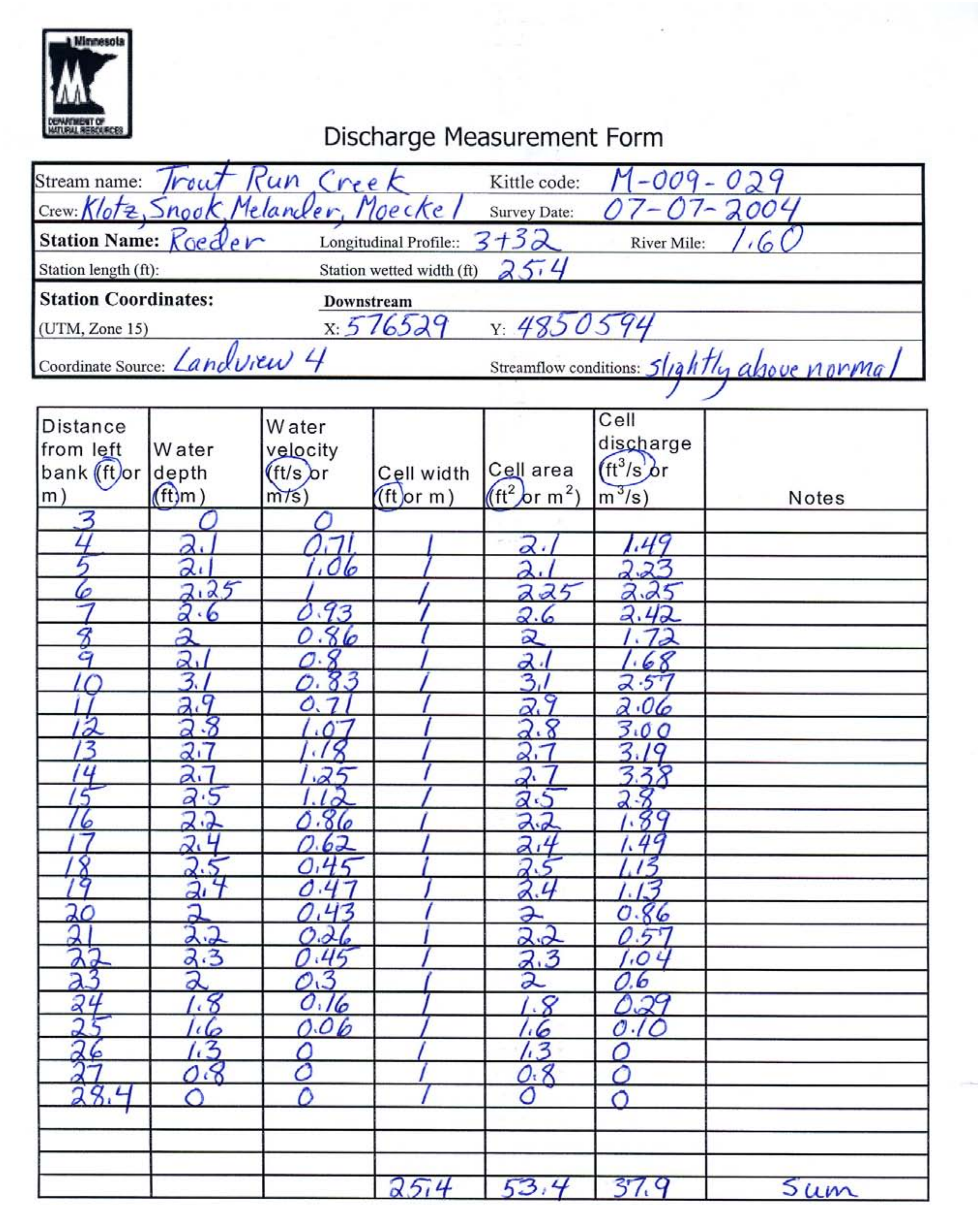
Using a Flowmeter. To use a flowmeter, mount the probe on a wading rod. Set the water depth on the wading rod; it will automatically set the flowmeter to 0.6 of the water depth (mean velocity for a position). Hold the probe facing into the current. Stand downstream and far enough back to avoid interfering with the flow of water passing the meter (Figure 37). Depending on the flowmeter, wait at least 30 seconds for the velocity reading to stabilize. Take either one or two meter readings at each location, depending on the water depth, as described below:

1. For water depths (d) <2.4 ft (0.75 m), measure velocity once at 0.6 d from the water surface (e.g., if water is 1.2 ft deep, measure velocity at 0.72 ft from the water surface). A flowmeter wading rod (Figure 37) will automatically set the flowmeter to the correct depth.

2. For depths (d)>2.4 ft (0.75 m), measure velocity at 0.2 d and 0.8 d. Calculate a mean for these two readings to determine the velocity for that cross section.

Note: If the water is too deep for a wading rod, seek assistance.

Figure 37. Measuring water velocity with a flowmeter (mechanical type) and wading rod.



Minnesota
DEPARTMENT OF NATURAL RESOURCES

Discharge Measurement Form

Stream name: Trout Run Creek Kittle code: M-009-029
Crew: Klotz, Snook, Melander, Moeckel Survey Date: 07-07-2004
Station Name: Roeder Longitudinal Profile:: 3+32 River Mile: 1.60
Station length (ft): Station wetted width (ft) 25.4
Station Coordinates: **Downstream**
(UTM, Zone 15) X: 576529 Y: 4850594
Coordinate Source: Landview 4 Streamflow conditions: slightly above normal

Distance from left bank ([✓ ft] or m)	Water depth ([✓ ft] m)	Water velocity ([✓ ft/s] or m/s)	Cell width ([✓ ft] or m)	Cell area ([✓ ft^2] or m^2)	Cell discharge ([✓ ft^3/s] or m^3/s)	Notes
3	0	0				
4	2.1	0.71	1	2.1	1.49	
5	2.1	1.06	1	2.1	2.23	
6	2.25	1	1	2.25	2.25	
7	2.6	0.93	1	2.6	2.42	
8	2	0.86	1	2	1.72	
9	2.1	0.8	1	2.1	1.68	
10	3.1	0.83	1	3.1	2.57	
11	2.9	0.71	1	2.9	2.06	
12	2.8	1.07	1	2.8	3.00	
13	2.7	1.18	1	2.7	3.19	
14	2.7	1.25	1	2.7	3.38	
15	2.5	1.12	1	2.5	2.8	
16	2.2	0.86	1	2.2	1.89	
17	2.4	0.62	1	2.4	1.49	
18	2.5	0.45	1	2.5	1.13	
19	2.4	0.47	1	2.4	1.13	
20	2	0.43	1	2	0.86	
21	2.2	0.26	1	2.2	0.57	
22	2.3	0.45	1	2.3	1.04	
23	2	0.3	1	2	0.6	
24	1.8	0.16	1	1.8	0.29	
25	1.6	0.06	1	1.6	0.10	
26	1.3	0	1	1.3	0	
27	0.8	0	1	0.8	0	
28.4	0	0	1	0	0	
			25.4	53.4	37.9	Sum

Figure 38. Example field form for collecting stream discharge.

Springs, Seeps, Sinkholes, Stream Sinks, Discharges

As part of an initial stream survey, the location of known springs, seeps, sinkholes, stream sinks, and discharges are documented on a map (see initial survey methods page 24; see Map 2, Figure 13).

If you encounter any undocumented springs, fill out a Spring Data Sheet (Figure 29, blank form in appendix 1) and update map 2.

In order to facilitate updating the statewide spring database, a copy of this form should be sent to:

Groundwater Hydrologist
DNR Waters
2300 Silver Creek Road
Rochester, MN 55906
(jeff.green@dnr.state.mn.us)

Geomorphology and Fish Habitat

Geomorphology and Fish Habitat Checklist

1. ____ Channel geometry measurements (pages 81-83)
2. ____ Longitudinal profile survey (pages 84–90)
3. ____ Channel cross-section survey (pages 91–97)
4. ____ Channel substrate measurements (page 99)
5. ____ Larger fishes cover measurements (pages 100–102)
6. ____ Bank Erosion Height Index BEHI (pages 103-106)
7. ____ Near Bank Stress NBS (pages 107-113)
8. ____ Stream classification (page 114)
9. ____ Stream condition assessment (pages 114–121)
10. ____ Minnesota Stream Habitat Assessment (MSHA; pages 50–64)
11. ____ Additional required data (page 124)

Geomorphic data help us understand the processes and characteristics of stream systems, provide fish habitat information, facilitate stream comparisons within a watershed and between regions, and provide a common framework for communication. A major reason for using geomorphic data collection methods is that they are scientifically sound and produce repeatable results. The nature of the geomorphic data we collect will vary according to the specific survey needs and our desired level of understanding. However, there is valuable stream habitat information that would not be obtained through a geomorphic survey alone (e.g., fish cover). Therefore, the general approach to obtaining in-stream habitat data will be to collect geomorphic data and additional habitat data concurrently. The following pages describe techniques for collecting geomorphic and habitat data.

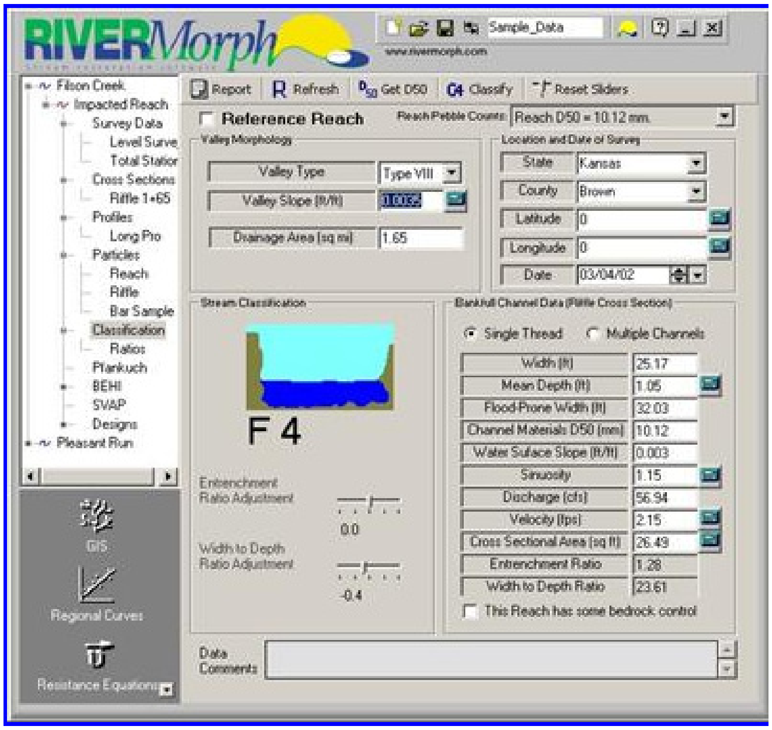
The following are standardized survey methodologies and the data collected should be considered a minimum. It is not the intent of this manual to limit the amounts and types of data staff can collect. If, for instance, additional information is needed to address a specific management question or continue an existing data set, then collection of that information is encouraged. However, management of data gathered beyond the scope of this manual will be the responsibility of the individual who collects the data, since a standardized database cannot accommodate all potential data inputs.

The book “Applied River Morphology” (Rosgen 1996) will be required as a reference for this section. This book is available through www.wildlandhydrology.com. Also, a review of basic surveying techniques (Harrelson et al. 1994; see Appendix 6) will be necessary.

Advanced users who are calculating stream bank erosion rates should refer to “Watershed Assessment of River Stability and Sediment Supply (WARSSS)” (Rosgen 2006) as an additional reference. This book provides more detailed information on some procedures and analyses.

The general concept of this section is to use field measurements obtained from longitudinal profile and cross-section surveys to describe stream morphology and fish habitat. With the exception of fish cover, methods described in this section are standard methods as described by Rosgen (1994), and as taught in the fluvial geomorphology training courses offered by Division of Ecological Services personnel. A licensed copy of RIVERMorph software will be distributed to each Area office on a rugged tablet computer to assist in entering and analyzing geomorphic data. In addition, portions of the following section were taken from Bain and Stevenson (1999).

RIVERMorph
Stream Restoration Software



☐ Reference Reach

Reach Pebble Counts: Reach D50 = 10.12 mm.

Valley Type: Type VIII

Valley Slope (ft/ft): [illegible]

Drainage Area (sq mi): 1.65

State: Kansas

County: Brown

Latitude: 0

Longitude: 0

Date: 03/04/02

F 4

Entrenchment Ratio Adjustment: 0.0

Width to Depth Ratio Adjustment: -0.4

● Single Thread ○ Multiple Channels

Width (ft)	25.17
Mean Depth (ft)	1.05
Flood-Prone Width (ft)	32.03
Channel Materials D50 (mm)	10.12
Water Suface Slope (ft/ft)	0.003
Sinuosity	1.15
Discharge (cfs)	56.94
Velocity (fps)	2.15
Cross Sectional Area (sq ft)	26.49
Entrenchment Ratio	1.28
Width to Depth Ratio	23.61

☐ This Reach has some bedrock control

RIVERMorph is the stream assessment and restoration software adopted by the Section of Fisheries to store and analyze geomorphic data. While this manual includes some information to direct the user to the proper location for data entry, the RIVERMorph user manual should be read to learn data entry techniques and understand how to use analysis tools.

(©2002-2006 RIVERMorph, LLC)

Channel Geometry Measurements (Pattern)

Channel geometry measurements should be measured directly from the most recent aerial photos using the GIS function of RIVERMorph. However, if there is not a high quality photo available in which the entire reach of stream is visible, due to canopy blocking the stream, geometry measurements should be taken in the field. Keep in mind that geometry is used to describe reach wide characteristics, so measurements should not be restricted to just the sample station. With the exception of sinuosity (K), multiple measurements should be taken for each metric to determine the maximum, minimum and mean values. The following variable can be recorded directly into the **Ratios** node of RIVERMorph, in the “Pattern” tab. RIVERMorph will calculate the appropriate geometry ratios including; Meander Length Ratio (L_m/W_{bkf}), Radius of Curvature to Riffle Width (R_c/W_{bkf}), Meander Width Ratio (W_{blt}/W_{bkf}), etc. Pattern geometry variables are illustrated in Figure 39.

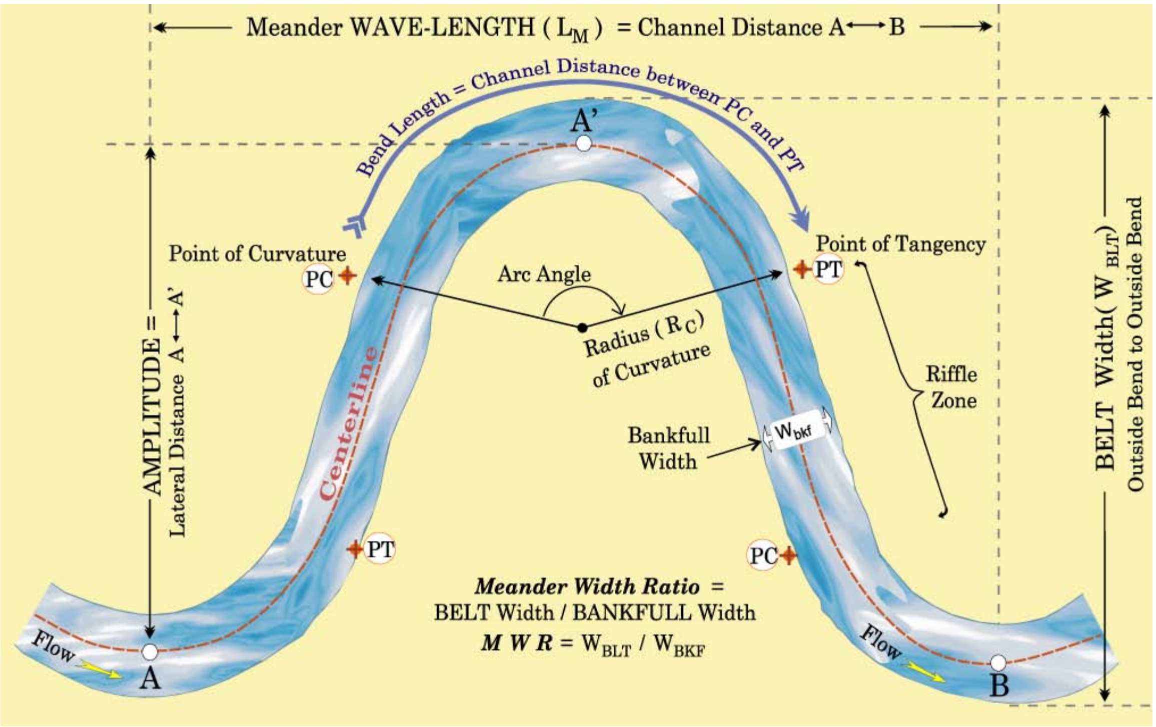


Figure 39. Channel geometry measurements (© Wildland Hydrology, Rosgen 2006).

Sinuosity (K) – When measuring sinuosity in the field, valley length (VL) and stream length (SL) should be measured on a long enough length of stream to adequately represent the sinuosity of the reach. This often requires measuring a section of stream that is longer than the sample reach. ($K=SL/VL$) Valley length measurements should be measured following the valley centerline, not simply following the stream meander centerline.

Meander Length (L_m) – Meander length is the longitudinal (down/parallel with valley) distance between the apex of two sequential meanders. Meander length is negatively correlated with sinuosity. Meander length ratio is the meander length divided by the bankfull width. (See Figure 39)

Radius of Curvature (R_c) – The radius of the circular arc portion of a meander, measured from a center point on the inside of the curve to the center of the channel. (See Figure 39) On compound bends, there will be two R_C's, one in each corner.

Belt Width (W_{blt}) – Belt width is a measure of lateral containment of the channel within its valley. Measure the longest distance perpendicular to the valley slope from outside bend to outside bend (Figure 39).

Stream Map. A site map should be sketched for each sampling station (see example map in Figure 40). Site maps of each sampling station can be a valuable reference tool when referring back to data after being away from the stream for a period of time. In the case of smaller streams with heavy canopy that prevents good aerial photo coverage, site maps can show changes in pattern over time. Detailed maps can also provide a visual reference to the amount of cover available in a sampling station.

Attach a blank sheet of paper with the entire sampling zone sketched. Note important physical features on the map using standard symbols where possible. Note any changes that have occurred since the time of the aerial photo. Describe the sampling path taken and provide any other relevant information. For full surveys, include location of benchmarks, start and end of longitudinal profile, photo points and cross-section(s). Consider adding location of terraces and any important habitat features.

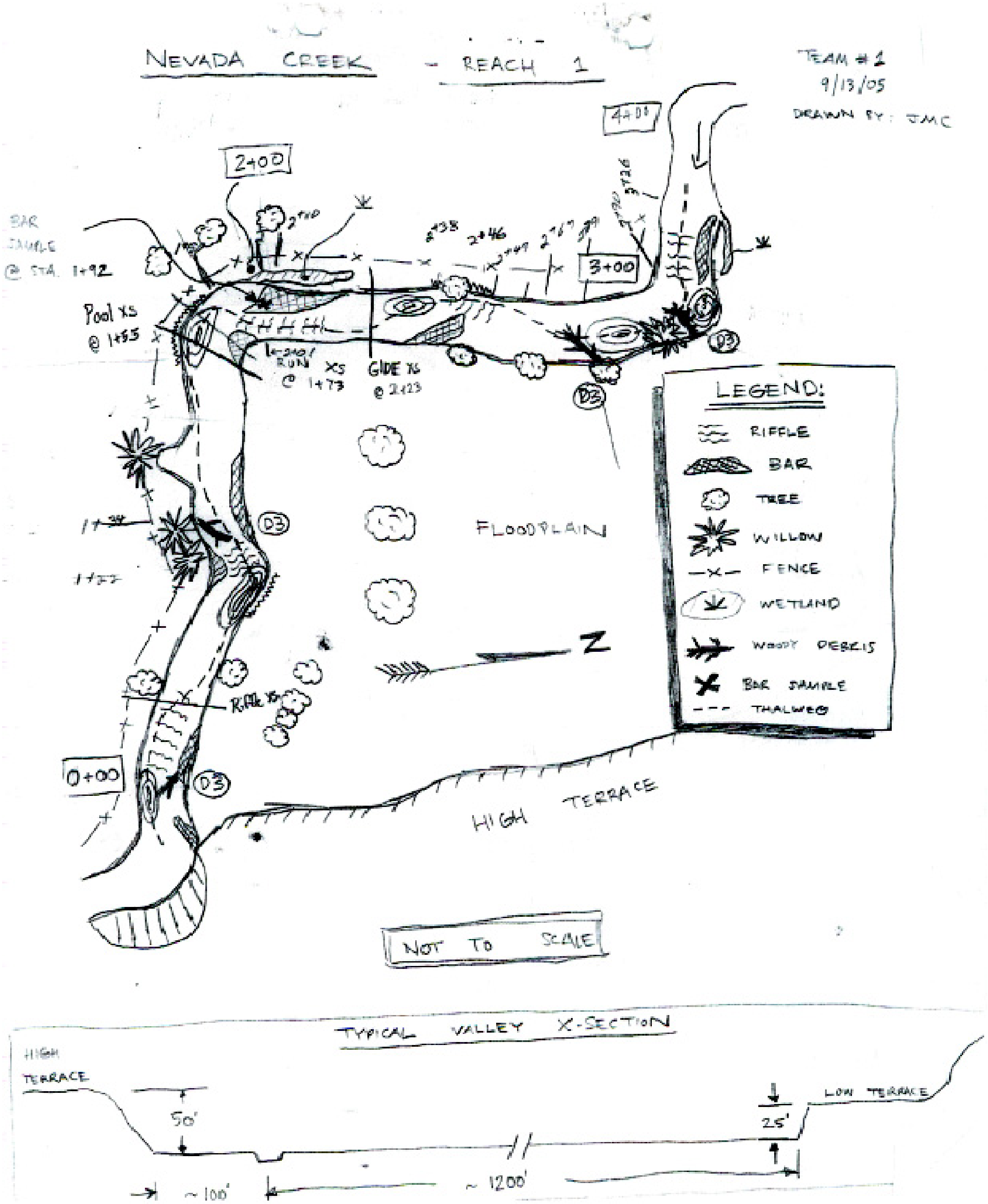


Figure 40. Example stream site-map sketch, including map legend and valley cross-section.

Longitudinal Profile Survey (Profile)

Step 1. Establish the Longitudinal Profile. The longitudinal profile should be 35 times the wetted width or two full meander widths, whichever is shorter, with a minimum length of 150 m and a maximum length of 500 m. Begin and end the profile at the downstream boundary of a similar bed feature (e.g., riffle, run, pool, glide, or cascade). For example, if you begin the longitudinal profile at the downstream boundary of a riffle, you should also end it at the downstream boundary of a riffle. The longitudinal profile length may be extended if data needs or site conditions warrant.

Step 2. Survey the Longitudinal Profile. Collect thalweg and water surface elevations along the longitudinal profile beginning at the upstream boundary (Figure 41). Record data on the Longitudinal Profile Recording Sheet or directly into the **Profile** node in RIVERMorph (see examples in Figures 42a – 42d, blank form in appendix 1). If the level is moved during the profile, using a turning point, the survey loop should be closed by surveying back to the original BM to check for errors. An example longitudinal profile is shown in Figure 43.

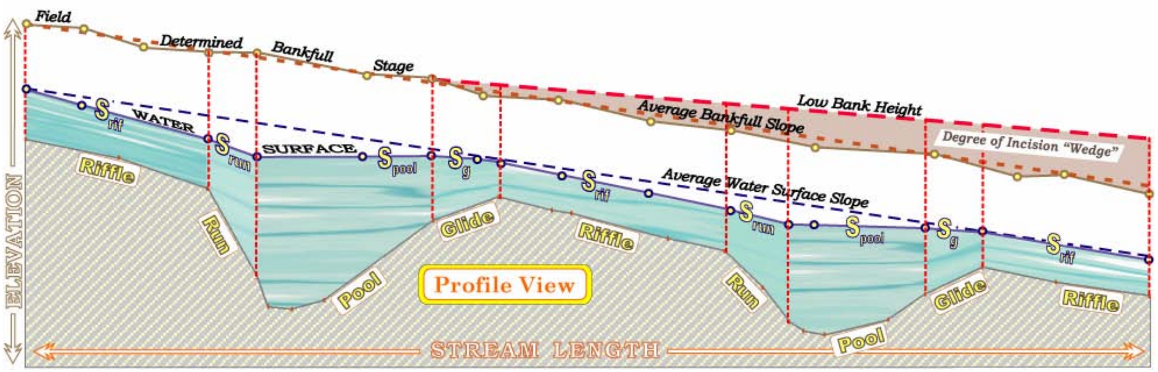
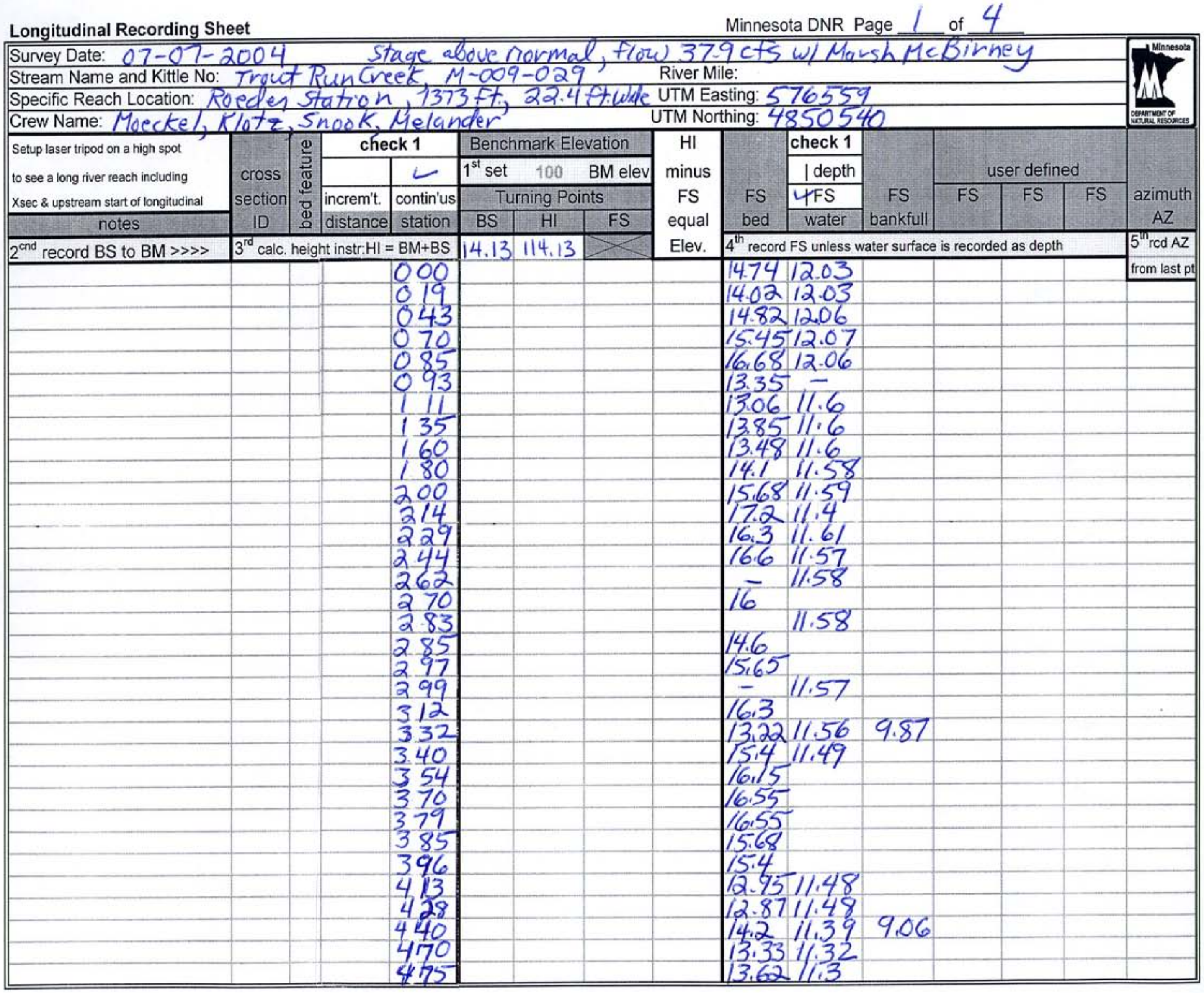


Figure 41. Longitudinal profile showing bed features and locations of thalweg, water surface and bankfull elevations (© Wildland Hydrology, Rosgen 2006).

Procedure 2-1. Take Thalweg Elevation Readings. Take elevation readings at a sufficient number of points in the thalweg to accurately describe the shape, depth, and lengths of bed features (e.g., pools, riffles, runs, glides, cascades) along the profile. At a minimum, take thalweg elevations at the top, middle, and bottom of each bed feature and in the deepest point in each pool (Figure 41).

Procedure 2-2. Take Water Surface Elevation Readings. Take water surface elevation readings at each station at which a thalweg elevation is measured.



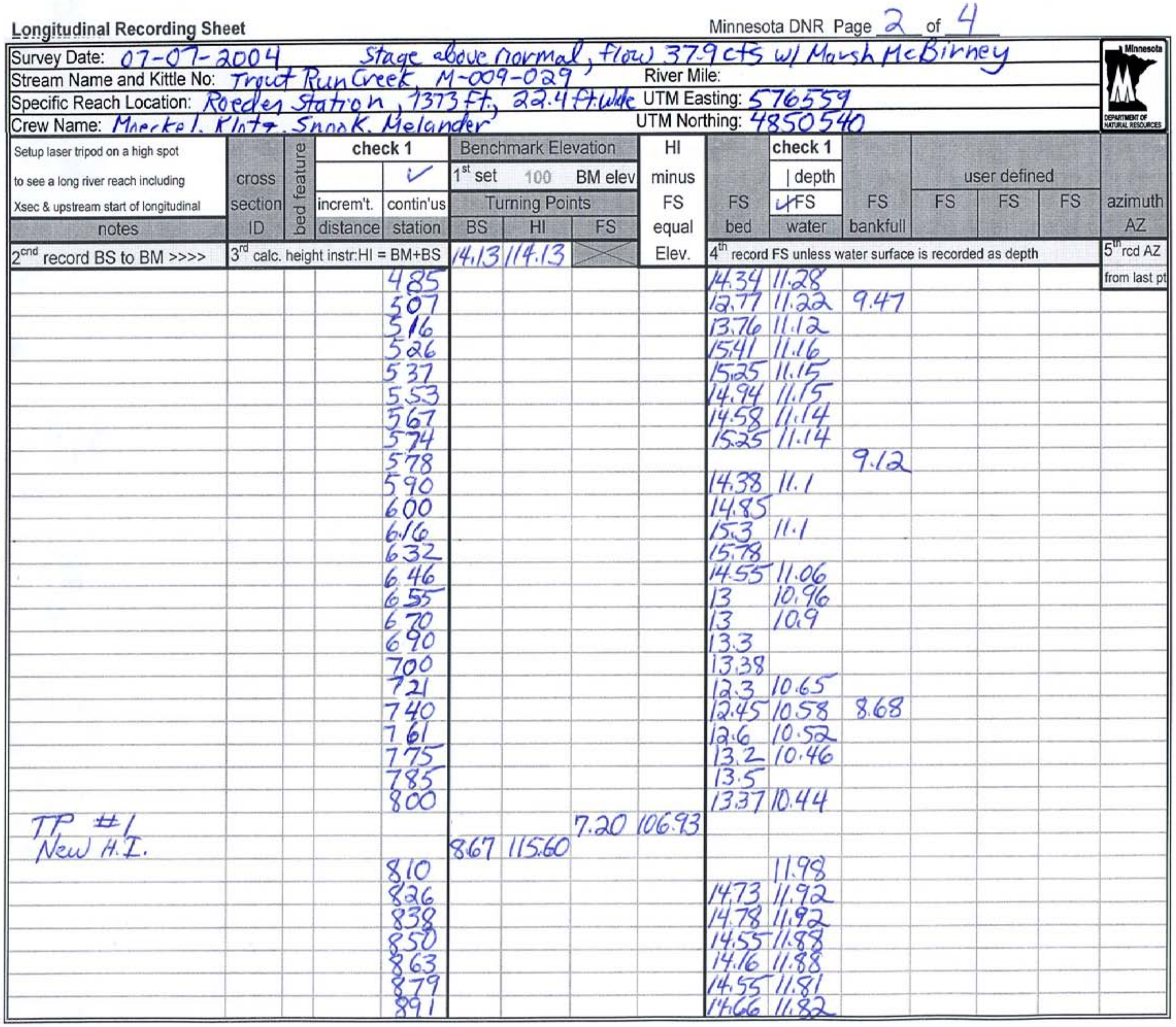
Longitudinal Recording Sheet

Minnesota DNR Page 1 of 4

Survey Date: 07-07-2004 Stage above normal, flow 37.9 cfs w/ Marsh McBirney
Stream Name and Kittle No: Trout Run Creek M-009-029 River Mile:
Specific Reach Location: Roeder Station, 1373 ft, 22.4 ft wide UTM Easting: 576559
Crew Name: Moeckel, Klotz, Snook, Melander UTM Northing: 4850540

Setup laser tripod on a high spot to see a long river reach including Xsec & upstream start of longitudinal			check 1	✓	Benchmark Elevation 1st set 100 BM elev			HI minus FS equal		check 1 | depth		user defined			
notes	cross section ID	bed feature	increm't. distance	contin'us station	Turning Points BS	HI	FS		FS bed	↓FS water	FS bankfull	FS	FS	FS	azimuth AZ
2cnd record BS to BM >>>>	3rd calc. height instr:HI = BM+BS				14.13	114.13	☒	Elev.	4th record FS unless water surface is recorded as depth						5th rcd AZ from last pt
				000					14.74	12.03					
				019					14.02	12.03					
				043					14.82	12.06					
				070					15.45	12.07					
				085					16.68	12.06					
				093					13.35	–					
				111					13.06	11.6					
				135					13.85	11.6					
				160					13.48	11.6					
				180					14.1	11.58					
				200					15.68	11.59					
				214					17.2	11.4					
				229					16.3	11.61					
				244					16.6	11.57					
				262					–	11.58					
				270					16						
				283						11.58					
				285					14.6						
				297					15.65						
				299					–	11.57					
				312					16.3						
				332					13.22	11.56	9.87				
				3.40					15.4	11.49					
				354					16.15						
				370					16.55						
				379					16.55						
				385					15.68						
				396					15.4						
				413					12.95	11.48					
				428					12.87	11.48					
				440					14.2	11.39	9.06				
				470					13.33	11.32					
				475					13.62	11.3					

Figure 42a. Example longitudinal profile field sheet.

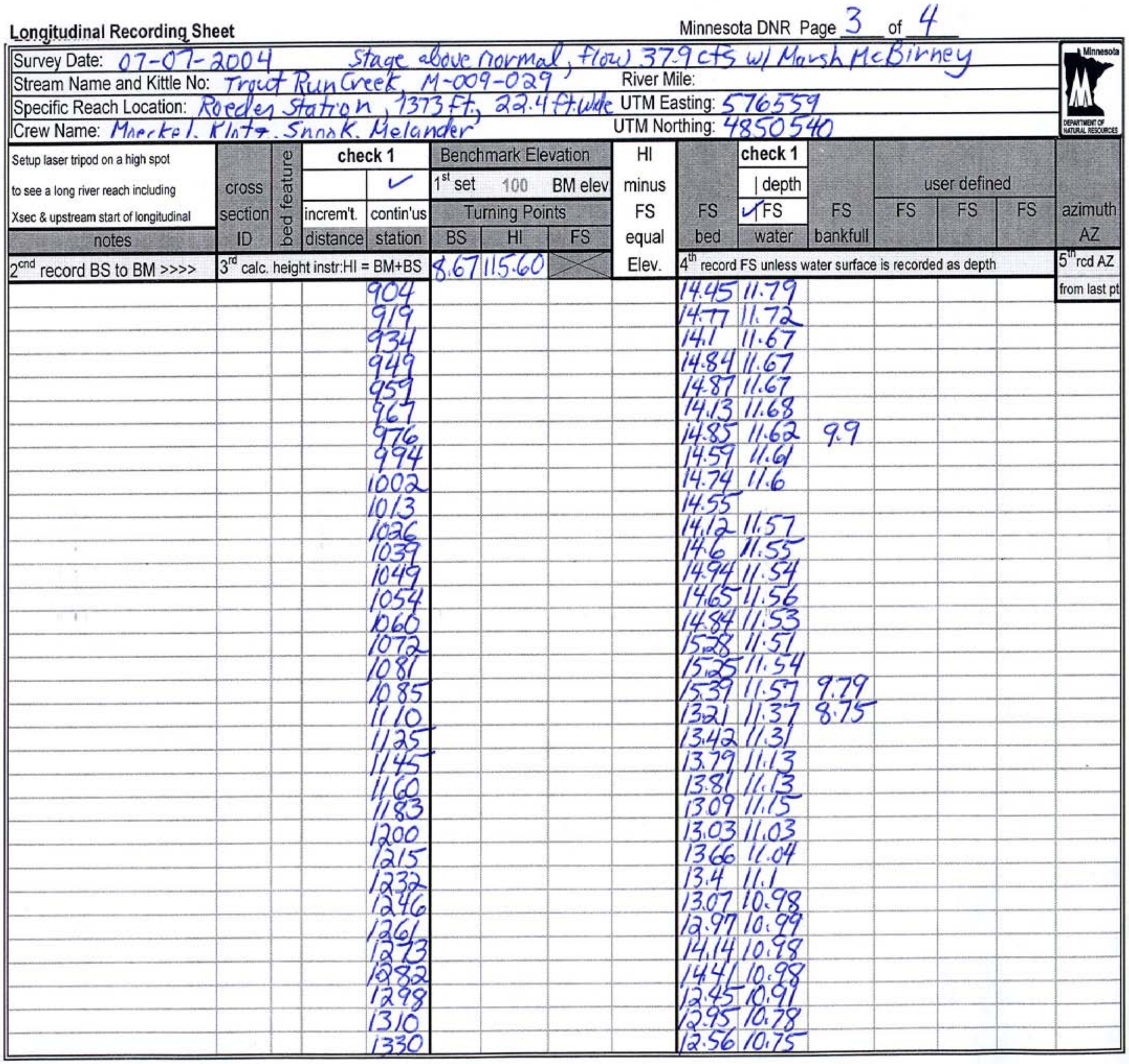


Longitudinal Recording Sheet Minnesota DNR Page 2 of 4

Survey Date: 07-07-2004 Stage above normal, flow 37.9 cfs w/ Marsh McBirney
Stream Name and Kittle No: Trout Run Creek, M-009-029 River Mile:
Specific Reach Location: Roeder Station, 1373 ft, 22.4 ft wide UTM Easting: 576559
Crew Name: Maeckel, Klotz, Snook, Melander UTM Northing: 4850540

Setup laser tripod on a high spot to see a long river reach including Xsec & upstream start of longitudinal	cross section	bed feature	check 1		Benchmark Elevation			HI minus FS equal		check 1		user defined			
				✓	1st set	100	BM elev			| depth					
			increm't.	contin'us	Turning Points				FS	✓FS	FS	FS	FS	FS	azimuth
notes	ID		distance	station	BS	HI	FS		bed	water	bankfull				AZ
2cnd record BS to BM >>>>	3rd calc. height instr:HI = BM+BS				14.13	114.13	☒	Elev.	4th record FS unless water surface is recorded as depth						5th rcd AZ
				485					14.34	11.28					from last pt
				507					12.77	11.22	9.47				
				516					13.76	11.12					
				526					15.41	11.16					
				537					15.25	11.15					
				553					14.94	11.15					
				567					14.58	11.14					
				574					15.25	11.14					
				578							9.12				
				590					14.38	11.1					
				600					14.85						
				616					15.3	11.1					
				632					15.78						
				646					14.55	11.06					
				655					13	10.96					
				670					13	10.9					
				690					13.3						
				700					13.38						
				721					12.3	10.65					
				740					12.45	10.58	8.68				
				761					12.6	10.52					
				775					13.2	10.46					
				785					13.5						
				800					13.37	10.44					
TP #1							7.20	106.93							
New H.I.					8.67	115.60									
				810						11.98					
				826					14.73	11.92					
				838					14.78	11.92					
				850					14.55	11.88					
				863					14.16	11.88					
				879					14.55	11.81					
				891					14.66	11.82					

Figure 42b. Example longitudinal profile field sheet.



Longitudinal Recording Sheet

Minnesota DNR Page 3 of 4

Survey Date: 07-07-2004 Stage above normal, flow 37.9 cfs w/ Marsh McBirney

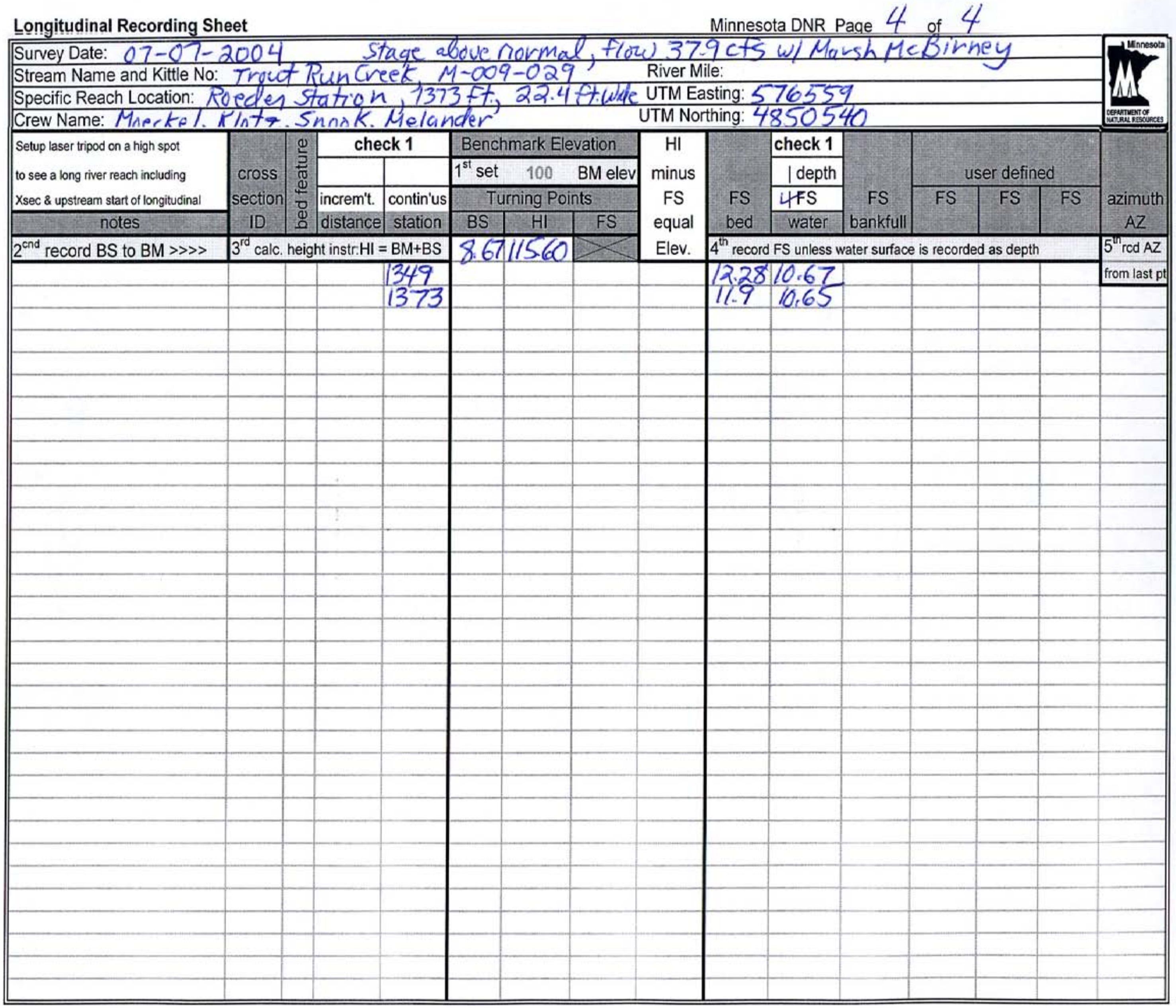
Stream Name and Kittle No: Trout Run Creek, M-009-029 River Mile:

Specific Reach Location: Roeder Station, 1373 ft, 22.4 ft wide UTM Easting: 576559

Crew Name: Maeckel. Klotz. Snook. Melander UTM Northing: 4850540

Setup laser tripod on a high spot to see a long river reach including Xsec & upstream start of longitudinal	cross section ID	bed feature	check 1		Benchmark Elevation			HI minus FS equal Elev.		check 1		user defined			azimuth AZ
				✓	1st set	100	BM elev			| depth					
					Turning Points										
notes			increm't. distance	contin'us station	BS	HI	FS		FS bed	✓ FS water	FS bankfull	FS	FS	FS	
2cnd record BS to BM >>>>	3rd calc. height instr:HI = BM+BS				8.67	115.60			4th record FS unless water surface is recorded as depth						5th rcd AZ
				904					14.45	11.79					from last pt
				919					14.77	11.72					
				934					14.1	11.67					
				949					14.84	11.67					
				959					14.87	11.67					
				967					14.13	11.68					
				976					14.85	11.62	9.9				
				994					14.59	11.61					
				1002					14.74	11.6					
				1013					14.55						
				1026					14.12	11.57					
				1039					14.6	11.55					
				1049					14.94	11.54					
				1054					14.65	11.56					
				1060					14.84	11.53					
				1072					15.28	11.51					
				1081					15.25	11.54					
				1085					15.39	11.57	9.79				
				1110					13.21	11.37	8.75				
				1125					13.42	11.31					
				1145					13.79	11.13					
				1160					13.81	11.13					
				1183					13.09	11.15					
				1200					13.03	11.03					
				1215					13.66	11.04					
				1232					13.4	11.1					
				1246					13.07	10.98					
				1261					12.97	10.99					
				1273					14.14	10.98					
				1282					14.41	10.98					
				1298					12.45	10.91					
				1310					12.95	10.78					
				1330					12.56	10.75					

Figure 42c. Example longitudinal profile field sheet.



Longitudinal Recording Sheet

Minnesota DNR Page 4 of 4

Survey Date: 07-07-2004 Stage above normal, flow 37.9 cfs w/ Marsh McBirney

Stream Name and Kittle No: Trout Run Creek, M-009-029 River Mile:

Specific Reach Location: Roeder Station, 1373 ft, 22.4 ft wide UTM Easting: 576559

Crew Name: Maerkel, Klotz, Snook, Melander UTM Northing: 4850540

Setup laser tripod on a high spot to see a long river reach including Xsec & upstream start of longitudinal notes	cross section ID	bed feature	check 1 increm't. distance	contin'us station	Benchmark Elevation 1st set 100 Turning Points BS	BM elev HI	FS	HI minus FS equal	FS bed	check 1 | depth 4FS water	FS bankfull	user defined FS	FS	FS	azimuth AZ
2cnd record BS to BM >>>>	3rd calc. height instr:HI = BM+BS				8.67	11560		Elev.	4th record FS unless water surface is recorded as depth						5th rcd AZ
				1349					12.28	10.67					from last pt
				1373					11.9	10.65					

Figure 42d. Example longitudinal profile field sheet.

Step 3. Analyze Longitudinal Profile Data

Procedure 3-1. **Calculate Average Water Surface Slope**. By sample site: Use the water surface elevations from similar bed features (e.g., the tops of two riffles) to calculate water surface slope. It is preferable to use the tops of riffles because they are hydrologic controls. Use data from bed features located as close to the upstream and downstream boundaries as is possible to get an average water surface slope for the entire station. To calculate the slope, divide the vertical height change (rise) by the longitudinal distance (run) of the stream segment. When using RIVERMorph, slope can be estimated using the measurement tool.

By bed feature: Determine the slope for each individual bed feature (facet) found in the site and calculate the average slope across similar habitat types (e.g., average riffle slope). To measure facet slopes in RIVERMorph, use the “profile” tab in the **Ratios** node.

Procedure 3-2. Calculate Percent of Station by Bed Feature. Use the lengths of each bed feature (pool, riffle, run, glide, and cascade) to calculate the percentage of the site composed of each. Individual bed feature lengths can be measured in the **Ratios** node of RIVERMorph under the “profile” tab, and the program will calculate max, min and means.

Procedure 3-3. Measure Thalweg Depth. In the **Ratios** node of RIVERMorph, under the “profile” tab, measure bankfull depth at the midpoint of each bed. Use the measure tool to measure the distance from the bankfull slope line to the thalweg. In pools, measure bankfull depth at the deepest point.

Procedure 3-4. Calculate Water Depth. Water depth distribution at the time of the survey can be determined by comparing the water surface and streambed elevations. Water depth distribution at other discharges can be estimated using stage/discharge relationships. Results will go in a report (yet to be determined).

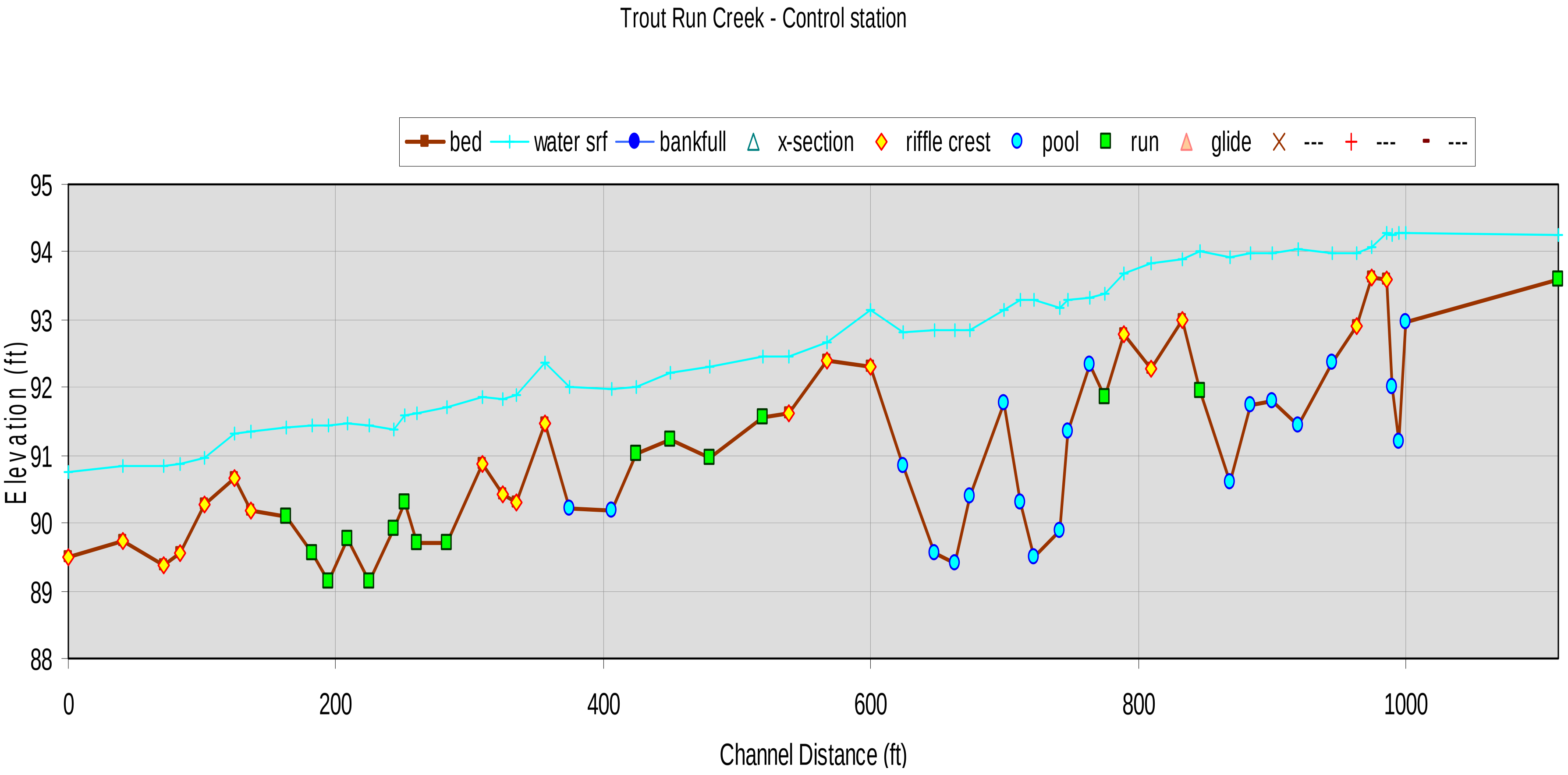


Figure 43. Example longitudinal profile of Trout Run Creek (M-009-029, Fillmore County, MN) at Station 8.63 (Control). The blue line is waters surface. Data collected summer 2006.

Channel Cross-Section Survey (Dimension)

Survey a minimum of one cross-section per similar reach. The cross-section should be located within the longitudinal profile and positioned within a riffle whenever possible. If riffles are not present in the reach, position the cross section within a run. Additional cross-sections located through other bed features are optional, but encouraged. Remember to record the stationing of the cross-section on the longitudinal profile. Two field data sheets will be required for conducting a stream channel cross-section survey:

a. the Channel Cross-section form, and
b. the Pebble Count recording field sheet

Step 1. Determine Bankfull Stage. The bankfull stage (sometimes referred to as bankfull height) is the water surface elevation at flows primarily responsible for channel formation (Dunne and Leopold 1978), which correspond to, on average, the 1.5-year recurrence interval (Rosgen 1996). It is also typically the water height when the stream channel begins to access its flood plain. However, it is not always the top of the high bank. Bankfull stage can only be determined in the field. The most accurate indicator of bankfull elevation is the top of the highest depositional features, such as point bars and central bars. In most stable streams and stream types, this corresponds to the floodplain elevation. Other indicators of the relative location of bankfull stage are: (1) a change in the size distribution of substrate or bank particles, (2) a break in the slope of the banks, (3) stains on rocks, and (4) root hairs exposed below an intact soil layer (Rosgen 1996). Correct identification of bankfull elevation is critical, as much of the analysis of stream stability and habitat quality is based on measurements and analysis related to this elevation. Comparing bankfull elevations recorded while conducting the longitudinal profile can help to determine the correct bankfull elevation. Most people tend to underestimate bankfull elevation, but care must also be taken to prevent identifying a low terrace as the bankfull elevation. A terrace is a remnant bankfull feature formed under different hydrologic conditions. When gages or regional curve data are available, bankfull elevation can be calibrated by comparing flow and cross-sectional area data from the study site cross-section to the regional curve or USGS gage data. Useful guides to identifying bankfull indicators include: pages 33–36 of Harrelson et al. (1994) located in the electronic appendices (Appendix 6), pages 5–8 and 5–9 of Rosgen (1996); and USDA Forest Service (2005), a reference CD included which should be viewed prior to one’s first attempt to identify bankfull elevation.

Step 2. Survey the Cross Section. The channel cross section is surveyed by determining the endpoints of the cross section, establishing a temporary benchmark, and measuring elevations along the transect (Figure 44). Record data on the Cross Section Recording Sheet (example in Figure 45, blank form in appendix 1).

Procedure 2-1. Establish the Cross Section. Lay the channel cross-section perpendicular to stream flow. Drive a stake into the ground on the left and right sides of the stream to establish the endpoints of the cross section. Locate endpoint stakes at a ground elevation more than one maximum bankfull depth higher than the bankfull stage determined in Step 1. In most cases, the endpoint markers will be temporary stakes. Permanent markers or stakes may be desirable if long-term monitoring of the specific cross-section is planned.

Maximum bankfull depth can be estimated by identifying where the cross section will be located and estimating the vertical distance between the thalweg substrate elevation and the bankfull stage elevation.

Once the endpoint stakes are in place, attach the zero end of a measuring tape to the stake on the left side of the stream (when facing downstream), stretch the tape tightly across the cross section, and attach it to the endpoint stake on the right.

Procedure 2-2. Establish a Temporary Benchmark. A temporary benchmark will establish a relative elevation to serve as a control point for the cross section and longitudinal profile. Generally, a spike near the base of a healthy tree is the best option for a benchmark. The spike should be located so that the staff can rest upright and level on top of the spike, and should be below the elevation of the level. Placing two benchmarks is recommended in case the original is lost.

Unless there is an existing benchmark with a known elevation, assign 100 ft as the elevation of BM1. Record any additional benchmark elevations relative to BM1. You do not need to establish a permanent, monumented benchmark. If possible, however, use a "permanent" existing structure located within a reasonable distance. This will allow better monitoring for channel aggradation or degradation. Benchmark location descriptions should be recorded that are thorough and include UTM coordinates. Their location should also be noted on the site map.

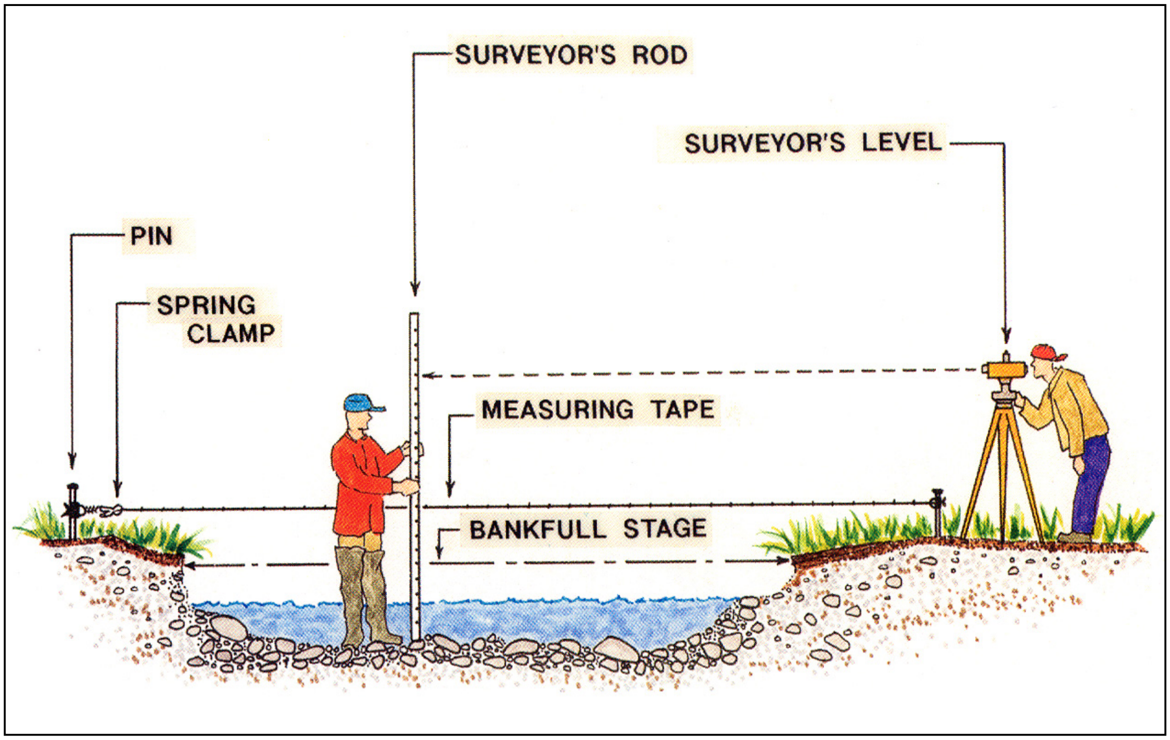
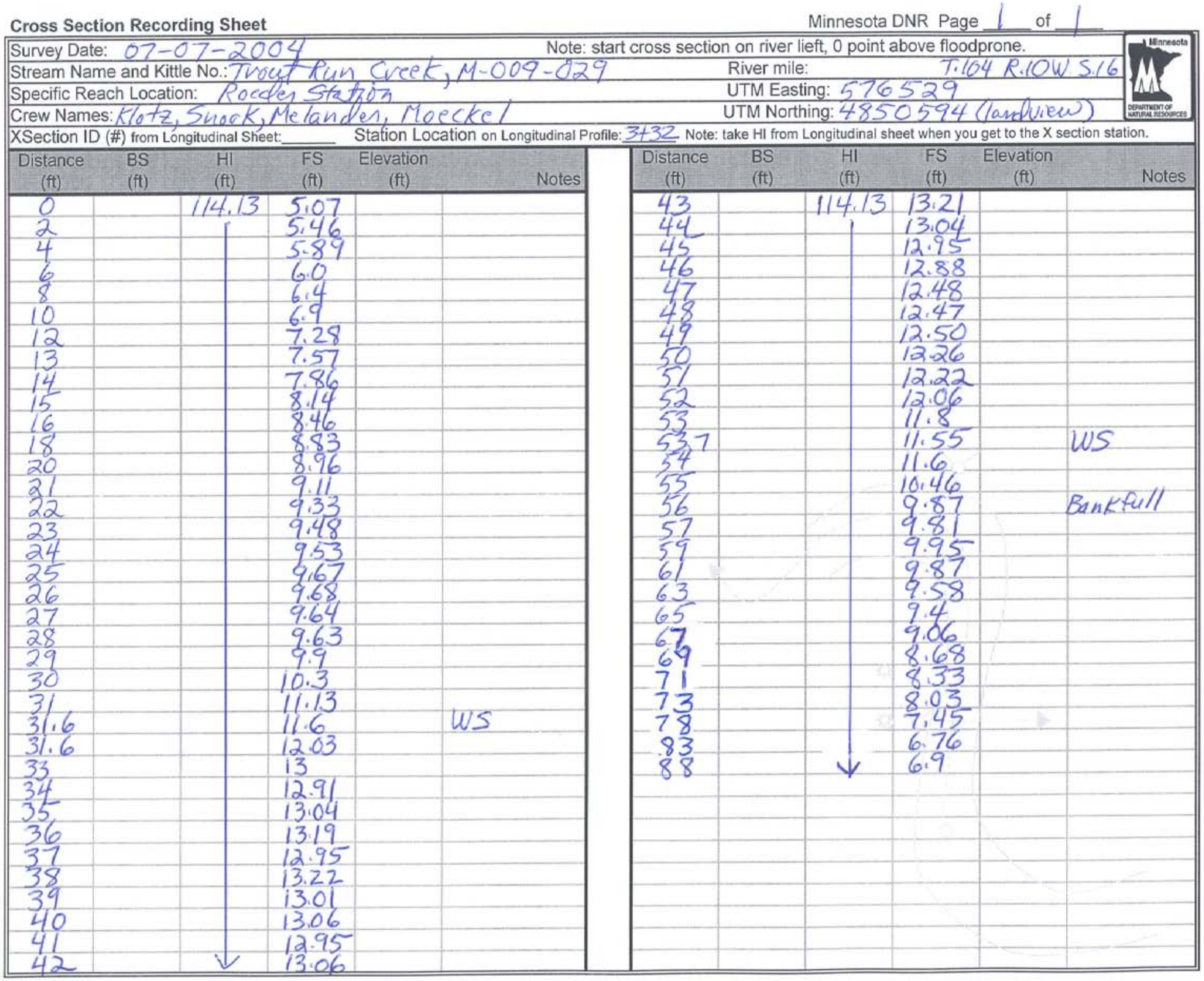


Figure 44. Conducting a stream channel cross-section survey (from Rosgen 1996, © Wildland Hydrology).



Cross Section Recording Sheet

Minnesota DNR Page 1 of 1

Survey Date: 07-07-2004

Note: start cross section on river lieft, 0 point above floodprone.

Stream Name and Kittle No.: Trout Run Creek, M-009-029

River mile: T.104 R.10W S.16

Specific Reach Location: Roeder Station

UTM Easting: 576529

Crew Names: Klotz, Snook, Melander, Moeckel

UTM Northing: 4850594 (landview)

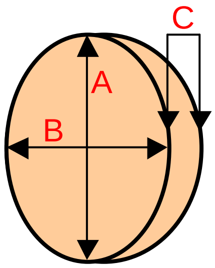
XSection ID (#) from Longitudinal Sheet:______ Station Location on Longitudinal Profile: 3+32 Note: take HI from Longitudinal sheet when you get to the X section station.

Distance (ft)	BS (ft)	HI (ft)	FS (ft)	Elevation (ft)	Notes
0		114.13	5.07		
2			5.46		
4			5.89		
6			6.0		
8			6.4		
10			6.9		
12			7.28		
13			7.57		
14			7.86		
15			8.14		
16			8.46		
18			8.83		
20			8.96		
21			9.11		
22			9.33		
23			9.48		
24			9.53		
25			9.67		
26			9.68		
27			9.64		
28			9.63		
29			9.9		
30			10.3		
31			11.13		
31.6			11.6		WS
31.6			12.03		
33			13		
34			12.91		
35			13.04		
36			13.19		
37			12.95		
38			13.22		
39			13.01		
40			13.06		
41			12.95		
42			13.06		

Distance (ft)	BS (ft)	HI (ft)	FS (ft)	Elevation (ft)	Notes
43		114.13	13.21		
44			13.04		
45			12.95		
46			12.88		
47			12.48		
48			12.47		
49			12.50		
50			12.26		
51			12.22		
52			12.06		
53			11.8		
53.7			11.55		WS
54			11.6		
55			10.46		
56			9.87		Bankfull
57			9.81		
59			9.95		
61			9.87		
63			9.58		
65			9.4		
67			9.06		
69			8.68		
71			8.33		
73			8.03		
78			7.45		
83			6.76		
88			6.9		

Figure 45. Example cross-section recording field sheet.

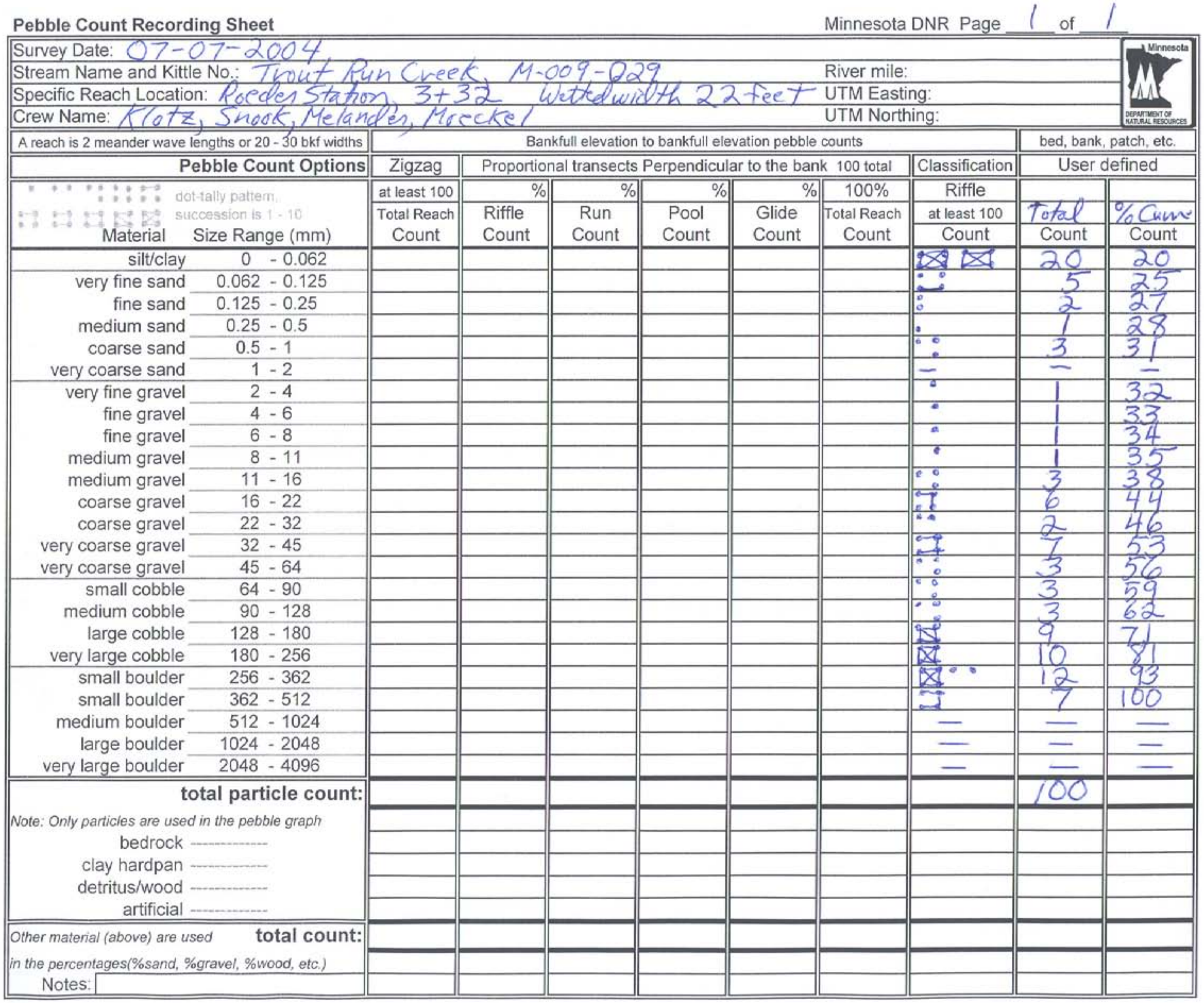
Procedure 2-3. Measure Elevations. Set up a laser level where you can take elevation readings of the benchmark and the entire length of the cross section. Take an elevation reading on the top of the benchmark and enter this in the "Backsight" (BS) column. Add the BS value to the BM elevation to get the instrument height (HI) on the recording sheet. This will remain the instrument height for the entire cross-section unless a level turn is necessary, which is rare for cross-section surveys. The BS column will only be further needed in case of level turn. Next, take elevation readings across the cross section beginning on the left side. At a minimum, take elevation readings at each change in important feature, including: the ground next to the endpoint stakes, slope breaks, bankfull stage (left and right), water surface at the left and right water's edge, and the thalweg substrate. In most cases, you will take many more points than just these. Take as many elevation points as needed to provide a detailed plot across the cross section. For each point, record the distance as read from the measuring (distance), the elevation reading (FS) and any comment of interest (e.g., left bankfull stage, water surface reading, etc). The column "Elevation" on the recording sheet is used for adjusting FS readings by instrument height; in most cases this field will be left blank as this procedure will usually be done automatically by the analysis program.



A. Longest axis
B. Intermediate axis
C. Shortest axis

Figure 46. Particle axes.

Step 3. Sample Cross-Section Substrate Particle Composition. Describe the stream channel substrate particle composition along the cross section within the active bed of the channel using the Wolman (1954) pebble count procedure as follows: Begin at either side of the stream. (Unless you are establishing a permanently monumented cross-section to monitor for changes in substrate composition, only the active bed of the stream is sampled to provide the best estimate of roughness for velocity and flow estimations.) Without looking, reach down to the substrate and pick up the first particle the tip of your index finger touches. Measure the width of the particle along the intermediate axis (Figure 46). Heavily embedded or very large particles can be measured in place. If the main goal of the cross-section particle count is to determine the D_{84} size for velocity and flow calculations, in the case of boulder-bed, bed-rock and sand-bed channels, use the mean protrusion height (dune height for sand-bed streams), measured from the bed surface to the tip of the protruding particle (Rosgen 2006). Tally each measurement in the appropriate category on the Pebble Count Recording Sheet (example form in Figure 47, blank form in appendix 1) or enter directly into RIVERMorph in the **Particles** node. Be sure to choose "riffle" in the Sample Type pull down window, so the program knows to use this data for flow and velocity calculations. Proceed across the cross section, measuring a total of 100 individual substrate particles.



Pebble Count Recording Sheet

Minnesota DNR Page 1 of 1

Survey Date: 07-07-2004

Stream Name and Kittle No.: Trout Run Creek, M-009-029

Specific Reach Location: Roeder Station, 3+32 Wetted width 22 feet

Crew Name: Klotz, Snook, Melander, Moeckel

River mile:

UTM Easting:

UTM Northing:

A reach is 2 meander wave lengths or 20 - 30 bkf widths

			Bankfull elevation to bankfull elevation pebble counts						bed, bank, patch, etc.	
	Pebble Count Options	Zigzag	Proportional transects Perpendicular to the bank 100 total					Classification	User defined	
dot-tally pattern, succession is 1 - 10		at least 100	%	%	%	%	100%	Riffle		
Material	Size Range (mm)	Total Reach Count	Riffle Count	Run Count	Pool Count	Glide Count	Total Reach Count	at least 100 Count	Total Count	% Cum Count
silt/clay	0 - 0.062							☒ ☒	20	20
very fine sand	0.062 - 0.125								5	25
fine sand	0.125 - 0.25								2	27
medium sand	0.25 - 0.5								1	28
coarse sand	0.5 - 1								3	31
very coarse sand	1 - 2							—	—	—
very fine gravel	2 - 4								1	32
fine gravel	4 - 6								1	33
fine gravel	6 - 8								1	34
medium gravel	8 - 11								1	35
medium gravel	11 - 16								3	38
coarse gravel	16 - 22								6	44
coarse gravel	22 - 32								2	46
very coarse gravel	32 - 45								7	53
very coarse gravel	45 - 64								3	56
small cobble	64 - 90								3	59
medium cobble	90 - 128								3	62
large cobble	128 - 180							☒	9	71
very large cobble	180 - 256							☒	10	81
small boulder	256 - 362							☒	12	93
small boulder	362 - 512								7	100
medium boulder	512 - 1024							—	—	—
large boulder	1024 - 2048							—	—	—
very large boulder	2048 - 4096							—	—	—
total particle count:									100	
Note: Only particles are used in the pebble graph										
bedrock	------------									
clay hardpan	------------									
detritus/wood	------------									
artificial	------------									
Other material (above) are used	**total count:**									
in the percentages(%sand, %gravel, %wood, etc.)										
Notes:										

Figure 47. Example pebble-count recording field sheet.

Step 4. Measure Flood Prone Area Width (*W_{fpa}*). Rosgen (1996) defines the typical flood-prone area of the channel as the land below the stage elevation corresponding to twice D_{max} ,which usually includes the active flood plain and low terrace. To determine the upper flood prone area stage, multiply D_{max} by two. The flood prone area width is the distance between the right and left flood prone area stage elevations.

Step 5. Calculate Cross-section Data. Calculate the following parameters and record them on the Stream Survey Morphological Description Summary Sheet field form (Figure 48) or directly into RIVERMorph:

Bankfull Width (W_{bkf}). The distance between the right and left bankfull elevations.

Bankfull Cross-section Area (A_{bkf}). The sum of cell areas below bankfull elevation.

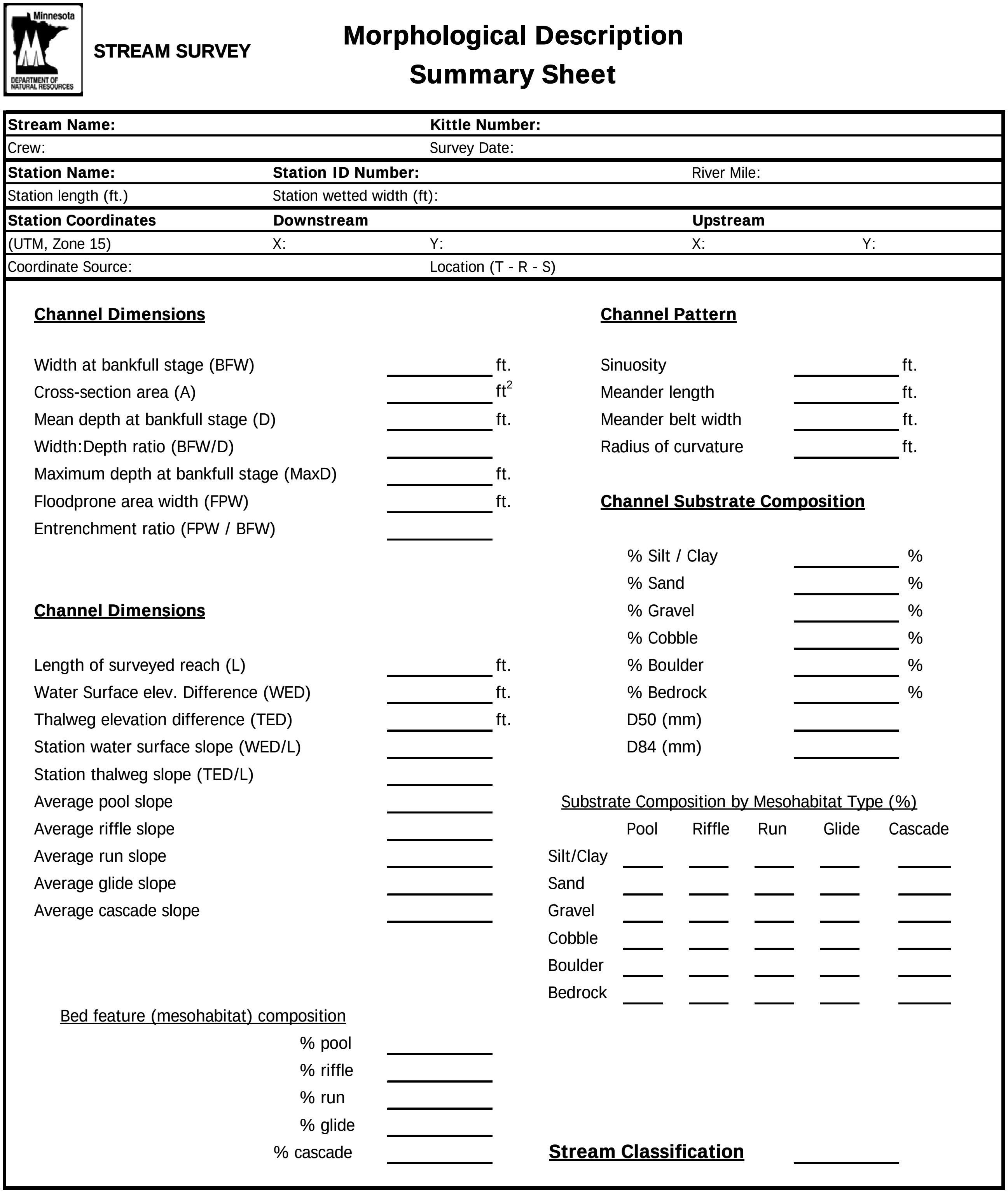
Mean Bankfull Depth (d_{bkf}). Calculate d_{bkf} as (A_{bkf}/W_{bkf})

Width:Depth Ratio. The width to depth ratio is an indicator of the shape of a channel cross-section calculated as (W_{bkf}/d_{bkf}).

Maximum Depth at Bankfull Stage (D_{max}). The distance between the bankfull stage elevation and the lowest elevation along the cross section (i.e., the thalweg).

Entrenchment Ratio (ER). The entrenchment ratio is an index describing the vertical containment of a river channel and is calculated at (W_{fpa}/W_{bkf}).

Substrate Composition. Calculate the percentage of sand, gravel, cobble, boulder, and bedrock for the cross section. Identify the median particle diameter (D_{50}) using a cumulative size frequency plot as demonstrated in Figure 49. If the substrate particle composition has a bimodal distribution and the D_{50} particle is not present along the cross section, use the dominant particle size (i.e., the particle size with greatest number of observations). The D_{84} particle size should also be determined for use in velocity and flow calculations.



STREAM SURVEY

Morphological Description Summary Sheet

Stream Name: **Kittle Number:**
Crew: Survey Date:

Station Name: **Station ID Number:** River Mile:
Station length (ft.) Station wetted width (ft):

Station Coordinates	**Downstream**		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:

Coordinate Source: Location (T - R - S)

Channel Dimensions

Width at bankfull stage (BFW) ____________ ft.
Cross-section area (A) ____________ ft^2
Mean depth at bankfull stage (D) ____________ ft.
Width:Depth ratio (BFW/D) ____________
Maximum depth at bankfull stage (MaxD) ____________ ft.
Floodprone area width (FPW) ____________ ft.
Entrenchment ratio (FPW / BFW) ____________

Channel Dimensions

Length of surveyed reach (L) ____________ ft.
Water Surface elev. Difference (WED) ____________ ft.
Thalweg elevation difference (TED) ____________ ft.
Station water surface slope (WED/L) ____________
Station thalweg slope (TED/L) ____________
Average pool slope ____________
Average riffle slope ____________
Average run slope ____________
Average glide slope ____________
Average cascade slope ____________

Bed feature (mesohabitat) composition

% pool ____________
% riffle ____________
% run ____________
% glide ____________
% cascade ____________

Channel Pattern

Sinuosity ____________ ft.
Meander length ____________ ft.
Meander belt width ____________ ft.
Radius of curvature ____________ ft.

Channel Substrate Composition

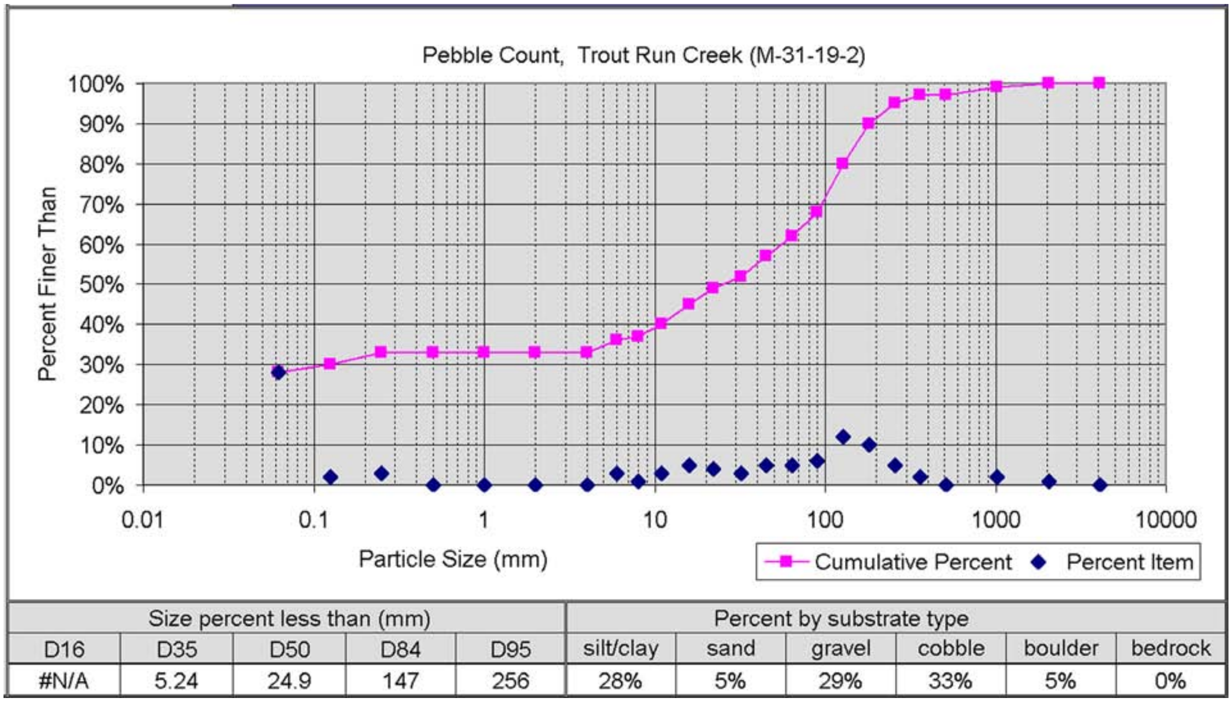
% Silt / Clay ____________ %
% Sand ____________ %
% Gravel ____________ %
% Cobble ____________ %
% Boulder ____________ %
% Bedrock ____________ %
D50 (mm) ____________
D84 (mm) ____________

Substrate Composition by Mesohabitat Type (%)

	Pool	Riffle	Run	Glide	Cascade
Silt/Clay	____	____	____	____	____
Sand	____	____	____	____	____
Gravel	____	____	____	____	____
Cobble	____	____	____	____	____
Boulder	____	____	____	____	____
Bedrock	____	____	____	____	____

Stream Classification ____________

Figure 48. Example summary form for reporting stream morphological descriptors (channel dimension, pattern, profile and substrate composition).



Size percent less than (mm)					Percent by substrate type					
D16	D35	D50	D84	D95	silt/clay	sand	gravel	cobble	boulder	bedrock
#N/A	5.24	24.9	147	256	28%	5%	29%	33%	5%	0%

Figure 49. Example pebble count, showing percent distribution by particle size (blue), cumulative percent (red), diameter at 35th, 50th, 84th, and 95th percentiles, and percentage by substrate type.

Channel Substrate Measurements

Step 1. Sample Station Substrate Particle Composition. Use the Wolman (1954) pebble count method as described in the Channel Cross-Section Survey section above to collect substrate particle data representing the entire length of the sampling station. Proceed in a zigzag pattern through the longitudinal profile collecting data up to bankfull stage. Record data using the Pebble Count Recording field sheet or directly into the particle node in RIVERmorph. Choose “Reach” in the *Sample Type* pull-down window so the program knows to use these data for determining stream classification. Experience has shown there is a tendency to avoid deep water and/or to space samples unevenly (such as when you get toward the end of the profile and realize you still need a total of 100 samples). Make every effort to set a zigzag pattern that transverses all habitat units within the profile in an unbiased manner. On-site planning before you begin collecting data is advised.

Step 2. Analyze Station Substrate Particle Composition Data. Calculate the percentage of silt/clay, sand, gravel, cobble, boulder, and bedrock for the site. Identify the median particle diameter (D_{50}) using a cumulative size frequency plot as demonstrated in Figure 49. If the substrate particle composition has a bimodal distribution and the D_{50} particle is not present at a site, use the dominant particle size (i.e., the particle size with greatest number of observations).

Cover for Larger Fishes

For this manual, cover for larger fishes is defined as an object that provides instream shelter for a fish that is at least 0.2 m (8 in) total length. The object must be at least 0.3 m (12 in) long and 0.3 m (12 in) wide. We will follow the general lotic cover definitions of Simonson et al. (1994) with some modifications (primarily associated with water depth requirements). Much of this text was copied directly from Simonson et al. (1994).

Step 1. Collect Fish Cover Data. Collect fish cover data along the longitudinal profile of the stream reach. For each cover object encountered, record the cover type, plan-view length and width, and bed feature in which the cover object was located on the Stream Survey: Cover for Larger Fishes data form (Figure 50). Record cover type as follows:

1. ***Undercut banks (UCB)*** – Banks that overhang the water by at least 0.3 m. For the bank to be considered cover, the bottom must be no more than 0.1 m above the water surface. In-stream habitat structures, such as lunker structures, belong in this category.

2. ***Overhanging vegetation (OHV)*** – Thick vegetation overhanging the water that meets the above criteria for cover.

3. ***Woody debris (WD)*** – Large pieces or aggregations of smaller pieces of wood (e.g., logs, large tree branches, root tangles) located in or in contact with water.

4. ***Other debris (OD)*** – Pieces of human-made debris found in or in contact with water. Examples include old tires, abandoned farm implements, and discarded home appliances.

5. ***Boulders (BO)*** – Rocks that are >0.26 m long and that are in or in contact with water. Large pieces of concrete and other artificial rocky aggregates also belong in this category.

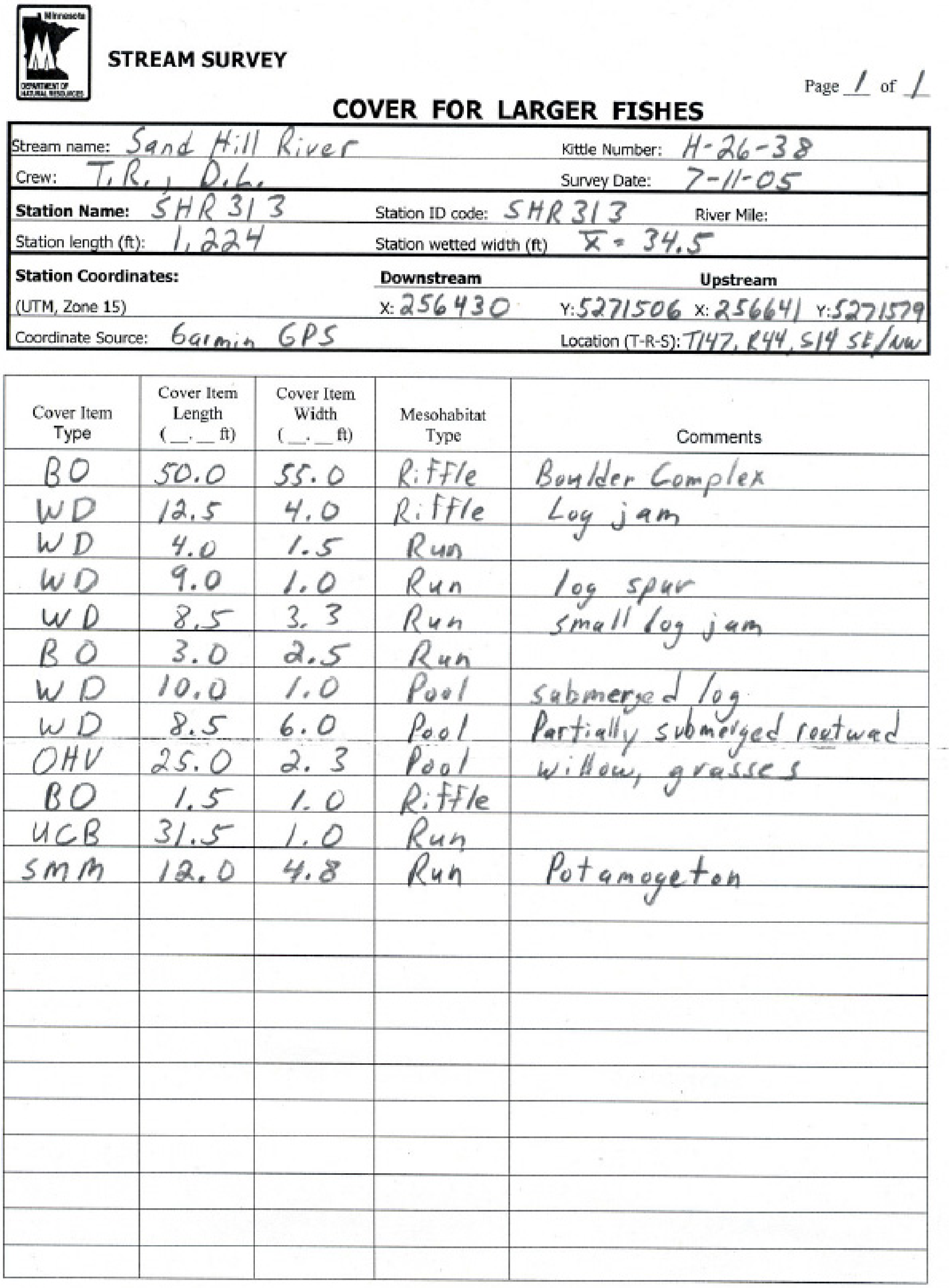
6. ***Submerged macrophytes (SMM)*** – Vascular plants that normally have all or nearly all their biomass below the surface of the water. To count as cover, submerged macrophytes must be thick or dense enough to provide shelter or visual isolation for fishes.

7. ***Emergent macrophytes (EMM)*** – Vascular plants that normally have a significant portion of their biomass above the surface of the water. To count as cover, emergent macrophytes must be must be thick or dense enough to provide shelter or visual isolation for fishes.

Step 2. Analyze Cover Data. The general approach is to report the percentage of stream surface area covered by each cover type. It is important to repeat that this is evaluating cover availability for larger (> 0.2 m) fishes only. Evaluation of cover availability for smaller fishes (e.g., inherently smaller species, juveniles, young-of-the-year) will likely require the use of additional data, such as the substrate particle composition information obtained during the longitudinal profile survey. Analysis results will go in a report (yet to be determined).

Procedure 2-1. Analyze by Sample Site. Calculate the percentage of the station's water surface area occupied by each cover type using the station length, average wetted width and dimensions of each individual cover object measured.

Procedure 2-2. Analyze by Bed Feature Type. Stratify the cover data by bed feature (i.e., pool, riffle, run, glide, cascade). Calculate the percentage of water surface area occupied by each cover type for each bed feature.



STREAM SURVEY

Page 1 of 1

COVER FOR LARGER FISHES

Stream name: Sand Hill River
Kittle Number: H-26-38
Crew: T.R., D.L.
Survey Date: 7-11-05
Station Name: SHR313
Station ID code: SHR313
River Mile:
Station length (ft): 1,224
Station wetted width (ft) $\bar{x}$ = 34.5

Station Coordinates:
(UTM, Zone 15)
Downstream X: 256430 Y: 5271506
Upstream X: 256641 Y: 5271579
Coordinate Source: Garmin GPS
Location (T-R-S): T147, R44, S14 SE/NW

Cover Item Type	Cover Item Length (__.__ ft)	Cover Item Width (__.__ ft)	Mesohabitat Type	Comments
BO	50.0	55.0	Riffle	Boulder Complex
WD	12.5	4.0	Riffle	Log jam
WD	4.0	1.5	Run	
WD	9.0	1.0	Run	log spur
WD	8.5	3.3	Run	small log jam
BO	3.0	2.5	Run	
WD	10.0	1.0	Pool	submerged log
WD	8.5	6.0	Pool	Partially submerged rootwad
OHV	25.0	2.3	Pool	willow, grasses
BO	1.5	1.0	Riffle	
UCB	31.5	1.0	Run	
SMM	12.0	4.8	Run	Potamogeton

Figure 50. Example "Cover for Larger Fishes" field form.

Predicting Stream Bank Erosion Rates

The prediction of stream bank erosion rates uses the "Bank Assessment for Non-point source Consequences of Sediment" (BANCS) method. This method as published by Rosgen (2001a, 2006) utilizes two bank erodibility estimation tools: the Bank Erosion Hazard Index (BEHI), and Near Bank Stress (NBS). The application involves evaluating the bank characteristics and flow distribution along river reaches and mapping various risk ratings commensurate with bank and channel changes. An estimate of erosion rate is made, and then multiplied times the bank height times the length of bank of a similar condition, providing an estimate of cubic yards and/or tons of sediment/year. This information can be compared to the sediment yield data to apportion the amount of sediment potentially contributed by streambanks.

The Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) assessment sections were excerpted from WARSSS (Rosgen 2006) and reprinted with permission from Wildland Hydrology.

The Bank Erosion Hazard Index (from Rosgen 2006)

The Bank Erosion Hazard Index (BEHI) evaluates the susceptibility to erosion for multiple erosional processes. The BEHI model is a process-integration approach that does not isolate individual processes of erosion (such as surface erosion, fluvial entrainment or mass erosion). The process integrates multiple variables that relate to “combined” erosional processes leading to annual erosion rates. Erosion risk is then established for a variety of BEHI variables and is eventually used to establish corresponding streambank erosion rates.

The individual BEHI variables used for the erosion prediction model are broken into seven categories:

1. Study bank height /bankfull height (bank height ratio);
2. Root depth/bank height (root depth ratio);
3. Weighted root density;
4. Bank angle;
5. Surface protection;
6. Bank material; and
7. Stratification of bank material.

For the purpose of estimating BEHI, note that "bankfull height" and "Study Bank Height" are measured from toe of slope, not the thalweg (see Figure 51).

To calculate Bank Erosion Hazard Index (BEHI), use the Stream Survey: Stream Bank Erodibility Potential form (Figure 52, blank form in appendix 1) or enter data directly into RIVERMorph in the **BEHI** node. BEHI is based on the first five variables listed above. The measured ratios and measured variables are converted to BEHI Scores using the graphs in Figure 53 (also found on the back of the BEHI form). Calculate an index for each variable and make appropriate adjustments for bank material and stratification. Then sum the index scores and determine the BEHI as Very Low, Low, Moderate, High, Very High, or Extreme. Descriptions of the variables, with photos can be found on pages 5-58 through 5-64 of Rosgen (2006). See the attached example for calculating BEHI (Figure 52).

BEHI should be calculated for the entire length of the longitudinal profile station. At each point the BEHI rating changes, recalculate the BEHI, record station length and draw the stationing on the site map. BEHI should be calculated for the entire length of the longitudinal profile station. At each point the BEHI rating changes, recalculate the BEHI, record station length and draw the stationing on the site map (example map in Figure 57; it may be necessary to draw a second map, with just the channel outline, specifically for BEHI/NBS stationing).

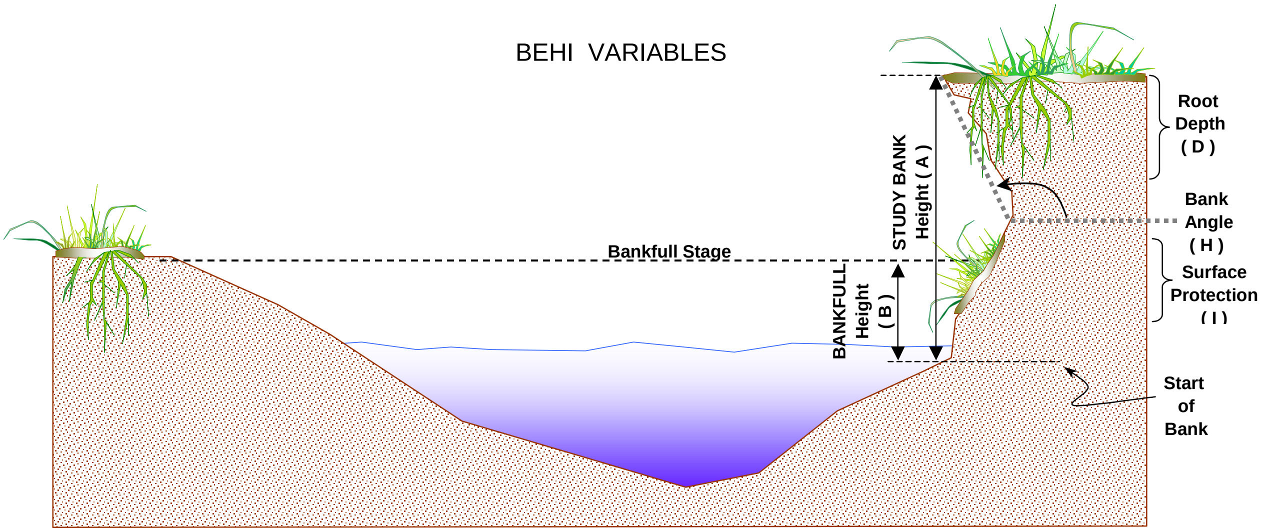
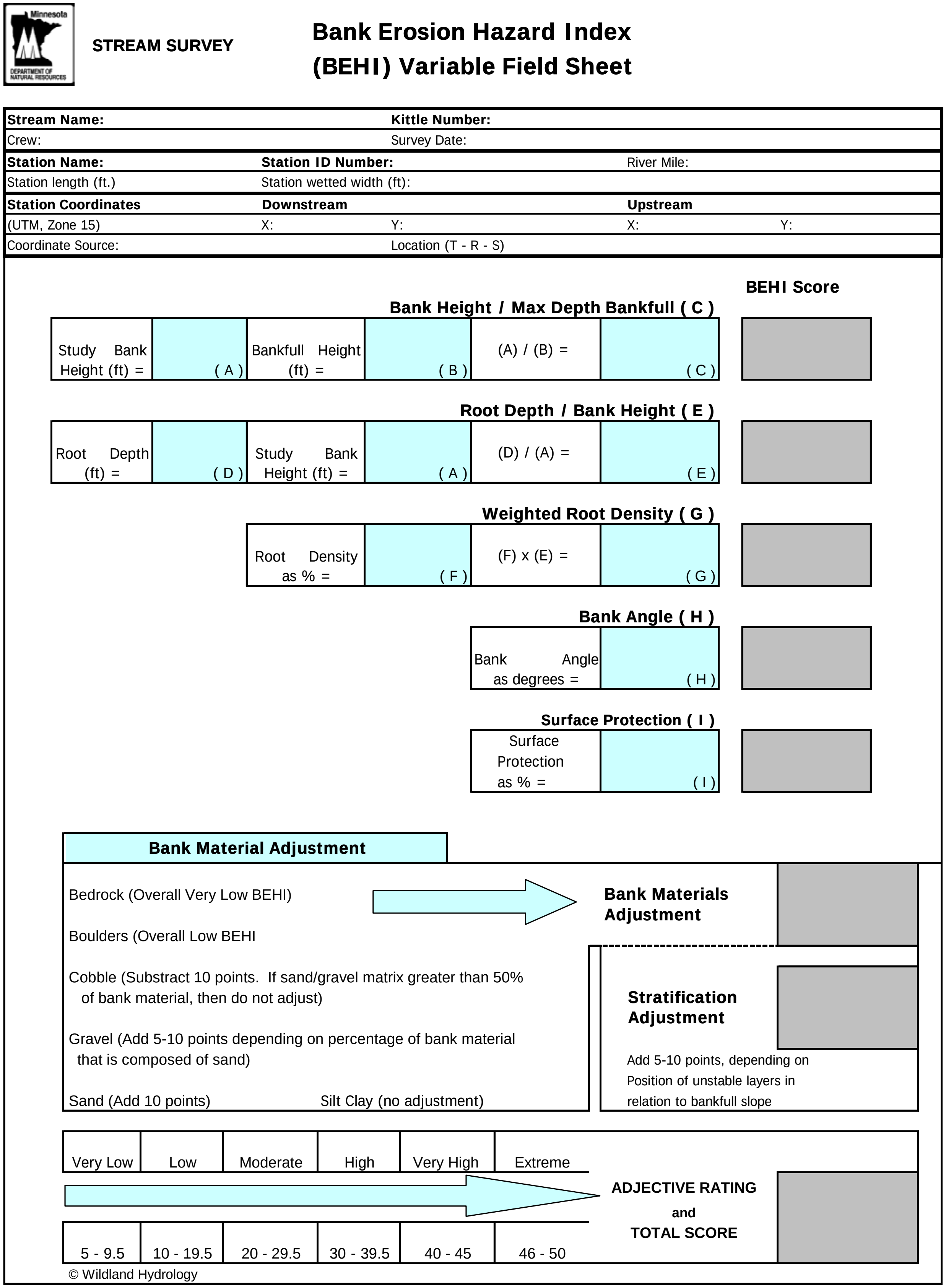


Figure 51. Streambank cross-section illustrating some of the variables surveyed to estimate Bank Erosion Hazard Index (BEHI). Note that bankfull height and study bank height are measured from the tow of the slope, not the thalweg. From Rosgen (2006), © Wildland Hydrology.



STREAM SURVEY

Bank Erosion Hazard Index (BEHI) Variable Field Sheet

Stream Name: **Kittle Number:**
Crew: Survey Date:
Station Name: **Station ID Number:** River Mile:
Station length (ft.) Station wetted width (ft):
Station Coordinates **Downstream** **Upstream**
(UTM, Zone 15) X: Y: X: Y:
Coordinate Source: Location (T - R - S)

BEHI Score

Bank Height / Max Depth Bankfull (C)
Study Bank Height (ft) = (A) Bankfull Height (ft) = (B) (A) / (B) = (C)

Root Depth / Bank Height (E)
Root Depth (ft) = (D) Study Bank Height (ft) = (A) (D) / (A) = (E)

Weighted Root Density (G)
Root Density as % = (F) (F) x (E) = (G)

Bank Angle (H)
Bank Angle as degrees = (H)

Surface Protection (I)
Surface Protection as % = (I)

Bank Material Adjustment

Bedrock (Overall Very Low BEHI)

Boulders (Overall Low BEHI

Cobble (Substract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points) Silt Clay (no adjustment)

Bank Materials Adjustment

Stratification Adjustment

Add 5-10 points, depending on Position of unstable layers in relation to bankfull slope

Very Low	Low	Moderate	High	Very High	Extreme
5 - 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	46 - 50

ADJECTIVE RATING and TOTAL SCORE

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Figure 52. Example Bank Erosion Hazard Index field calculation form. Adapted from Rosgen (2006), © Wildland Hydrology.

STREAMBANK ERODIBILITY VARIABLES

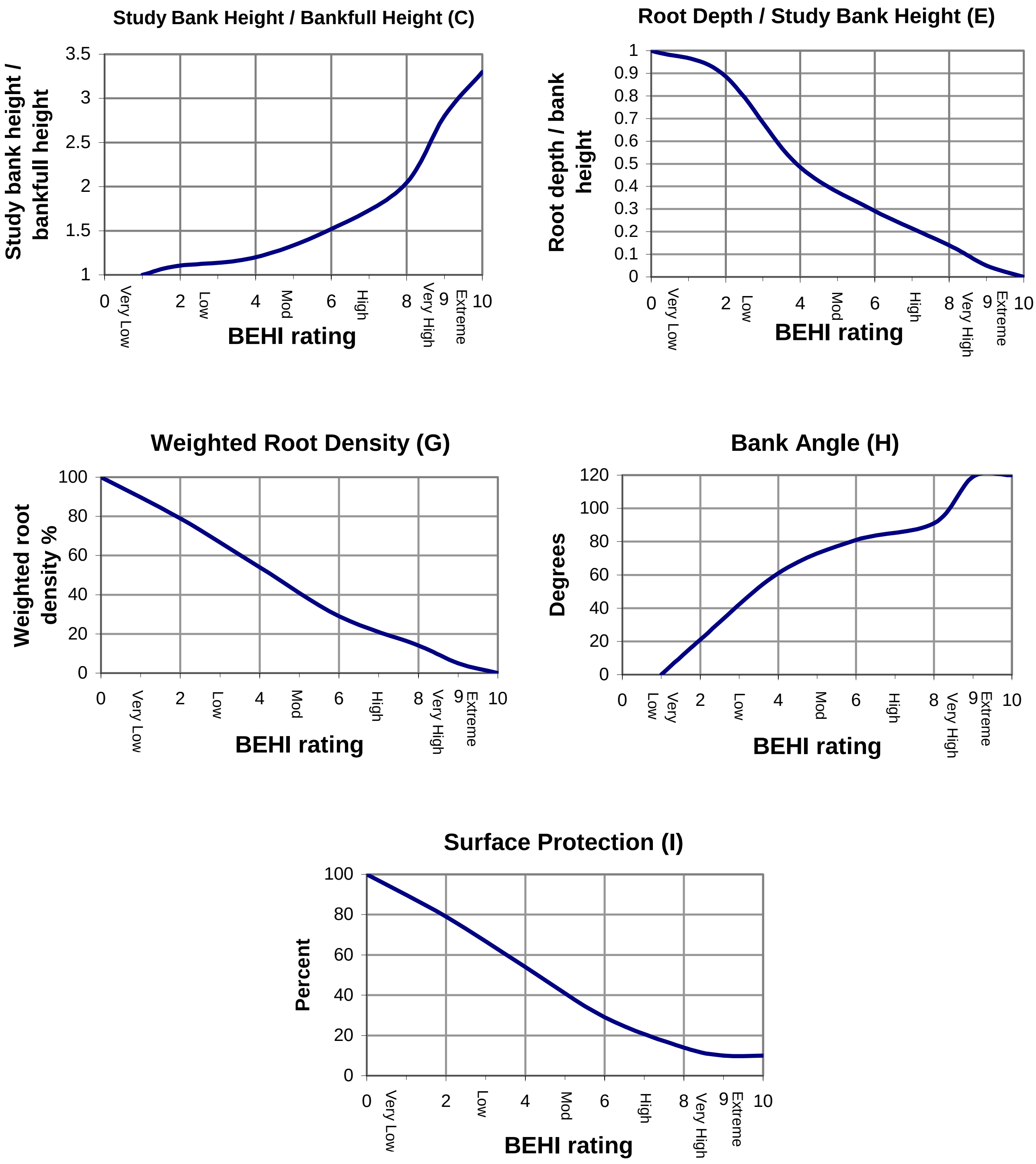


Figure 53. Streambank erodibility criteria used for the Bank Erosion Hazard Index (BEHI) rating. From Rosgen (2006), © Wildland Hydrology.

Near-Bank Stress (NBS) (From Rosgen 2006)

Annual streambank erosion rate prediction must include the Near-Bank Stress (NBS) assessment associated with energy distribution against streambanks. NBS determinations are broken into seven different options. The NBS variables used in the prediction methodology indicate potential disproportionate energy distribution in the near-bank region (the third of the channel cross-section associated with the bank being evaluated), which can accelerate streambank erosion. For example, in some instances, the presence of a gravel bar directs the velocity vectors directly into a bank and increases the local energy slope; erosion rates are then higher. *The user must select one or more of the methods that best represent the onsite conditions. The average of all methods is not recommended; in practice, the resultant highest near-bank stress consequence method is selected.* The Stream Survey: Near Bank Stress Form (Figure 52) is used to determine an NBS rating using one or more of the seven methods:

1. Channel pattern, transverse bar or split channel/central bar creating NBS/high velocity gradient;
2. Ratio of radius of curvature to bankfull width (R_c/W_{bkf});
3. Ratio of pool slope to average water surface slope (S_p/S);
4. Ratio of pool slope to riffle slope (S_p/S_{rif});
5. Ratio of near-bank maximum depth to bankfull mean depth (d_{nb}/d_{bkf});
6. Ratio of near-bank shear stress to bankfull shear stress ($\vartheta_{nb}/\vartheta_{bkf}$); and
7. Velocity profiles/isovels/velocity gradient.

The various levels (I-IV) in The Stream Survey: Near Bank Stress Form (Figure 52) are associated with the level of detail of the assessment (Level I being the most broad and rapid and Level IV being the most complex and time-consuming). *The levels are not necessarily synonymous with reliability of prediction.* NBS ratings and method used can be entered into RIVERMorph in the **BEHI** node. More detailed descriptions of each method can be found in pages 5-67 through 5-77 in Rosgen (2006).

As with BEHI, NBS should be calculated for the entire length of the longitudinal profile station. At each point the NBS rating changes, recalculate the NBS, record station length and draw the stationing on the same site map used to record BEHI (example map in Figure 57). Use The Stream Survey: Annual Streambank Erosion Estimates / Calculations Summary Form (Figure 58) to record combined BEHI and NBS ratings with station lengths, if data is not entered in the **BEHI** node of RIVERMorph. To estimate the bank erosion rates use the plots in Figure 54 and Figure 55 (from Rosgen 2006). Use the adjective NBS score with the appropriate BEHI line to determine the rate. Figure 54 (based on Colorado streams) applies to streams found in sedimentary and/or metamorphic geology. Figure 55 (based on Yellowstone streams) applies to streams found in areas associated with alpine glaciation and/or volcanism.

Upon entry of all BEHI and NBS ratings and station lengths, RIVERMorph can generate an estimate of stream bank erosion rates. Dominant BEHI/NBS ratings are also used for evaluating lateral stability (pg 5-78 Rosgen 2006).

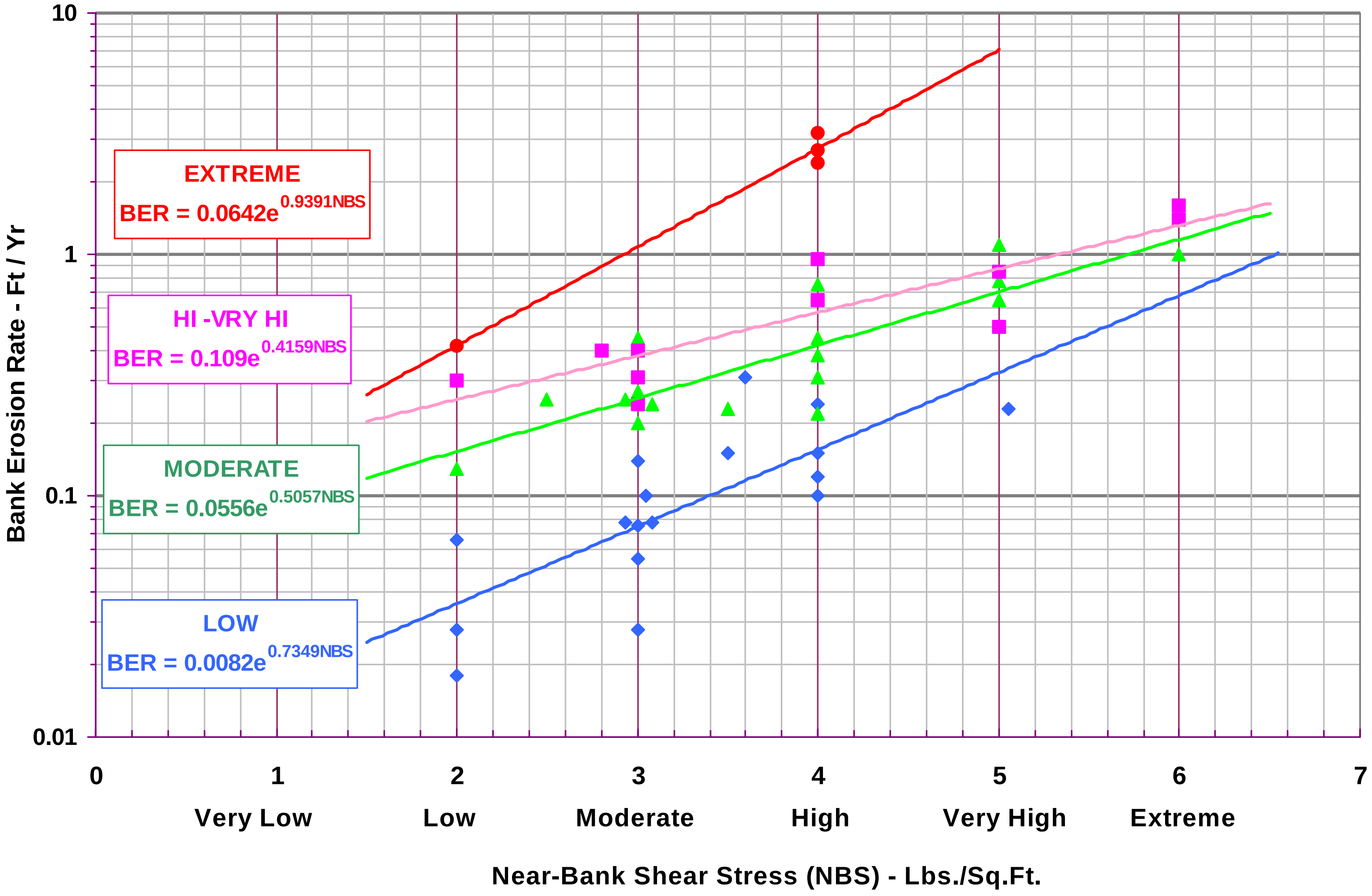


Figure 54. Prediction of Annual Streambank Erosion Rates using Colorado USDA Forest Service (1989) data for streams found in sedimentary and/or metamorphic geology. From Rosgen (2001a, 2006), © Wildland Hydrology.

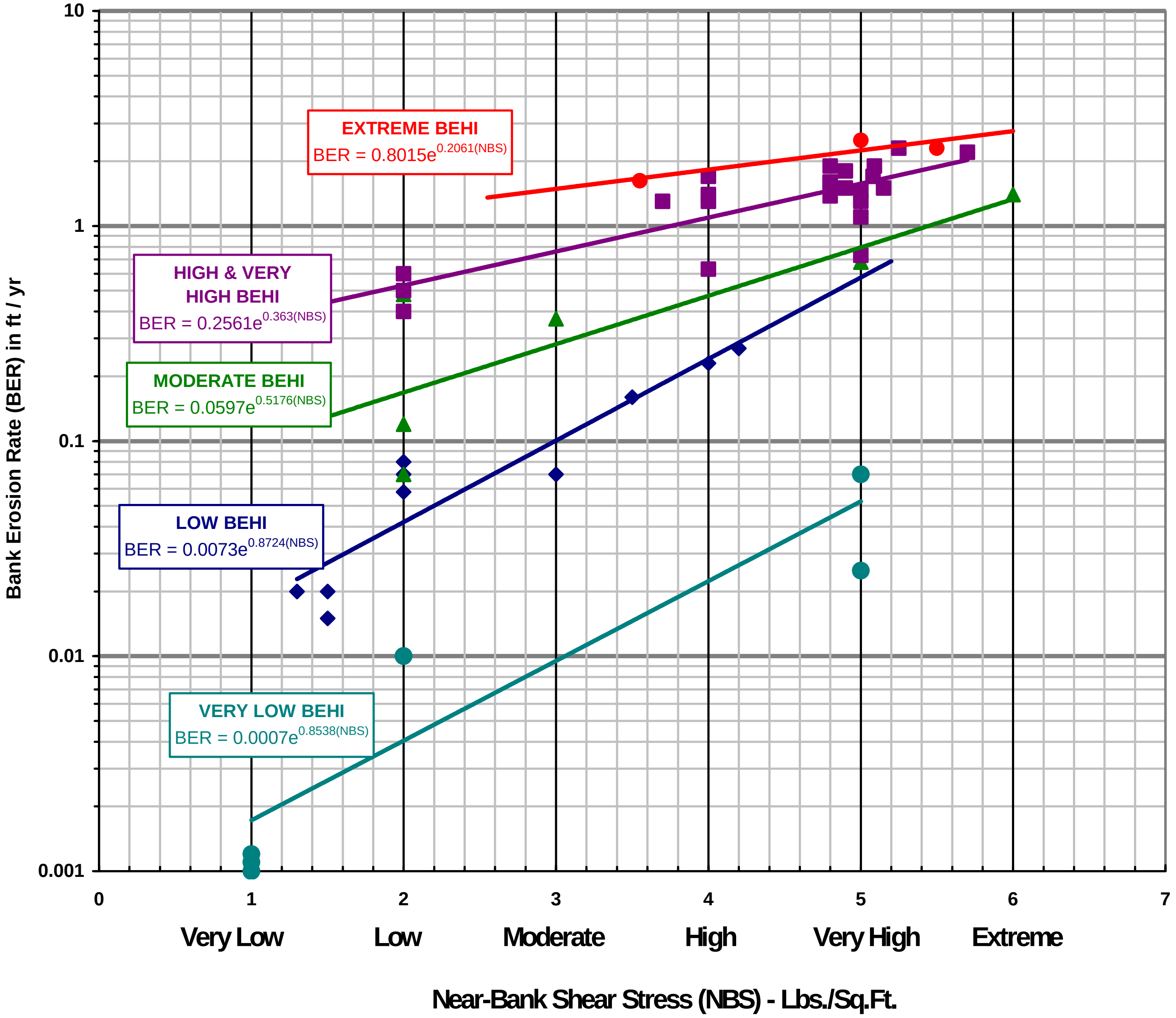
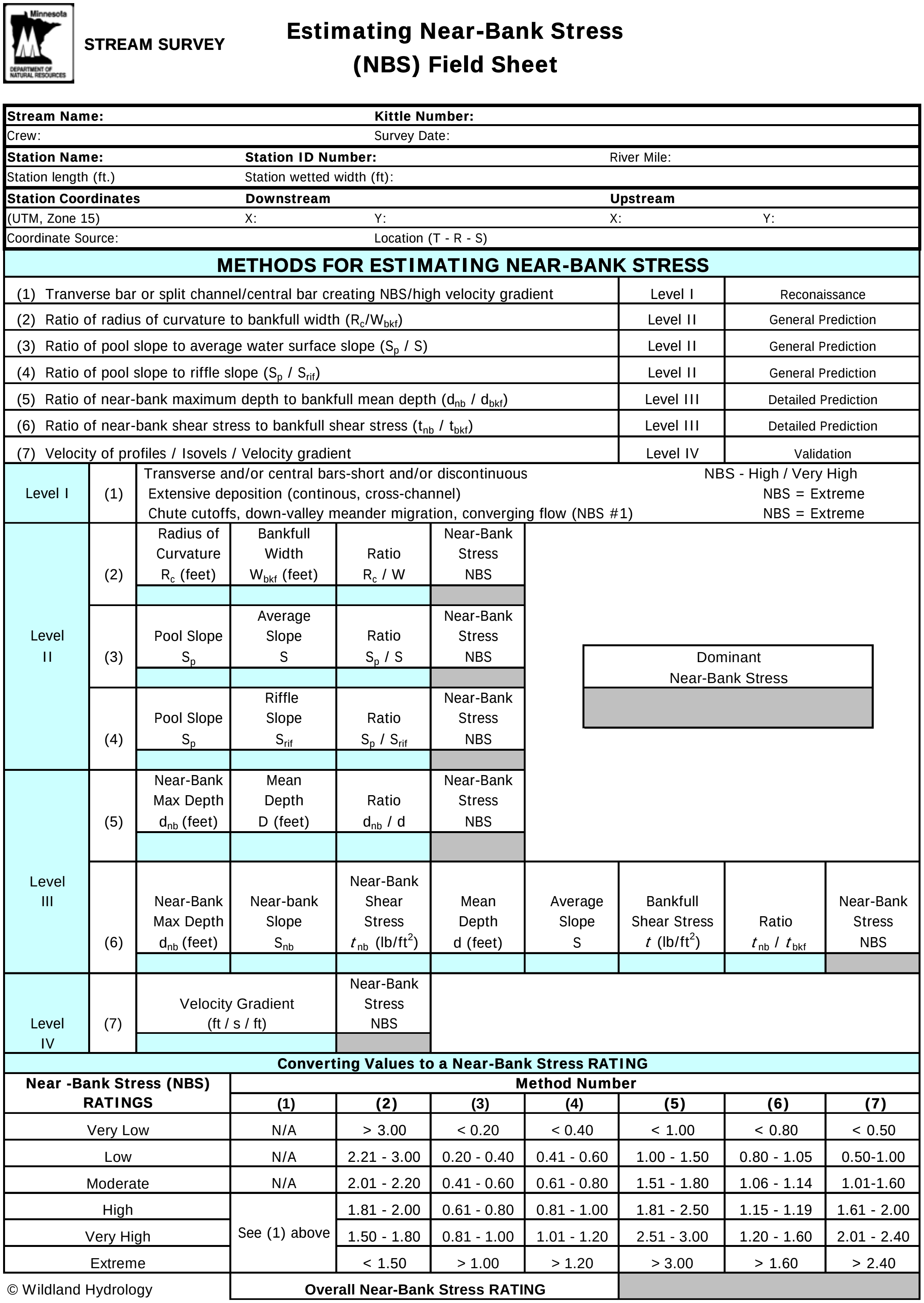


Figure 55. Prediction of Annual Streambank Erosion Rates using Yellowstone National Park (1989) data for streams found in alpine glaciation and/or volcanism areas. From Rosgen (2001a, 2006), © Wildland Hydrology.



STREAM SURVEY

Estimating Near-Bank Stress (NBS) Field Sheet

Stream Name:		**Kittle Number:**		
Crew:		Survey Date:		
Station Name:	**Station ID Number:**		River Mile:	
Station length (ft.)	Station wetted width (ft):			
Station Coordinates	**Downstream**		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:
Coordinate Source:		Location (T - R - S)		

METHODS FOR ESTIMATING NEAR-BANK STRESS

(1) Tranverse bar or split channel/central bar creating NBS/high velocity gradient	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c/W_{bkf})	Level II	General Prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)	Level II	General Prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})	Level II	General Prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})	Level III	Detailed Prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (t_{nb} / t_{bkf})	Level III	Detailed Prediction
(7) Velocity of profiles / Isovels / Velocity gradient	Level IV	Validation

Level I	(1)	Transverse and/or central bars-short and/or discontinuous	NBS - High / Very High
		Extensive deposition (continous, cross-channel)	NBS = Extreme
		Chute cutoffs, down-valley meander migration, converging flow (NBS #1)	NBS = Extreme

Level II	(2)	Radius of Curvature R_c (feet)	Bankfull Width W_{bkf} (feet)	Ratio R_c / W	Near-Bank Stress NBS
	(3)	Pool Slope S_p	Average Slope S	Ratio S_p / S	Near-Bank Stress NBS
	(4)	Pool Slope S_p	Riffle Slope S_{rif}	Ratio S_p / S_{rif}	Near-Bank Stress NBS

Dominant Near-Bank Stress

Level III	(5)	Near-Bank Max Depth d_{nb} (feet)	Mean Depth D (feet)	Ratio d_{nb} / d	Near-Bank Stress NBS

Level III	(6)	Near-Bank Max Depth d_{nb} (feet)	Near-bank Slope S_{nb}	Near-Bank Shear Stress t_{nb} (lb/ft^2)	Mean Depth d (feet)	Average Slope S	Bankfull Shear Stress t (lb/ft^2)	Ratio t_{nb} / t_{bkf}	Near-Bank Stress NBS

Level IV	(7)	Velocity Gradient (ft / s / ft)	Near-Bank Stress NBS

Converting Values to a Near-Bank Stress RATING

Near -Bank Stress (NBS) RATINGS	Method Number						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Very Low	N/A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N/A	2.21 - 3.00	0.20 - 0.40	0.41 - 0.60	1.00 - 1.50	0.80 - 1.05	0.50-1.00
Moderate	N/A	2.01 - 2.20	0.41 - 0.60	0.61 - 0.80	1.51 - 1.80	1.06 - 1.14	1.01-1.60
High	See (1) above	1.81 - 2.00	0.61 - 0.80	0.81 - 1.00	1.81 - 2.50	1.15 - 1.19	1.61 - 2.00
Very High		1.50 - 1.80	0.81 - 1.00	1.01 - 1.20	2.51 - 3.00	1.20 - 1.60	2.01 - 2.40
Extreme		< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress RATING

Figure 56. Example Near-Bank Stress (NBS) field form. Adapted from Rosgen (2006), © Wildland Hydrology.

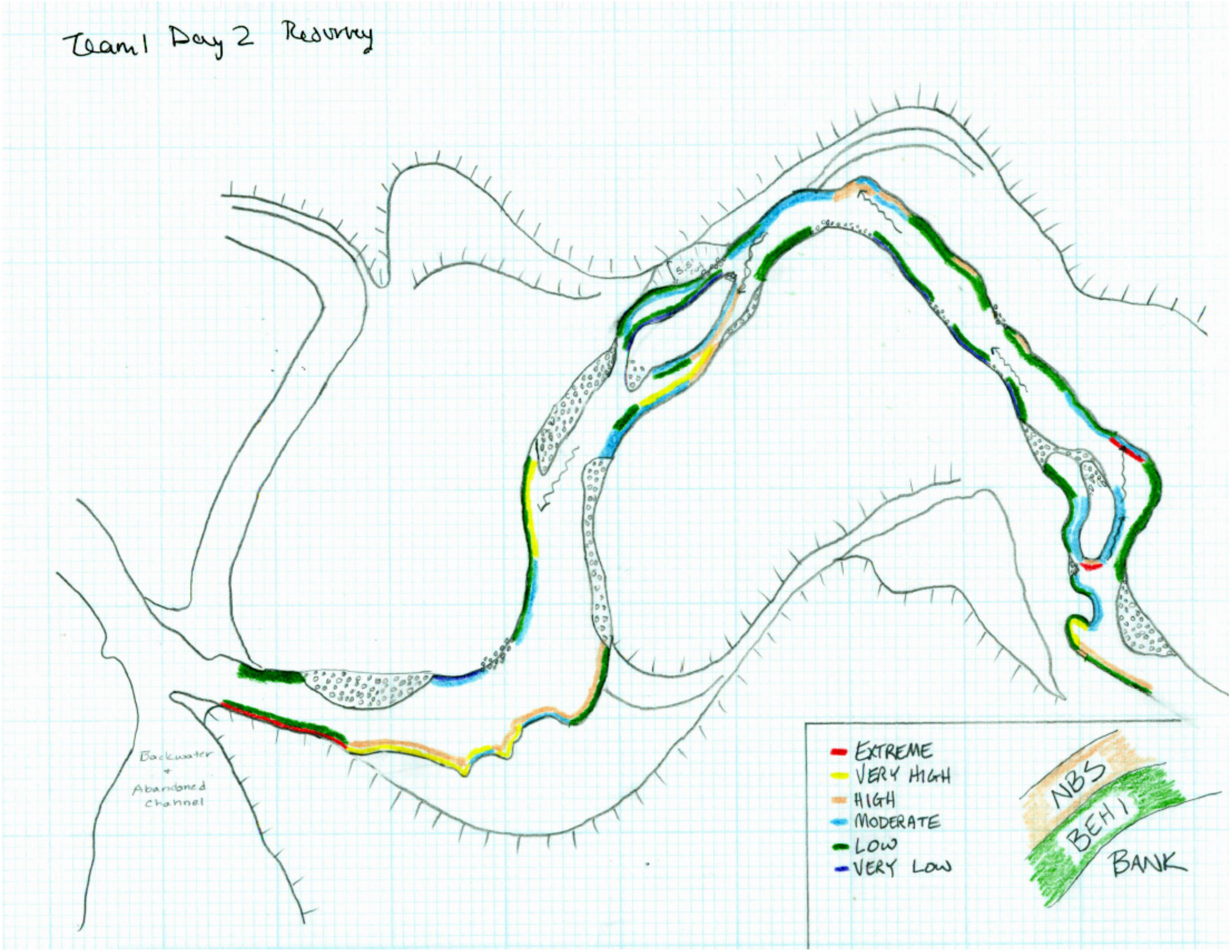


Figure 57. Example field sketch map showing Bank Erosion Hazard Index (BEHI) and Near-Bank-Stress (NBS) ratings.

STREAM SURVEY

Annual Streambank Erosion Estimates / Calculations Summary Form

Stream Name: **Kittle Number:**

Crew: Survey Date:

Station Name: **Station ID Number:** River Mile:

Station length (ft.) Station wetted width (ft):

Station Coordinates **Downstream** **Upstream**

(UTM, Zone 15) X: Y: X: Y:

Coordinate Source: Location (T - R - S)

Stream Type: Graph Used: Total BANK Length: Ft.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Item	Station Ft.	BEHI (adjective)	NEAR-BANK STRESS (adjective)	BANK EROSION RATE (ft./yr.)	LENGTH of Bank (ft.)	Bank HEIGHT (ft.)	EROSION Subtotal (4)x(5)x(6) (ft.^{3} / yr.)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							

Sum (Feet^3 / Year) EROSION Sub-Totals for each BEHI / NBS Combination	Total Erosion Feet^3 / Year =
Convert EROSION (Feet^3 / Year) to (Yards^3 / Year)	Total Erosion Yards^3 / Year =
C Convert EROSION (Yards^3 / Year) to (Tons / Year) (multiply Total EROSION (Yards^3 / Year) by 1.3)	Total Erosion Tons / Year =
Calculate EROSION per unit LENGTH of Channel. (Divide Total EROSION (Tons/Year) by Total Length of CHANNEL (ft.) surveyed)	Total Erosion Tons / Yr. / Ft. =

Figure 58. Example summary form for estimating annual streambank erosion. Adapted from Rosgen (2006, © Wildland Hydrology).

Stream Classification

Use the channel cross-section and longitudinal data and the Stream Survey: Morphological Description Summary Sheet (Figure 48) to summarize the data and assign a stream classification (Rosgen 1996) to the station. Summary sheets can also be generated in RIVERMorph. Be sure to complete the **Classification** node in RIVERMorph before proceeding.

Assessment of Stream Condition

The stream condition assessment will determine the stability of the stream channel, suggest sources of sediment, identify problem banks contributing excess sediment (if applicable), and indicate sample station condition or state. This assessment uses 10 additional variables to more fully describe stream condition beyond the fundamental morphological template. Methods and instructions below were taken (sometimes verbatim) from Rosgen (1996).

Step 1. Describe Channel Influencing Variables.

Procedure 1-1. Characterize riparian vegetation. Characterize the riparian vegetation as described in the riparian methods (see pages 134-137).

Procedure 1-2. Characterize flow regime. First, determine whether the stream flow is ephemeral, intermittent, or perennial. Using the Stream Survey: Stream Condition Assessment (1 of 2) form (Figure 59a), assign a category (E,S,I, or P) and specific category (1–6) to the flow regime.

Procedure 1-3. Classify stream size. Using the predetermined bankfull width to classify the stream’s size according to the categories listed on the Stream Survey: Stream Condition Assessment (1 of 2) form (Figure 59a).

Procedure 1-4. Classify depositional features. Classify depositional features (bars) by comparing them with those shown in Figures 6–10 and 6–11 in Rosgen (1996). Select the category that most closely matches your observations on the Stream Survey: Stream Condition Assessment (1 of 2) form (Figure 59a).

Procedure 1-5. Classify meander pattern. Using aerial photographs, select the meander pattern category on the Stream Survey: Stream Condition Assessment (1 of 2) form (Figure 59a) that most closely matches that of the stream in question. See Figures 6–12, 6–13, 6–14, and 6–15 in Rosgen (1996) for illustrations of the meander patterns.

Procedure 1-6. Classify stream channel debris/blockages. Use the Stream Survey: Stream Condition Assessment (2 of 2) form (Figure 59b) to characterize debris and blockages by size and extent. Surveyor can choose up to three categories: one from D1-D6, and/or one from D7-D9, and/or D10.

Procedure 1-7. Classify Bank Erosion Hazard Index (BEHI). Fill out the BEHI form as previously discussed (example in Figure 52).

Procedure 1-8. Evaluate channel stability. Evaluate channel stability using the rating system developed by Pfankuch (1975), included in this manual as Appendix 5. Adjustments, developed by Rosgen (1996), should be applied to Pfankuch scores during analysis in order to improve evaluations by incorporating the natural inherent value range differences among different stream types (see Table 5). The conversion table that is to be applied to the Pfankuch score is located on the backside of the channel stability evaluation form located in Appendix 1. Complete one representative channel stability evaluation (see example in Figure 60) at each sample station. Conduct the channel stability evaluation as follows [taken directly or paraphrased from Pfankuch (1975, Appendix 5) and Rosgen (1996)]:

Keep the following questions in mind while scoring each item listed in the evaluation:

2. What are the magnitudes of the hydraulic forces at work to detach and transport the various organic and inorganic bank and channel components?

3. How resistant are these components to the recent stream flow forces exerted on them?

4. What is the capacity of the stream to adjust and recover from potential changes in flow volume and/or increases in sediment production?

Using the Pfankuch Form Codes scoring sheet (Table 6) assign the appropriate score to each factor listed on the Stream Survey: Channel Stability Evaluation form (Figure 60). RIVERMorph has a **Pfankuck** node in which scores can be entered. Click on the question mark on the left of the screen for a brief description of each variable. Assign scores within three distinct zones: the upper bank, the lower bank, and the bottom, defined as follows:

Upper bank – The portion of the channel lying within the flood plain between the flood-prone stage elevation and the bankfull stage.

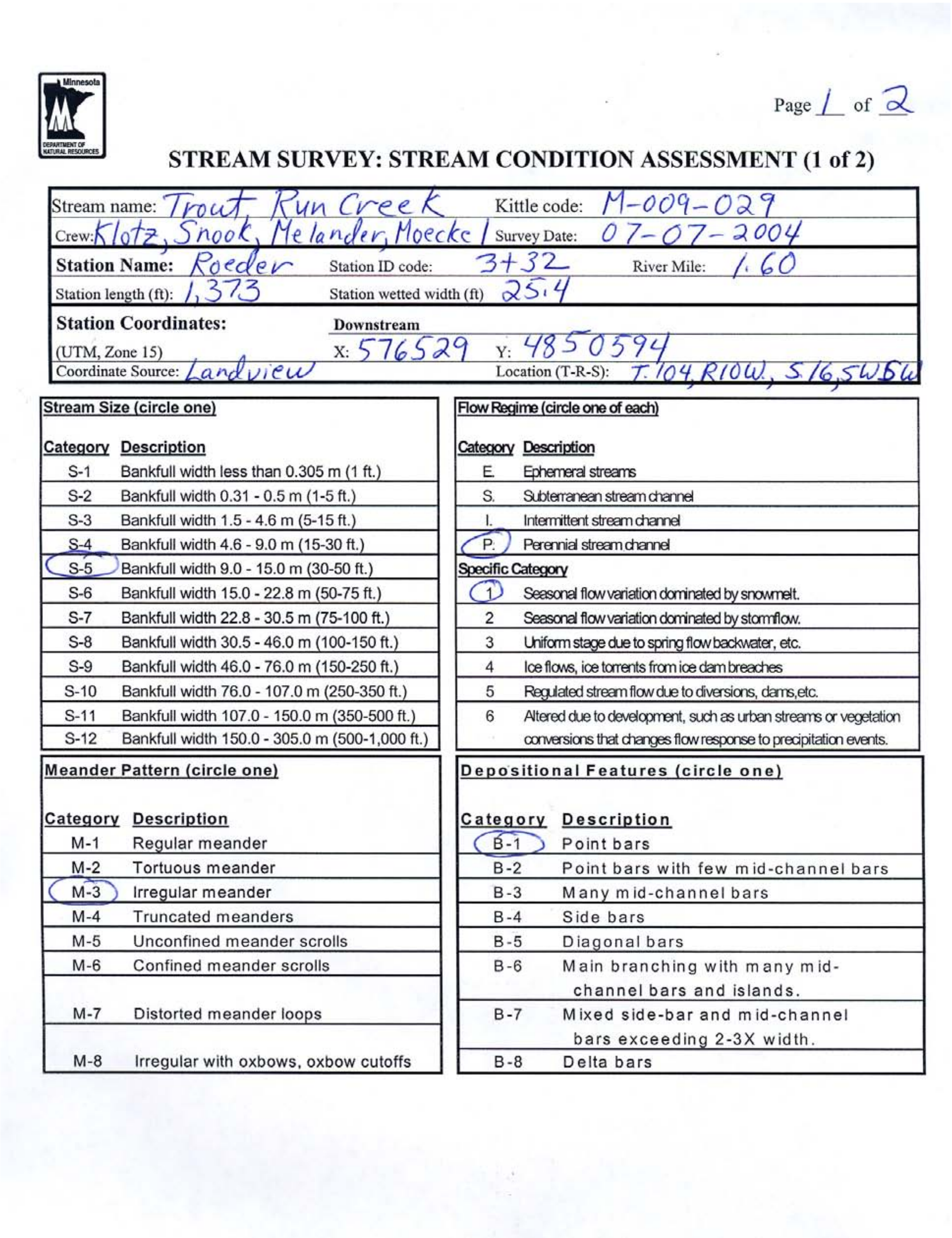
Lower bank–The portion of the channel lying between the bankfull stage and the water's edge during summer low flows.

Bottom – The portion of the channel that is totally submerged during summer low flows.

Further explanation of criteria can be found in Pfankuch (1975). Avoid keying on a single indicator, or small group of indicators, when assigning scores. If you believe the appropriate score falls between two values, assign an intermediate score.

Tally the scores to arrive at a total score for the sample station. Using the stream type, as determined on the "Morphological Description Summary Sheet," stream classification (Figure 48; page 114), and Table 5, convert the total score to a sample site condition of "good", "fair," or "poor."

Step 2. Summarize the data. Use the Stream Condition Assessment (1 of 2) form and Stream Condition Assessment (2 of 2) form to document and summarize the conclusions regarding stream condition arrived at through the stream channel assessment.



Page 1 of 2

STREAM SURVEY: STREAM CONDITION ASSESSMENT (1 of 2)

Stream name: Trout Run Creek Kittle code: M-009-029
Crew: Klotz, Snook, Melander, Moeckel Survey Date: 07-07-2004
Station Name: Roeder Station ID code: 3+32 River Mile: 1.60
Station length (ft): 1,373 Station wetted width (ft) 25.4
Station Coordinates: **Downstream**
(UTM, Zone 15) X: 576529 Y: 4850594
Coordinate Source: Landview Location (T-R-S): T.104, R10W, S16, SWSW

Stream Size (circle one)

Category	Description
S-1	Bankfull width less than 0.305 m (1 ft.)
S-2	Bankfull width 0.31 - 0.5 m (1-5 ft.)
S-3	Bankfull width 1.5 - 4.6 m (5-15 ft.)
S-4	Bankfull width 4.6 - 9.0 m (15-30 ft.)
[✓ S-5]	Bankfull width 9.0 - 15.0 m (30-50 ft.)
S-6	Bankfull width 15.0 - 22.8 m (50-75 ft.)
S-7	Bankfull width 22.8 - 30.5 m (75-100 ft.)
S-8	Bankfull width 30.5 - 46.0 m (100-150 ft.)
S-9	Bankfull width 46.0 - 76.0 m (150-250 ft.)
S-10	Bankfull width 76.0 - 107.0 m (250-350 ft.)
S-11	Bankfull width 107.0 - 150.0 m (350-500 ft.)
S-12	Bankfull width 150.0 - 305.0 m (500-1,000 ft.)

Flow Regime (circle one of each)

Category	Description
E.	Ephemeral streams
S.	Subterranean stream channel
I.	Intermittent stream channel
[✓ P.]	Perennial stream channel
Specific Category	
[✓ 1]	Seasonal flow variation dominated by snowmelt.
2	Seasonal flow variation dominated by stormflow.
3	Uniform stage due to spring flow backwater, etc.
4	Ice flows, ice torrents from ice dam breaches
5	Regulated stream flow due to diversions, dams,etc.
6	Altered due to development, such as urban streams or vegetation conversions that changes flow response to precipitation events.

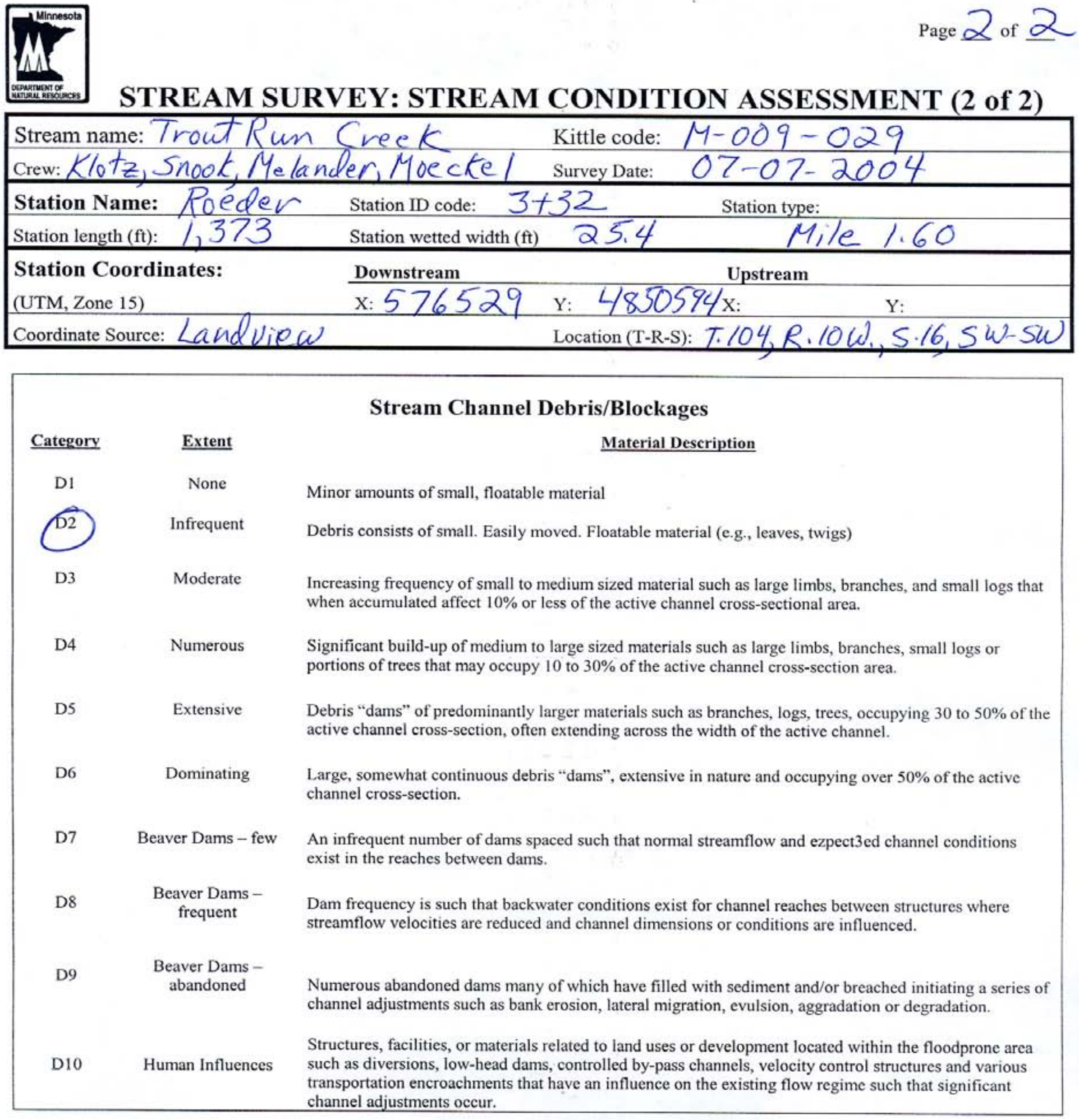
Meander Pattern (circle one)

Category	Description
M-1	Regular meander
M-2	Tortuous meander
[✓ M-3]	Irregular meander
M-4	Truncated meanders
M-5	Unconfined meander scrolls
M-6	Confined meander scrolls
M-7	Distorted meander loops
M-8	Irregular with oxbows, oxbow cutoffs

Depositional Features (circle one)

Category	Description
[✓ B-1]	Point bars
B-2	Point bars with few mid-channel bars
B-3	Many mid-channel bars
B-4	Side bars
B-5	Diagonal bars
B-6	Main branching with many mid-channel bars and islands.
B-7	Mixed side-bar and mid-channel bars exceeding 2-3X width.
B-8	Delta bars

Figure 59a. Example Stream Condition Assessment field form, page 1. Adapted from Rosgen (1996, © Wildland Hydrology).



Page 2 of 2

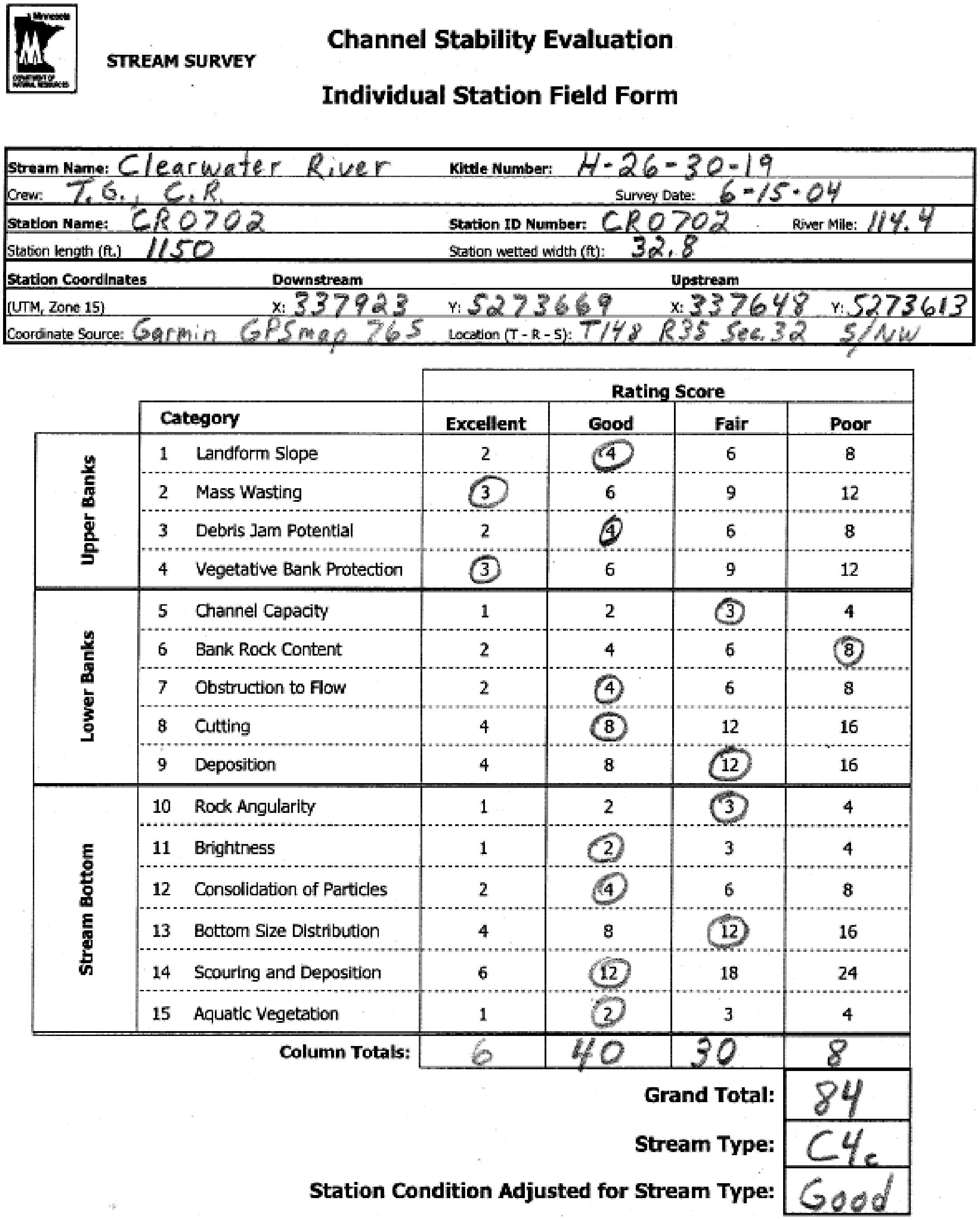
STREAM SURVEY: STREAM CONDITION ASSESSMENT (2 of 2)

Stream name: Trout Run Creek
Kittle code: M-009-029
Crew: Klotz, Snook, Melander, Moeckel
Survey Date: 07-07-2004
Station Name: Roeder
Station ID code: 3+32
Station type:
Station length (ft): 1,373
Station wetted width (ft) 25.4
Mile 1.60
Station Coordinates: (UTM, Zone 15)
Downstream X: 576529 Y: 4850594
Upstream X: Y:
Coordinate Source: Landview
Location (T-R-S): T.104, R.10W., S.16, SW-SW

Stream Channel Debris/Blockages

Category	**Extent**	**Material Description**
D1	None	Minor amounts of small, floatable material
[✓ D2]	Infrequent	Debris consists of small. Easily moved. Floatable material (e.g., leaves, twigs)
D3	Moderate	Increasing frequency of small to medium sized material such as large limbs, branches, and small logs that when accumulated affect 10% or less of the active channel cross-sectional area.
D4	Numerous	Significant build-up of medium to large sized materials such as large limbs, branches, small logs or portions of trees that may occupy 10 to 30% of the active channel cross-section area.
D5	Extensive	Debris "dams" of predominantly larger materials such as branches, logs, trees, occupying 30 to 50% of the active channel cross-section, often extending across the width of the active channel.
D6	Dominating	Large, somewhat continuous debris "dams", extensive in nature and occupying over 50% of the active channel cross-section.
D7	Beaver Dams – few	An infrequent number of dams spaced such that normal streamflow and ezpect3ed channel conditions exist in the reaches between dams.
D8	Beaver Dams – frequent	Dam frequency is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.
D9	Beaver Dams – abandoned	Numerous abandoned dams many of which have filled with sediment and/or breached initiating a series of channel adjustments such as bank erosion, lateral migration, evulsion, aggradation or degradation.
D10	Human Influences	Structures, facilities, or materials related to land uses or development located within the floodprone area such as diversions, low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime such that significant channel adjustments occur.

Figure 59b. Example Stream Condition Assessment field form, page 2. Adapted from Rosgen (2006, © Wildland Hydrology).



STREAM SURVEY

Channel Stability Evaluation

Individual Station Field Form

Stream Name: Clearwater River **Kittle Number:** H-26-30-19
Crew: T.G., C.R. Survey Date: 6-15-04
Station Name: CR0702 **Station ID Number:** CR0702 River Mile: 114.4
Station length (ft.) 1150 Station wetted width (ft): 32.8
Station Coordinates **Downstream** **Upstream**
(UTM, Zone 15) X: 337923 Y: 5273669 X: 337648 Y: 5273613
Coordinate Source: Garmin GPSmap 76S Location (T - R - S): T148 R35 Sec.32 S/NW

			Rating Score			
		Category	**Excellent**	**Good**	**Fair**	**Poor**
Upper Banks	1	Landform Slope	2	[✓ 4]	6	8
	2	Mass Wasting	[✓ 3]	6	9	12
	3	Debris Jam Potential	2	[✓ 4]	6	8
	4	Vegetative Bank Protection	[✓ 3]	6	9	12
Lower Banks	5	Channel Capacity	1	2	[✓ 3]	4
	6	Bank Rock Content	2	4	6	[✓ 8]
	7	Obstruction to Flow	2	[✓ 4]	6	8
	8	Cutting	4	[✓ 8]	12	16
	9	Deposition	4	8	[✓ 12]	16
Stream Bottom	10	Rock Angularity	1	2	[✓ 3]	4
	11	Brightness	1	[✓ 2]	3	4
	12	Consolidation of Particles	2	[✓ 4]	6	8
	13	Bottom Size Distribution	4	8	[✓ 12]	16
	14	Scouring and Deposition	6	[✓ 12]	18	24
	15	Aquatic Vegetation	1	[✓ 2]	3	4
		Column Totals:	6	40	30	8

Grand Total: 84
Stream Type: C4c
Station Condition Adjusted for Stream Type: Good

Figure 60. Example Channel Stability Evaluation field form. Adapted from Rosgen (2006, © Wildland Hydrology).

Table 5. Conversion of channel stability scores to sample site condition by stream type (from Rosgen 1996, © Wildland Hydrology).

Stream Type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
Good	38–43	38–43	54–90	60–95	50–80	38–45	38–45	40–60	40–64	40–64	48–68	40–60
Fair	44–47	44–47	91–129	96–132	96–142	81–110	46–58	46–58	61–78	65–84	69–88	61–78
Poor	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+

Stream Type	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**
Good	38–50	38–50	60–85	70–90	70–90	60–85	85–107	85–107	85–107	67–98
Fair	51–61	51–61	86–105	91–110	91–110	86–105	108–132	108–132	108–132	99–125
Poor	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream Type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**
Good	40–63	40–63	40–63	40–63	40–63	50–75	50–75	40–63
Fair	64–86	64–86	64–86	64–86	64–86	76–96	76–96	64–86
Poor	87+	87+	87+	87+	87+	97+	97+	87+

Stream Type	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
Good	60–85	60–85	85–110	85–110	90–115	80–95	40–60	40–60	85–107	85–107	90–112	85–107
Fair	86–105	86–105	111–125	111–125	116–130	96–110	61–78	61–78	108–120	108–120	113–125	108–120
Poor	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Table 6. Pfankuch Form Codes scoring sheet for adjusting channel stability scores (from Rosgen 2006 as modified from Pfankuch 1975).

Stream: **Location:** **Valley Type:** **Observers:** **Date:**

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species & less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water, too.	1	Common. Algae forms in low velocity and pool areas. Moss here, too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =		**Good total =**		**Fair total =**		**Poor total =**	

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+
Stream type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**		
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107		
Fair (Mod. unstable)	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120		
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+		

*Rating should be adjusted to potential stream type, not existing.

Grand total =

Existing stream type =

***Potential stream type =**

Modified channel stability rating =

Step 3. Document With Photographs. Take at least five photos (digital preferred) per sample station: facing upstream from the downstream station boundary; facing downstream from the upstream station boundary; one facing upstream and one facing downstream from the surveyed cross section; and one facing across the surveyed cross section. Additional photo documentation of areas and features of interest within and/or immediately adjacent to the sample station is encouraged. Document and reference photographs using the Stream Survey: Photo Documentation Sheet (Figure 61 and Figure 62).

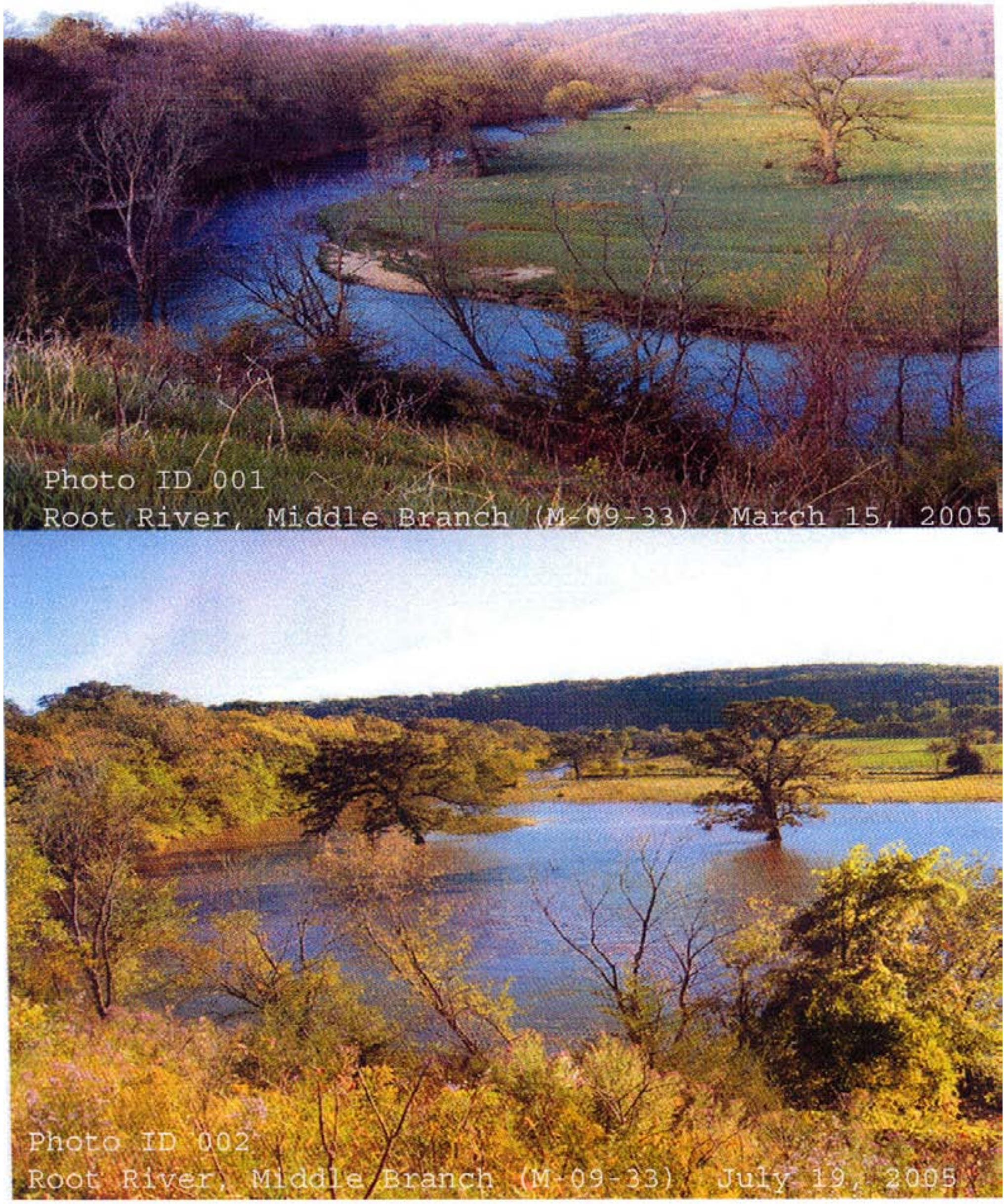
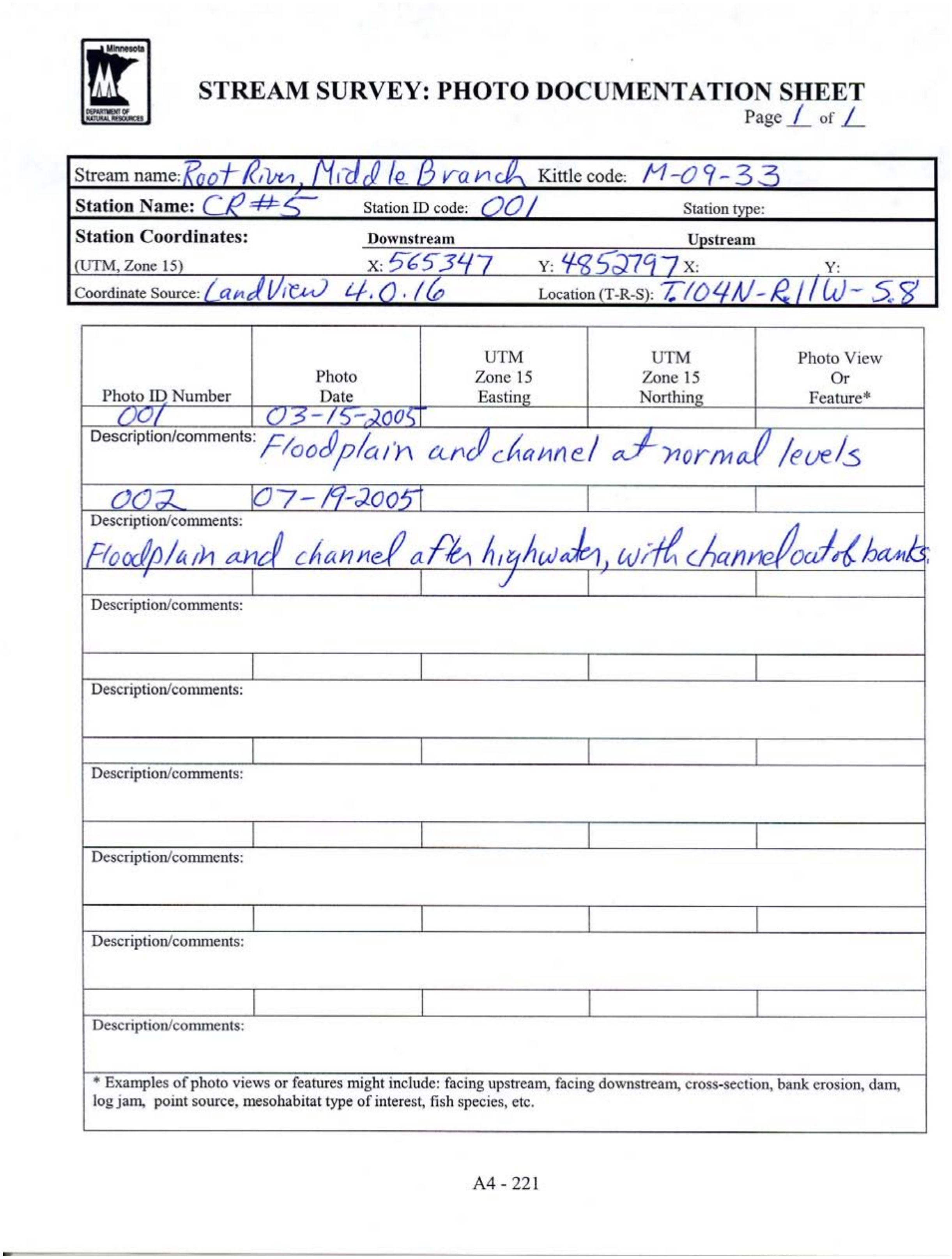


Figure 61. Example photo documentation of flood event on Middle Branch Root River, summer 2005.



Minnesota DEPARTMENT OF NATURAL RESOURCES

STREAM SURVEY: PHOTO DOCUMENTATION SHEET

Page 1 of 1

Stream name: Root River, Middle Branch Kittle code: M-09-33

Station Name: CR #5 Station ID code: 001 Station type:

Station Coordinates: **Downstream** **Upstream**

(UTM, Zone 15) X: 565347 Y: 4852797 X: Y:

Coordinate Source: LandView 4.0.16 Location (T-R-S): T.104N-R.11W-S.8

Photo ID Number	Photo Date	UTM Zone 15 Easting	UTM Zone 15 Northing	Photo View Or Feature*
001	03-15-2005			
Description/comments: Floodplain and channel at normal levels				
002	07-19-2005			
Description/comments: Floodplain and channel after highwater, with channel out of banks.				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				

* Examples of photo views or features might include: facing upstream, facing downstream, cross-section, bank erosion, dam, log jam, point source, mesohabitat type of interest, fish species, etc.

A4 - 221

Figure 62. Example photo documentation field sheet (see photos in Figure 61).

Additional Required Data

The variables below are required to maintain compatibility with previous stream survey data sets used to classify streams (Thorn and Anderson 1999) and characterize cold-water and warm-water stream habitat (Anderson 1983; Thorn 1988a, 1988b, 1990, 1992; Thorn and Anderson 1993, 2001; Thorn et al. 1997).

Wetted Width. Measure the wetted width once across each habitat type (pool, riffle, run, glide, or cascade) in the station and calculate mean station width with weighted percentages as described in MNDNR (1978). In addition to providing general information about the stream, this information can be used for maintaining an existing database if desired and also for assigning stream classification following Thorn and Anderson (1999).

Mean Depth. Calculate the mean depth following MNDNR (1978). Make two depth measurements of each cross section where the wetted width was measured, halfway between the deepest point along the cross section (the thalweg) and the shoreline. Calculate mean depth for the station using a weighted average following MNDNR (1978). In addition to providing general information about the stream, this information can be used for maintaining an existing database if desired and also for assigning stream classification following Thorn and Anderson (1999).

Bank Erosion. Visually characterize bank erosion for the entire station as light, moderate, or severe following MNDNR (1978). In addition to providing general information about the stream, this information can be used for maintaining an existing database if desired and also for assigning stream classification following Thorn and Anderson (1999).

Ecological Classification. Classify the stream as either cold water = 1 or warm water (i.e., noncold water) = 2. This variable will be used for stream classification following Thorn and Anderson (1999).

Shade. Following MNDNR (1978), assign a rating of light (0–25%), moderate (26–75%), or heavy (>75%).

Embeddedness. Embeddedness is the degree to which coarse gravel and rubble/cobble (rocks 16–260 mm diameter) are surrounded by or covered with sand, silt, and other fine substrates <2 mm in diameter (Simonson et al. 1994). Visually estimate (to the nearest 25% interval) the average amount of embeddedness within a 0.3 m x 0.3 m quadrate on the stream bottom centered on each point located at the top of each riffle on the longitudinal profile.

Water Quality

Water Quality Checklist

1. ____ Air temperature (page 65)
2. ____ Water temperature (pages 65-67)
3. ____ pH (page 67)
4. ____ Dissolved oxygen (pages 67-68)
5. ____ Conductivity (page 68)
6. ____ Transparency (page 68)
7. ____ Longitudinal temperature profile (pages 126-127)
8. ____ Laboratory water quality parameters (pages 127–128)

Water Quality Methods

Follow protocol listed under water quality methods in the initial survey portion of this manual for parameters: air temperature, water temperature, point sampling, continuous monitoring, pH, dissolved oxygen, conductivity and transparency.

Water Sampling Instructions

The Minnesota Department of Agriculture (MDA) provides analytical laboratory services for the DNR. It is important that you follow these basic protocols for collecting, handling, and transporting water samples.

Before Sampling. Follow the established sampling schedule whenever possible. If extenuating circumstances require your sampling schedule to be changed, please notify the sampling coordinator so he or she can coordinate the changes with the laboratory.

Bottles, sample labels, and submittal forms will be delivered to the project leader at least one week before sampling is scheduled to begin. Please review your sampling materials when you receive them to confirm they are sufficient for your project needs.

During and After Sampling. Collect samples following the guidelines of the Section of Fisheries lake or stream survey manuals. Special assessment projects may have their own unique set of sampling guidelines. In most cases, one two–liter brown high-density polyethylene bottle will be used per site. Collect samples as early in the week as practical.

Clearly label each sample bottle by location using the labels provided or other labels of choice. Recommended label types are adhesive tags or tape.

The old card-type tags attached by rubber bands are not recommended because they have a tendency to fall off, particularly if they get wet.

Use a single-copy sample submittal form for each set of samples. Make sure the sample site identifications on the form match exactly those on the bottle labels. Place the sample submittal form in a zip-lock bag and tape it to the underside of the cooler lid before shipping.

Carefully pack samples on ice in coolers and transport them or ship them by common carrier such as Speedy or UPS to the laboratory as soon as practical. If there will be a delay in shipping, keep samples on ice or refrigerated. The preferred method for keeping samples chilled during shipment is to use ice cubes in sealed bags that tend to conform to the cooler contents. Artificial ice packs are less efficient in keeping samples chilled, but may be used if real ice is not readily available. Indicate clearly on the cooler the return address so cooler and bottles may be returned to you. Ship samples to:

Minnesota Department of Agriculture
Laboratory Services/Sample Receiving
601 Robert Street North
St. Paul, MN 55155-2331
Tel 651-201-6669

Address all questions regarding your samples to:

Sampling Coordinator
MNDNR Division of Ecological Services
500 Lafayette Rd., Box 25
St. Paul, MN 55155-4025
Tel 651-259-5078
Fax 651-296-1811

Continuous Temperature Monitoring. Use of continuously recording water temperature loggers is required for full stream surveys and recommended on initial stream surveys. Refer to the methods for continuous recording temperature monitors in the initial survey section on pages 66-67. Use the Continuous Water Temperature Recording Field Sheet to document thermometer station data (blank form in Appendix 1).

Longitudinal Temperature Profile. When obtaining comparable water temperature data for an entire stream, a series of riffle temperatures must be taken in a short period of time at easily accessible points along the stream.

Take temperatures only in July and August under the following conditions:

1. Stream flow is nearly normal with no precipitation during the previous 48 hours.
2. The weather is clear.
3. Air temperature is at least 24°C.
4. Stream temperature is at its daily maximum, as previously determined by taking a series of readings at one station throughout the day. Maximum daily stream temperatures usually occur in late afternoon.

A temperature profile may also be obtained by placing recording thermometers in riffles at intervals along the stream and recording water temperatures and air temperatures for three to five days (example profile in Figure 63). This eliminates the need to collect temperature data in a short period of time and also provides information on temperature fluctuation. If substantial temperature differences are noted between two observation points, more observations are necessary to determine where the change occurs.

Record information about the temperature loggers or water temperatures, including whether hand thermometers are used. Record the date, location (including GPS coordinates), air temperature, time of day, water stage, and cloud cover on the Longitudinal Water Temperature Profile form (Figure 64). An example output from recording thermometer appears in Figure 65.

A temperature profile determines the portion of a stream suitable for various game fish species. The upper temperature limit for long-term survival of brook trout is approximately 20°C and brown trout 24°C. Walleye, northern pike, and smallmouth bass prefer temperatures no greater than 21°C, but will survive at much higher temperatures. Channel catfish and some nongame fish species prosper at temperatures above 27°C.

Laboratory Water Quality Parameters

The MDA will analyze total alkalinity, total dissolved solids, total phosphorus, and chloride from water samples collected by the following procedure. (As part of statewide data requests, the laboratory will continue measuring pH, conductivity, and chlorophyll a on this water sample.) The MDA will set up sample schedules for all DNR Fisheries areas completing full stream surveys.

Collect water samples during periods of normal or near-normal flow. Use clean two-liter, opaque containers, rinsed at least once with water from the point of collection. One sample per reach is recommended with a minimum of two samples per stream. Additional samples may be needed where pollution is suspected.

Collect the water sample as follows:

1. Label (with indelible ink on the sample tags) the bottle with the stream name, kittle number, station number, air temperature, water temperature, date, and time.
2. Just before sampling, remove the cap and rinse the bottle three times with water from the point of collection. Avoid touching the inside of the bottle or the cap.
3. In general, sample away from the stream bank in the main current. Never sample stagnant water. The outside curve of the stream is often a good place to sample, since the main current tends to hug this bank.
4. In shallow stretches, carefully wade into the center current to collect the sample. Try to disturb as little bottom sediment as possible. In any case, be careful not to collect water that has sediment from bottom disturbance. Stand facing upstream. Collect the water sample on your upstream side, in front of you. You may also tape your bottle to an extension pole to sample from deeper water.
5. Use a boat for deep sites. Try to maneuver the boat into the center of the main current to collect the water sample. Carefully reach over the side and collect the water sample on the upstream side of the boat.
6. Hold the bottle near its base and plunge it (opening downward) below the water surface. If you are using an extension pole, remove the cap, turn the bottle upside down, and plunge it into the water, facing upstream. Collect a water sample 20 to 30 centimeters beneath the surface or midway between the surface and the bottom if the stream reach is shallow.
7. Turn the bottle underwater into the current and away from you. In slow-moving stream reaches, push the bottle underneath the surface and away from you in an upstream direction.
8. Recap the bottle carefully, remembering not to touch the inside.
9. Fill in the bottle number and/or site information on the Water Quality Laboratory Analysis Form (Figure 66). This is important because it tells the lab coordinator which bottle goes with which site.
10. Carefully pack samples on ice in coolers and transport or ship by common carrier such as Speedy or UPS to the laboratory within 48 hours of collection and preferably on the day of collection. If there is a delay in shipping, keep the samples on ice or refrigerated until they can be transported to the lab. The preferred method of keeping samples chilled is to use ice cubes in sealed bags that tend to conform to the cooler contents. Artificial ice packs are less efficient in keeping samples chilled, but may be use if real ice is not readily available.

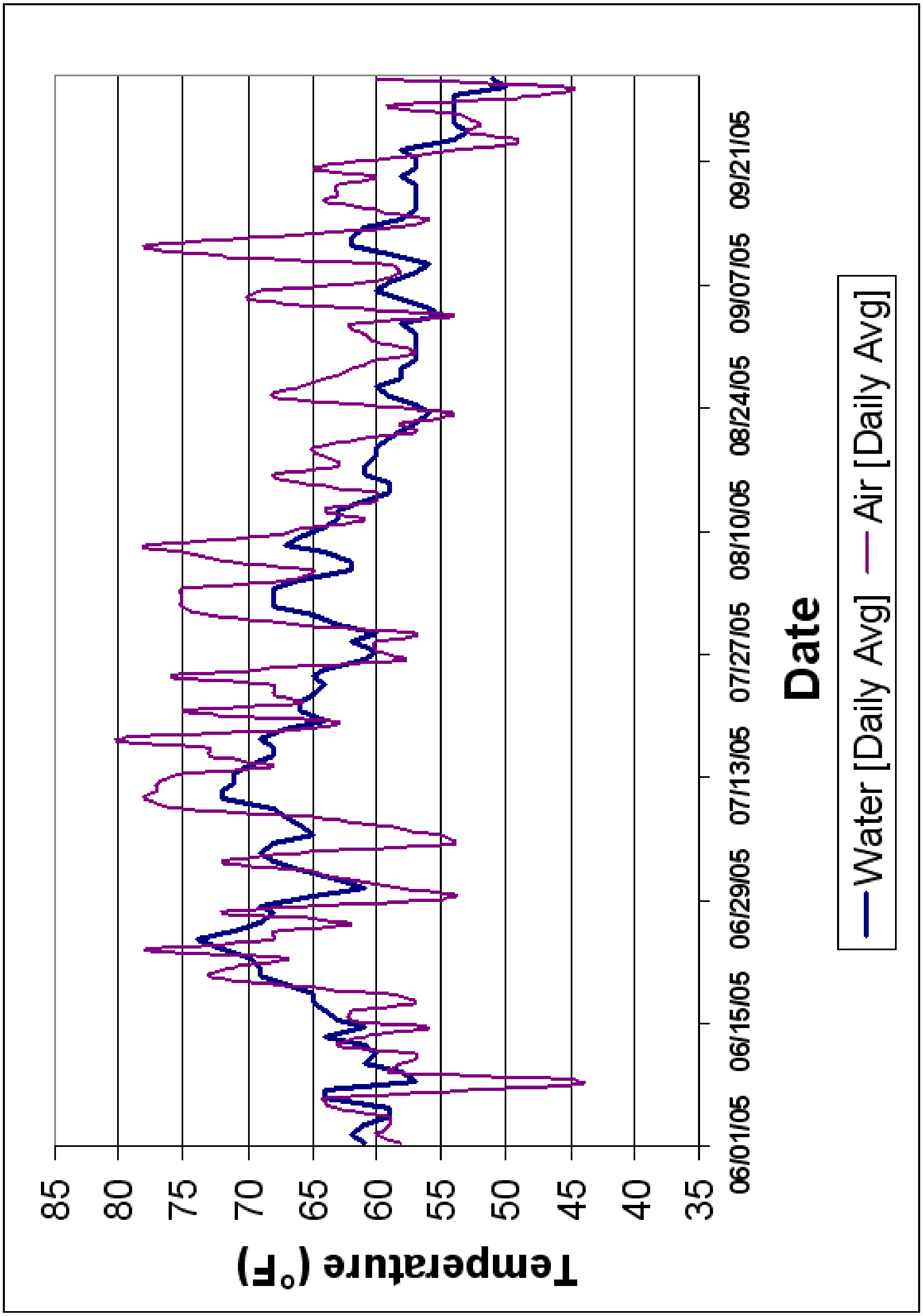
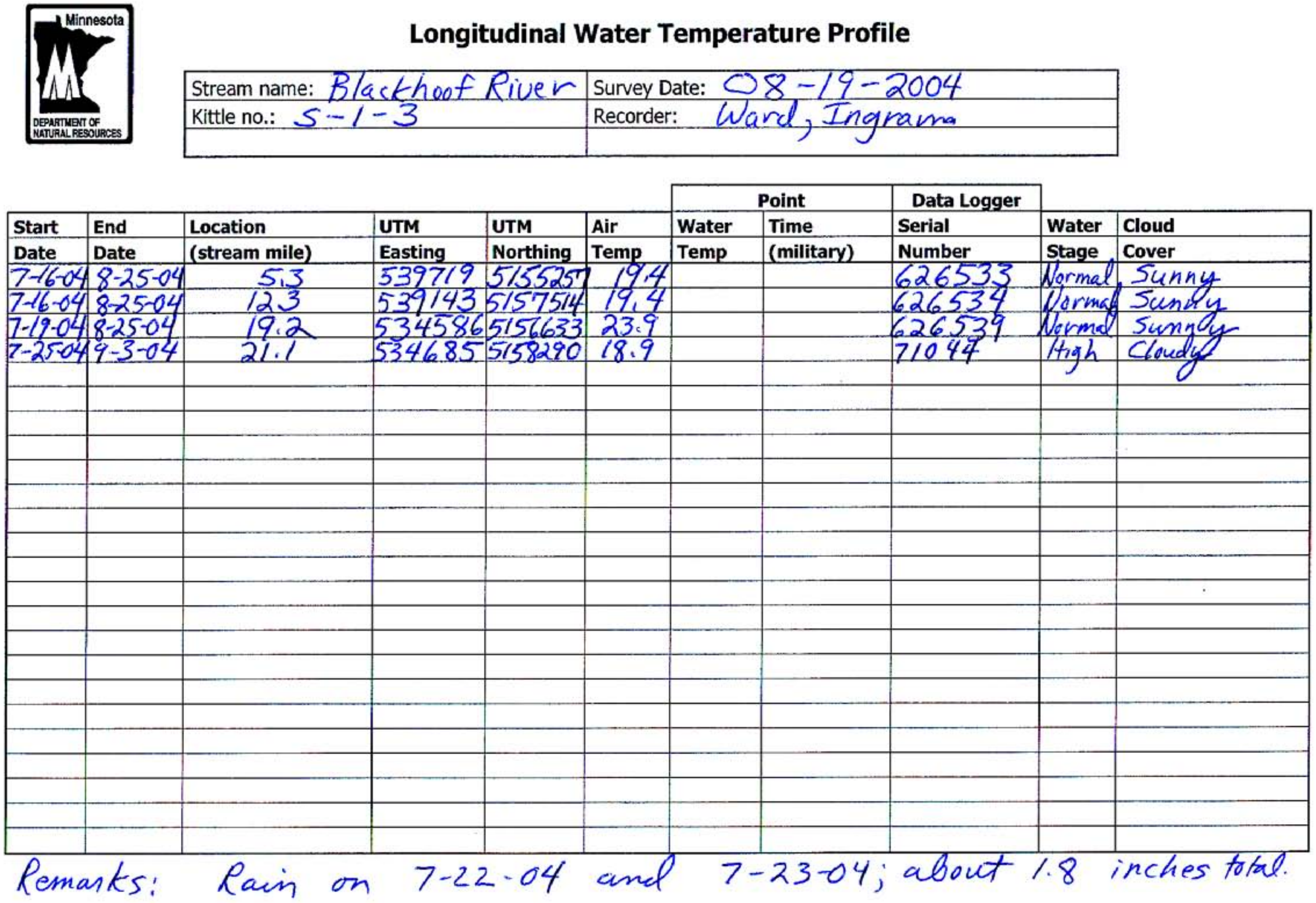


Figure 63. Mean daily water temperature graph for the Blackhoof River, MN (S-001-003) at Highway 104 (mile 12.4), summer 2005.



Longitudinal Water Temperature Profile

Stream name: Blackhoof River
Survey Date: 08-19-2004
Kittle no.: S-1-3
Recorder: Ward, Ingram

						Point		Data Logger		
Start Date	End Date	Location (stream mile)	UTM Easting	UTM Northing	Air Temp	Water Temp	Time (military)	Serial Number	Water Stage	Cloud Cover
7-16-04	8-25-04	5.3	539719	5155257	19.4			626533	Normal	Sunny
7-16-04	8-25-04	12.3	539143	5157514	19.4			626534	Normal	Sunny
7-19-04	8-25-04	19.2	534586	5156633	23.9			626539	Normal	Sunny
7-25-04	9-3-04	21.1	534685	5158290	18.9			71044	High	Cloudy

Remarks: Rain on 7-22-04 and 7-23-04; about 1.8 inches total.

Figure 64. Example longitudinal water temperature profile field sheet.

Location: Blackhoof River (S-001-003) at Highway 104 (mile 12.4)
Logger # : 626533

Date	Time	Temp (°F)
6/1/05	0:00	64
6/1/05	1:00	63
6/1/05	2:00	62
6/1/05	3:00	61
6/1/05	4:00	60
6/1/05	5:00	59
6/1/05	6:00	59
6/1/05	7:00	59
6/1/05	8:00	59
6/1/05	9:00	59
6/1/05	10:00	60
6/1/05	11:00	60
6/1/05	12:00	61
6/1/05	13:00	61
6/1/05	14:00	62
6/1/05	15:00	62
6/1/05	16:00	63
6/1/05	17:00	63
6/1/05	18:00	63
6/1/05	19:00	63
6/1/05	20:00	63
6/1/05	21:00	63
6/1/05	22:00	62
6/1/05	23:00	62
6/2/05	0:00	61
6/2/05	1:00	61
6/2/05	2:00	61
6/2/05	3:00	60
6/2/05	4:00	59
6/2/05	5:00	59
6/2/05	6:00	58
6/2/05	7:00	58
6/2/05	8:00	58
6/2/05	9:00	58
6/2/05	10:00	58
6/2/05	11:00	59
6/2/05	12:00	61
6/2/05	13:00	62
6/2/05	14:00	63
6/2/05	15:00	64
6/2/05	16:00	65
6/2/05	17:00	65
6/2/05	18:00	65
6/2/05	19:00	65
6/2/05	20:00	65
6/2/05	21:00	65
6/2/05	22:00	64
6/2/05	23:00	64
6/3/05	0:00	63
6/3/05	1:00	63
6/3/05	2:00	62
6/3/05	3:00	61
6/3/05	4:00	60
6/3/05	5:00	59
6/3/05	6:00	58
6/3/05	7:00	58
6/3/05	8:00	58
6/3/05	9:00	58
6/3/05	10:00	59
6/3/05	11:00	59
6/3/05	12:00	60
6/3/05	13:00	61
6/3/05	14:00	63
6/3/05	15:00	63
6/3/05	16:00	63
6/3/05	17:00	63
6/3/05	18:00	63
6/3/05	19:00	63
6/3/05	20:00	63
6/3/05	21:00	63
6/3/05	22:00	63
6/3/05	23:00	63
6/4/05	0:00	62
6/4/05	1:00	62
6/4/05	2:00	61
6/4/05	3:00	61
6/4/05	4:00	60
6/4/05	5:00	59
6/4/05	6:00	59
6/4/05	7:00	59
6/4/05	8:00	58
6/4/05	9:00	58
6/4/05	10:00	59
6/4/05	11:00	59
6/4/05	12:00	59
6/4/05	13:00	59
6/4/05	14:00	59
6/4/05	15:00	59
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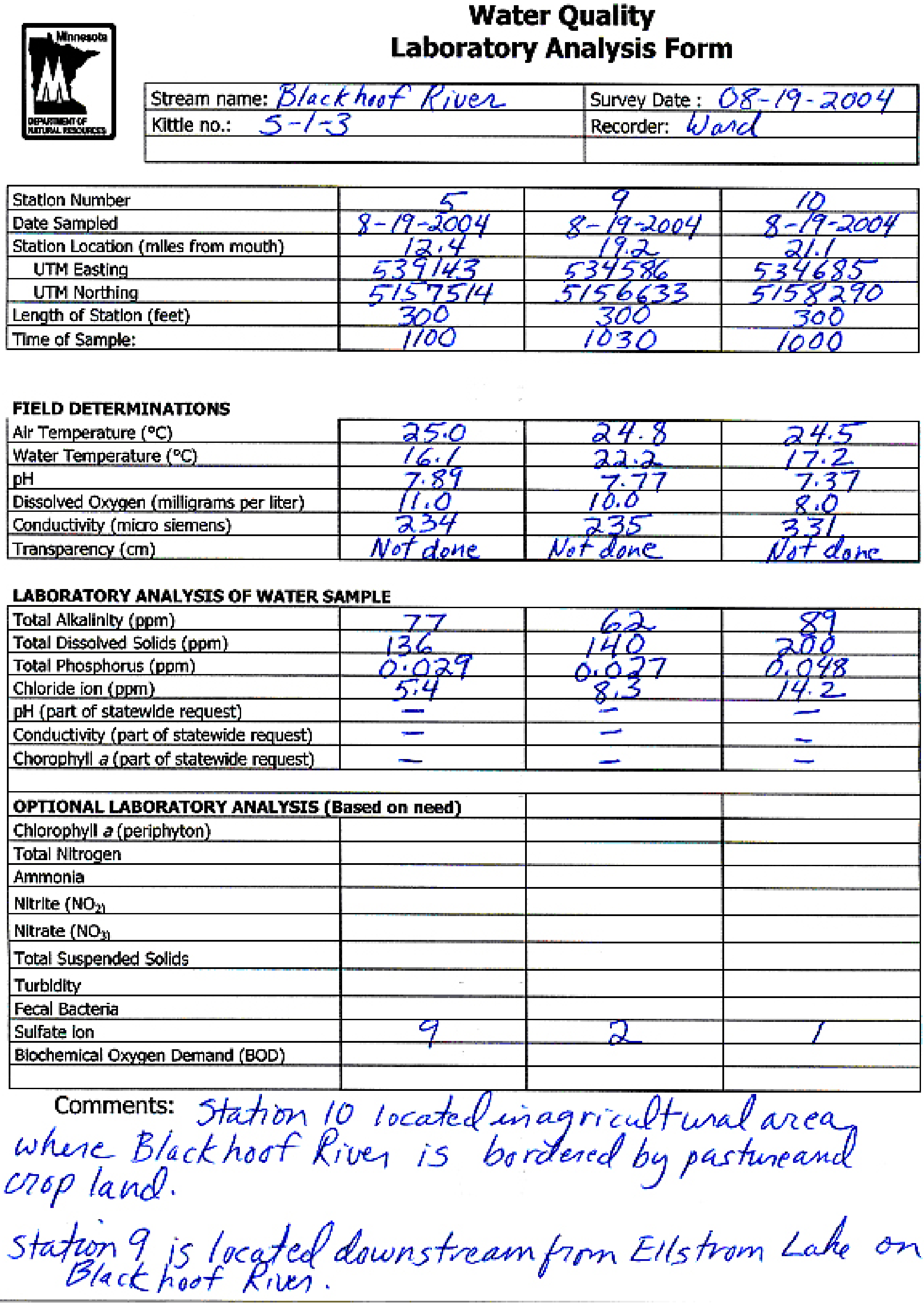
6/4/05	19:00	59
6/4/05	20:00	59
6/4/05	21:00	59
6/4/05	22:00	59
6/4/05	23:00	58
6/5/05	0:00	58
6/5/05	1:00	58
6/5/05	2:00	57
6/5/05	3:00	57
6/5/05	4:00	57
6/5/05	5:00	57
6/5/05	6:00	57
6/5/05	7:00	56
6/5/05	8:00	56
6/5/05	9:00	56
6/5/05	10:00	56
6/5/05	11:00	57
6/5/05	12:00	57
6/5/05	13:00	59
6/5/05	14:00	60
6/5/05	15:00	61
6/5/05	16:00	62
6/5/05	17:00	62
6/5/05	18:00	62
6/5/05	19:00	62
6/5/05	20:00	62
6/5/05	21:00	62
6/5/05	22:00	62
6/5/05	23:00	63
6/6/05	0:00	63
6/6/05	1:00	63
6/6/05	2:00	62
6/6/05	3:00	62
6/6/05	4:00	61
6/6/05	5:00	61
6/6/05	6:00	60
6/6/05	7:00	60
6/6/05	8:00	60
6/6/05	9:00	60
6/6/05	10:00	60
6/6/05	11:00	61
6/6/05	12:00	62
6/6/05	13:00	63
6/6/05	14:00	65
6/6/05	15:00	66
6/6/05	16:00	67
6/6/05	17:00	67

Figure 65. Example continuous temperature recording output table.



Water Quality
Laboratory Analysis Form

Stream name: Blackhoof River	Survey Date : 08-19-2004
Kittle no.: 5-1-3	Recorder: Ward

Station Number	5	9	10
Date Sampled	8-19-2004	8-19-2004	8-19-2004
Station Location (miles from mouth)	12.4	19.2	21.1
UTM Easting	539143	534586	534685
UTM Northing	5157514	5156633	5158290
Length of Station (feet)	300	300	300
Time of Sample:	1100	1030	1000

FIELD DETERMINATIONS

Air Temperature (°C)	25.0	24.8	24.5
Water Temperature (°C)	16.1	22.2	17.2
pH	7.89	7.77	7.37
Dissolved Oxygen (milligrams per liter)	11.0	10.0	8.0
Conductivity (micro siemens)	234	235	331
Transparency (cm)	Not done	Not done	Not done

LABORATORY ANALYSIS OF WATER SAMPLE

Total Alkalinity (ppm)	77	62	89
Total Dissolved Solids (ppm)	136	140	200
Total Phosphorus (ppm)	0.029	0.027	0.048
Chloride ion (ppm)	5.4	8.3	14.2
pH (part of statewide request)	—	—	—
Conductivity (part of statewide request)	—	—	—
Chorophyll *a* (part of statewide request)	—	—	—
OPTIONAL LABORATORY ANALYSIS (Based on need)			
Chlorophyll *a* (periphyton)			
Total Nitrogen			
Ammonia			
Nitrite (NO_2)			
Nitrate (NO_3)			
Total Suspended Solids			
Turbidity			
Fecal Bacteria			
Sulfate Ion	9	2	1
Biochemical Oxygen Demand (BOD)			

Comments: Station 10 located in agricultural area where Blackhoof River is bordered by pasture and crop land.

station 9 is located downstream from Ellstrom Lake on Blackhoof River.

Figure 66. Example water quality laboratory analysis field form.

Biology

Biology Checklist (Full Survey)

1. ____ Riparian vegetation survey (pages 134–137)
2. ____ Aquatic plant survey (pages 138–139)
3. ____ Aquatic invertebrate survey (pages 140–143)
4. ____ Fish community survey (pages 144–154)

Biology Survey Methods

Take biological measurements at least at one station per similar reach in conjunction with other stream survey measures such as geomorphology. Sample additional stations if necessary to ensure an adequate representation of biological communities within the reach.

Biology Survey Equipment

Brush ax/machete
Bug repellent
Head net (for bugs)
Polarized sunglasses
Watch
Compass
Maps
Hip chain
Tape measure (100 m)
Manual
Field sheets
Flagging tape/paint/rebar
Pencil
GPS unit
Field forms
Clipboard
Tube scales (gm)
Digital scale for individual weights
Measuring board (mm)
Fish-holding equipment (e.g., metal tubs, in-stream cages, buckets)
Electrofishing (backpack, stream, or mini-boom-shocker) and/or other collecting gear (seine, minnow traps, trap nets, etc.)
Blocking nets
Field fish identification key (preferably copied in write-in-the-rain paper)
Protective gear (gloves, waders, etc.)

First aid kit
Scale envelopes
Knife
Scissors and/or side cutters
Forceps/tweezers
Dip nets (1/8-inch mesh recommended for fish community surveys)
Kick net (D-frame net) 600 mm mesh
Wide mouth nalgene or glass jars
Zip-lock bags/whirl-paks
10% formalin, buffered
Ethanol/isopropyl/formaldehyde
Current meter
Camera
Thermometer
Aquatic plant identification key, if necessary

Riparian Vegetation Survey

Riparian area assessments must be conducted during summer because plant growth and coverage varies seasonally (Mills and Stevenson 1999).

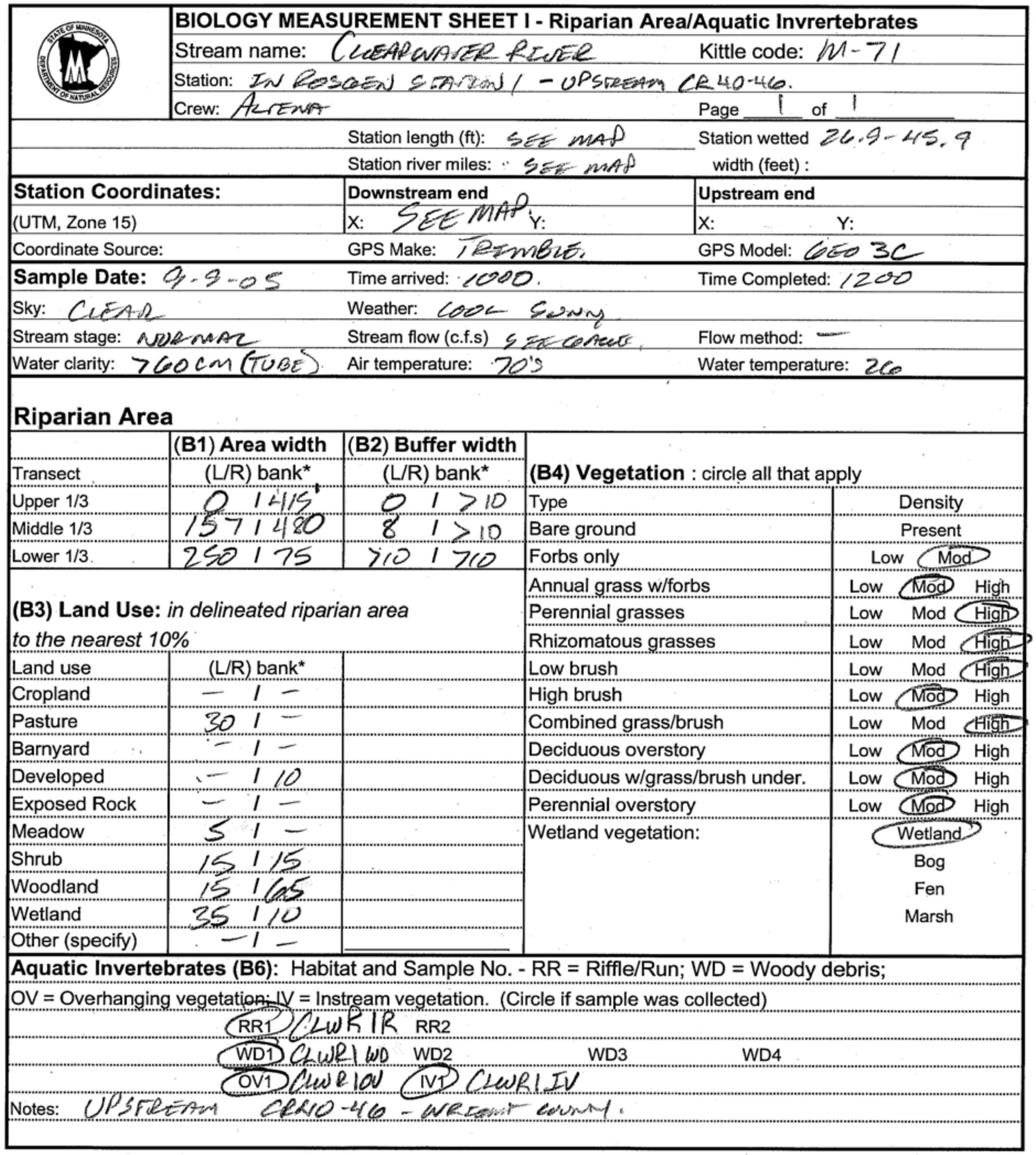
Step 1. Delineate and Measure the Width of the Riparian Ecotone Area (B1). Verry et al. (2004) proposed delineation of the riparian ecotone as the flood-prone area width plus 30 m (98 ft) on each side. The flood-prone area width is that described in the geomorphology section and is measured on the riffle cross section.

Start by setting up a laser level and cross section at the riffle and determine the elevation at bankfull. Then determine the elevation of the deepest point in the riffle cross section. Calculate the difference between these two elevations and subtract this difference from the bankfull elevation to determine the elevation of the flood-prone area. For example, if the bankfull elevation is 33 m and the elevation of the deepest part of the stream is 36 m, then the difference between these elevations equals three meters. Then subtract 3 m from the bankfull elevation of 33 m to determine the flood-prone elevation, which would be 30 m. Set the laser level detector on the surveyor's rod to the height that is equivalent to an elevation of 30 m and walk out on a line perpendicular to the stream channel until you detect where this elevation exists. Mark the location and repeat on the other side of the stream. Then measure the distance between these two points and add an additional 30 m to determine to each side of the width of the riparian ecotone area. Record this value on the field sheet (Biology Measurement Sheet 1 – Riparian Area/Aquatic Invertebrates, example in Figure 67). Note that this example assumes you are using the rod readings on the stadia rod. If you are working directly with the elevations recorded, add the differences to the bankfull elevation (i.e., the bankfull elevation will be higher than the maximum depth elevation and the flood-prone elevation will be even higher). For additional guidance see Verry et al. (2004).

Step 2. Qualitatively Assess Riparian Land Use (B3). Visually estimate the predominant land uses within the delineated riparian ecotone area to the nearest 10%. Follow guidelines in Simonson et al. (1993), MPCA (2000), and WDNR (2002). Estimate percentage of land use types separately on the left and right banks. Visual estimates should be made by two persons independently; record a mean of their estimates on the data collection sheet (Figure 67). The predominant land use types are shown in Table 7.

Step 3. Measure Buffer Zone Width (B2). Establish three transects perpendicular to the stream at approximately the upper one-third, middle one-third, and lower one-third of the sampling stations' length. Measure the buffer zone widths on both banks for each transect to the nearest meter if the buffer width is less than 10 m. If the buffer width is greater than 10 m, record it as ">10 m" (MPCA 2004; WDNR 2002). Measurements begin at the apparent water's edge on the day of the survey and extend either to the end of the buffer (see below) or to 10 m, whichever distance is less.

To calculate a mean value for the station, sum the six measurements and divide by 6 (Nerbonne and Vondracek 2001). For buffer width values greater than 10 m, use 10 m in the calculations. Intact buffer zones are defined as contiguous land that is undisturbed. Meadow, shrub, woodland, wetland, and exposed rock (see Table 7) are considered undisturbed buffer (MPCA 2004; WDNR 2002). Disturbed lands include agricultural crops, animal pasture, clear-cut forest, and urban and residential land uses.



BIOLOGY MEASUREMENT SHEET I - Riparian Area/Aquatic Invrertebrates

Stream name: CLEARWATER RIVER

Kittle code: M-71

Station: IN ROSGEN STATION 1 - UPSTREAM CR40-46.

Crew: ALTENA

Page 1 of 1

Station length (ft): SEE MAP

Station river miles: SEE MAP

Station wetted width (feet): 26.9-45.9

Station Coordinates: (UTM, Zone 15)

Downstream end X: SEE MAP Y:

Upstream end X: Y:

Coordinate Source:

GPS Make: TRIMBLE.

GPS Model: GEO 3C

Sample Date: 9-9-05

Time arrived: 1000.

Time Completed: 1200

Sky: CLEAR

Weather: COOL SUNNY

Stream stage: NORMAL

Stream flow (c.f.s) SEE CONNIE.

Flow method: —

Water clarity: 760 CM (TUBE)

Air temperature: 70'S

Water temperature: 26

Riparian Area

	(B1) Area width	(B2) Buffer width
Transect	(L/R) bank*	(L/R) bank*
Upper 1/3	0 / 415'	0 / >10
Middle 1/3	157 / 480	8 / >10
Lower 1/3	250 / 75	>10 / >10

(B3) Land Use: *in delineated riparian area to the nearest 10%*

Land use	(L/R) bank*	
Cropland	— / —	
Pasture	30 / —	
Barnyard	— / —	
Developed	— / 10	
Exposed Rock	— / —	
Meadow	5 / —	
Shrub	15 / 15	
Woodland	15 / 65	
Wetland	35 / 10	
Other (specify)	— / —	

(B4) Vegetation : circle all that apply

Type	Density
Bare ground	Present
Forbs only	Low [✓ Mod]
Annual grass w/forbs	Low [✓ Mod] High
Perennial grasses	Low Mod [✓ High]
Rhizomatous grasses	Low Mod [✓ High]
Low brush	Low Mod [✓ High]
High brush	Low [✓ Mod] High
Combined grass/brush	Low Mod [✓ High]
Deciduous overstory	Low [✓ Mod] High
Deciduous w/grass/brush under.	Low [✓ Mod] High
Perennial overstory	Low [✓ Mod] High
Wetland vegetation:	[✓ Wetland] Bog Fen Marsh

Aquatic Invertebrates (B6): Habitat and Sample No. - RR = Riffle/Run; WD = Woody debris; OV = Overhanging vegetation; IV = Instream vegetation. (Circle if sample was collected)

[✓ RR1] CLWR1R RR2

[✓ WD1] CLWR1WD WD2 WD3 WD4

[✓ OV1] CLWR1OV [✓ IV1] CLWR1IV

Notes: UPSTREAM CR40-46 - WRIGHT COUNTY.

Figure 67. Example riparian area and aquatic invertebrate collection field sheet.

Table 7. Qualitative riparian land use/land cover types.

Cropland – Land that is cultivated with crops for forage or cover, including areas under intensive cropping or rotation or that are regularly mowed for hay.

Pasture – Land that is regularly grazed by livestock.

Barnyard – Land associated with farmsteads and the adjoining farmyard area, including grain storage facilities, barns, farmhouses, and feedlots (areas used to confine and feed high densities of livestock).

Developed – Land that has been modified (rural or urban) for commercial, industrial, or residential use, including commercial buildings/structures, parking lots, all roads, railroads, power utilities, residential buildings, lawns, parks, golf courses, ball fields, etc.

Exposed rock – Natural areas of rock outcrops that lack appreciable soil development or vegetative cover.

Meadow – Land dominated by grasses and forbs with little woody vegetation (<5% woody) and not subject to regular mowing or grazing.

Shrub – Land consisting primarily of woody vegetation less than 3 m in height. Typical shrubs include alder, dogwood, and willows.

Woodland – Land dominated by deciduous or coniferous tree species generally taller than 3 m.

Wetland – Low-lying areas that are saturated or inundated with water frequently or for considerable periods of time (generally >5 months) on an annual basis (Cowardin et al. 1979). Wetlands include bogs, marshes, and swamps, and contain vegetation adapted for life in saturated conditions.

Other – If a land-use category other than one of those listed above is predominant, specify the type.

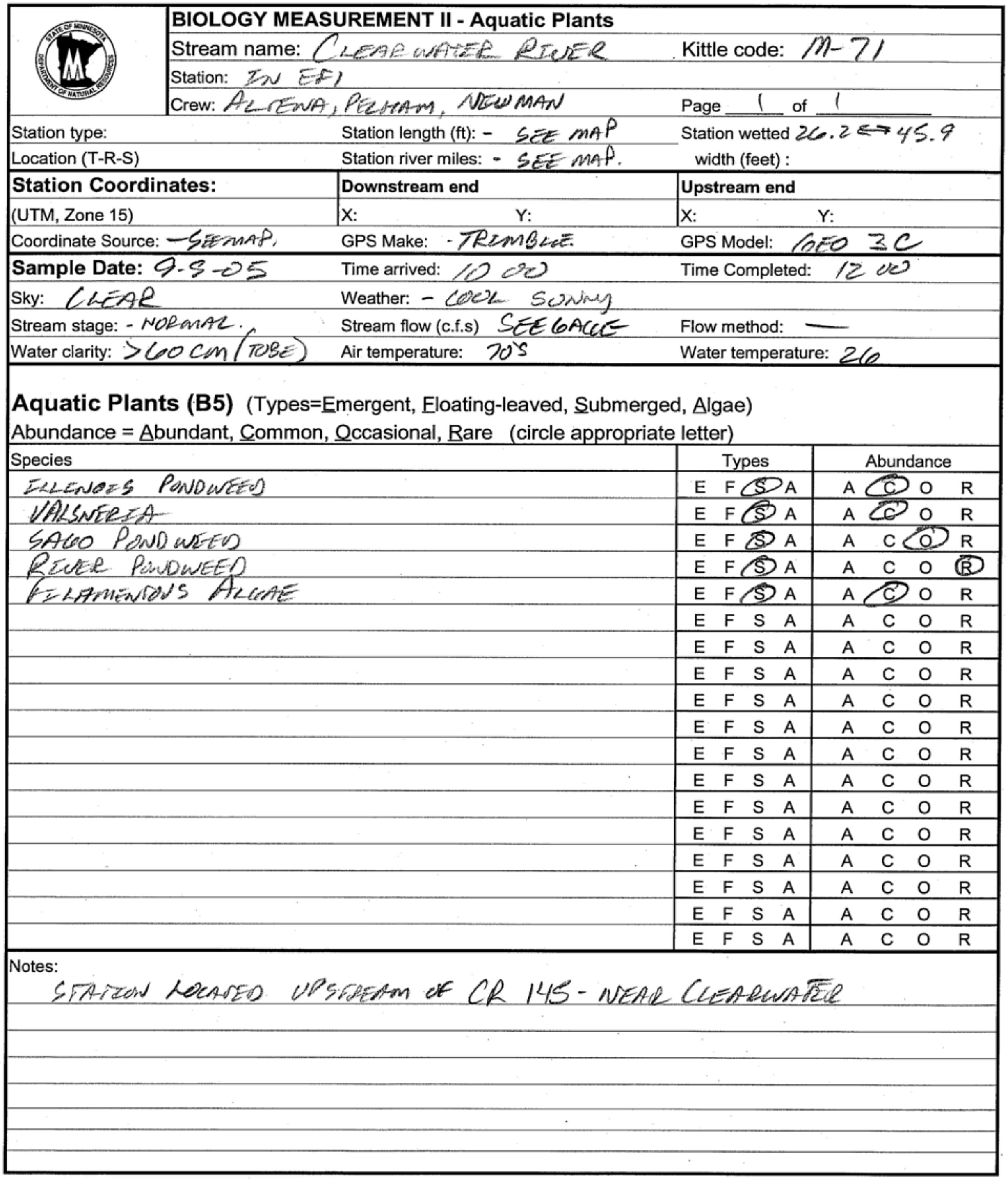
Aquatic Plant Survey

Assess aquatic plants in midsummer beginning near July 1. Additional information on aquatic plants may be collected as part of the geomorphology and fish habitat survey.

Step 1. Walk through the study station in an upstream direction and record on the Biology Measurement II – Aquatic Plants form (example in Figure 68) all aquatic plant species observed (B5).

Step 2. When you reach the upstream boundary of the station, record the abundance (B5) of each species in the study station as abundant, common, occasional, or rare.

Step 3. If you wish, digitally photograph and document the locations of vegetation beds forming significant habitat for invertebrates and fish.



BIOLOGY MEASUREMENT II - Aquatic Plants

Stream name: CLEARWATER RIVER

Kittle code: M-71

Station: IN EFI

Crew: ALTENA, PELHAM, NEWMAN

Page 1 of 1

Station type:

Location (T-R-S)

Station length (ft): - SEE MAP

Station river miles: - SEE MAP.

Station wetted width (feet) : 26.2 ↔ 45.9

Station Coordinates:	**Downstream end**		**Upstream end**	
(UTM, Zone 15)	X:	Y:	X:	Y:

Coordinate Source: —SEE MAP.

GPS Make: - TRIMBLE.

GPS Model: GEO 3C

Sample Date: 9-8-05

Time arrived: 10 00

Time Completed: 12 00

Sky: CLEAR

Weather: - COOL SUNNY

Stream stage: - NORMAL.

Stream flow (c.f.s) SEE GAGE

Flow method: —

Water clarity: >60 CM (TUBE)

Air temperature: 70'S

Water temperature: 26

Aquatic Plants (B5) (Types=Emergent, Floating-leaved, Submerged, Algae)

Abundance = Abundant, Common, Occasional, Rare (circle appropriate letter)

Species	Types	Abundance
ILLENOIS PONDWEED	E F [✓ S] A	A [✓ C] O R
VALSNERIA	E F [✓ S] A	A [✓ C] O R
SAGO POND WEED	E F [✓ S] A	A C [✓ O] R
RIVER PONDWEED	E F [✓ S] A	A C O [✓ R]
FILAMENTOUS ALGAE	E F [✓ S] A	A [✓ C] O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R

Notes:

STATION LOCATED UPSTREAM OF CR 145 - NEAR CLEARWATER

Figure 68. Example aquatic plant field sheet.

Aquatic Invertebrate Survey

The optimum time for sampling invertebrates is either early spring or late fall. In summer, many insects have emerged as adults, have laid eggs, or may be in early stages, so they may be either missed completely or not identifiable. Early spring, after snowmelt but before the water has warmed significantly, is a good time for sampling. Many invertebrates are in late life stages, waiting for the water to warm for emergence. A second good time period is late fall (very late September to mid-October). Many insects are in later growth, and hold in streams throughout winter. Once a time period is set, repeat it in future surveys. Sample three habitat types if they are present: (1) riffle/run (heterogeneous substrate such as rocks and cobble; sample two areas); (2) woody debris (sample four distinct areas); and (3) in-stream or overhanging vegetation (sample two areas). Make sure the specific areas sampled are representative of the habitat type.

For sampling invertebrates in other habitats, such as soft sediments, or with alternative gears/seasonal times, contact the invertebrate biologist at the address below for appropriate collection guidelines.

Step 1. Sample Riffle/Run Habitat. Approach the sampling area from downstream with a 600 mm kick net (D-frame). Place the net against the stream bottom. From the area 25 cm (12 in) in front of the net, pick up any rock baseball-size or larger, hold in front of the net, and rub the entire surface to remove invertebrates. Look at the rock when done to make sure you haven’t missed any invertebrates. If it is clean, place the rock outside of the sample area. Repeat for other rocks in the sample area. When rocks have been cleaned, use your foot to stir up the sediment in the sample area in front of the net for one minute. Remove invertebrates from any rocks, sticks or other larger chunks of debris you find, place them in a wide-mouth nalgene or glass jar, and remove the debris from the site. Look at net and remove invertebrates clinging to it. Move to a different spot within the riffle and repeat the above process using the same jar. If jar is more than two-thirds full, or contains large amounts of algae or organic material, divide the material into two jars. Circle the appropriate collection indicator on the Biology Measurement Sheet I – Riparian Area/Aquatic Invertebrates form (Figure 67) and proceed to the next sample.

Step 2. Sample Woody Debris Habitat. Good habitats include root wads, accumulations of branches, fallen trees, and any other pieces of wood that have been submerged. Some types of woody debris should not be sampled. First, newly introduced debris is not generally good habitat. For example, if a tree has recently fallen, still retains leaves and the bark is tight, it is generally too recent to have developed a stable and diverse invertebrate community. Large accumulations of branches, sticks and other wood are too habitats to sample, as are root wads. Downed trees can be good habitats, however and single large-diameter pieces of wood are less optimal than greater numbers of smaller diameter branches.

For root wads, push the net into the underside of the root wad repeatedly, working from a downstream direction. For large debris accumulations, working from the downstream side, push the net into and below the debris. Lift up the net and repeatedly push it into the debris mass. If you can reach pieces, brush them off with your hands while the net is held downstream so dislodged invertebrates are swept into the net. If bark is loose on pieces of wood, pull it off to expose invertebrates for collecting. If there are both debris piles and root wads, sample both. Spend approximately one minute collecting at each sample area and sample four distinct areas. Remove large wood pieces from sampling area after examining for clinging invertebrates to reduce sample volume. Combine all collected invertebrates in a separate jar.

Step 3. Sample In-stream or Overhanging Vegetation. Approach these areas from a downstream direction. For overhanging vegetation, push the net underwater and bring it up into the vegetation, shaking the vegetation to dislodge any clinging invertebrates. For in-stream vegetation, work the net through the vegetation in an upstream direction. Try not to stir up or dig the net into the soft sediments on the stream bottom. If there is sufficient area, try and sample an approximately 0.5 meter-long area of both types of vegetation. Remove large pieces of vegetation from sampling area after examining for attached invertebrates to reduce sample volume. Sample two different areas and combine the samples in a separate jar. Samples from in-stream and overhanging vegetation can be combined into a single sample for a given sampling station.

Step 4. Label Jars. Place a paper label written in pencil in each jar, and preserve each sample with 100% ethanol. Be sure that the jars are no more than two-thirds full of sample material. Place a tape label on the outside of the jar. Both labels should contain the following information: stream name, kittle number, reach name or ID number, sample date, sampling station, collection personnel, and habitat type.

Step 5. Sort Samples. In the lab, sort organisms from debris under a microscope or using a hand lens or other type of magnification. A stain such as rose bengal can be added to help you differentiate invertebrates from other material. Place material in a container and add sufficient water so the material is covered but not floating freely. Examine the material, looking carefully for attached organisms as well as caddisflies that may have retracted into their cases. Place all organisms found into a labeled jar filled with 80% ethanol. If you are in doubt as to whether something is an invertebrate, place it into the jar.

After you think you have everything, gently swirl the contents of the dish or mix them with forceps and reexamine the entire contents. If the second time reveals a large number of organisms missed on the first pass, repeat. Then discard the debris, refill the container with more material, and repeat until the entire sample has been picked through. If the jar becomes more than two-thirds full, start a second jar. Place the label from the field into the jar or securely attach it to the outside of the jar. If sample is in multiple jars, tape the jars together. Repeat sorting process for each habitat type sampled, keeping habitat types separate. Send all sorted invertebrate samples to:

Invertebrate Biologist, Division of Ecological Services
Minnesota Department of Natural Resources
500 Lafayette Road, Box 25
St. Paul, MN 55155

After analyzing samples, DNR Ecological Services will provide results in spreadsheet / table format. See Table 8 for example invertebrate analysis results.

Table 8. Example aquatic invertebrate sample results (all habitats combined). Data is from the Shell Rock River (I-030, Freeborn County, MN), collected October 24, 2006.

Taxa	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**
EPHEMEROPTERA					
Baetidae					
Baetis sp.	1				1
?Callibaetis sp.		2	6	1	
Caenidae					
Caenis sp.	2		1		
Ephemeridae					
?Hexagenia sp.	1				
Heptageniidae					
Stenonema integrum	1				
Potamanthidae					
Anthopotamus sp.	2	1			
TRICHOPTERA					
Hydropsychidae	5	3			
Cheumatopsyche sp.	1	6		1	1
Hydropsyche orris		1			
Hydroptilidae					
Hydroptila sp.		1		1	
Leptoceridae					
Oecetis sp.		1			
ODONATA					
Coenagrionidae				1	
Ischnura sp.	4	10	2		
COLEOPTERA					
Elmidae					
Dubiraphia sp.		1			
Gyrinidae					
Gyrinus sp.	1				
Haliplidae					
Peltodytes sp.					1
Hydrophilidae					
Tropisternus sp.		1			
HETEROPTERA					
Corixidae	11	10	26	45	10
Hesperocorixa sp.			1		
Palmacorixa sp.	2				1
Sigara sp.	1	1			
Trichocorixa sp.	18	19	42	12	18
Notonectidae					
Buenoa sp.	1				
Notonecta sp.	1			1	
Nepidae					
Ranatra sp.		1		1	
DIPTERA					
Chironomidae	48	200	54	98	5
Non-insect taxa					
CRUSTACEA					
Amphipoda					
Hyalella azteca	1	10	3		5
MOLLUSCA					
Helisoma sp.		1			
Fossaria sp.		3		1	
Physella sp.	2	27	8		
?Planorbula sp.			1		
ANNELIDA					
Naididae	20	8	3	20	50
Hirudinea			2		
HYDRACHNIDA	1				
TRICLADIDA		31	17		

Fish Community Survey

Sample fish communities during daylight hours from mid-June through mid-September during periods of optimal water clarity and flow. Optimal time is when water levels are at or below base-flow conditions. Avoid sampling immediately following unusually high- or low-flow periods.

This portion of the manual describes accepted methods for sampling fish populations and communities. Traditional surveys focusing primarily on indices of game fish population abundance (e.g., catch-per-unit-effort, traditional population assessments) are considered supplemental surveys.

Specific methods vary by management area, so sampling details are left to the discretion of area supervisors. Some guidelines for population assessments are provided in the supplemental survey part of this manual.

Electrofishing. Electrofishing is the primary method used to sample stream fishes, although other gears can be used as necessary (see supplemental surveys). Three types of electrofishing gear are acceptable and described below. Take care to select the gear type that will most effectively sample the fish community. Gear selection is dictated by stream width, depth, and station accessibility. General guidelines for determining appropriate gear type and safe use are as follows (also refer to Appendix 4):

> **Backpack**. Generally used in small, wadeable streams (<8 m mean stream wetted width MSW). A single electrofishing run is conducted in an upstream direction. In very small streams (<2 m wide) it is possible to sample most of the available habitat, but in larger streams it is often necessary to meander between habitat types. Two people are needed, one to carry the unit and operate the anode and another to collect or measure fish.
>
> **Stream-shocker**. Used in larger, wadeable streams and rivers (typically >8 m MSW). The stream-shocker is a towable unit that can effectively sample larger streams because it has additional power capabilities and employs two anodes, thus increasing the electrofishing zone. At least three people are required for operation, one to control the electrofisher and two to direct the anodes and net fish. A single electrofishing run is conducted in an upstream direction, weaving between habitat types. When access to the sampling station is difficult for the stream shocker or the station is wide and shallow, it may be necessary to use two backpack electrofishers simultaneously instead.

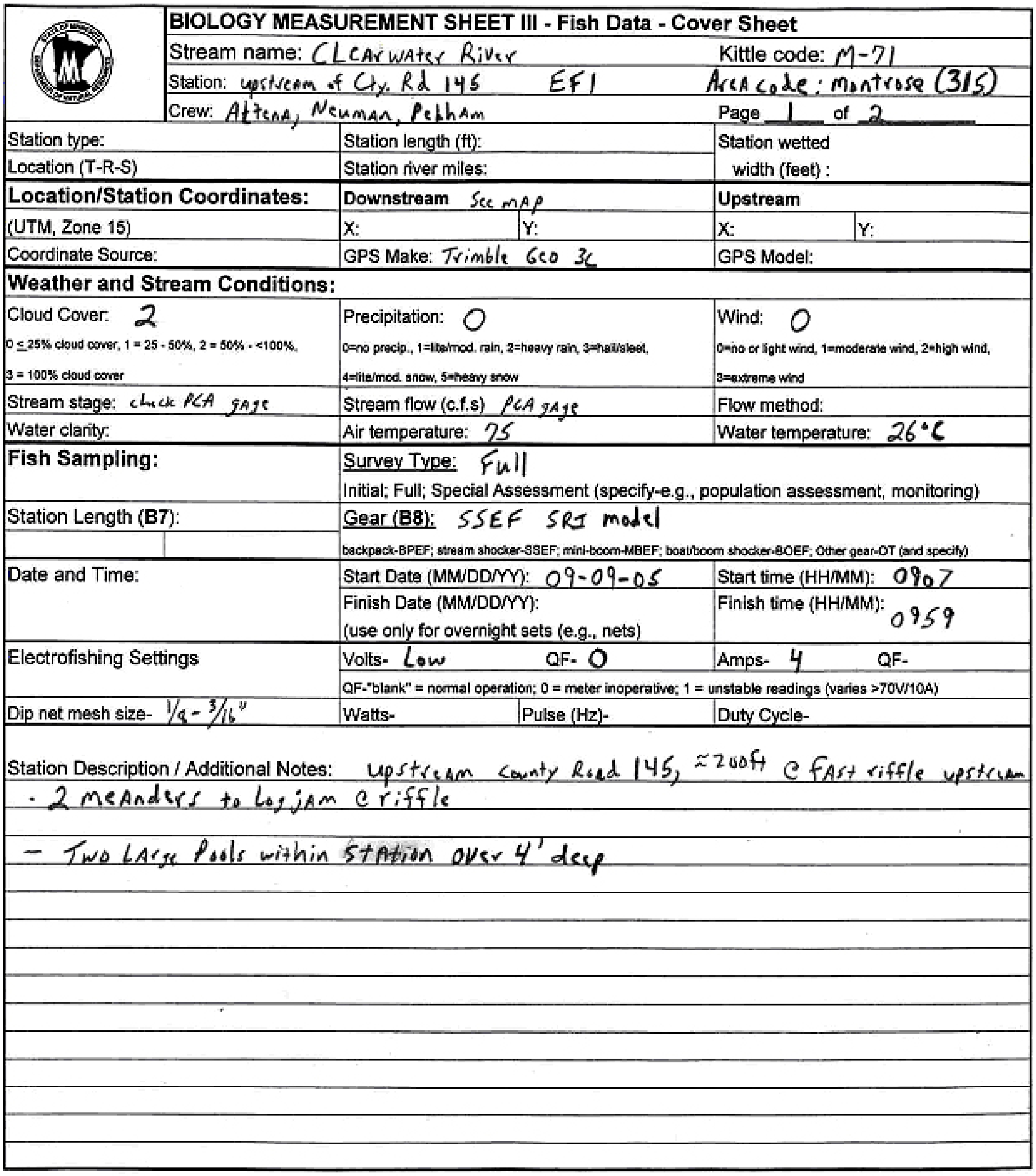
Mini-boom. Used in marginally wadeable streams and rivers that are either too wide or that have frequent pools too deep to sample with a stream-shocker. The mini-boom electrofisher is a flat-bottom boat that is light enough to be portaged, yet provides a stable work platform. Two people are required, one to collect fish on the bow and the other to operate the boat, monitor the control box, and ensure the safety of the fish collector. An electrofishing run is conducted in a downstream direction, weaving between habitat types.

Sampling efficiency is influenced by water clarity, flow, and the experience and organization of the electrofishing crew. Other factors can influence sampling efficiency also (see Appendix 4).

Step 1. Establish the Sampling Station (B7). Sampling stations for assessing fish communities are about 35 times the MSW, with a minimum of 150 meters and a maximum of 500 meters (Lyons 1992). The MSW is traditionally based on the mean of 10 stream-width measurements throughout the station, including all habitat types (runs, riffles, and pools). However, in practice, stream width will likely be based on a fewer number of transects. Measure station length by running along the thalweg, marking the top and bottom of the reach with marking tape. The station should not contain major tributaries, dams, or bridge/road crossings. Record the exact location of the downstream limit of each station in latitude and longitude or UTM and in terms of miles from the mouth (station 0.0= the stream mouth, station 1.0=1 mile upstream from the mouth, etc.). Record a full description, using natural landmarks or artificial benchmarks (e.g., rebar stakes driven into the bank), for beginning and end of each station. Measure the length of stream sampled for fish to the nearest meter following the center of the stream. If insufficient numbers of target game fish species are collected to generate population indices such as length-frequency histograms or age & growth data, survey personnel can continue sampling either upstream or downstream from the station to collect additional fish. However, information from these additional fish, such as numbers and weights, should be recorded separately from that collected from the station. Record weather and stream conditions at time of sampling on the Biology Measurement Sheet III – Fish Data – Cover Sheet (Figure 69).

Step 2. Record Gear Type (B8). Record the type of electrofishing or optional gear used as indicated on the Biology Measurement Sheet III – Fish Data – Cover Sheet. If desired, record the following electrofishing settings: volts, amps, pulse (Hz), duty cycle, and watts. Record the mesh size of dip nets if it differs from the recommended 1/8 inch.

Step 3. Electrofish. Electrofishing can be hazardous; adhere to DNR electrofishing guidelines (MNDNR 1999).



BIOLOGY MEASUREMENT SHEET III - Fish Data - Cover Sheet

Stream name: CLearwater River

Kittle code: M-71

Station: upstream of Cty. Rd 145 EF1

Area code: Montrose (315)

Crew: Altena, Neuman, Pekham

Page 1 of 2

Station type:

Station length (ft):

Station wetted width (feet) :

Location (T-R-S)

Station river miles:

Location/Station Coordinates:

Downstream See map

Upstream

(UTM, Zone 15)

X:

Y:

X:

Y:

Coordinate Source:

GPS Make: Trimble Geo 3c

GPS Model:

Weather and Stream Conditions:

Cloud Cover: 2

0 ≤ 25% cloud cover, 1 = 25 - 50%, 2 = 50% - <100%, 3 = 100% cloud cover

Precipitation: 0

0=no precip., 1=lite/mod. rain, 2=heavy rain, 3=hail/sleet, 4=lite/mod. snow, 5=heavy snow

Wind: 0

0=no or light wind, 1=moderate wind, 2=high wind, 3=extreme wind

Stream stage: check PCA gage

Stream flow (c.f.s) PCA gage

Flow method:

Water clarity:

Air temperature: 75

Water temperature: 26°C

Fish Sampling:

Survey Type: Full

Initial; Full; Special Assessment (specify-e.g., population assessment, monitoring)

Station Length (**B7**):

Gear (B8): SSEF SRI model

backpack-BPEF; stream shocker-SSEF; mini-boom-MBEF; boat/boom shocker-BOEF; Other gear-OT (and specify)

Date and Time:

Start Date (MM/DD/YY): 09-09-05

Start time (HH/MM): 0907

Finish Date (MM/DD/YY):

(use only for overnight sets (e.g., nets)

Finish time (HH/MM): 0959

Electrofishing Settings

Volts- Low

QF- 0

Amps- 4

QF-

QF-"blank" = normal operation; 0 = meter inoperative; 1 = unstable readings (varies >70V/10A)

Dip net mesh size- 1/4 - 3/16"

Watts-

Pulse (Hz)-

Duty Cycle-

Station Description / Additional Notes: upstream County Road 145, ≈200ft @ fast riffle upstream

- 2 meanders to logjam @ riffle

– Two Large Pools within station over 4' deep

Figure 69. Example fishes data field sheet (cover sheet, page 1).

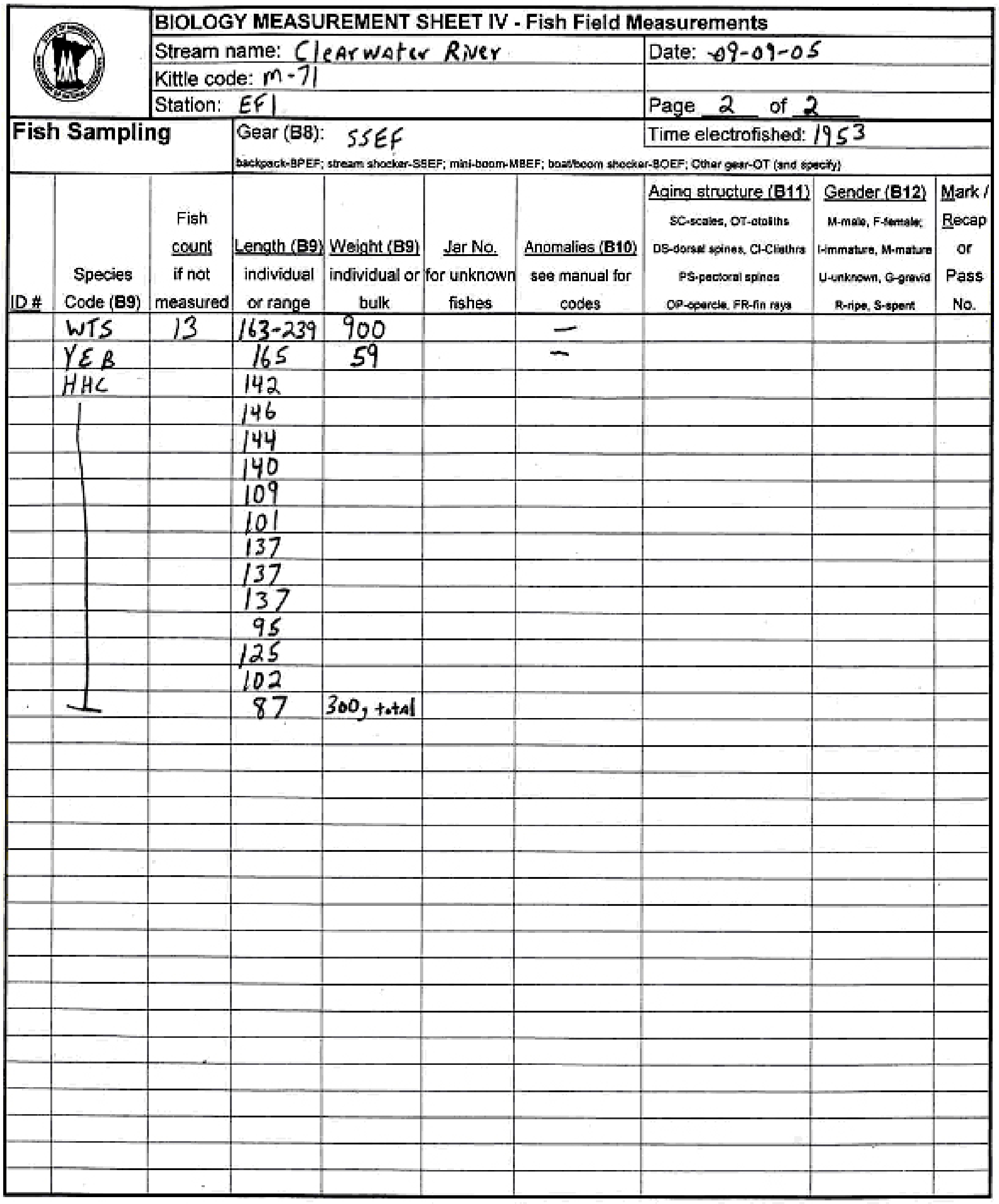
Start electrofishing at a shallow riffle or other physical barrier at the downstream end of the station, proceed upstream (but see variation for mini-boom shocker above), and end at a similar barrier on the upstream end of the station. In the absence of physical barriers, block nets may be placed at the downstream and upstream ends of the station before sampling. Attempt to capture all fish observed in the station.

Try hard to minimize handling mortality with approaches such as using aeration, quickly sorting fish into wet containers, and frequently replacing their water supply. Treat fish according to the guidelines adopted by the American Fisheries Society, American Institute of Fisheries Research Biologists, and American Society of Ichthyologists and Herpetologists (Use of Fishes in Research Committee 2004). Do not subject fish to excessive use of fish sampling gears. Always return unneeded fish to the water body if healthy. Fish kept and used in later analyses or that have been injured severely should be euthanized immediately after capture using an appropriate technique (Use of Fishes in Research Committee 2004).

Record the date and time fish sampling was started and finished on the Biology Measurement Sheet III – Fish Data – Cover Sheet (Figure 69) and, if desired, the actual number of minutes and seconds of time electrofished on the Biology Measurement Sheet IV – Fish Field Measurements (Figure 70).

Step 4. Identify and Enumerate Fishes (B9). Identify and record fishes on the Biology Measurement Sheet IV – Fish Field Measurements (Figure 70) using accepted American Fisheries Society common names (Nelson et al. 2004). Any abbreviations used should be consistent with species abbreviations in the latest version of the Minnesota DNR Manual of Instructions for Lake Survey. Accurate species-level identification of each fish collected (including hybrids) is essential. Taxonomic references for identification of fishes from Minnesota include Hatch and Schmidt (2004), Eddy and Underhill (1974), Phillips et al. (1982), Becker (1983), Page and Burr (1991), and Pflieger (1997). The latter is particularly useful in the identification of minnow and sucker species. Electronic versions of two of these keys are included on the accompanying CD, Appendix 9 (Becker 1983), and Appendix 10 (Eddy and Underhill 1974).

If you can’t identify a fish to species, send a sub-sample of specimens to the Division of Ecological Services for identification. Preserve specimens in 10% formalin and label each container with the following information: stream name, kittle number, station coordinates (GPS), date, gear used, and names of collectors.



BIOLOGY MEASUREMENT SHEET IV - Fish Field Measurements

Stream name: Clearwater River

Date: 09-09-05

Kittle code: M-71

Station: EF1

Page 2 of 2

Fish Sampling

Gear (B8): SSEF

Time electrofished: 1953

backpack-BPEF; stream shocker-SSEF; mini-boom-MBEF; boat/boom shocker-BOEF; Other gear-OT (and specify)

ID #	Species Code (B9)	Fish count if not measured	Length (B9) individual or range	Weight (B9) individual or bulk	Jar No. for unknown fishes	Anomalies (B10) see manual for codes	Aging structure (B11) SC-scales, OT-otoliths DS-dorsal spines, CI-Cliethra PS-pectoral spines OP-opercle, FR-fin rays	Gender (B12) M-male, F-female; I-immature, M-mature U-unknown, G-gravid R-ripe, S-spent	Mark / Recap or Pass No.
	WTS	13	163-239	900		–			
	YEB		165	59		–			
	HHC		142						
			146						
			144						
			140						
			109						
			101						
			137						
			137						
			137						
			95						
			125						
			102						
			87	300g total					

Figure 70. Example fishes data field sheet (page 2).

Voucher fish or species for verification and historical cataloging when their identification is unknown or if the species is unreported from the drainage basin. Preserve voucher specimens in 10% formalin and label them using museum grade archival paper and a formalin/alcohol-proof pen or pencil). The label should include the stream name, kittle number, site location, collection date, collectors' names, and some form of sample identification code. Send unknown or questionable specimens to the Bell Museum of Natural History for identification, verification, or cataloging. Contact the curator of fishes (612-624-6292 or fish@bellmuseum.org) for specific instructions.

The Bell Museum represents an indispensable resource for the identification and comparison of fish specimens. In addition to an extensive fish collection, the Bell Museum maintains a Web site with information on the distribution and ecology of native and introduced species (http://www.gen.umn.edu/research/fish/fishes/Default.htm). The MPCA Biomonitoring Unit also maintains a small reference collection in St. Paul.

Step 5. Measure and Weigh Species of Particular Interest (B9). Record game fish and other species of special interest on the Biology Measurement Sheet IV – Fish Field Measurements (Figure 70). Record individual lengths for all non young-of-the-year (YOY) game fish and for at least 50 YOY game fish (if captured) per station. Measure to the nearest millimeter the distance from the anterior-most part of the fish to the posterior-most tip of the caudal fin while it is being compressed. A length range will suffice for non-game fish, unless the objectives of the survey require more information.

Individual weights of all game fishes are required for five measured fish from each 10 mm length group up to 300 mm, and 10 fish from each 25 mm length group for all game fish over 300 mm. Take all weights in grams using appropriate scales with sufficient precision for the weight category. Batch weigh non-game fishes to the nearest gram. Individual weights of additional game fishes or non-game fishes are optional.

Step 6. Record Anomalies (B10). Record the total number and type of anomalies (deformations, tumors, discoloration, open sores, etc.) observed using the following anomaly codes: (AW)-anchor worm; (AR)-Argulus; (BT)-bass tapeworm; (BW)-bladder worm; (F)-fungus; (GP)-gill parasites; (I)-Ich; (L)-leeches; (LC)-lymphocystis; (LS)-lymphosarcoma; (M)-myofibrogranuloma; (N)-neascus; (OH)-open sores/hemorrhage; (SK)-skeletal deformities; (SL)-slime discoloration; (T)-tumors; (TR)-Triaenophorus; (YG)-yellow grub; (O)-other (describe in comments section). See Appendix 7 for further information about anomalies.

Step 7. Collect appropriate Ageing Structures from species of particular interest (B11). Age and growth determinations are optional and considered a supplemental survey. Specific protocols for collection of aging structures can be found in the supplemental survey part of this manual or in the latest version of the Minnesota DNR Manual of Instructions for Lake Survey. If structures are collected, they should be noted on the field sheet.

Step 8. Determine Sex and Stage of Maturity (B12). Record sex and stage of maturity for game fish when apparent. If game fish are sacrificed for aging purposes, determine sex and stage of maturity using internal observations. Record the sex code first, followed by the stage of maturity code (e.g., a gravid female would be recorded as “FG”).

Step 9. Release Fish. Immediately release back to the stream all fish still alive after processing.

Fish Population Indices. With these data, managers should be able to formulate numerous population indices; such as size structure indices (e.g., length-frequency, proportional stock density), catch-per-unit-effort estimates, and growth rates for species of management interest. Selection of specific indices is left to the discretion of area supervisors.

Step 10. Calculate an Index of Biotic Integrity Score. With only slight variations in the stream sampling protocols (MPCA 2004) normally employed by MNDNR Fisheries, data can be collected in a manner allowing for use in calculating an Index of Biotic Integrity (IBI) for streams. An IBI uses selected attributes of the aquatic species assemblage, termed metrics, to assess the overall health of the biological community. Each metric represents a quantifiable attribute of the biological assemblage that changes in a predictable way with varying levels of human influence. Metrics in a typical fish IBI fall into three broad categories: 1) species richness and composition, 2) trophic composition and reproductive function, and 3) fish abundance and condition. Most IBIs include one or more metrics from each of these categories.

A unitless score is assigned to each metric, quantifying how far any particular metric value deviates from a range of reference values. When these metric scores are summed, the resulting IBI score characterizes the biological integrity or health of a site (Karr et al. 1986). Examples of metrics used to calculate IBI scores for selected basins in Minnesota can be found in a series of IBI guidance documents available through the MPCA Biological Monitoring Unit (Bailey et al. 1994, Niemela et al. 1998, 1999; Niemela and Feist 2000, 2002).

A single, comprehensive IBI has not been developed for Minnesota’s wadeable streams, although several exist at the level of individual basins

(Table 9). Assessments of fish communities in all basins of the state are ongoing or have already been completed by the MPCA, DNR, and USGS. Upon completion of a statewide dataset and subsequent evaluation, a statewide IBI framework for wadeable streams will be developed.

Selected large (nonwadeable) rivers in Minnesota have been included in existing IBI assessments (Niemela and Feist 2000, 2002), although there are caveats associated with their application. A regional IBI for cold-water streams of the upper midwestern United States, including Minnesota, has been developed (Mundahl and Simon 1999). IBI development for the Mississippi River mainstem below the Twin Cities is ongoing (U.S. Environmental Protection Agency 2004). Other useful resources include the Wisconsin Warmwater IBI (Lyons et al. 2001).

To begin calculating an IBI score for a station, summarize the fish data from Biology Measurement Sheet IV – Fish Field Measurements after checking for errors and making sure all fish have been properly identified to species. Do not include fish less than 25 mm long. For each species, determine abundance, batch weight, and number of individuals with DELT. Next, select the appropriate IBI (Table 9) and assign species composition, trophic, and reproductive designations to each species, if appropriate, following the designations in the IBI selected. Follow the scoring protocols in the IBI selected for each metric and sum those metric values for an overall IBI score (see example below). Most published IBIs referenced in this manual provide some guides to interpreting your scores.

Example: A fish community sample was collected on the Clearwater River in late summer 2005 at station EF1. The Clearwater River is in Wright County and is a tributary of the Upper Mississippi River in central Minnesota. We selected the Upper Mississippi River IBI (Table 10) developed by Niemela and Feist (2002) for use in assessing this fish community. The Upper Mississippi River basin IBI has four options depending on the drainage area upstream from the study site: <5 mi^2*, 5 to 35 mi*^{2}*, 35 to 200 mi*^{2}*, and >200 mi*^{2}*. Based on the drainage area upstream from the study site, we selected the IBI for the 35 to 200 mi*^{2} *drainage area. Table 11 summarizes the fish species collected, their abundance, and appropriate species composition, trophic, and reproductive classifications*.

Table 9. Status of IBI development in the major river basins of Minnesota.

Basin Name	**Development Status**	**Reference**
Red River of the North	IBI development complete for Lake Agassiz Plain Ecoregion only. Full assessment beginning in 2005.	Niemela et al. (1998, 1999)
Rainy River	Full assessment beginning in 2005.	
Upper Mississippi River	IBI development complete.	Niemela and Feist (2002)
Lake Superior River	Stream assessment complete. No IBI developed.	
St. Croix River	IBI development complete.	Niemela and Feist (2000)
Minnesota River	IBI development complete.	Bailey et al. (1994)
Missouri River	Stream assessment complete. No IBI developed.	At present, suggest using Milewski et al. (2001)
Lower Mississippi River	Stream assessment complete. No IBI developed.	
Cedar River	Stream assessment complete. No IBI developed.	
Des Moines River	Stream assessment complete. No IBI developed.	
Coldwater streams throughout MN	IBI development complete.	Mundahl and Simon (1999)

Table 10. Example fish community data collected from the Clearwater River in late summer 2005 and designation of each species by composition, trophic status, and reproductive guild, where appropriate, for subsequent calculation of an IBI score. The site was sampled with a tote-barge stream shocker for 834 ft (254 m).

Species	Darter, sculpin, or madtom	Wetland sp.	Tolerant/ Intolerant	Trophic class	Repro.	Number captured
Common shiner					Sl[2]	1
Hornyhead chub			Int	Inv[1]		64
Longnose dace			Int	Inv	Sl	5
Creek chub			Tol			2
White sucker			Tol		Sl	17
Tadpole madtom	X	X		Inv		1
Yellow bullhead		X				2
Northern pike		X		Pi[3]		1
Green sunfish			Tol			2
Pumpkinseed				Inv		1
Largemouth bass				Pi		10
Total collected						106

[1] Invertivore feeder
[2] Simple lithophilous spawner
[3] Piscivore feeder

The Upper Mississippi River Basin IBI of Niemala and Feist (2002) uses 10 metrics to determine a score for a site. Based on tables 8 and 9, we can calculate the IBI score as follows:

Total number of species = 11 (score = 2)
Number of darter, sculpin, and madtom species = 1 (score = 2)
Number of wetland species = 3 (score = 10)
Number of intolerant species = 2 (score = 5)
Percent tolerant species 21/106 = 20% (score = 10)
Number of invertivore species = 4 (score = 5)
Number of piscivore species = 2 (score = 5)
Percent simple lithophilous spawners = 23/106 = 22% (score = 2)
Number of fish per 100 meters = (106–21 tolerant individuals =
85 fish/254 m = 0.33 fish/m = 33 fish/100 m (score = 10)
Percent DELT anomalies = 0 (score = 10)

Total score = 61

Table 11. Scoring criteria for the 10 metrics used to calculate an IBI score for streams with a drainage area between 35 mi2 and 200 mi2 in the Upper Mississippi River Basin of central Minnesota (from Niemala and Feist 2002).

	Scoring Criteria				
Metric	10	7	5	2	0
Species richness and composition metrics					
Total number of species	20 or more	16–19	12–15	8–11	0–7
Number of darter, sculpin, and madtom species	4 or more	3	2	**1**	0
Number of wetland species[1]	3 or more		1 or 2		0
Number of intolerant species	4 or more	3	2	1	0
Percent tolerant species	0–35	36–50	51–65	66–80	81–100
Trophic and reproductive metrics					
Number of invertivore species[1]	8 or more	6 or 7	4 or 5	2 or 3	0 or 1
Number of piscivore species	5 or more	4	2 or 3	1	0
Percent simple lithophils	61–100	46–60	31–45	16–30	0–15
Fish abundance and condition					
Number of fish per 100 meters[1]	5 or more				0
Percent DELT anomalies	0 or 1		2 or 3		4 or more

[1] does not include tolerant species

Supplemental Surveys

Water Quality

Water quality parameters that might be included in a supplemental survey are listed below. See pages 127–128 for collection and shipping instructions for water quality samples. If contaminants are suspected (e.g. mercury, other heavy metals, pesticides, fluorinated hydrocarbons, endomorphic inhibitors), contact the U. S. Environmental Protection Agency, MPCA, or Division of Ecological Services for additional advice.

Chlorophyll a (Periphyton).

Nitrogen. Nitrates, Nitrites, Ammonia, Organic Nitrogen.

Fecal Bacteria. Contact the Division of Ecological Services for sampling protocol.

Biochemical Oxygen Demand (BOD). Index of biochemical degradable organics present, determined by measuring oxygen consumed over a standard period of time. Most BOD is due to organically bound carbon compounds, but BOD also can include other oxygen-consuming forms such as sulfides, ferrous iron, and reduced forms of nitrogen (NO_2, NH_3). High BOD could indicate susceptibility to loss of dissolved oxygen, leading to possible fish kills.

Chloride. High levels may be indicative of sewage or road-salt runoff.

Dissolved Oxygen (DO). Critical to fish survival. Less than 2 ppm persisting for any length of time is usually fatal.

Mercury. Methyl mercury (MM) is generally found at very low levels in surface waters. Higher levels could indicate the presence of an industrial source of mercury nearby or old residues from some earlier pollution. MM can enter food chain and lead to high levels of mercury in upper trophic stages of the fishery.

pH. This is the level of hydrogen ion activity; unusually high or low levels could be due to any number of causes. Sudden significant changes in pH can be detrimental to fish and other aquatic life.

Sulfate. Typically higher in mineralized waters of western Minnesota. Wild rice grows best in waters with sulphate/iron concentrations of less than 10 ppm.

Temperature. Unusually hot or cold temperatures could indicate runoff from some nearby industrial or other human activity.

Total Alkalinity (TA). This is a measurement of the ability of water to resist acidification, which is essentially a measurement of carbonates, bicarbonates, and (in very high pH water) hydroxides. It is generally a fairly stable parameter except in very poorly buffered waters.

Total Dissolved Solids (TDS), Conductivity. High TDS values are found in association with fertile and productive waters for fish.

Total Nitrogen (TN). Total nitrogen includes dissolved nitrogen (ammonia and nitrite), plus organic nitrogen. High levels of ammonia or organic nitrogen could be an indicator of pollution such as sewage. It may occasionally be the limiting nutrient for algal growth if phosphorus levels are high.

Total Phosphorus (TP). Usually the limiting nutrient that determines productivity in an aquatic environment. High TP can stimulate growth of algae in nuisance quantities. High levels of orthophosphorus may indicate fertilizer or animal waste runoff.

Biology Surveys

Riparian Vegetation. Qualitative assessment of riparian vegetation within the delineated riparian ecotone area will follow categories and methodology in Rosgen (1996) (Table 12). There are 12 categories of riparian vegetation, each with one to three abundance groups. One person should record the abundance group for each type of riparian vegetation category present. If a riparian vegetation category is not present, leave it blank. Assess left and right banks independently.

Table 12. Summary categories used to describe vegetation patterns in riparian areas along Minnesota streams, after Rosgen (1996).
© Wildland Hydrology

Summary Category		***Density***	***Code***
1.	Bare		RV 1
2.	Forbs only	Low density Moderate density	2a 2b
3.	Annual grass with forbs	Low density Moderate density High density	3a 3b 3c
4.	Perennial grass	Low density Moderate density High density	4a 4b 4c
5.	Rhizomatous grasses (bluegrass, grasslike plants, sedges, rushes)	Low density Moderate density High density	5a 5b 5c
6.	Low brush	Low density Moderate density High density	6a 6b 6c
7.	High brush	Low density Moderate density High density	7a 7b 7c
8.	Combination grass/brush	Low density Moderate density High density	8a 8b 8c
9.	Deciduous overstory	Low density Moderate density High density	9a 9b 9c
10.	Deciduous with brush / grass understory	Low density Moderate density High density	10a 10b 10c
11.	Perennial overstory	Low density Moderate density High density	11a 11b 11c
12.	Wetland vegetation community	 Bog Fen Marsh	12a 12b 12c RV 12d

Table 13. Example summary of riparian zone characteristics, from two stations on Trout Run Creek (M-009-029), Fillmore County, MN, summer 2006 survey.

	Station			
	2.50		4.46	
Variable	Left bank	Right bank	Left bank	Right bank
RIPARIAN ZONE				
Ecotone area width (m)				
Buffer width (m)				
Riparian land use (%)				
Cropland	0	0	0	0
Pasture	0	0	100	0
Barnyard	0	0	0	0
Developed	10	0	0	0
Exposed rock	0	0	0	0
Meadow	0	20	0	0
Shrub	0	60	0	20
Woodland	10	20	0	80
Wetland	80	0	0	0
Other (specify)	0	0	0	0

Table 14. Aquatic plant survey (presence/absence) for stations on Trout Run Creek (M-009-029), Fillmore County, MN, summer 2006. A=abundant, C=common, O=occasional, R=rare

	Station (river miles from mouth)						
Aquatic plant	11.90	10.21	8.63	7.35	4.46	2.50	0.98
Water cress (*Rorippa nasturtium-aquaticum*)	O	C	R	-	O	O	O
Curly-leafed Pondweed (*Potamogeton crispus*)	-	O	O	A	C	C	O
Horned Pondweed (*Zannichellia palustris*)	A	-	R	-	C	O	O
Water Buttercup (*Ranunculus* sp.)	-	O	A	A	O	A	A
Common waterweed (*Elodea canadensis*)	-	-	-	A	R	O	-
American Brooklime (*Veronica americana*)	A	A	R	O	O	C	-
Spotted Touch-me-not (*Impatiens capensis*)	A	-	-	A	O	A	R
Algae	-	O	-	A	O	-	-
Small duckweed (*Lemna minor*)	-	-	-	-	-	C	-
Reed Canary (*Phalaris arundinacea*)	C	-	O	-	-	-	R

Fish Aging

Collect appropriate aging structures from at least five (preferably 10) fish from each 10 mm length group whenever possible for fish <300 mm. For fish >300 mm, collect scales from 10 or more fish from each 25 mm group, if possible. Otoliths, scales, fin rays, cleithrum, or operculum are some of the typical structures collected for age information (see Table 15). The structure collected depends on the needs of the inventory and the characteristics of the species. Use aging structures that do not require sacrificing fish, especially when sensitive populations are involved. Field guidelines for specific structures are listed below.

Table 15. Recommended hard part body structures to use for aging selected fishes.

Structure (Code)	**Species**
Scales (SC)	All species
Otoliths (OT)	Walleye, crappie, bluegill, largemouth and smallmouth bass, lake trout, catfish
Dorsal spines (DS)	Walleye
Pectoral spines (PS)	Sturgeon, catfish
Cliethra (CL)	Northern pike, muskellunge
Fin rays (FR)	Trout, salmon
Opercle (OP)	Yellow perch, walleye, largemouth and smallmouth bass

Scales. Scale samples are taken from different locations on the body in different species. For salmonids, remove scales from the area between the posterior edge of the dorsal fin and the lateral line, approximately two scale rows above the lateral line on the left side of the fish. Before sampling scales, clear away dirt and excess mucilage from the area to be sampled. Remove scales by scraping them away from the skin with the blade of a clean knife or with small forceps. Collect enough scales to ensure that several readable scales are obtained. Air-drying is sufficient for preservation of scales, especially if scales will be analyzed soon after collection. However, if left too long, scales can turn cloudy, obscuring circulii. Scales can be frozen for long-term preservation. Scales from old fish can be difficult to interpret, so fin rays and otoliths (in special cases) are preferred structures for aging these fishes.

Fin Rays and Spines. To remove fin rays, use scissors or a sharp knife to cut perpendicular to the length of the ray or spine. Cut close to the body (except for sturgeon, where the cut must be made approximately 5 mm from the fin articulation to avoid cutting the fin artery) to ensure that all annuli will be present in the removed fin ray. Using a scalpel or scissors, separate the ray from the remainder of the fin by carefully cutting through the skin between the rays. Generally fin rays are taken from the left pelvic fin. For catfish, pectoral spines can be removed by holding the spine in the relaxed position (next to the body) then rotating towards the top of the head until the spine becomes dislocated. By progressively rotating the spine, the entire spine and the articulation process can be removed. Occasionally, with larger individuals, a scalpel or scissors should be used to separate the skin and fin from the spine. Clean fin rays and spines in distilled water and air-dry. Freeze for long-term storage.

Otoliths. Otoliths (ear stones) are harder to collect than scales. Otoliths collection requires killing the fish and should be performed when non-lethal methods cannot be employed or are insufficient. Otoliths are collected by removing the gills and breaking the bone that connects to the spinal column (see http://cbl.umces.edu/~secor/otolith-manual.html). More references on otoliths can be found at http://life.bio.sunysb.edu/ee/seatrout/otolith_references.html.

Once it is exposed, carefully remove the otolith with fine forceps to prevent breakage. After drying, otoliths can be stored in a labeled scale envelope or in a labeled vial containing a solution of glycerin, glycerin/water, or glycerin/alcohol. Glycerin has a mild clearing effect on the otoliths making them easier to read. Do not use formalin to preserve otoliths or fish from which otoliths may later be taken.

Cleithra and Opercular Bones. Cleithra and opercular bones are structures that can be useful for aging northern pike, walleye, or perch. The procedure requires killing the fish. The operculum is easily removed with dissecting scissors and cutting along the anterior border of the gill cover. The cleithrum is a bony structure that supports the posterior border of the gill cavity and is usually covered by the posterior portion of the gill cover. Expose the cleithrum by lifting the gill cover. Push the thumb between the posterior edge of the cleithrum and the muscle and connective tissue. Separate the inner surface of the cleithrum from the underlying soft tissue. Move the thumb along the inner surface of the cleithrum dorsally toward the posterior end of the cleithrum to loosen the bone. Push the thumb or index finger through the connective tissues at the anterior end of the cleithrum and pull away from its dorsal joining point. When the dorsal tip of the cleithrum has been released, grasp it between the thumb and index finger and pull out from the body toward the front, exposing the anterior tip. Clean the cleithrum in hot water to remove excess tissue and oils and allow it to air dry for several days. After drying, the cleithrum should be read within two weeks. If left too long, cleithra turn opaque, making it difficult to discern annuli.

Fish Sampling

Numerous alternative collection gears can be used to samples fishes in special situations or habitats.

Pre-positioned Area Electrofisher (PAE). PAEs can be used to estimate fish abundance by specific habitat types. PAEs can be placed in varying habitats and activated for times designated by the sampling crew. Try to activate consistently so samples can be compared. For each sample, the PAE should be in place and undisturbed for at least 15 minutes. After 15 minutes, two crewmembers should position themselves downstream of the PAE with a seine or dip nets. Typical on times are variable, however, 20–50 seconds has been used with success. Try to capture all individuals present. Station replication has also varied; however, 10 to 20 samples within 180 m have been reported (Bowen and Freeman 1998).

Seines. Seining may be used to help determine species diversity. Refer to MNDNR (1993) for further instructions.

Minnow Traps. The most commonly used minnow traps are ¼-in wire-mesh cylindrical traps. They are commonly 18 in long and 8 in diameter, with entrance holes at both ends. They are sometimes baited with pieces of bread, meal, fish eggs, or even vegetation, depending on the target species. Set time is commonly 24 hours.

Trotlines or Set Lines. Trotlines can be used in rivers with species that respond well to baited hooks (catfish and sturgeon). Arterburn and Berry (2002) suggest that larger catfish can be effectively sampled with the use of trotlines. Trotlines can be constructed or purchased and modified to have 13.2 m main lines, 136.0 kg test twine, and 2.0 m tie-off lines (used to attach trotlines to bank vegetation or large woody debris). Ten dropper lines, each 30.5 cm and made of 81.6 kg test twine or monofilament spaced 1.2 m apart, are attached to each trotline with 3/0 barrel swivels at both ends. Bait either 3/0 O'Shaughnessy or modified circle hooks with bait appropriate to the selected species (e.g., worms for sturgeon, cut sucker for channel catfish, live bullhead for flathead catfish). Bait choices and hook sizes can vary depending on the species of interest. Trot lines are typically set by attaching one end to a fixed object (usually woody debris near shore), stretching them downstream at approximately a 45° angle from the point of origin, and weighting them with an anchor on the downstream end. Sets are typically placed overnight and catch information is characterized by number of fish/hook-day. Several trotlines have been used in areas where electrofishing has also taken place to sample larger individuals in a given reach. See Appendix 8 for a description of methods used to sample the Minnesota River in southwestern Minnesota.

Limb Lines/Yo-yo. Limb lines and yo-yo style automatic reels can be effective ways to sample, very much like set lines or trotlines. Short lines, typically near some form of specific habitat, are baited and left overnight. Mechanical devices such as yo-yo reels aid in setting the hook on the fish. Effort and catch rates are expressed in hook-days and number of fish/hook-day, respectively.

Snorkeling. Snorkeling can be used in clear streams as a supplement to electrofishing with some success. However, a defined objective of identifying a select few species may be necessary to avoid confusion. Methods for snorkeling have varied considerably in the literature from sampling large streams (85 m, Mullner et al. 1998) to sampling in streams less than 10 m (Schill and Griffith 1984). In large systems observers were positioned using a length of flexible PVC tubing with designated markers indicating site lanes. The observer line floated downstream with 5 to 11 individuals counting fish. Observers were “calibrated” to recognize size and species of fish common to that stream at a set distance relative to water clarity. Most snorkel sampling has been performed during daylight hours between 1000 and 1530. For smaller streams an individual snorkeled all reaches by slowly swimming upstream through the reach in a zigzag pattern. Typically, observers are “calibrated” to recognize size groups of a select few species, and fish are identified, counted, and placed in size groups.

Angling. Consider angling if presence/absence information is needed. In some cases, mostly due to habitat complexity, angling may be an alternative to capture select species. Record effort in person-hours and bait types to aid in repeatability.

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Contents of Appendices

Contents of Appendices 174

Appendix 1. Blank field forms 175

1. Hydrology field forms 175
2. Geomorphology and fish cover field forms 180
3. Water quality field forms 206
4. Biology field forms 214
5. Miscellaneous field forms 224

Appendix 2. Table for translating USGS Hydrologic Units and Minnesota DNR Major Watershed numbers 230

Appendix 3. Minnesota Stream Identification System (Kittle Number) 234

Appendix 4. Guidelines for the Selection and Safe Use of Electrofishing Gear 242

Electronic Appendices. Additional appendices are contained on the CD accompanying this manual.

Appendix 5. Stream Reach Inventory and Channel Stability Evaluation: A Watershed Management Procedure (Pfankuch 1975).

Appendix 6. Stream Channel Reference Sites: An Illustrated Guide to Field Technique (Harrelson et. al. 1994).

Appendix 7. Introduction to Common Fish Diseases.

Appendix 8. Trot Line Use.

Appendix 9. Key to Fishes of Wisconsin (Becker 1983).

Appendix 10. Artificial Key to the Families of Fishes in Minnesota (Eddy and Underhill (1974).

1. Hydrology Field Forms

1. Discharge measurement form
2. Spring data field sheet

Discharge Measurement Form

Stream name:

Kittle number:

Crew:

Survey Date:

Station Name:

Longitudinal Profile:

River Mile:

Station length (ft):

Station wetted width (ft)

Station Coordinates:

Downstream

(UTM, Zone 15)

X:

Y:

Coordinate Source:

Streamflow conditions:

Distance from left bank (ft or m)	**Water depth (ft:m)**	**Water velocity (ft/s or m/s)**	**Cell width (ft or m)**	**Cell area (ft2 or m2)**	**Cell discharge (ft3/s or m3/s)**	**Notes**

SPRING DATA FIELD SHEET

STREAM SURVEY:

Stream Name:

Kittle Number:

Survey Date:

Crew Names:

Area Office:

Spring Location Information

Spring Name:

County

Sample Date:

Distance from stream (ft.):

GPS Coordinates (UTM, Zone 15) X: Y:

Coordinate Source:

Legal Description (T-R-S):

Landowner information (Name, address, telephone number):

Spring Physical and Chemical Parameters

Elevation (ft. above sea level):

pH:

Spring Water Temperature (°F):

Dissolved Oxygen (ppm):

Air Temperature (°F):

Turbidity:

Spring flow (c.f.s):

Flow method:

Spring Description, additional field information (attach digital photographs if possible).

Mail a copy to:

Groundwater Hydrologist
DNR Waters
2300 Silver Creek Road
Rochester, MN 55906
(jeff.green@dnr.state.mn.us)

2. Geomorphology and Fish Habitat Field Forms

1. Cross-section Recording Sheet
2. Longitudinal Profile Recording Sheet
3. Pebble Count Recording Sheet
4. Cover for Larger Fishes
5. Morphological Description Summary Sheet
6. Stream Condition Assessment (1 of 2)
   Stream Condition Assessment (2 of 2)
7. Channel Stability Evaluation Individual Station field Form
   Page 2 - Table for Conversion of Stability Rating to Reach Condition by Stream Type
8. Pfankuch Form Codes (for use with Channel Stability Evaluation form)
9. Bank Erosion Hazard Index (BEHI) Variable Field Sheet
   BEHI Variable field sheet (page 2), streambank erodibility variables
10. Estimating Near Bank Shear Stress (NBS) Field Form
11. Annual Streambank Erosion Estimates / Calculations Summary Form
12. Minnesota Stream Habitat Assessment (MSHA; 1 of 2)
    Minnesota Stream Habitat Assessment (MSHA; 2 of 2)

Cross-section Recording Sheet

Minnesota DNR Page _____ of _____

Survey Date: Note: start cross section on river lieft, 0 point above floodprone.

Stream Name and Kittle No.: River mile:

Specific Reach Location: UTM Easting:

Crew Names: UTM Northing:

XSection ID (#) from Longitudinal Sheet:_______ Station Location on Longitudinal Profile:_______ Note: take HI from Longitudinal sheet when you get to the X section station.

Distance (ft)	BS (ft)	HI (ft)	FS (ft)	Elevation (ft)	Notes

Distance (ft)	BS (ft)	HI (ft)	FS (ft)	Elevation (ft)	Notes

Longitudinal Recording Sheet Minnesota DNR Page _____ of ______

Survey Date:

Stream Name and Kittle No: River Mile:

Specific Reach Location: UTM Easting:

Crew Name: UTM Northing:

Setup laser tripod on a high spot		bed feature	**check 1**		Benchmark Elevation			HI		**check 1**					
to see a long river reach including	cross				1st set	100	BM elev	minus		| depth		user defined			
Xsec & upstream start of longitudinal	section		increm't.	contin'us	Turning Points			FS	FS	| FS	FS	FS	FS	FS	azimuth
notes	ID		distance	station	BS	HI	FS	equal	bed	water	bankfull				AZ
2cnd record BS to BM >>>>	3rd calc. height instr:HI = BM+BS						☒	Elev.	4th record FS unless water surface is recorded as depth						5th rcd AZ
															from last pt

Pebble Count Recording Sheet

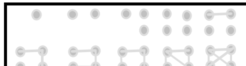
Minnesota DNR Page _____ of _____

Survey Date:

Stream Name and Kittle No.: River mile:

Specific Reach Location: UTM Easting:

Crew Name: UTM Northing:



A reach is 2 meander wave lengths or 20 - 30 bkf widths		Bankfull elevation to bankfull elevation pebble counts							bed, bank, patch, etc.	
Pebble Count Options		Zigzag	Proportional transects Perpendicular to the bank 100 total					Classification	User defined	
dot-tally pattern, succession is 1 - 10		at least 100	%	%	%	%	100%	Riffle		
		Total Reach	Riffle	Run	Pool	Glide	Total Reach	at least 100		
Material	Size Range (mm)	Count	Count	Count	Count	Count	Count	Count	Count	Count
silt/clay	0 - 0.062									
very fine sand	0.062 - 0.125									
fine sand	0.125 - 0.25									
medium sand	0.25 - 0.5									
coarse sand	0.5 - 1									
very coarse sand	1 - 2									
very fine gravel	2 - 4									
fine gravel	4 - 6									
fine gravel	6 - 8									
medium gravel	8 - 11									
medium gravel	11 - 16									
coarse gravel	16 - 22									
coarse gravel	22 - 32									
very coarse gravel	32 - 45									
very coarse gravel	45 - 64									
small cobble	64 - 90									
medium cobble	90 - 128									
large cobble	128 - 180									
very large cobble	180 - 256									
small boulder	256 - 362									
small boulder	362 - 512									
medium boulder	512 - 1024									
large boulder	1024 - 2048									
very large boulder	2048 - 4096									
	total particle count:									
Note: Only particles are used in the pebble graph										
bedrock	-------------									
clay hardpan	-------------									
detritus/wood	-------------									
artificial	-------------									
Other material (above) are used	**total count:**									
in the percentages(%sand, %gravel, %wood, etc.)										
Notes:										

STREAM SURVEY

Page ___ of ___

COVER FOR LARGER FISHES

Stream name:
Kittle Number:
Crew:
Survey Date:

Station Name:
Station ID code:
River Mile:
Station length (ft):
Station wetted width (ft)

Station Coordinates: **Downstream** **Upstream**
(UTM, Zone 15) X: Y: X: Y:
Coordinate Source:
Location (T-R-S):

Cover Item Type	Cover Item Length (__. __ ft)	Cover Item Width (__. __ ft)	Mesohabitat Type	Comments

STREAM SURVEY

Morphological Description
Summary Sheet

Stream Name:		**Kittle Number:**		
Crew:		Survey Date:		
Station Name:	**Station ID Number:**		River Mile:	
Station length (ft.)	Station wetted width (ft):			
Station Coordinates	**Downstream**		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:
Coordinate Source:		Location (T - R - S)		

Channel Dimensions

Width at bankfull stage (BFW)	____________	ft.
Cross-section area (A)	____________	ft^2
Mean depth at bankfull stage (D)	____________	ft.
Width:Depth ratio (BFW/D)	____________	
Maximum depth at bankfull stage (MaxD)	____________	ft.
Floodprone area width (FPW)	____________	ft.
Entrenchment ratio (FPW / BFW)	____________	

Channel Dimensions

Length of surveyed reach (L)	____________	ft.
Water Surface elev. Difference (WED)	____________	ft.
Thalweg elevation difference (TED)	____________	ft.
Station water surface slope (WED/L)	____________	
Station thalweg slope (TED/L)	____________	
Average pool slope	____________	
Average riffle slope	____________	
Average run slope	____________	
Average glide slope	____________	
Average cascade slope	____________	

Bed feature (mesohabitat) composition

% pool	____________
% riffle	____________
% run	____________
% glide	____________
% cascade	____________

Channel Pattern

Sinuosity	____________	ft.
Meander length	____________	ft.
Meander belt width	____________	ft.
Radius of curvature	____________	ft.

Channel Substrate Composition

% Silt / Clay	____________	%
% Sand	____________	%
% Gravel	____________	%
% Cobble	____________	%
% Boulder	____________	%
% Bedrock	____________	%
D50 (mm)	____________	
D84 (mm)	____________	

Substrate Composition by Mesohabitat Type (%)

	Pool	Riffle	Run	Glide	Cascade
Silt/Clay	____	____	____	____	____
Sand	____	____	____	____	____
Gravel	____	____	____	____	____
Cobble	____	____	____	____	____
Boulder	____	____	____	____	____
Bedrock	____	____	____	____	____

Stream Classification ____________

STREAM SURVEY

Page ___ of ___

STREAM CONDITION ASSESSMENT (1 of 2)

Stream name:

Kittle number:

Crew:

Survey Date:

Station Name:

Station ID code:

River Mile:

Station length (ft):

Station wetted width (ft)

Station Coordinates:

Downstream

(UTM, Zone 15)

X:

Y:

Coordinate Source:

Location (T-R-S):

Stream Size (circle one)

Category	Description
S-1	Bankfull width less than 0.305 m (1 ft)
S-2	Bankfull width 0.31 -.5 m (1-5 ft)
S-3	Bankfull width 1.5 - 4.6 m (5-15 ft)
S-4	Bankfull width 4.6 - 9.0 m (15-30 ft)
S-5	Bankfull width 9.0 - 15.0 m (30-50 ft)
S-6	Bankfull width 15.0 - 22.8 m (50-75 ft)
S-7	Bankfull width 22.8 - 30.5 m (75-100 ft)
S-8	Bankfull width 30.5 - 46.0 m (100-150 ft)
S-9	Bankfull width 46.0 - 76.0 m (150-250 ft)
S-10	Bankfull width 76.0 - 107.0 m (250-350 ft)
S-11	Bankfull width 107.0 - 150.0 m (350-500 ft)
S-12	Bankfull width 150.0 - 305.0 m (500-1,000 ft)

Flow Regime (circle one of each)

Category	Description
E.	Ephemeral streams
S.	Subterranean stream channel
I.	Intermittent stream channel
P.	Perennial stream channel
Specific Category	
1	Seasonal flow variation dominated by snowmelt.
2	Seasonal flow variation dominated by stormflow.
3	Uniform stage due to spring flow backwater, etc.
4	Ice flows, ice torrents from ice dam breaches
5	Regulated stream flow due to diversions, dams,etc.
6	Altered due to development, such as urban streams or vegetation conversions that changes flow responses to precipitation events

Meander Pattern (circle one)

Category	Description
M-1	Regular meander
M-2	Tortuous meander
M-3	Irregular meander
M-4	Truncated meanders
M-5	Unconfined meander scrolls
M-6	Confined meander scrolls
M-7	Distorted meander loops
M-8	Irregular with oxbows, oxbow cutoffs

Depositional Features (circle one)

Category	Description
B-1	Point bars
B-2	Point bars with few mid-channel bars
B-3	Many mid-channel bars
B-4	Side bars
B-5	Diagonal bars
B-6	Main branching with many mid-channel bars and islands
B-7	Mixed side-bar and mid-channel bars exceeding 2-3X width
B-8	Delta bars

STREAM SURVEY

Page ___ of ___

STREAM CONDITION ASSESSMENT (2 of 2)

Stream name:
Kittle number:
Crew:
Survey Date:

Station Name:
Station ID code:
River Mile:
Station length (ft):
Station wetted width (ft)

Station Coordinates:
Downstream
(UTM, Zone 15)
X:
Y:
Coordinate Source:
Location (T-R-S):

Stream Channel Debris/Blockages

Category	Extent	Material Description
D1	None	Minor amounts of small, floatable material
D2	Infrequent	Debris consists of small. Easily moved. Floatable material (e.g., leaves, twigs)
D3	Moderate	Increasing frequency of small to medium sized material such as large limbs, branches, and small logs that when accumulated affect 10% or less of the active channel cross-sectional area.
D4	Numerous	Significant build-up of medium to large sized materials such as large limbs, branches, small logs or portions of trees that may occupy 10 to 30% of the active channel cross-section area.
D5	Extensive	Debris “dams” of predominantly larger materials such as branches, logs, trees, occupying 30 to 50% of the active channel cross-section, often extending across the width of the active channel.
D6	Dominating	Large, somewhat continuous debris “dams”, extensive in nature and occupying over 50% of the active channel cross-section.
D7	Beaver Dams – few	An infrequent number of dams spaced such that normal streamflow and ezpect3ed channel conditions exist in the reaches between dams.
D8	Beaver Dams – frequent	Dam frequency is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.
D9	Beaver Dams – abandoned	Numerous abandoned dams many of which have filled with sediment and/or breached initiating a series of channel adjustments such as bank erosion, lateral migration, evulsion, aggradation or degradation.
D10	Human Influences	Structures, facilities, or materials related to land uses or development located within the floodprone area such as diversions, low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime such that significant channel adjustments occur.

STREAM SURVEY

Channel Stability Evaluation

Individual Station Field Form

Stream Name: **Kittle Number:**

Crew: Survey Date:

Station Name: **Station ID Number:** River Mile:

Station length (ft.) Station wetted width (ft):

Station Coordinates **Downstream** **Upstream**

(UTM, Zone 15) X: Y: X: Y:

Coordinate Source: Location (T - R - S):

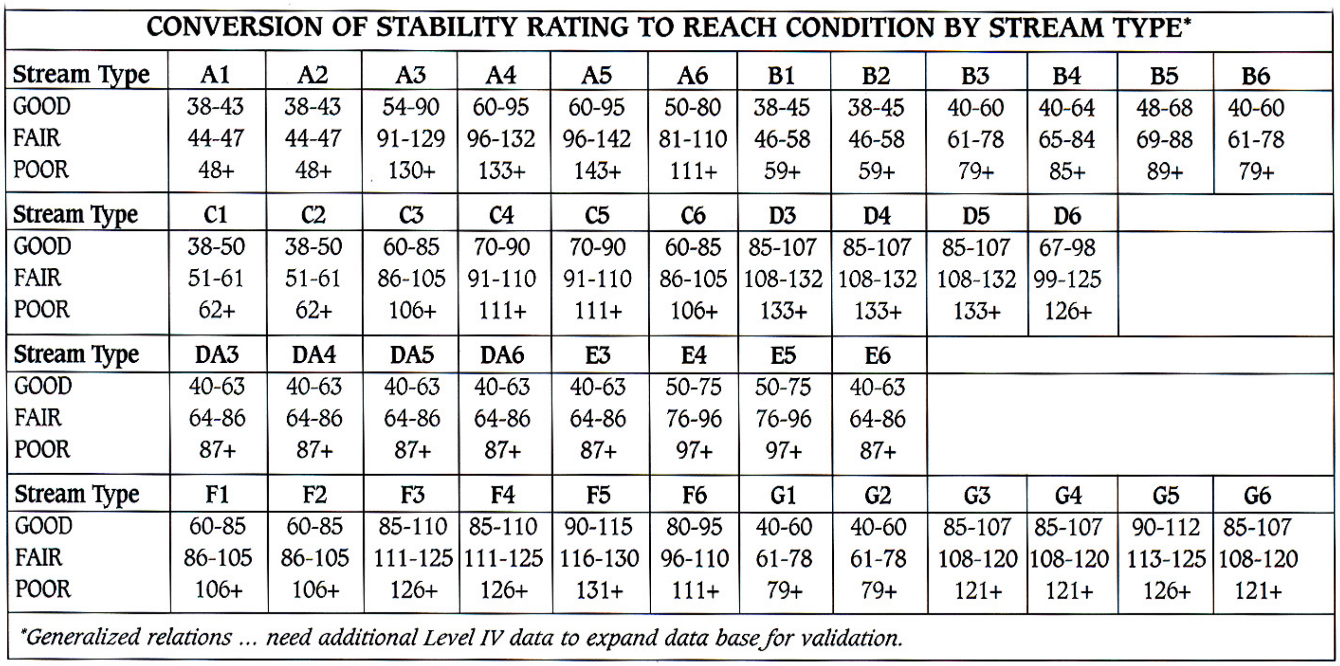
			Rating Score			
	Category		**Excellent**	**Good**	**Fair**	**Poor**
Upper Banks	1	Landform Slope	2	4	6	8
	2	Mass Wasting	3	6	9	12
	3	Debris Jam Potential	2	4	6	8
	4	Vegetative Bank Protection	3	6	9	12
Lower Banks	5	Channel Capacity	1	2	3	4
	6	Bank Rock Content	2	4	6	8
	7	Obstruction to Flow	2	4	6	8
	8	Cutting	4	8	12	16
	9	Deposition	4	8	12	16
Stream Bottom	10	Rock Angularity	1	2	3	4
	11	Brightness	1	2	3	4
	12	Consolidation of Particles	2	4	6	8
	13	Bottom Size Distribution	4	8	12	16
	14	Scouring and Deposition	6	12	18	24
	15	Aquatic Vegetation	1	2	3	4
		Column Totals:				

Grand Total:

Stream Type:

Station Condition Adjusted for Stream Type:

Channel Stability Evaluation Individual Station Field Form – Page 2



CONVERSION OF STABILITY RATING TO REACH CONDITION BY STREAM TYPE*

Stream Type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
GOOD	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60
FAIR	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78
POOR	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+
Stream Type	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**		
GOOD	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98		
FAIR	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125		
POOR	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+		
Stream Type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**				
GOOD	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63				
FAIR	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86				
POOR	87+	87+	87+	87+	87+	97+	97+	87+				
Stream Type	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
GOOD	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
FAIR	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
POOR	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

**Generalized relations ... need additional Level IV data to expand data base for validation.*

Channel stability Evaluation (Pfankuch, 1975)

Stream: **Location:** **Valley Type:** **Observers:** **Date:**

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species & less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water, too.	1	Common. Algae forms in low velocity and pool areas. Moss here, too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =		**Good total =**		**Fair total =**		**Poor total =**	

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable)	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	
Existing stream type =	
***Potential stream type =**	
Modified channel stability rating =	

From Rosgen (2006) as modified from Pfankuch (1975), © Wildland Hydrology

*Rating should be adjusted to potential stream type, not existing.

Minnesota
DEPARTMENT OF NATURAL RESOURCES

STREAM SURVEY

Bank Erosion Hazard Index (BEHI) Variable Field Sheet

Stream Name:		**Kittle Number:**		
Crew:		Survey Date:		
Station Name:	**Station ID Number:**		**River Mile:**	
Station length (ft.)	Station wetted width (ft):			
Station Coordinates	**Downstream**		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:
Coordinate Source:		Location (T - R - S)		

BEHI Score

Bank Height / Max Depth Bankfull (C)

Study Bank Height (ft) =	(A)	Bankfull Height (ft) =	(B)	(A) / (B) =	(C)	

Root Depth / Bank Height (E)

Root Depth (ft) =	(D)	Study Bank Height (ft) =	(A)	(D) / (A) =	(E)	

Weighted Root Density (G)

Root Density as % =	(F)	(F) x (E) =	(G)	

Bank Angle (H)

Bank Angle as degrees =	(H)	

Surface Protection (I)

Surface Protection as % =	(I)	

Bank Material Adjustment

Bedrock (Overall Very Low BEHI)

Boulders (Overall Low BEHI

Cobble (Substract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt Clay (no adjustment)

Bank Materials Adjustment

Stratification Adjustment

Add 5-10 points, depending on Position of unstable layers in relation to bankfull slope

Very Low	Low	Moderate	High	Very High	Extreme
5 - 9.5	10 - 19.5	20 - 29.5	30 - 39.5	40 - 45	46 - 50

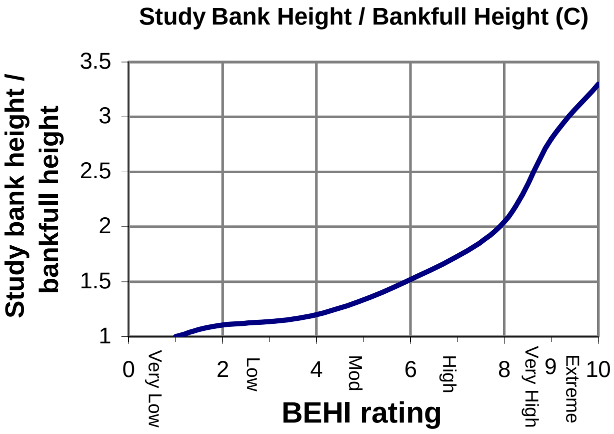
ADJECTIVE RATING

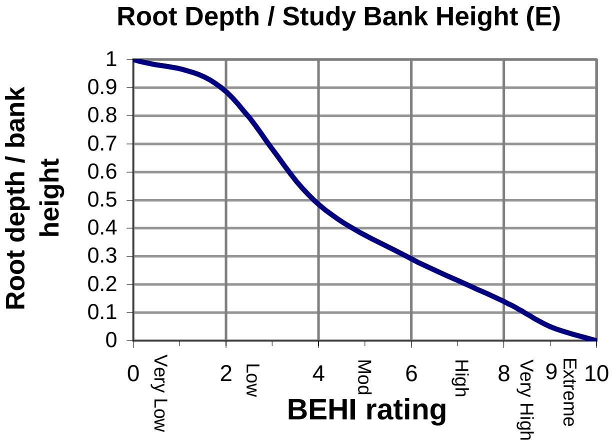
and

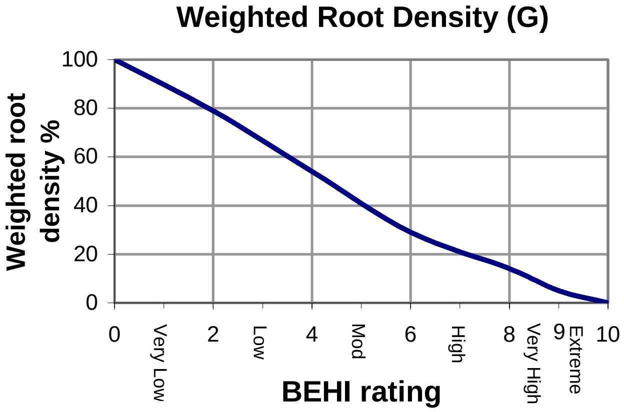
TOTAL SCORE

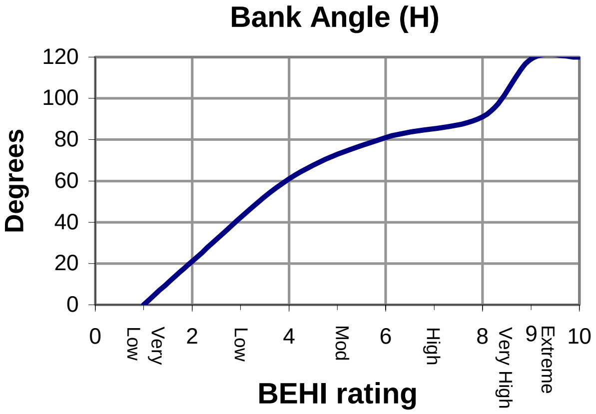
Bank Erosion Hazard Index (BEHI)
Variable Field Sheet (page 2)

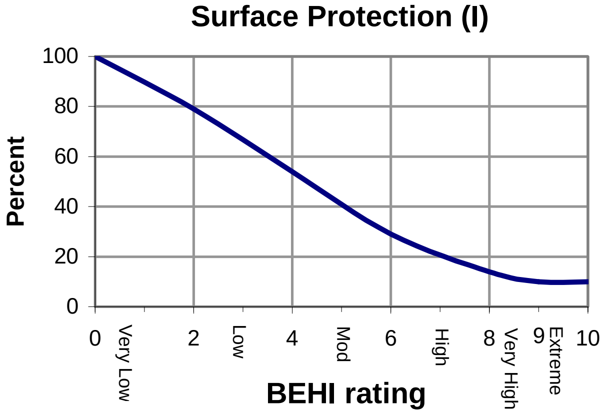
STREAMBANK ERODIBILITY VARIABLES











STREAM SURVEY

Estimating Near-Bank Stress (NBS) Field Sheet

Stream Name: **Kittle Number:**
Crew: Survey Date:
Station Name: **Station ID Number:** River Mile:
Station length (ft.) Station wetted width (ft):
Station Coordinates **Downstream** **Upstream**
(UTM, Zone 15) X: Y: X: Y:
Coordinate Source: Location (T - R - S)

METHODS FOR ESTIMATING NEAR-BANK STRESS

(1) Tranverse bar or split channel/central bar creating NBS/high velocity gradient	Level I	Reconaissance
(2) Ratio of radius of curvature to bankfull width (R_c/W_{bkf})	Level II	General Prediction
(3) Ratio of pool slope to average water surface slope (S_p / S)	Level II	General Prediction
(4) Ratio of pool slope to riffle slope (S_p / S_{rif})	Level II	General Prediction
(5) Ratio of near-bank maximum depth to bankfull mean depth (d_{nb} / d_{bkf})	Level III	Detailed Prediction
(6) Ratio of near-bank shear stress to bankfull shear stress (t_{nb} / t_{bkf})	Level III	Detailed Prediction
(7) Velocity of profiles / Isovels / Velocity gradient	Level IV	Validation

Level I	(1)	Transverse and/or central bars-short and/or discontinuous	NBS - High / Very High
		Extensive deposition (continous, cross-channel)	NBS = Extreme
		Chute cutoffs, down-valley meander migration, converging flow (NBS #1)	NBS = Extreme

Level II	(2)	Radius of Curvature R_c (feet)	Bankfull Width W_{bkf} (feet)	Ratio R_c / W	Near-Bank Stress NBS
	(3)	Pool Slope S_p	Average Slope S	Ratio S_p / S	Near-Bank Stress NBS
	(4)	Pool Slope S_p	Riffle Slope S_{rif}	Ratio S_p / S_{rif}	Near-Bank Stress NBS

Dominant Near-Bank Stress

Level III	(5)	Near-Bank Max Depth d_{nb} (feet)	Mean Depth D (feet)	Ratio d_{nb} / d	Near-Bank Stress NBS

Level III	(6)	Near-Bank Max Depth d_{nb} (feet)	Near-bank Slope S_{nb}	Near-Bank Shear Stress t_{nb} (lb/ft^2)	Mean Depth d (feet)	Average Slope S	Bankfull Shear Stress t (lb/ft^2)	Ratio t_{nb} / t_{bkf}	Near-Bank Stress NBS

Level IV	(7)	Velocity Gradient (ft / s / ft)	Near-Bank Stress NBS

Converting Values to a Near-Bank Stress RATING

Near -Bank Stress (NBS) RATINGS	**Method Number**						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Very Low	N/A	> 3.00	< 0.20	< 0.40	< 1.00	< 0.80	< 0.50
Low	N/A	2.21 - 3.00	0.20 - 0.40	0.41 - 0.60	1.00 - 1.50	0.80 - 1.05	0.50-1.00
Moderate	N/A	2.01 - 2.20	0.41 - 0.60	0.61 - 0.80	1.51 - 1.80	1.06 - 1.14	1.01-1.60
High	See (1) above	1.81 - 2.00	0.61 - 0.80	0.81 - 1.00	1.81 - 2.50	1.15 - 1.19	1.61 - 2.00
Very High		1.50 - 1.80	0.81 - 1.00	1.01 - 1.20	2.51 - 3.00	1.20 - 1.60	2.01 - 2.40
Extreme		< 1.50	> 1.00	> 1.20	> 3.00	> 1.60	> 2.40

Overall Near-Bank Stress RATING

STREAM SURVEY

Annual Streambank Erosion Estimates / Calculations Summary Form

Stream Name: **Kittle Number:**
Crew: Survey Date:

Station Name: **Station ID Number:** River Mile:
Station length (ft.) Station wetted width (ft):

Station Coordinates **Downstream** **Upstream**
(UTM, Zone 15) X: Y: X: Y:
Coordinate Source: Location (T - R - S)

Stream Type: Graph Used: Total BANK Length: Ft.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Item	Station Ft.	BEHI (adjective)	NEAR-BANK STRESS (adjective)	BANK EROSION RATE (ft./yr.)	LENGTH of Bank (ft.)	Bank HEIGHT (ft.)	EROSION Subtotal (4)x(5)x(6) (ft.^{3} / yr.)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							

Sum (Feet^3 / Year) EROSION <u>Sub-Totals</u> for each BEHI / NBS Combination	Total Erosion Feet^3 / Year =
Convert EROSION (Feet^3 / Year) to (Yards^3 / Year)	Total Erosion Yards^3 / Year =
C Convert EROSION (Yards^3 / Year) to (Tons / Year) (multiply Total EROSION (Yards^3 / Year) by 1.3)	Total Erosion Tons / Year =
Calculate EROSION per unit LENGTH of Channel. (Divide Total EROSION (Tons/Year) by Total Length of CHANNEL (ft.) surveyed)	Total Erosion Tons / Yr. / Ft. =

Minnesota
DEPARTMENT OF NATURAL RESOURCES

STREAM SURVEY

Minnesota Stream Habitat Assessment (MSHA) Field Sheet

MSHA Score: ☐
Max = 100

Stream Name: **Kittle Number:**
Crew: Survey Date:
Station Name: **Station ID Number:** River Mile:
Station length (ft.) Station wetted width (ft):
Station Coordinates **Downstream** **Upstream**
(UTM, Zone 15) X: Y: X: Y:
Coordinate Source: Location (T - R - S)

2] Surrounding Land Use (check the most predominant or check two and average scores) L = left bank R = right bank facing downstream

L	R		L	R	
☐	☐	Forest, Wetland, Prairie, Shrub [5]	☐	☐	Residential / Park [2]
☐	☐	Old Field / Hay Field [3]	☐	☐	Urban / Industrial [0]
☐	☐	Fenced Pasture [2]	☐	☐	Open Pasture [0]
☐	☐	Conservation Tillage, No Till [2]	☐	☐	Row Crop [0]

LAND USE ☐
Max = 5

3] Riparian Zone (check the most predominant)

A. Riparian Width

L	R		
☐	☐	Extensive (> 300 ft.)	[5]
☐	☐	Wide (150 - 300 ft.)	[4]
☐	☐	Moderate (30 - 150 ft.)	[3]
☐	☐	Narrow (15 - 30 ft.)	[2]
☐	☐	Very Narrow (3 - 15 ft.)	[1]
☐	☐	None	[0]

C. Bank Erosion

L	R		
☐	☐	None	[5]
☐	☐	Little (5 - 25%)	[4]
☐	☐	Moderate (25 - 50%)	[3]
☐	☐	Heavy (50 - 75%)	[2]
☐	☐	Severe (75 - 100%)	[1]

E. Shade

☐	☐	Heavy (>75%)	[5]
☐	☐	Substantial (50 - 75%)	[4]
☐	☐	Moderate (25 - 50%)	[2]
☐	☐	Light (5 - 25%)	[1]
☐	☐	None	[0]

B. Riparian Cover (rank)

L	R	
☐	☐	Trees
☐	☐	Shrubs
☐	☐	Grasses / Forbs

D. Bank Cover (rank)

L	R	
☐	☐	Trees
☐	☐	Shrubs
☐	☐	Grasses / Forbs
☐	☐	Bare Soil
☐	☐	Rock

F. Average Bank Height

L. ________ ft.
R. ________ ft.

RIPARIAN ☐
Max = 15

4] Instream Zone

A. Substrate (check two for each channel type)

	[10] Boulder	[9] Cobble	[8] Gravel	[7] Sand	[5] Clay	[5] Bedrock	[2] Silt	[1] Muck	[1] Detritus	[0] Sludge	Channel Type (%)
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	________

B. Embeddedness

- ☐ None [5]
- ☐ Light [3]
- ☐ Moderate [1]
- ☐ Severe [-1]
- ☐ No coarse substrate

D. Water Color

- ☐ Clear
- ☐ Stained
- ☐ Turbid
- ☐ Brown
- ☐ Green
- ☐ Other (specify)

C. Substrate Types

- ☐ >4 [2]
- ☐ <=4 [0]

SUBSTRATE ☐
Max = 27

E. Cover Type (check all that apply)

☐	Undercut Bank	[1]
☐	Overhanging vegetatior	[1]
☐	Deep Pools	[1]
☐	Logs or Woody Debris	[1]
☐	Boulders	[1]
☐	Rootwads	[1]

☐ Macrophytes [1]
- ☐ Emergent
- ☐ Floating Leaf
- ☐ Submergent

F. Cover Amount (check one)

☐	Extensive (>50%)	[10]
☐	Moderate (25 - 50%)	[7]
☐	Sparse (5 - 25%)	[3]
☐	Nearly Absent	[0]
☐	Choking Vegetation only	[-1]

COVER ☐
Max = 17

5] Channel Morphology

A. Depth Variability

☐	greatest depth >4X shallow depth	[6]
☐	greatest depth 2-4X shallow depth	[3]
☐	greatest depth <2X shallow depth	[0]

B. Channel Stability

☐	High	[9]
☐	Moderate	[6]
☐	Low	[3]
☐	Very Low	[0]

C. Velocity Types (check all that apply)

☐	Torrential	[-1]
☐	Fast	[1]
☐	Moderate	[1]
☐	Slow	[1]
☐	Eddies	[1]
☐	Interstitial	[-1]
☐	Intermittent	[-2]

D. Sinuosity

☐	High	[6]
☐	Moderate	[4]
☐	Low	[2]
☐	None	[0]

E. Pool Width / Riffle Width

☐	Pool Width > Riffle Width	[2]
☐	Pool Width = Riffle Width	[1]
☐	Pool Width < Riffle Width	[0]
☐	No Riffle	[0]

F. Channel Development

☐	Excellent	[9]
☐	Good	[6]
☐	Fair	[3]
☐	Poor	[0]

G. Present Water Level

- ☐ Flood
- ☐ High
- ☐ Normal
- ☐ Low
- ☐ Interstitial

i. Reach Gradient

__________ ft. mile

CHANNEL MORPHOLOGY ☐
Max = 36

NEARSTREAM OBSERVATIONS

Riparian width		Riparian cover		Shade	Bank height		Bank cover		Bank erosion	
L (ft)	R	L	R		L (ft)	R	L	R	L	R

INSTREAM OBSERVATIONS

Channel Type	Length (ft.)	Width (ft.)	Depth max/avg (ft.)	Substrate	Embed.	Cover type	Cover amount	Velocity type

	Total length (ft.)	Total width (ft.)	Total depth max/avg (ft.)
POOLS			
RIFFLES			
RUNS			
TOTAL			
AVERAGE			
Water Clarity (ft.)			

6] Sources of Pollution Observed at Site

L	R	
☐	☐	**Feedlots**
☐	☐	**Livestock Grazing**
☐	☐	**Dump (type)**
☐	☐	**Tiling Outfalls**
☐	☐	**Storm Sewer Outfalls**
☐	☐	**Gully Erosion**
☐	☐	**Sheet Erosion**
☐	☐	**Other (specify)**
☐	☐	**Other (specify)**
☐	☐	**None**

7] Flow Restrictions

____

____

____

8] Evidence of High Water:

____

____

____

9] Photographs

Number	Location	Number	Location

3. Water Quality Field Forms

1. Longitudinal Water Temperature Profile
2. Continuous Water Temperature Recording Field Sheet
3. Water Quality Laboratory Analysis Form

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Longitudinal Water Temperature Profile

Stream Name: **Kittle Number:**

Crew (Recorder): **Survey Date:** **Page ____ of _____**

						Point		Data Logger		
Start Date	**End Date**	**Location (river mile)**	**UTM Easting**	**UTM Northing**	**Air Temp.**	**Water Temp.**	**Time (military)**	**Serial Number**	**Water Stage**	**Cloud Cover**

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STREAM SURVEY

Continuous Water Temperature Recording Field Sheet

Stream Name: **Kittle Number:**

Crew: **Survey Date:**

Start Date	End Date	Station Name	Station Number	River Mile	Location (T-R-S-QS)	UTM Easting	UTM Northing	Data Logger Serial Number	Comments

Additional Comments:

Water Quality Analysis Form

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Stream name:	Survey Date :
Kittle no.:	Recorder:

Station Number			
Date Sampled			
Station Location (miles from mouth)			
UTM Easting			
UTM Northing			
Length of Station (feet)			
Time of Sample:			

FIELD DETERMINATIONS

Air Temperature (°C)			
Water Temperature (°C)			
pH			
Dissolved Oxygen (milligrams per liter)			
Conductivity (micro siemens)			
Transparency (cm)			

LABORATORY ANALYSIS OF WATER SAMPLE

Total Alkalinity (ppm)			
Total Dissolved Solids (ppm)			
Total Phosphorus (ppm)			
Chloride ion (ppm)			
pH (part of statewide request)			
Conductivity (part of statewide request)			
Chlorophyll *a* (part of statewide request)			
OPTIONAL LABORATORY ANALYSIS (Based on need)			
Chlorophyll *a* (periphyton)			
Total Nitrogen			
Ammonia			
Nitrite (NO_2)			
Nitrate (NO_3)			
Total Suspended Solids			
Turbidity			
Fecal Bacteria			
Sulfate ion			
Biochemical Oxygen Demand (BOD)			

Comments:

4. Biology Field Forms

1. Biology Measurement Sheet I - Riparian Area/Aquatic Invertebrates
2. Biology Measurement II - Aquatic Plants
3. Biology Measurement Sheet III - Fish Data–Cover Sheet
4. Biology Measurement Sheet IV - Fish Field Measurements

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BIOLOGY MEASUREMENT SHEET I - Riparian Area/Aquatic Invertebrates

Stream name: Kittle number:

Station:

Crew: Page ______ of ____________

Station length (ft):

Station river miles:

Station wetted width (feet) :

Station Coordinates:	**Downstream end**		**Upstream end**	
(UTM, Zone 15)	X:	Y:	X:	Y:

Coordinate Source: GPS Make: GPS Model:

Sample Date: Time arrived: Time Completed:

Sky: Weather:

Stream stage: Stream flow (c.f.s) Flow method:

Water clarity: Air temperature: Water temperature:

Riparian Area

	(**B1**) **Area width**	(**B2**) **Buffer width**
Transect	(L/R) bank*	(L/R) bank*
Upper 1/3	/	/
Middle 1/3	/	/
Lower 1/3	/	/

(B4) Vegetation : circle all that apply

Type	Density		
Bare ground	Present		
Forbs only	Low	Mod	
Annual grass w/forbs	Low	Mod	High
Perennial grasses	Low	Mod	High
Rhizomatous grasses	Low	Mod	High
Low brush	Low	Mod	High
High brush	Low	Mod	High
Combined grass/brush	Low	Mod	High
Deciduous overstory	Low	Mod	High
Deciduous w/grass/brush under.	Low	Mod	High
Perennial overstory	Low	Mod	High
Wetland vegetation:	Wetland Bog Fen Marsh		

(B3) Land Use: *in delineated riparian area to the nearest 10%*

Land use	(L/R) bank*	
Cropland	/	
Pasture	/	
Barnyard	/	
Developed	/	
Exposed Rock	/	
Meadow	/	
Shrub	/	
Woodland	/	
Wetland	/	
Other (specify)	/	________________

Aquatic Invertebrates (B6): Habitat and Sample No. - RR = Riffle/Run; WD = Woody debris;

OV = Overhanging vegetation; IV = Instream vegetation. (Circle if sample was collected)

RR1	RR2		
WD1	WD2	WD3	WD4
OV1	IV1		

Notes:

BIOLOGY MEASUREMENT II - Aquatic Plants

Stream name: Kittle number:

Station:

Crew: Page ______ of ____________

Station type: Station length (ft): Station wetted

Location (T-R-S) Station river miles: width (feet) :

Station Coordinates:	**Downstream end**		**Upstream end**	
(UTM, Zone 15)	X:	Y:	X:	Y:

Coordinate Source: GPS Make: GPS Model:

Sample Date: Time arrived: Time Completed:

Sky: Weather:

Stream stage: Stream flow (c.f.s) Flow method:

Water clarity: Air temperature: Water temperature:

Aquatic Plants (B5) (Types=Emergent, Floating-leaved, Submerged, Algae)

Abundance = Abundant, Common, Occasional, Rare (circle appropriate letter)

Species	Types	Abundance
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R
	E F S A	A C O R

Notes:

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BIOLOGY MEASUREMENT SHEET III - Fish Data - Cover Sheet

Stream name: Kittle number:

Station:

Crew: Page ______ of ____________

Station type:

Station length (ft):

Station wetted width (feet) :

Location (T-R-S)

Station river miles:

Location/Station Coordinates:

	Downstream		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:
Coordinate Source:	GPS Make:		GPS Model:	

Weather and Stream Conditions:

Cloud Cover: 0 ≤ 25% cloud cover, 1 = 25 - 50%, 2 = 50% - <100%, 3 = 100% cloud cover	Precipitation: 0=no precip., 1=lite/mod. rain, 2=heavy rain, 3=hail/sleet, 4=lite/mod. snow, 5=heavy snow	Wind: 0=no or light wind, 1=moderate wind, 2=high wind, 3=extreme wind
Stream stage:	Stream flow (c.f.s)	Flow method:
Water clarity:	Air temperature:	Water temperature:

Fish Sampling:

Survey Type:

Initial; Full; Special Assessment (specify-e.g., population assessment, monitoring)

Station Length (**B7**):

Gear (**B8**):

backpack-BPEF; stream shocker-SSEF; mini-boom-MBEF; boat/boom shocker-BOEF; Other gear-OT (and specify)

Date and Time:

Start Date (MM/DD/YY): Start time (HH/MM):

Finish Date (MM/DD/YY): Finish time (HH/MM):

(use only for overnight sets (e.g., nets)

Electrofishing Settings

Volts- QF- Amps- QF-

QF-"blank" = normal operation; 0 = meter inoperative; 1 = unstable readings (varies >70V/10A)

Dip net mesh size- Watts- Pulse (Hz)- Duty Cycle-

Station Description / Additional Notes:

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BIOLOGY MEASUREMENT SHEET IV - Fish Field Measurements

Stream name:
Date:
Kittle number:
Station:
Page _____ of ______

Fish Sampling

Gear (**B8**):
Time electrofished:

backpack-BPEF; stream shocker-SSEF; mini-boom-MBEF; boat/boom shocker-BOEF; Other gear-OT (and specify)

ID #	Species Code (**B9**)	Fish count if not measured	Length (**B9**) individual or range	Weight (**B9**) individual or bulk	Jar No. for unknown fishes	Anomalies (**B10**) see manual for codes	Aging structure (**B11**) SC-scales, OT-otoliths DS-dorsal spines, CI-Cliethra PS-pectoral spines OP-opercle, FR-fin rays	Gender (**B12**) M-male, F-female; I-immature, M-mature U-unknown, G-gravid R-ripe, S-spent	Mark / Recap or Pass No.

5. Miscellaneous Field Forms

1. Connectivity Field Form
2. Photo Documentation Sheet

STREAM SURVEY

Connectivity Field Form

Date: ____________

Location:

Stream Name: ____________ Kittle Number ____________

County: ____________ Road Name: ____________

Township: ____________ Range: ____________ Section: ____________

Stream Mile: ______ GPS: Northing-____________ Easting- ____________

Type of Crossing:

☐ Bridge

☐ culvert(s) Num. (if mult.) ______

☐ Other: ____________

Culvert Description:

Length: ______ ft

Diameter: ______ inches

Material ☐ galvanized

☐ concrete

☐ other

Slope: ☐ matches stream

☐ flat

☐ inverted

Alignment: ☐ proper

☐ misaligned

Depth: ☐ buried (substrate throughout)

☐ same as stream bottom

☐ perched

Mult. Offset: Yes No N/A

Culvert Condition:

☐ good

☐ fair

☐ poor

Fish Passage Barrier: Yes No

(If "Yes", explain in comments)

Road (Trail) Data:

Surface: ____________

Width: ____________

Jurisdiction: ____________

Stream Characteristics:

Bankfull width ______ ft. (away from culv.)

Aggradation evident upstream Yes No

Degradation evident downstream Yes No

culvert location ☐ riffle (straight)

☐ pool

Channelization at crossing Yes No

Describe: ____________

____

____

Other Conditions

☐ Stream bank erosion near crossing

☐ Road embankment erosion

☐ Pool formation below culvert

☐ Beaver activity at crossing

☐ Sedimentation from road surface

Comments: ____________

____

____

____

____

____

____

____

____

____

Observer's name(s): ____________

Connectivity Field Form

KEY WORD	DESCRIPTION
Location:	
Road Name	Include road number, and local name if known.
Stream Mile	Optional if have twn, range and sec.
Type of Crossing:	
Culvert(s)	Num. = number of culverts if multiple culverts present.
Road Data:	
Surface	Type of road surface (bituminous, gravel, concrete, etc).
Width	Width of road surface at crossing.
Jurisdiction	Who maintains road (State, county, private, etc.)?
Culvert Description:	
Diameter	Measured at widest (width, not height) point for non-round culverts and bridges
Slope	Does culvert slope appear to match stream slope? Does it have no slope (flat)? Or is it inverted (sloped backwards)?
Alignment	Is culvert aligned with natural stream channel (thalweg) or does the stream have to make a sharp turn to enter, or is the culv. outlet directing flow into a stream bank?
Depth	Does the bottom of the culvert appear to be buried below the thalweg elevation? Does it have sediment in it? (For pool locations, may not contain sediment.) Need longitudinal profile for accurate determination.
Mult. Offset	If there are multiple culverts, are they offset so the flow is directed through the thalweg culvert at low flows?
Stream Characteristics:	
Bankfull Width	Measure stream bankfull (not water surface) width in a riffle, away from the influence of the culvert.
Aggradation/ Degradation	Is there evidence that the channel has aggraded (excess sediment) above the culvert or degadation (scoured) below the culvert? (Unsure - leave blank)
Comments:	Can include: floodplain culverts present, age of crossing or plans for replacement, recommendations for improvement, history of road overtopping or washout, location relative to critical habitat, if culvert is proper length (too short = too steep of a toe slope), if slopes were actually surveyed, amount perched, water velocity through crossing, age of culvert (if known), description of nature of barrier to fish passage if present (velocity, depth, jump), etc.

STREAM SURVEY

PHOTO DOCUMENTATION SHEET

Page ___ of ___

Stream name: **Kittle Number:**

Station Name: Station ID code: River Mile:

Station Coordinates:	**Downstream**		**Upstream**	
(UTM, Zone 15)	X:	Y:	X:	Y:

Coordinate Source: Location (T-R-S):

Photo ID Number	Photo Date	UTM Zone 15 Easting	UTM Zone 15 Northing	Photo View Or Feature*
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				
Description/comments:				

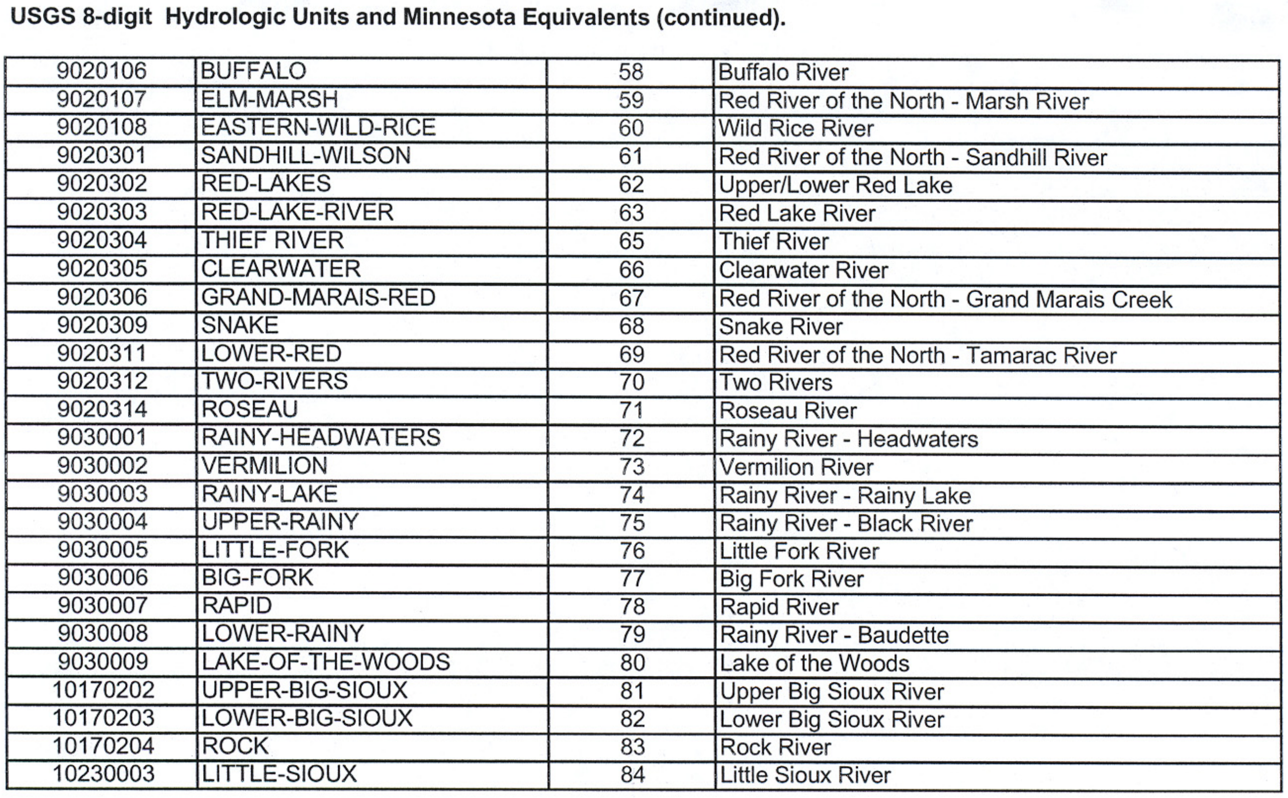
* Examples of photo views or features might include: facing upstream, facing downstream, cross-section, bank erosion, dam, log jam, point source, mesohabitat type of interest, fish species, etc.

Appendix 2. Table for translating USGS Hydrologic Units and Minnesota DNR Major Watershed numbers (continued on next page).

USGS 8-digit Hydrologic Units and Minnesota Equivalents

USGS HUC-8	USGS Name	DNR Major #	Minnesota Name
4010101	BAPTISM-BRULE	1	Lake Superior - North
4010102	BEAVER-LESTER	2	Lake Superior - South
4010201	ST-LOUIS	3	St. Louis River
4010202	CLOQUET	4	Cloquet River
4010301	BEARTRAP-NEMADJI	5	Nemadji River
7010101	MISSISSIPPI-HEADWATERS	7	Mississippi River - Headwaters
7010102	LEECH-LAKE	8	Leech Lake River
7010103	PRAIRIE-WILLOW	9	Mississippi River - Grand Rapids
7010104	ELK-NOKASIPPI	10	Mississippi River - Brainerd
7010105	PINE	11	Pine River
7010106	CROW-WING	12	Crow Wing River
7010107	REDEYE	13	Redeye River
7010108	LONG-PRAIRIE	14	Long Prairie River
7010201	PLATTE-SPUNK	15	Mississippi River - Sartell
7010202	SAUK	16	Sauk River
7010203	CLEARWATER-ELK	17	Mississippi River - St. Cloud
7010204	CROW	18	North Fork Crow River
7010205	SOUTH-FORK-CROW	19	South Fork Crow River
7010206	TWIN-CITIES	20	Mississippi River - Twin Cities
7010207	RUM	21	Rum River
7020001	UPPER-MINNESOTA	22	Minnesota River - Headwaters
7020002	POMME-DE-TERRE	23	Pomme de Terre River
7020003	LAC-QUI-PARLE	24	Lac Qui Parle River
7020004	HAWK-YELLOW-MEDICINE	25	Minnesota River - Yellow Medicine River
7020005	CHIPPEWA	26	Chippewa River
7020006	REDWOOD	27	Redwood River
7020007	MIDDLE-MINNESOTA	28	Minnesota River - Mankato
7020008	COTTONWOOD	29	Cottonwood River
7020009	BLUE-EARTH	30	Blue Earth River
7020010	WATONWAN	31	Watonwan River
7020011	LE-SUEUR	32	Le Sueur River
7020012	LOWER-MINNESOTA	33	Lower Minnesota River
7030001	UPPER-ST-CROIX	34	Upper St. Croix River
7030003	KETTLE	35	Kettle River
7030004	SNAKE	36	Snake River
7030005	LOWER-ST-CROIX	37	Lower St. Croix River
7040001	RUSH-VERMILLION	38	Mississippi River - Lake Pepin
7040002	CANNON	39	Cannon River
7040003	BUFFALO-WHITEWATER	40	Mississippi River - Winona
7040004	ZUMBRO	41	Zumbro River
7040006	LACROSSE-PINE	42	Mississippi River - La Crescent
7040008	ROOT	43	Root River
7060001	COON-YELLOW	44	Mississippi River - Reno
7060002	UPPER-IOWA	46	Upper Iowa River
7080102	UPPER-WAPSIPINICON	47	Upper Wapsipinicon River
7080201	UPPER-CEDAR	48	Cedar River
7080202	SHELL-ROCK	49	Shell Rock River
7080203	WINNEBAGO	50	Winnebago River
7100001	DES-MOINES-HEADWATERS	51	Des Moines River - Headwaters
7100002	UPPER-DES-MOINES	52	Lower Des Moines River
7100003	EAST-FORK-DES-MOINES	53	East Fork Des Moines River
9020101	BOIS-DE-SIOUX	54	Bois de Sioux River
9020102	MUSTINKA	55	Mustinka River
9020103	OTTER-TAIL	56	Otter Tail River
9020104	UPPER-RED	57	Upper Red River of the North

Appendix 2. Table for translating USGS Hydrologic Units and Minnesota DNR Major Watershed numbers (continued on next page).



USGS 8-digit Hydrologic Units and Minnesota Equivalents (continued).

9020106	BUFFALO	58	Buffalo River
9020107	ELM-MARSH	59	Red River of the North - Marsh River
9020108	EASTERN-WILD-RICE	60	Wild Rice River
9020301	SANDHILL-WILSON	61	Red River of the North - Sandhill River
9020302	RED-LAKES	62	Upper/Lower Red Lake
9020303	RED-LAKE-RIVER	63	Red Lake River
9020304	THIEF RIVER	65	Thief River
9020305	CLEARWATER	66	Clearwater River
9020306	GRAND-MARAIS-RED	67	Red River of the North - Grand Marais Creek
9020309	SNAKE	68	Snake River
9020311	LOWER-RED	69	Red River of the North - Tamarac River
9020312	TWO-RIVERS	70	Two Rivers
9020314	ROSEAU	71	Roseau River
9030001	RAINY-HEADWATERS	72	Rainy River - Headwaters
9030002	VERMILION	73	Vermilion River
9030003	RAINY-LAKE	74	Rainy River - Rainy Lake
9030004	UPPER-RAINY	75	Rainy River - Black River
9030005	LITTLE-FORK	76	Little Fork River
9030006	BIG-FORK	77	Big Fork River
9030007	RAPID	78	Rapid River
9030008	LOWER-RAINY	79	Rainy River - Baudette
9030009	LAKE-OF-THE-WOODS	80	Lake of the Woods
10170202	UPPER-BIG-SIOUX	81	Upper Big Sioux River
10170203	LOWER-BIG-SIOUX	82	Lower Big Sioux River
10170204	ROCK	83	Rock River
10230003	LITTLE-SIOUX	84	Little Sioux River

Appendix 2. Table for translating USGS Hydrologic Units and Minnesota DNR Major Watershed numbers (continued from previous page).

USGS 6-digit Hydrologic Units and Minnesota Equivalents

USGS HUC-6	USGS Name	DNR Majors	Minnesota Name
40101	NORTHWESTERN LAKE SUPERIOR	1,2	Lake Superior - North Shore
40102	ST. LOUIS RIVER BASIN	3, 4	St. Louis River
40103	SOUTHWESTERN LAKE SUPERIOR	5	Lake Superior - Nemadji River
70101	MISSISSIPPI HEADWATERS	6-14	Mississippi River - Headwaters
70102	UPPER MISSISSIPPI-CROW-RUM	15 - 21	Mississippi - Crow - Rum Rivers
70200	MINNESOTA RIVER BASIN	22 - 33	Minnesota River
70300	ST. CROIX RIVER BASIN	34 - 37	St. Croix River
70400	UPPER MISSISSIPPI-BLACK-ROOT	38 - 43	Lower Mississippi River
70600	UPPER MISSISSIPPI-MAQUOKETA-PLUM	44, 46	Mississippi River - Upper Iowa Rivers
70801	UPPER MISSISSIPPI-IOWA-SKUNK-WAPSIPINICON	47	Upper Wapsipinicon River
70802	IOWA RIVER BASIN	48 - 50	Cedar River
71000	DES MOINES RIVER BASIN	51 - 53	Des Moines River
90201	UPPER RED RIVER BASIN	54 - 60	Upper Red River of the North
90203	LOWER RED RIVER BASIN	61 - 71	Lower Red River of the North
90300	RAINY RIVER BASIN	72 - 80	Rainy River
101702	MISSOURI - BIG SIOUX	81 - 83	Big Sioux River
102300	MISSOURI - LITTLE SIOUX	84	Little Sioux River

USGS 4-digit Hydrologic Units and Minnesota Equivalents

USGS HUC-4	USGS Name	DNR Majors	Minnesota Name
401	WESTERN LAKE SUPERIOR	1-5	Western Lake Superior
701	MISSISSIPPI HEADWATERS	6-21	Mississippi River - Headwaters
702	MINNESOTA	22 - 33	Minnesota River
703	ST. CROIX	34 - 37	St. Croix River
704	UPPER MISSISSIPPI-BLACK-ROOT	38 - 43	Lower Mississippi River
706	UPPER MISSISSIPPI-MAQUOKETA-PLUM	44, 46	Mississippi River - Upper Iowa Rivers
708	UPPER MISSISSIPPI-IOWA-SKUNK-WAPSIPINICON	47 - 50	Cedar River
710	DES MOINES	51 - 53	Des Moines River
902	RED RIVER	54 - 71	Red River of the North
903	RAINY RIVER	72 - 80	Rainy River
1017	MISSOURI - BIG SIOUX	81 - 83	Missouri River - Big Sioux River
1023	MISSOURI - LITTLE SIOUX	84	Missouri River - Little Sioux River

USGS 2-digit Hydrologic Units and Minnesota Equivalents

USGS HUC-2	USGS Name	DNR Majors	Minnesota Name
4	GREAT LAKES	1-5	Great Lakes
7	UPPER MISSISSIPPI	6-53	Upper Mississippi River
9	SOURIS-RED-RAINY	54 - 80	Red River of the North - Rainy -Souris Rivers
10	MISSOURI	81 - 84	Missouri River

Appendix 3.

Minnesota Stream Identification System (Kittle Number)

The following 4 pages correspond to pages A7-A10 from MNDNR Special Publication 120 (1978).

These general principles are followed:

1. All streams will have a letter prefix indicating the main drainage basin into which they flow.
   M – Mississippi River basin
   S – St. Lawrence drainage basin
   H - Hudson Bay drainage basin
   I - Streams which flow through Iowa before joining the Mississippi

2. The main river systems will be numbered from the state line or from their mouths upstream, giving consecutive numbers to the tributaries as they enter the stream.

3. All tributary streams will be numbered from their junction with the main stream upstream. This number will be added following a hyphen to the number of the stream which it joins. (For example: M is the Mississippi River; M-50 is the St. Croix River; M-50-46 is the Kettle River; and M-50-46-10 is the Grindstone River.)

The numbers assigned to the tributaries will depend upon the maps that are used and the tributaries shown, so some streams may be missed. In the event of failure to note a stream in the initial numbering, a decimal system may be used to overcome this difficulty. For example: Between Big Trout Creek (having tributary number M-17) and Cedar Creek (having tributary number M-18) we find a small, but important tributary to the Mississippi River. This stream can be designated M-17.5. The use of the .5 rather than .1 leaves room for further correction if other streams have been omitted.

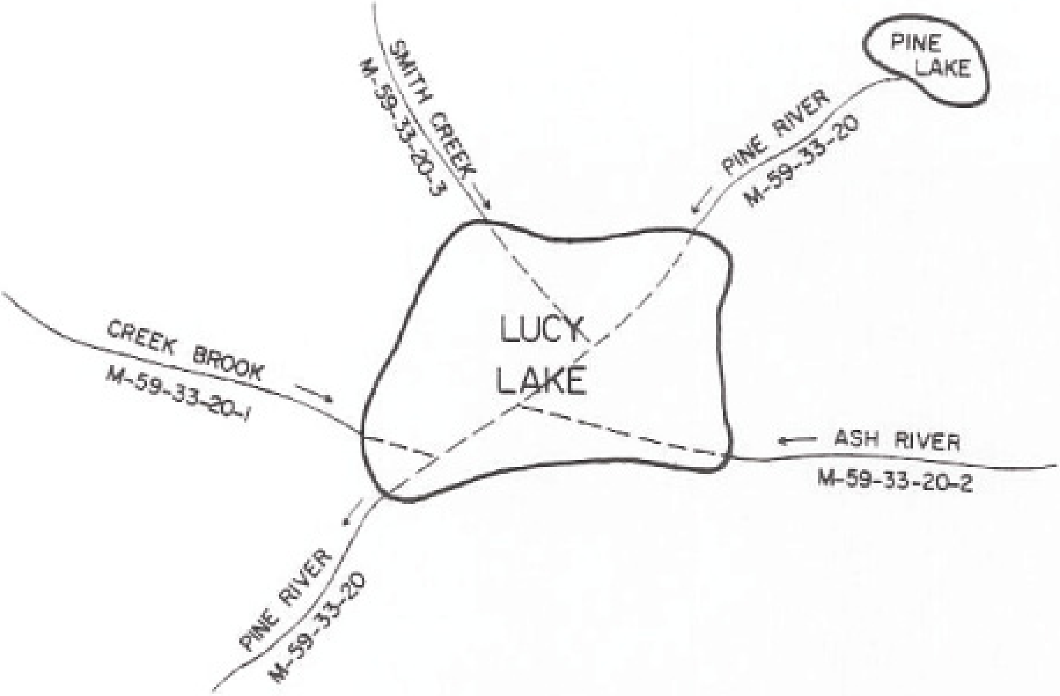
Minnesota tributaries to the Mississippi River will be numbered from the south boundary of the state upstream. The Mississippi itself is designated as M.

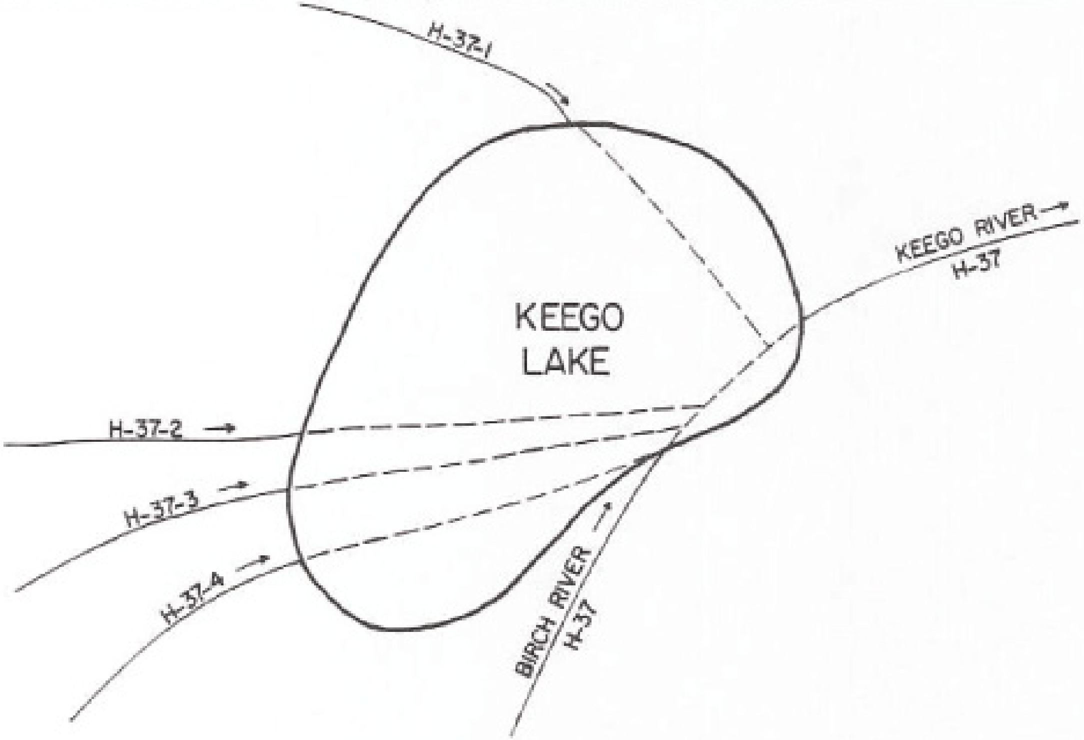
Streams which flow through Iowa before joining the Mississippi River will be numbered by point of exit, beginning at the eastern end of the southern boundary and proceeding westward to the western boundary of the state which will then be followed northward. Streams which flow through South Dakota before reaching Iowa will be listed here also.

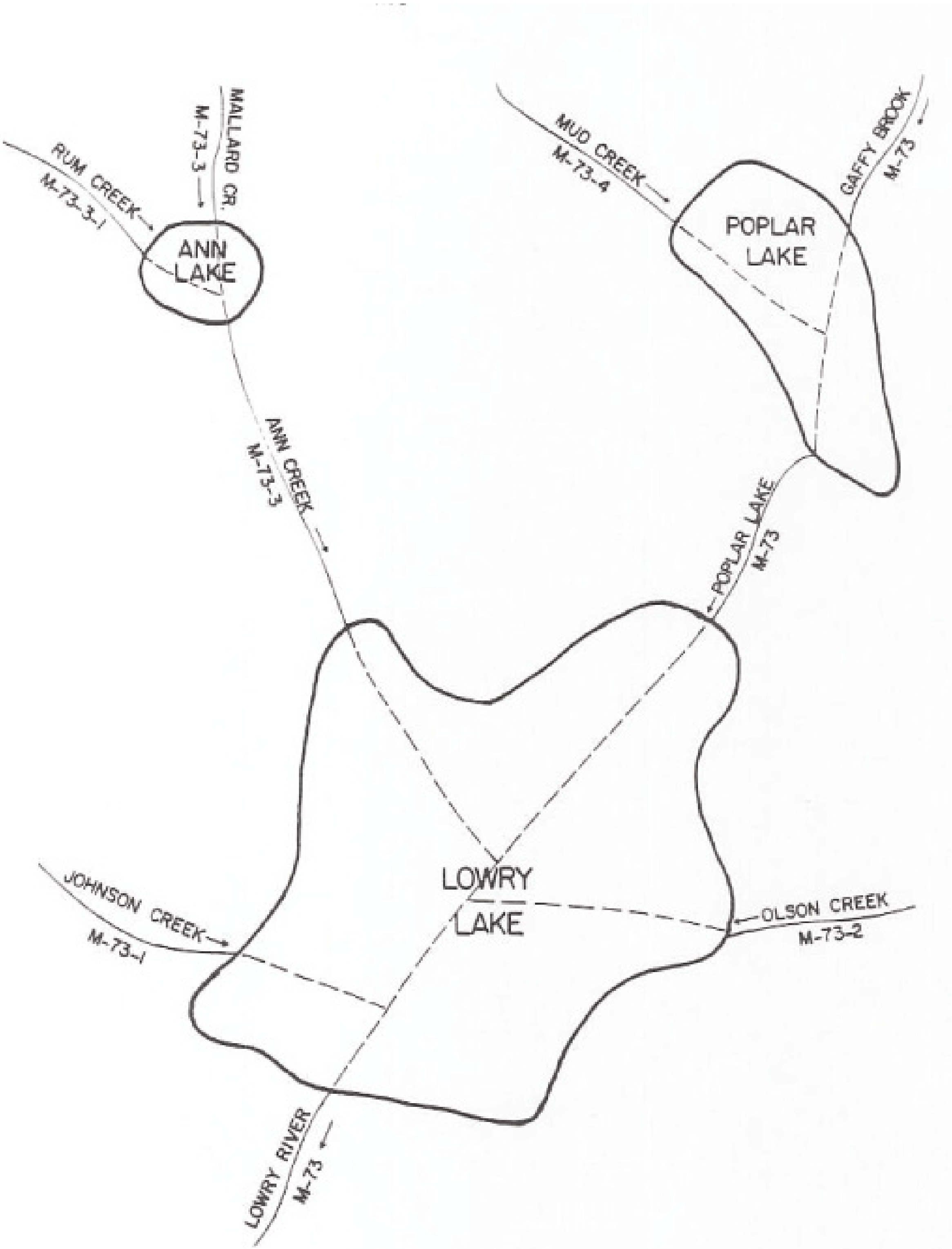
The Hudson Bay drainage tributaries would start with the Rainy River and be numbered westward by point of exit, to the Red River of the North. The Minnesota tributaries to the Rainy River would be numbered upstream proceeding eastward. The Minnesota tributaries to the Red River would be numbered upstream proceeding southward.

For the St. Lawrence drainage the streams would be numbered in a clockwise direction from the Wisconsin state line northward along the north shore of Lake Superior.

When a stream comes out of a lake into which one or more streams empty, handle the tributary numbers this way: Choose the main inlet (the one with the same name as the outlet, or the one that carries the most water) as the continuation of the outlet stream. Mentally draw a line connecting this inlet with the outlet (or imagine that the lake has dried up and only the streams remain). Then number the other inlet streams as tributary to this stream that runs through the lake bed. The following examples illustrate this procedure:


SMITH CREEK
M-59-33-20-3
PINE LAKE
PINE RIVER
M-59-33-20
LUCY LAKE
CREEK BROOK
M-59-33-20-1
ASH RIVER
M-59-33-20-2
PINE RIVER
M-59-33-20


H-37-1
KEEGO LAKE
KEEGO RIVER
H-37
H-37-2
H-37-3
H-37-4
BIRCH RIVER
H-37


RUM CREEK
M-73-3-1
MALLARD CR.
M-73-3
ANN LAKE
MUD CREEK
M-73-4
GAFFY BROOK
M-73
POPLAR LAKE
ANN CREEK
M-73-3
POPLAR LAKE
M-73
LOWRY LAKE
JOHNSON CREEK
M-73-1
OLSON CREEK
M-73-2
LOWRY RIVER
M-73

The following text is from MNDNR Fisheries documents on Kittle Number assigning, for the ArcView Kittle Coding Project (Jamie Schulz, DNR Fisheries Rochester, personal communication).

Additional Information on Assigning Kittle Numbers

If target streams do not have a Kittle Number assigned (check for file information and Kittle Number database), assign a tributary number (i.e., kittle number) assigned using methods as outlined in the DNR Fisheries Stream Survey Manual (MNDNR 1978; Appendix, pages A7-A10).

General Process:

- Identify the watercourse main channel from mouth to source by following the channel upstream; when branching occurs, the main channel should be defined as the stream course with greatest base flow.
- There should be a single kittle # from the mouth to the source.

Additional Scenarios

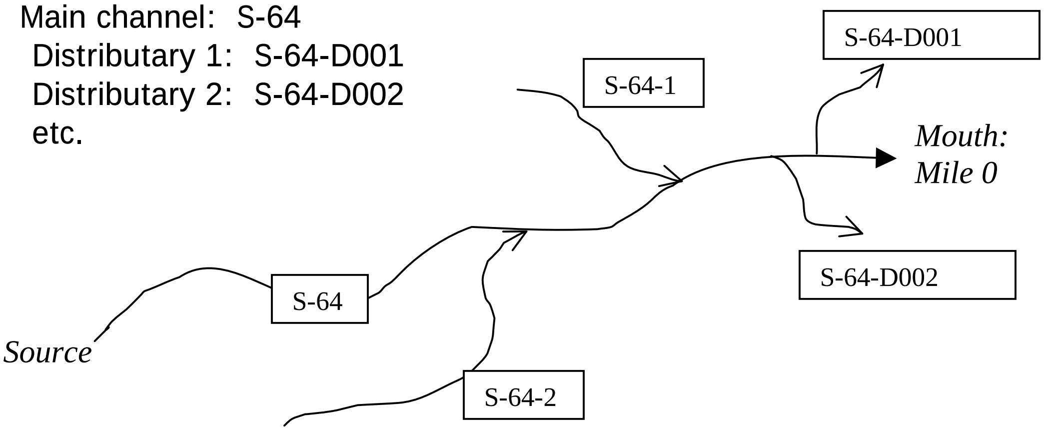
Distributaries:

These refer to streams which originate (have their source) on the main channel of a stream and flow away from the main channel. Distributaries are often found near the mouth of the main stream channel, as in a river delta.

Proposed Numbering Scheme:

Assign a unique code to each distributary as you move upstream from the mouth of the main channel. Numbers should become progressively higher as you move upstream. The distributary code should begin with the letter "D". Distributary codes, to the extent possible, should be assigned so numbers that retain the tributary / distributary hydraulic order.

e.g., Main channel: S-64
Distributary 1: S-64-D001
Distributary 2: S-64-D002
etc.

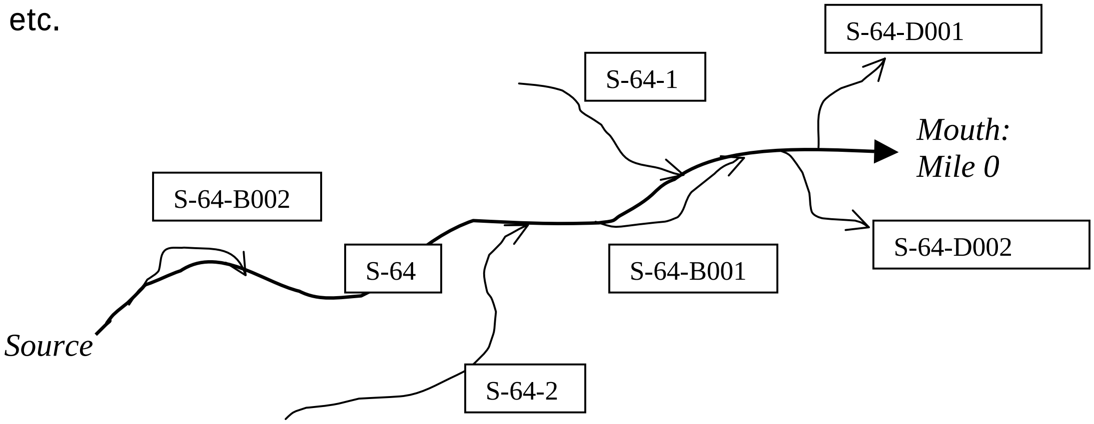


Braids

Assign a unique code to each braid as you move upstream from the mouth of the main channel. Numbers should become progressively higher as you move upstream.

e.g., Main channel: S-64-10

Braid 1: S-64-B001
Braid 2: S-64-B002
etc.



- Assign a unique kittle # to a braid if it is considered to be a distinct stream channel and is managed separately from the main channel
    - e.g., if electrofishing data from a braid is considered separate data from the main channel data and/or if you want to specifically display data on the braid instead of on the main channel (it needs a unique # different from the main channel).

- Don't assign a unique kittle # to a braid if the braid and the main channel are considered to be the same channel and are managed as one channel
    - e.g., if data collected on the braid is considered to represent data collected for the stream itself; in this case, data collected for the braid will be displayed on both channels simultaneously if both channels have the same kittle #.

- Don't assign a kittle # at all to a braid if the braid is a minor channel and doesn't meet either of the above conditions
    - e.g., if no data is collected on the braid and it is not considered part of the main channel.

PROBLEM CASES

(Editors note: the term 'route' below refers to a GIS technique that creates a single line entity for labeling with Kittle Numbers. This technique is part of a GIS methodology called 'dynamic segmentation.'

Scenario 1: (Refer to 1978 Stream Survey Manual, Appendix p. A9, Diagram 1)

a) Pine River (M-59-33-20) has its source at Pine Lake and mouth at mile 0. It flows through Lucy Lake.

Route: Include the lake connector through Lucy Lake as part of the measured route for Pine River, M-59-33-20 (i.e., add mile measures to the lake connector) because Pine River continues on after flowing through the lake

b) Other tributaries to Pine River enter Lucy Lake also.

Routes: Do not include the lake connectors through Lucy Lake as part of the measured routes for tributaries 1,2,3. (i.e., do not add mile measures to the lake connectors; assign tributary mile measure 0 at intersections with the lake boundary)

Scenario 2: (Refer to Stream Survey Manual, Appendix p. A9, Diagram 2)

a) H-37 changes its name from Birch River to Keego River as it flows through Keego Lake, although it retains the same kittle #. Two names can't be assigned to one route (H-37) in the GIS layer, although different names could be assigned to the individual stream arcs that make up the route.

***Route*:** (2 options)
Option 1. The two names could be defined as parts of the route H-37 in the new Streams Database (e.g., mile 0-5 is Keego River and mile 7-10 is Birch River). In this option, the lake connector would be part of the route and would be assigned mile measures.

It would be necessary to convert common mile measures used by area staff into mile measures on the route H-37. This could be accomplished within the eventual Stream Survey application (e.g., convert current mile 0 of Birch River at the intersection with Keego Lake to mile 7 of H-37)

Option 2. Assign different kittle numbers for Birch and Keego Rivers. This would allow staff to keep their current mile measures (e.g., for Birch, mile 0 defined at intersection with lake). Lake connectors would not be a part of routes.

This would be problematic if the main stream passed through many lakes and changed names many times, as in the next example (see Appendix, A10).
e.g., M-73 (changes name from Gaffy Brook to Poplar lake to Lowry River)

Notes:
Would it be difficult for areas to adapt to new mile measuring schemes? (as in changing mile 0 of Birch River to mile 7 of H-37).

- The river mile tool would help them to determine the proper mile measures, either by clicking on the stream or by entering GPS points. Use of GPS to mark beginning and end points would give the least subjective mile measures for survey work.

Comments:
Note: The assignment of route start/end points and mile measures may depend upon how data is stored by the area office. We will either need to adapt the Streams GIS layer to fit our existing data, or convert existing area data to reference the newly developed stream routes. This applies mostly to historical data, as new data entered within the (future) Stream Survey Application will be designed to work with the GIS layer.

References cited.

MNDNR (Minnesota Department of Natural Resources). 1978. Minnesota stream survey manual. Minnesota Department of Natural Resources, Section of Fisheries, Special Publication No. 120. St. Paul, Minnesota.

Appendix 4. Guidelines for the Selection and Safe Use of Electrofishing Gear

Selection of Gear – The most important consideration in choosing the proper electrofishing gear is the type of electric current best suited for collecting fishing under the existing environmental conditions.

The following excerpt from Vincent (1971) describes four types of current commonly used for electrofishing and the advantages and disadvantages of each:

1. Continuous direct current (D.C.) – this type has a continuous flow of unidirectional current between permanent positive and negative electrodes. This is the best type for electrofishing in rivers which have good brushy bank cover or where the turbidity is high (but not so high as to comprise excessive electrolyte) because: (1) the fish show strong galvanotaxus (a tendency to swim toward the positive electrode) and little galvanonarcosis (used here to mean the inability of fish to swim due to narcosis or to contraction of muscles) when near the positive electrode; thus fish can be brought to the surface for easy capture;
   (2) it is the least dangerous to the shocking crew, especially if the amperage is not high and (3) it causes the least tissue damage to the fish.

2. Full-pulsed direct (half-wave rectified alternating current) – This type has an interrupted flow of unidirectional current between permanent positive and negative electrodes. This is the best type of current for electrofishing in large open rivers which have little bank cover and little turbidity because the area of galvanotaxis is larger than with continuous D.C., but galvanonarcosis is common, making capture more difficult unless the water is open and clear. Also, this current may be effective in waters with too much electrolyte for continuous D.C. It is more dangerous to the shocking crew than continuous D.C., so lower amperages should be used. And it causes more tissue damage in fish than continuous D.C.

3. Half-pulsed direct current (have-wave rectified alternating current) – This type has an interrupted flow of

unidirectional current which fluctuates between full and half voltage. This is an intermediate current between continuous and full-pulsed D.C. Fish exhibit a greater degree of galvanotaxis than with full-pulsed D.C., but less than continuous D.C. They exhibit less galvanonarcosis than with full-pulsed D.C., but more than with continuous D.C.

4. Alternating current (A.C.) – This type of current has a continuous regular reversal of positive and negative poles. This is the poorest type of current for electrofishing because: (1) There is no galvanotaxis, so capturing fish is difficult; (2) it is the most dangerous to the shocking crew; and (3) tissue damage to fish is common.

Other more complex type of current used for electrofishing are described by Vilvert (1967).

The types of current discussed above can be employed in boom shocking rigs, backpack units, or portable stream shocking gear. Since electrofishing technology is changing so rapidly, no specific units will be recommended in this manual. However, the Central Office of the Section of fisheries maintains a file of electrofishing gear currently available and should be consulted before new gear is purchased.

<u>Problems Frequently Encountered in Electrofishing</u> – Novotny and Priegel (1974) discuss the various types of problems that may be encountered in capturing fish with electrofishing gear. The following discussion includes some of the problem areas encountered by Minnesota investigators. Possible solutions to these problems are discussed.

It is assumed that the electrofishing gear has been properly designed and assembled:

5. Water conductivity – Low water conductivity makes it very difficult to attain sufficient currents to produce useful electrofishing responses. Lennon and Parker (1958) who found extreme conductivities in Appalachian mountain streams, attacked this problem by adding salt to the water to improve electrofishing. Extremely high water conductivities call for currents too large to be supplied by portable equipment without special electrical control methods. For very high conductivity, D.C. is ineffective (Vincent 1971) and pulsed D.C. or A.C. may be more effective. Other factors that are important are voltage and

electrode size. In waters of low conductivity alternating current is more effective than direct current.

Table 1 reproduced from Novotny and Priegel (1971) lists guidelines for stream shocking with direct current. The portion of the table labeled “ineffective electrofishing” shows the conditions under which D.C. would not be expected to take fish. For example, a 250 volt D.C. generator with two 16 inch diameter anodes would be ineffective in water with a conductivity lower than 150 micromhos/cm.

6. Water clarity and vegetation – Turbid water and excessive vegetation restrict visibility and reduce the value of the immobilizing capabilities of the A.C. electrofishing gear. Pulsed D.C. and D.C. offer potential solutions to this problem.

7. Water depth – Fish which are immobilized at depths exceeding 3-4 feet are very difficult to capture by ordinary netting procedures. Pulsed D.C. and D.C. should help to overcome this problem.

8. Bottom materials – High conductivity bottom materials tend to “short circuit” the current out of the water into the bottom material reducing the electrofishing effectiveness and sometimes overloading the power source. Little can be done to remedy this situation except to avoid direct contact between electrodes and the bottom.

   If using D.C. gear, however, cathode contact with the bottom in effect increases the size of the cathode and may improve electrofishing efficiency assuming the anode does not contact the bottom.

9. Water temperature – The conductivity of water and water temperatures are more or less a straight line relationship; that is, as the temperature of the water increases, the conductivity of the water increases at an equivalent rate (Sigler 1969). Theoretically, success of electrofishing should increase with temperature. However, most investigators agree that salmonids are most easily captured by electrofishing at temperatures below 50 F.

10. Fish mortality – Mortalities caused by A.C. electrofishing probably are higher than those caused by D.C. or pulsed D.C. (Taylor et al. 1975) and the gross physical damage from A.C. can be severe (Hauck 1949).

11. Differential vulnerability – Most investigators agree that large fish of a given species are more easily shocked than small fish.

    Some species that have strong swimming ability, such as northern pike, are difficult to capture with electrofishing gear. Increasing boat speed or herding the fish into a dead-end channel may improve results.

    When using pulsed D.C., experimentation with wave forms or pulse rates may be necessary since reactions are different for different species.

12. Early detection of current by fish – In highly conductive waters, fish can detect an electric current before the intensity is great enough to produce galvanonarcosis or galvanotaxus. They escape by swimming ahead or to the side of the shocker.

    Some workers have found it advantageous to turn the electricity off at intervals and move the shocker ahead to “catch up” with the fish.

    Shocking along a shoreline also serves to bloc one avenue of escape.

13. Delayed surfacing – When using A.C. electrofishing gear, many narcotized fish do not surface until long after the shocker has passed. Some species such as channel catfish are especially prone to delayed surfacing.

    If boom shocking gear is used, a pick-up boat following at a distance is desirable. If this is not possible, the boat should turn around at intervals to look for narcotized fish.

    In waters below 40 F., many species of fish do not surface and must be netted off the bottom.

Determination of Proper Amperage – All electrofishing gear should be equipped with ammeters to determine the current to which the fish are subjected.

The operator should experiment with his electrofishing equipment to determine the minimum amperage required to effectively collect fish. Records should be maintained to relate shocking efficiency to water conductivity with a given shocking unit.

If alternating current is used, the operator should carefully observe the fish he captures to detect any physical damage such as broken backs, burns, etc. If any physical damage is apparent, amperage must be reduced.

If direct current is used, the reactions of the fish should be observed to determine which amperage produces greatest galvanotaxis. If the amperage is too high, galvanonarcosis will result making the fish difficult to capture.

Safety Procedures – The following list is a synthesis of the recommendations of Coffelt (1978), Jackson (1978), Novotny and Priegel (1974), Rawstron (1978), Sigler (1966), and various Minnesota workers.

Personnel

a. One and only one person should be in charge of the electrofishing operation.

b. All persons involved must be familiar with the operation of the equipment and should understand the principles of electrofishing.

c. All crew members should be familiar with first aid procedures, including cardio-pulmonary resuscitation (CPR).

d. If there are observers, make sure they are informed of the dangers involved.

e. An operator should not work:

    a. if he is fatigued
    b. by himself
    c. during an electrical storm

f. All operators should wear hipboots or waders that do not leak and have non-slip soles.

g. Both electrode and dip-net operators must wear electrical safety gloves. Even a pinhole leak destroys the insulating qualities of the gloves.

h. All personnel should wear life vests when working in boats or wading large streams.

i. Do not touch electrodes unless the power is off.

j. Do not risk losing your balance to net a narcotized fish that is out of reach.

k. Use hand signals or shortwave radio communications if the generator is excessively noisy.

l. The person in charge should tolerate no horseplay.

Equipment

1. A first aid kid should be available at all times.

2. A fire extinguishes should be on board all electrofishing boats with gasoline generators.

3. Do not use gasoline generators on backpack shockers.

4. Ear plugs should be available if generator is excessively noisy.

5. The following items should be made of non-conductive materials:

   a. booms
   b. dip-net handles
   c. electrode handles

6. Waterproof, low voltage, pressure activated switches should be installed on all electrode handles or on the front deck of a boom shocker.

7. All circuits should have circuit breakers or fuses.

8. All batteries should be enclosed in a leak proof container.

9. The rating of all wiring must be equal to or greater than the maximum voltage to be used.

10. Prior to connecting or disconnecting parts, make sure the unit is turned off.

11. Keep equipment in good working order. Check for loose connections and worn wires before each trip.

12. Keep boats used for boom shocking clean and uncluttered. Carry only essential equipment.

13. Electronic generators designed for commercial or domestic use may have one side of the output grounded to the frame. This creates a hazard when the machine is used for electric fishing,

since it can cause the supporting unit (boat, truck or even earth) to become "live." This internal ground should be disconnected.

14. An accumulation of static electricity can occur in electric generators. To prevent a severe shock, the generator frame should be grounded to the boat or earth with a grounding strap.
15. Boom shockers should be equipped with a hip-high safety rail around the front deck of the boat.

Table 1 – Proposed guidelines for stream shocking with direct current and two anodes (from Novotny and Priegel 1971).

			Voltage/Anode Size (diameter in inches)						
Conductivity (micromhos/cm)	Minimum required current (amperes)	Maximum current (amperes))	200	250	300	350	400	450	500
500	5.2	15.2	8,12	8	-	-	-	-	-
450	4.8	14.2	12	8	-	-	-	Generator	-
								Overloading	
400	4.4	12.8	12,16	8,12	8	-	-	-	-
350	4.0	11.5	12,16	A	8,12	8	-	-	-
300	3.7	10.2	12,16	A	A	8,12	8	8	-
250	3.3	8.8	16	12,16	A	8,12	8,12	8	8
200	2.9	7.5	16	12,16	A	A	8,12	8,12	8
150	2.5	6.3	-	16	12,16	A	8,12	8,12	8,12
100	2.1	4.7	-	-	12,16	12,16	A	A	8,12
80	1.8	4.0	-	-	16	12,16	12,16	A	A
60	1.5	3.2	-	Ineffective	-	16	12,16	12,16	12,16
40	1.2	2.5	-	Electrofishing	-	-	16	16	12,16
20	0.8	1.5	-	-	-	-	-	16	16

Notes: A represents 8; 12; 16

i. For electrofishing with one anode, the minimum required current is 50% of the table value.
ii. For electrofishing with three anodes, the minimum required current is 150% of the table value.
iii. The indicated anode sizes at various voltages are only suggestions—in all cases the current should be within the specific range and be within the rating of the generator being used.
iv. Best results will be attained with as large a current per anode as can be supplied within the specific range. Current per anode can be increased by:
  v. increasing voltage
  vi. using larger anodes
  vii. using fewer anodes
  viii. enlarging cathode

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