APPENDIX E
Stream Channel Assessment Module

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Introduction

Assessment of channel condition is one of the most difficult aspects of watershed analysis. This difficulty arises, in part, because channels are complex, dynamic systems. The channel assessment procedure presented here provides a framework for objectively assessing both past changes in channel morphology and processes and current channel conditions throughout a watershed. Although this procedure was developed for channels in the Pacific Northwest, the process orientation makes the general approach transferable to other regions with minimum modification.

Channels are defined by the transport of water and sediment confined between identifiable banks (Montgomery and Dietrich, 1989; Dietrich and Dunne, 1993). In spite of this basic similarity, there are many types of natural stream channels, reflecting spatial differences in channel processes, historical disturbance, lithologic and structural controls, and geologic history (e.g., Paustain et al., 1983; Rosgen, 1985; Frissel et al., 1986; Cupp, 1989; Montgomery and Buffington, 1993). Channel morphology reflects and inte-grates processes operating in a watershed because material eroded from hillslopes ultimately is delivered to and routed through the channel network. Consequently, channel condition provides a logical metric for diagnosing watershed conditions. Channel assessment would be impractical, however, were all channels unique in their potential response to disturbance or changes in watershed processes. Thus, a fundamental tenet of applying watershed analysis to stream channel assessment is that patterns in channel morphology and processes may be used to simplify the wide variety of natural channels into a manageable analysis framework.

Channel morphology and condition reflect the input of sediment, water, and wood to the channel, relative to the ability of the channel to either transport or store these inputs (Sullivan et al., 1987). Systematic and local differences in transport capacity and the nature and magnitude of inputs through a channel network result in a distribution of different channel types throughout a channel network, reflecting spatial differences in channel slope, flow depth, sediment supply, and the availability of large woody debris. Because of these differences, certain channels are more or less sensitive to similar changes in these input factors. Identification of differences in channel processes and sensitivity is a major goal of the channel assessment component of a watershed analysis.

The channel assessment method developed in this module stratifies the channel network to guide analysis and interpretation of channel condition and response potential. The different channel types so identified provide a coarse stratification of the channel network into reaches with similar channel-forming processes. Within each channel type, qualitative assessments of various indicators of channel history, transport capacity, and sediment supply provide for a more detailed diagnosis of channel condition and guide determination of major processes controlling channel morphology and habitat structure throughout the channel network. The assessment divides the channel network into segments that define areas of the network that respond to disturbance in a similar fashion based on similarities in channel-forming processes. This allows assessment of channel conditions on a watershed basis and provides a context for evaluating the influence of changes in land management on channel conditions and processes.

Critical Questions

The purpose of the channel assessment module is to guide development of information necessary to address several key questions critical to understanding channel processes and conditions in a watershed context:

What is the spatial distribution of channel response types?

Is there evidence of channel change from historic conditions?

What do existing channel conditions indicate about past and present active geomorphic processes?

What are the likely responses of channel reaches to potential changes in input factors?

What are the dominant channel- and habitat-forming processes in different parts of the channel network?

Answering these key questions relies on a combination of map, aerial photo, and field work. They may be answered at many levels of confidence and detail. The module developed here is designed to generate sufficient information to introduce sound information into forest land use decision making.

Assumptions

A number of fundamental assumptions underlie the approach developed here. The most fundamental requirement is that the analysis is based on the best available scientific information and techniques. Thus, the module analysis methods themselves are designed to change as newer methods are developed. The underlying assumptions and analysis framework, on the other hand, are not. Rather, these assumptions dictate a rigorous, yet flexible, framework for the analysis. Our primary assumptions include:

- Major changes in channel morphology are caused by changes in discharge, sediment supply, and vegetation influencing the channel (e.g., riparian and large woody debris).
- We can meaningfully simplify (classify) the complex array of natural channels.
- There is enough pattern in channel conditions to allow diagnosis of current conditions.
- The style and magnitude of potential response to input changes can be recognized.

An Overview of the Assessment and Products

The stream channel assessment is conducted using maps, aerial photographs and field observations. Based on this information, the analyst interprets stream processes relative to the critical questions for the watershed as a whole and for sub-areas within it. Watershed analysis requires the stream channel analyst to develop information to address each critical question. The method developed in this manual describes the standard channel assessment.

A series of exercises designed to either confidently answer the key questions, or identify more detailed information necessary to do so, is developed in the module. The objective of these exercises is to generate information sufficient to establish:

- *Channel segments liiely to respond similarly* to changes in the input factors (water, sediment, wood).
- *Historical changes* in channel morphology to identify past and continuing natural and management-related impacts.
- The *current channel condition* indicating the status of present regimes of input factors.
- The likely future response of channels with and without potential changes in input factors, given the nature of the channel and its present condition (*channel sensitivity*).
- Interpretation of the *habitat-forming processes* dependent on the geomorphic processes controlling channel morphology. The influence of channel processes on habitat attributes identified as important for fish or other aquatic organisms.

Each of these objectives is an integral component of the stream channel assessment. Together, these questions and objectives provide the foundation for assessing contemporary channel conditions and interpreting potential channel response. Only in smaller watersheds are channel form and dominant processes likely to be uniform throughout the basin. An important element of the assessment is to stratify the watershed into areas of similar condition and response, ultimately relating channel form and process to the terrain, geology, and disturbance history of the locale.

Products from the analysis consist of maps, interim worksheets, and narrative provided by the analyst. Interim work products captured on forms preserve the trail of information, observations, and logic used by the analyst in developing interpretations. These work products are easy to follow for review purposes, and importantly, make data available for monitoring hypotheses through future years as well as provide a data base against which to evaluate new assessment techniques. Narrative summaries are necessary for communication of results, but because of time limitations, they are intended to be short and focused. The analysis is expected to provide at a minimum the products listed in Table E-1.

The analysis consists of a series of steps that successively build the framework for assessing past, current, and potential future channel conditions. First, the analyst uses topographic maps to provide a general stratification of channel segments according to channel gradient and confinement. Each segment in the watershed is numbered on the *channel segment map* (Map E-1). Segment numbers are entered onto the *channel segment worksheet* (Form E-1) for easy reference of the distribution of segment types in the watershed and the probable response potential to changes in watershed processes and input factors. At sometime early on in the analysis, it is useful to do a one day reconnaissance survey of the watershed to verify gradient/confinement calls.

Next the analyst examines a series of historical aerial photographs to confirm channel confinement categorizations and to document past macroscopic channel changes such as changes in channel pattern and riparian canopy openings due to debris-flow scour or flooding. Remotely sensed data from each segment is recorded both on the *channel disturbance worksheet* (Form E-2) and in a narrative describing the overall history of the watershed as revealed by the aerial photographs.

Based on these preliminary analyses, the analyst selects representative channel segments for field inspection. (Field site selection rationale is recorded on Form E-3). At selected sites, the analyst makes qualitative and quantitative observations to assess channel conditions for interpretation of channel-and habitat-forming processes. These include features of the streambed, the active channel and the flood plain. Field observations can be recorded on the *channel assessment field data forms* (Form E-4).

Table E-1. Products of the Stream Channel Assessment

Critical Question	**Information Used**	**Product**
Distribution of Response Segments	• Topographic Maps	• Channel segment map (Map E-1) • Channel segment worksheet (Label Form E-1)
Evidence of Historic Change	• Aerial Photographs • Anecdotal Information	• Channel disturbance worksheet (Label form E-2) • Narrative summarizing historic watershed riparian width pattern
Current Channel Condition	• Field Observations	• Site selection rationale (Form E-3) • Field forms (Label form E-4) • Segment diagnostic worksheet (Label form E-5)
Channel Sensitivity to Changes in Input Factors	• All of the above	• Geomorphic unit map (Map E-2) • Geomorphic unit worksheet (Label form E-6) • Narrative describing dominant geomorphic processes and condition
Habitat-forming Processes	• Field Observations and Channel Sensitivity Worksheet	• Narrative describing habitat-forming processes by geomorphic unit

Once representative stream segments have been observed for streambed, active channel, and flood plain attributes, the analyst must interpret the channel-forming processes influencing both channel and habitat features using their experience and some guidance provided in this manual. Typically, a series of characteristics provides a reasonable indication of the current relations between sediment supply, transport capacity and flow obstructions governing channel processes and morphology. Additional features may indicate the occurrence of past changes in these regimes or the occurrence of catastrophic events such as dam-break floods or debris flows. In turn, the watershed, valley and channel conditions determine the availability of key habitat features for fish or other aquatic life. Conditions and observations regarding the channel- and habitat-forming processes for each segment visited in the field are summarized on the *channel segment summary worksheet* (Form E-5).

Since only a limited number of segments can be visited, the analysis will need to extrapolate the results from the channel segments sampled to the remainder of the segments in the watershed. The analyst classifies which stream segments look, behave, and respond to changes in input factors in a similar fashion. Data from field verified segments is then extrapolated to the entire grouping of segments. Extrapolation results and key information used in the determination is then summarized.

The next step is to interpret dominant channel- and habitat-forming processes, and determine segment sensitivity to each input factor. The analyst associates segments with similar responses with the watershed processes and characteristics that influence them. Typically, there will be an association of channel form with landforms, geology, and so on. The analyst will need to use all the information available including terrain, segment maps, field observations, and aerial photographic data to interpret geomorphic units, which delineate areas into similar governing processes and sensitivities to change. Clustering segments in this fashion will facilitate integration of results with other module results to develop a watershed-scale interpretation of the linkage between hillslope and channel processes during the synthesis phase of watershed analysis. The geomorphic units generated through this interpretation are delineated onto a geomorphic unit map (Map E-2). Based on the interpretation of dominant channel-forming processes, the analyst provides an assessment of channel sensitivities to future changes in input factors. Interpretations are recorded on the *Geomorphic Unit Worksheet (*Form E-6) and summarized in narrative form.

The channel analyst also discusses how channel-forming processes operating in each area are likely to determine the availability of key habitat qualities. Based on concerns raised by the fish module analysts regarding factors such as the qualities of spawning and rearing habitat in areas of particular interest in a watershed because of species use and critical habitat needs, the channel analyst provides a narrative describing how channel processes in those locations currently or potentially influence the factors specifically related to fisheries or other resource concerns identified in the other watershed analysis modules.

Qualifications

Channel assessment depends on highly-qualified individuals to interpret channel morphology and conditions. Channel assessment is a complicated undertaking that relies on both qualitative assessment of subtle differences in channel features and solid theoretical background in fluvial geomorphology. Certain skills, training, and experience are necessary for effectively implementing the standard channel assessment module. Level 2 analyses presuppose a higher level of training and ability to independently develop and implement relevant analyses to address issues and observations not satisfactorily explained by the standard analysis. While there are many possible backgrounds that could provide the foundation necessary for applying this module, the following criteria provide minimum expectations for the background of those performing the channel assessment module:

Skills: Level 1

Knowledge of the processes active in stream channels in forested and mountainous terrain and the ability to recognize and interpret hydraulic and geomorphic features of stream channels.

Thorough understanding of the principles of channel processes reviewed and synthesized in Channel Classification, Prediction of Channel Response, and Assessment of Channel Conditions (Montgomery and Buffington, 1993).

Additional Skills: Level 2

Experience with quantitative methods of channel assessment (e.g., sediment budgets).

Education and Training: Level 1

Bachelor's degree in geology or related field (civil engineering, hydrology) or specific course work in fluvial geomorphology.

Additional Education and Training: Level 2

M.S. degree in geology or related field (civil engineering, hydrology) with graduate course work in fluvial geomorphology.

Experience: Level 1

Two years field experience in channel assessment, or research in fluvial geomorphology.

Additional Experience: Level 2

Experience conducting relevant independent research or channel assessments.

Self-Evaluation
For Level 2 assessment: Ability to read and understand basic references on channel processes such as:

> **Richards**, K. 1982. Rivers--Form and Process in Alluvial Channels. Methuen and Co., N.Y., N.Y.
>
> **Leopold**, L.B., M.G. **Wolman**, and J.P. **Miller**, 1964. Fluvial processes in geomorphology. W.H. **Freeman**, San Francisco, CA.

Background Information

Initial information needs for the standard channel assessment are minimal, in keeping with the reconnaissance-level orientation. Further information needs may be identified during the course of the analysis, but topographic maps, photographs and other available historical information provide the background data for the standard channel assessment.

The following information is needed to conduct a channel assessment.

Maps
Topographic maps of the watershed (7.5 minute series required where available; finer scale encouraged for working maps).

Photographs
At least two sets of aerial photographs separated by a period of at least ten years (1:12,000 scale or better, if available). The more photographic sets that are available the higher the confidence possible in the remote sensing component of the channel assessment. Also, photographs taken following major storm events and harvest activities are particularly useful for assessing changes in channel conditions. Use the earliest and latest coverage available and decadal coverage for the intervening period, as available. The Mass Wasting Module analysts will also be using sets of historical photos, and sharing of photos between modules may be possible.

Other
Available historical data, anecdotal descriptions, and photographs of channels in the watershed.

Results of the channel assessment are presented on the official watershed base map to ensure mapping consistency between analysis modules.

If time is available, the analyst should also try to track down any studies that may have stream channel data, such as instream flow studies, or United States

Geological Survey (USGS) channel cross-section data from 9-207 forms. (Discharge measurement notes).

Analysis Procedure

There is a certain level of information necessary to analyze channel processes in a watershed context. The following procedure defines a standard methodology appropriate for watershed analysis and must be completed.

Level 1 and Level 2 watershed analysis levels specify the qualified individuals and time frames available for the assessment. Given the status of our scientific knowledge regarding watershed-scale fluvial processes, there are likely to be uncertainties in the interpretations of any assessment conducted according to these procedures. In addition, limitations of time and resources for performing the assessment, and the analyst's qualifications will also determine the degree of resolution and confidence in assessment interpretations.

It is expected that Level 1 assessments produce the standard products, which includes all forms and maps identified in the channel assessment report section of this chapter. Greater uncertainty of results and indeterminate interpretations can be expected, because less time for field-work is allowed. It is important that uncertainties be noted so that decisions based on this information can account for them. Level 2 analysis should be invoked when analysts are not satisfied with their ability to answer a critical question based on the standard analyses, and improving interpretations is considered important for decision-making.

Level 2 assessment requirements are more flexible and exploratory allowing the analyst to invest his or her effort in gathering data and observations as warranted by the nature of the question to be answered and the watershed situation to be resolved. Level 2 teams are expected to produce similar assessment products augmented by additional information for specific situations. This may include specific analyses of particular processes or sub-areas within the watershed. In addition, to facilitate the scientific review of assessment procedures, the format for presentation of results shown in the channel assessment report section must be followed when standard assessment forms are not used by Level 2 teams.

To aid in the interpretation of channel environments, the individual conducting the channel module should be communicating with the individuals conducting the appropriate modules (e.g., mass wasting, riparian, surface erosion and fish habitat) during the time of the assessment. This communication between module leaders is particularly important before, during and after field work. This is necessary for construction of working hypotheses regarding changes in the input variables, which other module leaders may be more familiar with, and the subsequent response of the channel.

Distribution of Channel Response Types

There is a need to initially identify similar channel segments in order to develop hypotheses for response potential throughout a watershed. Such an initial classification must be done from either topographic maps, aerial photographs, or digital terrain data. Channel attributes that may be so determined are typically restricted to slope, width, drainage area, and associated land forms. For this analysis, consider channel segments as the primary mapping unit of stream classification and watersheds as a series of channel segments defined by changes in gradient and confinement discernible at map scales of 1:24,000. Stream segment slope and confinement provide a useful orientation for stream classification in that valley morphology is insensitive to most disturbances of stream processes occurring over decades or centuries. A combination of gradient and confinement provides a simple method to distinguish response potential. The approach to stream classification em-ployed in the channel assessment module largely focuses on describing segments, understanding their distribution relative to watershed features, their probable condition under baseline and disturbed regimes, and their potential for biological productivity under a variety of conditions.

The influence of valley conditions on stream channels has been characterized in several classifications that describe relatively homogeneous lengths of stream contained within similar geomorphic settings (e.g., Paustain et al., 1983; Rosgen, 1985; Cupp, 1989). Stream segments are associated with valley gradient and are demarcated by contacts between lithologies of variable resistance, or by abrupt change in valley conditions or land forms. Gradient is a surrogate for stream energy, the dominant control on channel morphology. Confinement controls aspects of potential response and reflects the long-term history of a valley where past events, such as glaciation, leave an imprint. Gradient and confinement are also general indicators of transport capacity and the balance between sediment supply and transport capacity.

A simple method for categorizing channel response potential in terms of gradient and confinement was developed based on geomorphic reasoning and experience (Table E-2). Lacking more detailed information about channels, we may expect those with similar gradient and confinement to respond similarly to changes in input variables. These gradient classes generally correlate with morphologically distinct channel types (Montgomery and Buffington, 1993), but they are not absolute, and considerable overlap can exist depending upon local conditions. For example, the 8-20% gradient category may have a transition category that includes distinct geomorphic characteristics and thus results in a different set of responses to changes in input factors. This can be included in the assessment because the matrix is a first cut. Nonetheless, the channel response matrix (Table E-2) approximates sediment transport and response characteristics expected for channel segments defined through remote assessment. Furthermore, the response matrix provides a way to develop hypotheses about channel processes that may be tested through limited field observations.

The segment types in the channel response matrix (Table E-2) occur broadly in watersheds throughout the Pacific Northwest region and are for the most part independent of changes in erosion or hydrology caused by watershed disturbance. Segment types are expected to have similar characteristics under equivalent watershed conditions and to respond similarly to changes in sediment and hydrologic input to a watershed. From a conceptual standpoint, segments are seen as discrete lengths of stream, with characteristic spatio-temporal erosional and depositional profiles.

Table E-2. Channel Response Matrix

	SEDIMENT	DISCHARGE	WOOD		CATASTROPHIC EVENTS	
	FS _ Fine Sediment Deposition CS - Coarse Sediment Deposition	SC - Scour Depth SF - Scour Frequency BE - Bank Erosion	WL - Wood Loss WA - Wood Accumulation		DFS - Debris Flow Scour DFD - Debris Flow Deposition DB - Dam Break Flood	
VW > 4CW UNCONFINED	FS BE WA	WL SF FS BE	DB DFD BE CS SF WL	DFS/DFD DB WL	DFS	
2CW < VW < 4CW MODERATELY CONFINED	FS BE WA	CS BE SD WL FS	CS BE DB SD DFD WL SF	DFS/DFD DB SF WL	DFS	DFS
VW < 2CW CONFINED		CS WL	CS SD WL DFD DB	DFS/DFD DB SF WL	DFS	DFS
	<1.0 Pool-Riffle	1.0 - 2.0 Pool-Riffle, Plane-Bed	2.0 - 4.0 Plane-Bed, Forced Pool-Riffle	4.0 - 8.0 Step-Pool	8.0 - 20.0 Cascade	> 20.0 Colluvial

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Define the Channel Network

The channel network must be defined prior to identifying channel segments. Mapping and visiting all channels in a watershed is extremely time consuming and would make the assessment intractable. Instead, we differentiate between fluvial and mass-wasting dominated channels and adopt the approach of delineating the full extent of the channel network, but only analyzing in detail representative reaches of the fluvially-dominated portions of the channel network.

Defining the channel network entails locating its upper extent. There are many ways to approximate the extent of the channel network and the blue lines portrayed on topographic maps only rarely reflect the actual extent of the channel network (Morisawa, 1957; Mark, 1983). Field surveys show that the drainage area necessary to initiate a channel is inversely proportional to slope (Montgomery and Dietrich, 1988; 1989), allowing determination of channel network extent if the appropriate relation is known. When this relation is not known, as is generally the case, the extent of v-shaped, or crenulated, contours may be used to approximate the extent of the channel network (Morisawa, 1957). Preliminary data suggests in mountain drainage basins in the western United States that a gradient of approximately 20% defines the upper limit of fluvially-dominated systems (Seidl and Dietrich, 1992; Montgomery and Foufoula-Georgiou, in press). Field studies in the Pacific Northwest also have shown that mass-wasting processes, such as debris flows, are important sediment processes in channels steeper than approximately 15 to 20% (Benda, 1990). Consequently, these channels are investigated in the mass wasting module.

After delineating the entire channel network, channel reaches with less than a 20% gradient are included in the stream channel assessment and are labeled and numbered on the channel segment map. Channel reaches greater than 20% need to be delineated in order to identify the break point. The extent of the channel network used in the analysis may be modified based on field reconnaissance. The linkage between channels dominated by mass-wasting and fluvial processes should be considered during the analysis and prescription phase of watershed analysis. Labels and numbers also can be given to streams with gradients of greater than 20%, if needed for addressing specific resource concerns or linkages of hillslope and channel processes. For example, it is useful to label and number those channel reaches greater than 20% that directly enter fish-bearing water and drain a large proportion of a watershed. This gives the analyst an opportunity to check historic aerial photo review for mass wasting run-out areas.

Classify Segments
Once the channel network is delineated, it is divided into segments with similar gradient and confinement. A segment is a unique part of a stream with beginning and end-points corresponding to stream coordinates. As such, they are the basic stream mapping unit for all stream channel-oriented components of watershed analysis (Channel, Fish, Hydrology, and Riparian modules). The segments allow the analyst to interpret general expected variations in channel morphology and processes and provide a guide for focusing field work. It is important to divide the channel network into a minimum number of segments in order to facilitate the analysis. Although some judgment is required to delineate segments, the following criteria are suggested as a guide. (The analyst may also refer to the "Ambient Monitoring Program Manual" of July, 1993, edited by Schuett-Hames, et al., for guidance in identifying stream segments.)

Channel Gradient
Gradient is readily determined from topographic maps from the distance between contours. Six gradient ranges are used that generally correspond to gradients associated with changes in channel morphology that reflect relative transport capacity, and thus response potential (Table E-2). Gradient breaks need to be consistent for at least three consecutive contours. This will provide a minimum distance for each segment and will subsume short reaches of steeper or lower-gradient channel into longer reaches with more representative average slopes. If three consecutive contours is too long for low gradient reaches (e.g., less than 1%) or too short for steep gradient reaches (e.g., greater than 20%), then the analyst should make a decision on the minimum number of contours or distance and identify the criteria used in the methods section of the channel assessment report.

Confinement
Channel confinement is more difficult to determine, but it may be considered to be the ratio of the valley or flood plain width (VW), to the channel width (CW). Confinement is an important control on potential channel response. Channels with wide flood plains may shift laterally over the valley bottom, changing course, sinuosity, or pattern (e.g., meandering, braided) in response to disturbance, whereas channels confined by bedrock valley walls can only respond in other ways (e.g., bedform modification or channel armoring). Channel confinement generally cannot be measured directly from topographic maps, especially for small channels, because channel widths are not portrayed accurately. Wherever possible, confinement estimated from topographic maps should be confirmed with either aerial photographs or field observations. Each channel reach is classified as confined (VW < 2CW), moderately confined (2CW < VW < 4CW), or unconfined (VW > 4CW) (Table E-2).

In addition, it is also useful to delineate a stream segment break at major tributaries that contribute 10% or more of the total upslope drainage area. Although gradient and confinement may not change within a reach with a major incoming tributary, the tributary itself could influence channel features sufficiently that the segment could differ above and below the tributary.

Average segment length (distance between slope breaks) probably increases with watershed and stream size. The occurrence of segment types varies within watersheds according to stream size, and regionally according to differences in geology, geomorphology and climate. Again, it is important to check the gradient/confinement calls during the field sampling phase of the assessment report.

Numbering the Segments

Channel segments are assigned a number and classified following the convention illustrated in Figure E-1. Segments on the channel map are labeled with the gradient/confinement codes from Table E-2. A copy of this map should be provided to the fish habitat and riparian analysts upon completion. In larger watersheds with numerous tributaries, it may be useful to assign a letter code or prefix to each tributary system.

Recording Segments

Tabulation of the segment numbers on the channel segment worksheet (Form E-1) provides the analysts with a record of the frequency of segment types in the watershed. This information gives the analyst information on the frequency distribution of channel types and helps guide selection of representative channel segments for field observations.

Initial Interpretation of Response Segments

Segments are stream types determined by valley conditions and as such their location and morphology tend to remain constant over time frames important to forest management conditions. Segment types represent the "potential" of the stream and provide constraints on the probable form that the channel can have within it.

As an aide to planning the subsequent field component of the module, it is useful to synthesize segment information into general response potential zones. Classification of segments into source, transport, and response reaches using gradient criteria of greater than 20% for source, 3 to 20% for transport and less than 3% for response reaches reveals general patterns of sediment transport characteristics associated with reach-level morphologies (Montgomery and Buffington, 1993). The 3% gradient break unfortunately is not used to define segment categories, so the segment breaks will be different than the general response potential zones. Source reaches are likely to be storage sites for colluvium and they are subject to mass wasting events, and correspond to debris-flow dominated channels (Benda and Cundy, 1990). Within the fluvially-dominated channel network, transport reaches are likely to act as conduits for rapid sediment transport and delivery to downstream reaches. Response reaches, on the other hand, are most likely to exhibit pronounced and persistent morphologic adjustments to changes in sediment supply.

The distribution of source, transport, and response reaches governs the distribution of potential impacts and influences recovery times in the channel network (Montgomery and Buffington, 1993), as well as the composition and structure of the biologic communities inhabiting the stream channel. Thus, identification of these potential response zones in a watershed reveals spatial linkages between upstream sediment inputs and downstream response.

Transport reaches rapidly deliver sediment to downstream response reaches, where sediment is more gradually transported downstream. Response reaches immediately downstream of transport reaches thus are relatively susceptible to changes in sediment supply. Delineation of channel types and response zones also aids in selection of sites for field visits and for interpreting causes of historical channel change revealed during examination of aerial photographs. If a source, transport, and response map is made prior to aerial and field work it, should be modified when the field component of the assessment is complete.

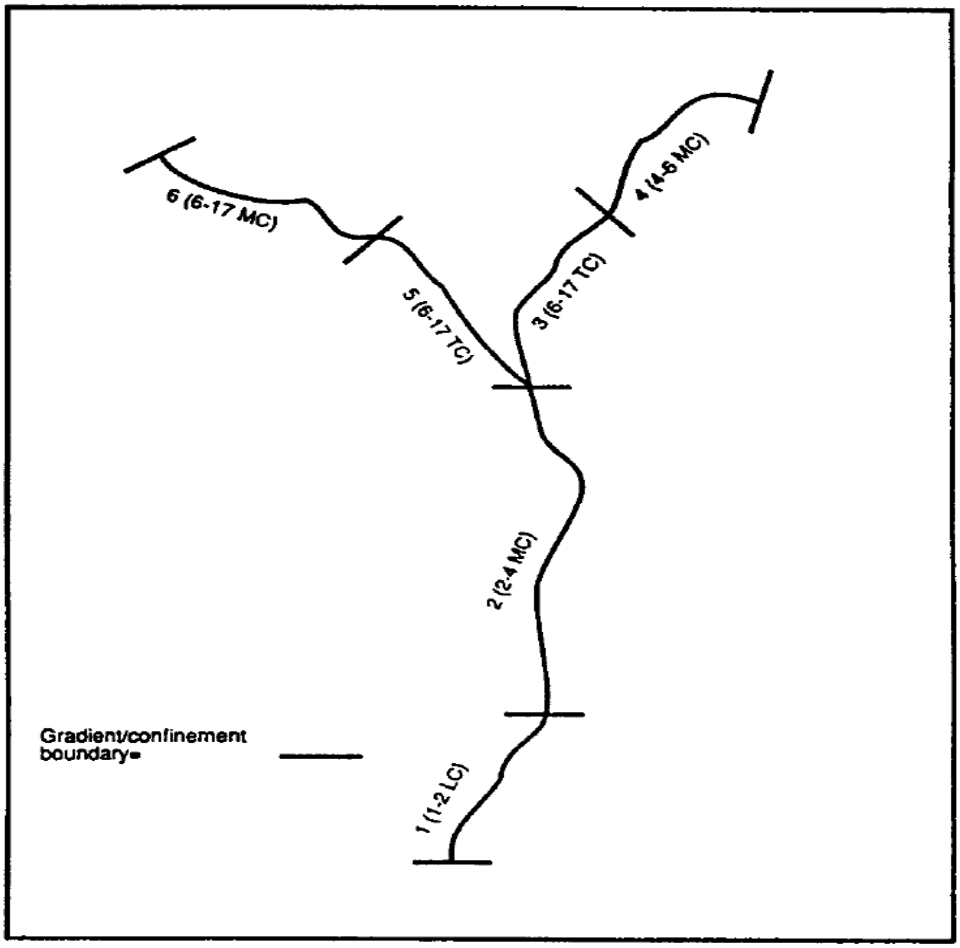

Figure E-1. Example of Channel Segment Labeling and Numbering

An example from the Tolt River

The channel network in the 100 mi^2 watershed was divided into 166 numbered segments (Figure E-2). Comparison of the channel response table with the channel segment worksheet (Figure E-3) provided the channel group with hypotheses for the type of input factors that may influence specific segments. Generalization of the channel segment map into transport and response segments (Figure E-4) allowed the channel group to identify areas that may be more sensitive to a change in input factors based on channel network position. These distributions helped interpret evidence of historic changes in channel conditions observed in subsequent analyses of aerial photographs.

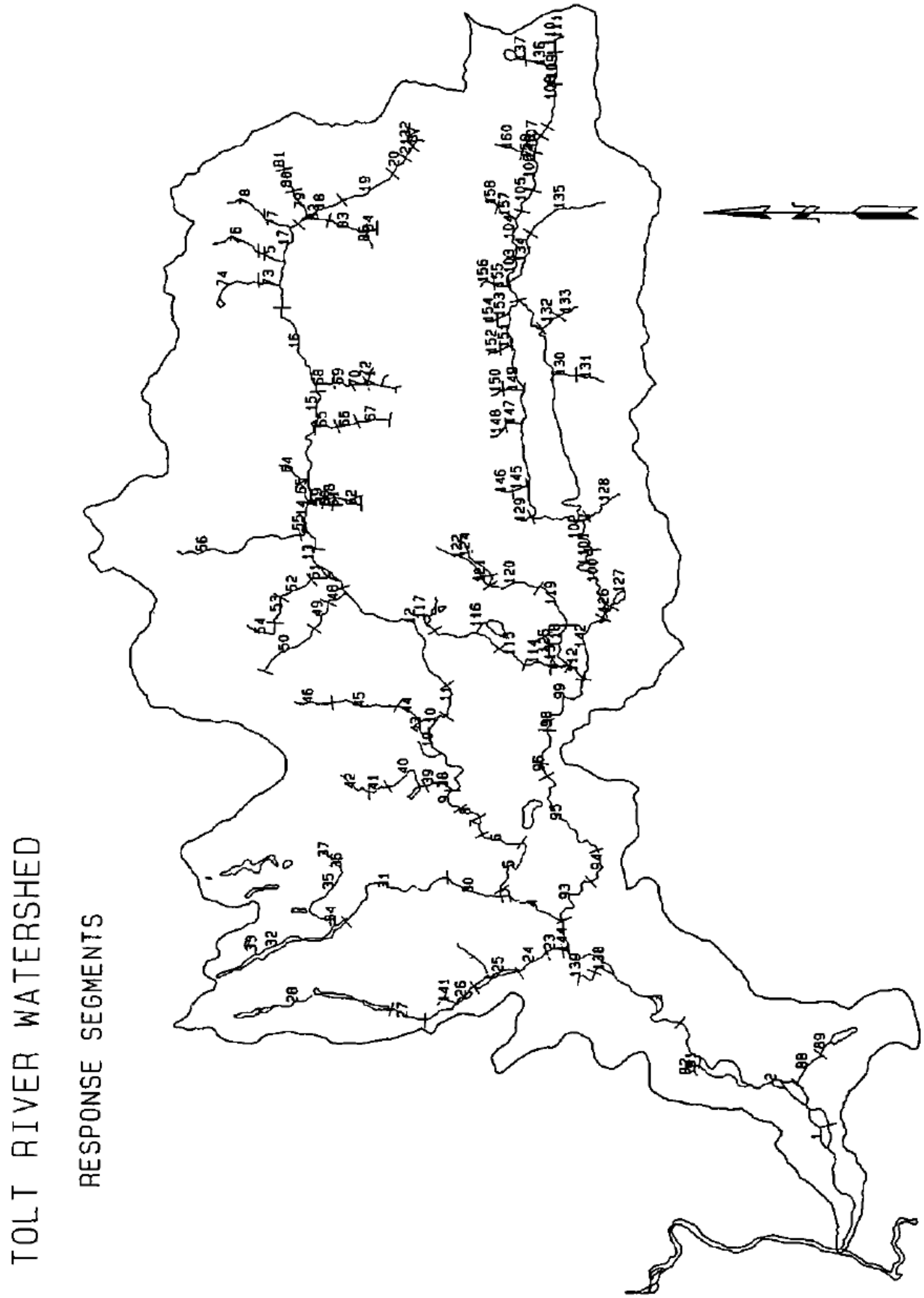

Figure E-2. Example of Channel Segment Labeling and Numbering

Form E-1. Channel Segment Worksheet

SEDIMENT
FS – Fine Sediment Deposition
CS - Coarse Sediment Deposition

DISCHARGE
SC - Scour Depth
SF - Scour Frequency
BE - Bank Erosion

WOOD
WL - Wood Loss
WA - Wood Accumulation

CATASTROPHIC EVENTS
DFS - Debris Flow Scour
DFD - Debris Flow Deposition
DB - Dam Break Flood

	<1.0 Pool-Riffle	1.0 - 2.0 Pool-Riffle, Plane-Bed	2.0 - 4.0 Plane-Bed, Forced Pool-Riffle	4.0 - 8.0 Step-Pool	8.0 - 20.0 Cascade	> 20.0 Colluvial
VW > 4CW UNCONFINED	1, 25, 114, 116, 2, 90, 13, 109, 28 (9)	15, 17, 103, 127, 138, 63 (6)				
2CW < VW < 4CW MODERATELY CONFINED	15, 119, 32 (3)	63, 11, 26, 31, 64, 93, 134, 97, 99, 105, 113, 117, 120, 125, 140, 141, 142 (17)	40, 54, 69, 89, 102, 104, 106, 121, 123, 135, 143, 144, 16, 35 141, 94, 19 (17)	46, 73, 108, 110, 132, 65 (6)	75, 77, 79, 91, 130 (5)	
VW < 2CW CONFINED		3, 5, 7, 14, 24, 27, 30, 39, 50, 115 (10)	10, 18, 83, 95, 98, 100, 118, 49, 6, 4 (10)	8, 23, 33, 4, 44, 56, 57, 101, 112, 139 (10)	9, 21, 29, 34, 36, 38, 45, 43, 47, 51, 53, 60, 66, 68, 70, 81, 82, 87, 88, 96, 107, 126, 128, 129, 133, 137 (26)	22, 37, 42, 48, 52, 58, 59, 61, 62, 67, 71, 72, 74, 76, 78, 80, 84, 85, 86, 92, 111, 122, 124, 126, 136, 31 (26)

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Figure E-3. Example of a Channel Segment Worksheet

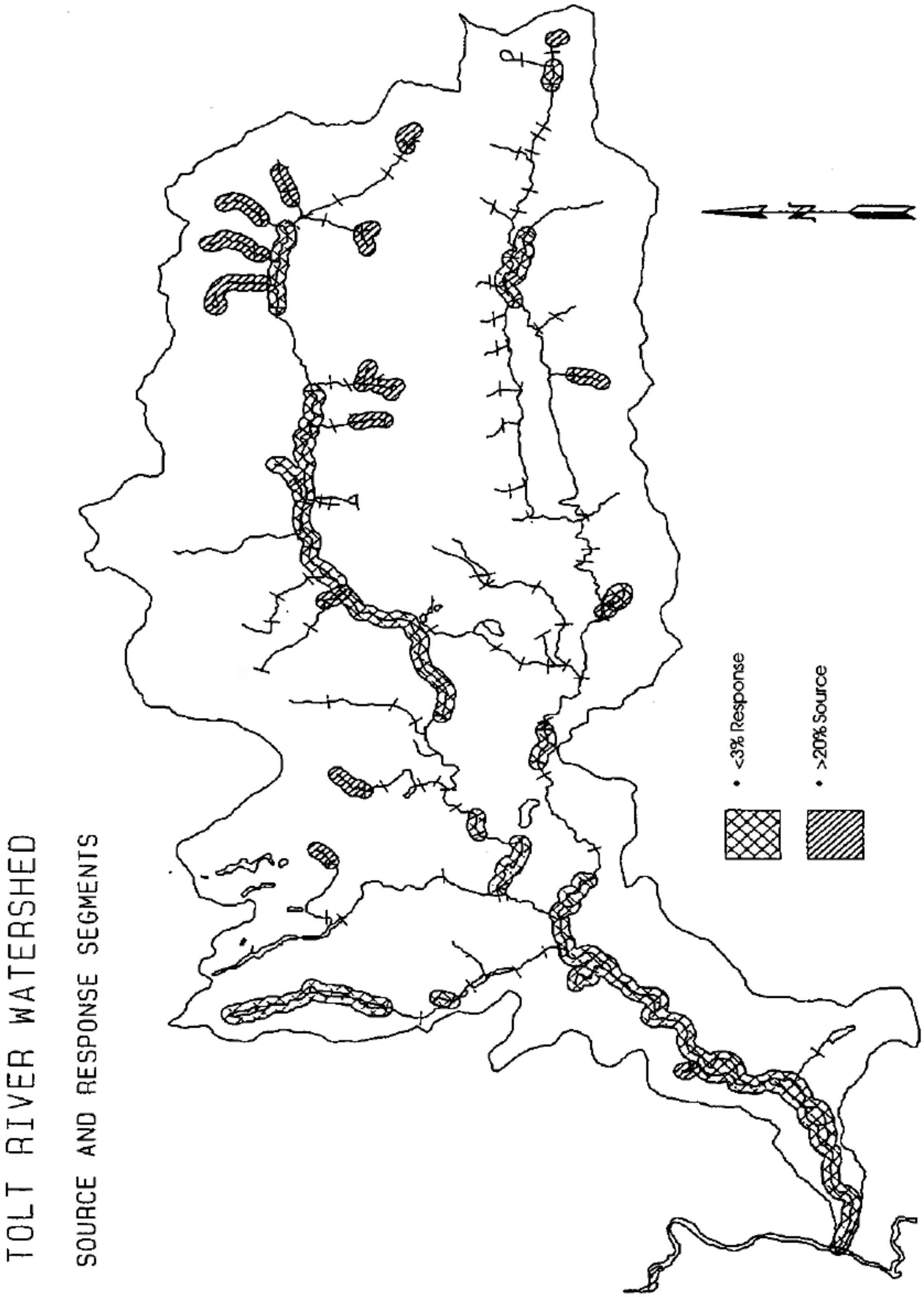

Figure E-4. Example of Source, Transport, and Response Reaches

Historic Changes

Historic changes and trends in channel attributes provide an important component of the context within which to assess current and potential future channel conditions. A wide variety of historical data are useful for reconstructing past channel change, and all available information should be utilized. In most cases, aerial photography will provide the primary source of historical data, although terrace and floodplain deposits can be mapped and dated to learn about past erosional regimes and channel response. Analyses that can be done with aerial photography largely address the question of historical trends in macroscopic channel morphology, such as channel widening, incision, migration, or transformation from a meandering to a braided channel pattern. Reconstruction of historic changes involves comparison of channel conditions through time with some reference standard to determine the degree of disturbance and recovery in a basin. Lacking other information, channel conditions apparent on the earliest available photographs may provide an appropriate reference standard.

Field interpretations allow further comparison of existing channel conditions to reference standards that define desirable channel conditions. The chosen reference conditions, however, must be appropriate for the channel type under consideration, as imposition of simple numerical standards (e.g., pools per mile) on all channel types is inappropriate. Aerial photo analysis is an efficient way to focus field effort, as well as a valuable indicator of past channel response.

Multiple-decade photo coverage is necessary to provide a reasonable determination of trends in channel condition through time. Accurate portrayal of these trends becomes very important when trying to infer causality through comparison of channel change with spatial or temporal patterns of natural and land-use disturbance (i.e., during construction of a diagnostic sediment budget). Evidence of change or trends through time can occur on both larger and more local scales. Large-scale changes in channel morphology may reflect landslide scour, flow diversions or additions from road drainage, and changes in sediment supply. Local changes can include bank erosion and channel widening following riparian disturbance and harvest, direct disturbance to the channel, depletion in the amount of in-channel wood, and increased or decreased pool frequency or area.

Interpreting Photos

Once the channel network has been segmented, the analyst examines aerial photographs for changes in channel width, bar positions and stability, wood loading, channel pattern, canopy opening and channel position. Channel widths should be compared at the same characteristic and recognizable points for each reach on successive aerial photographs. Measuring the same cross-sectional area (transect) allows the stream channel analyst to compare the change in channel width and area over time. For small channels, direct observation of channel width may not be possible due to dense riparian vegetation. In these channels, canopy opening provides a useful surrogate for channel width (Grant et al, 1984; Grant, 1988). In larger channels, gravel bar size and vegetation cover also can be seen and reconstructed through time.

Recording data

For each numbered channel segment, the analyst estimates and records whether the average width of the segment canopy opening increases, decreases or remains the same through each time interval in the photo record. The channel disturbance worksheet (Form E-2) provides a convenient method for documenting observations of channel conditions and change determined from aerial photograph analyses. For reaches that exhibit gross changes such as extensive widening or braiding, it is often useful to trace the active channel area for each photo year available. Channel area and width can be plotted over time to display changes in the channel. Other changes in channel conditions noted during aerial photograph analysis also are noted on Form E-2. (e.g., riparian disturbance, buffer size, road crossings, if yarding occurred across a channel, or if LWD was pulled). Segment selection is an iterative process; as sampling proceeds, questions will be raised that guide selection of additional field sampling segments. Consultation with the other analysts is critical in raising questions and identifying sites for field inspection.

The aerial photo analysis will also help guide site selection for field assessment, which will help the analyst answer other questions pertaining to interpretation of channel and fish habitat conditions.

The analyst should develop a brief narrative describing the overall results of the historic photo analysis for the watershed.

An example from the Tolt River

The channel disturbance worksheet from the Tolt River watershed analysis (Figure E-5) identifies locations where change has occurred (segment response number), the style of change (e.g., increased channel width), the period of change, and gives a brief description of disturbance indicators. For example, the upper North Fork Tolt (Segments 12 through 16) increased in width between 1945 and 1980, started to narrow between 1980 and 1990, and lost riparian and bar vegetation after several floods in 1990. Before 1954, all of the riparian vegetation was cut in these reaches. By 1954 there was evidence of extreme widening leading to channel braiding. Less intense widening subsequently occurred downstream. Widening continued until the late 1970's, when the upper North Fork started to narrow. At present, reaches of this braided section of the North Fork Tolt continue to narrow.

Channel Response Segment Number	Change in Channel Width (+ or -)	Time Interval (years)	Disturbance Indicators: Channel pattern change, alluvial fans, adjacent landsliding, channel widening, narrowing, catastropic damage
15 (1-2MC)	ΔW + '58-76 - '76-'87 90 upper ½ - '76-87 lower ½ + 87-90	32 years 1958 - 90	+'58-76; 100% of riparian veg harvested (~50% of harvest between '64-70) Narrowing of channel '76-87 - upper ½. Increased width in lower half during this period. Same trend continues to '90. "widening" is propagating downstream. Titicaca harvested '70-76. Two distinct areas of widening in segment, propagating downstream
16 (2-4 MC)	Ø	26 years	Bridge constructed between 64-70. Open trib at upper end of segment (Holman Cr) in '64 - remains open for entire period. 50% of riparian area cut pre-64; 100% by '76.
17 (1-2LC)	ΔW + '58-64 Ø '64-70 + '70-76 Ø 76-82 - 82-87 Ø 87-90 + 90-91	32 years 1958 - 1990	Sporadic increase in width from '58-'82, then decrease in 82-89 period. 50% of riparian area cut pre-64; 100% by '76, 4 open tribs; 1 debris flow in 64 - 2 closed and 2 open tribs by '89. Renewed widening in lower ½ between 90-91 ('90 Flood)
18 (2-4 TC)	+ '70-82 Ø 82-90 + 90-91	64-80-91 27 years 1964 - 91	Increased width slows between 82-87. Titicaca opened in between '70-'76 (enters mid-segment.) 0% riparian harvested in 64; 50% by 70; 100% by '76. Greatest enlargement between 70-76-82. No harvest upstream (NF, bndry at upper end of segment) Renewed widening between 90-91. '90 Flood effect
19 (2-4 MC)	- or Ø 64-87 + in '91 photos	27 years 1964 - 91 64-87-91	Appears widened in '64 photos; gradual narrowing thru '87. Increased vegetation on bars. '91 NF photos show channel open, splitting and braiding. '92 FS stream survey says extensive braiding - natural landslides from Red Mtn. upstream, mature forest has kept stream channel intact despite erodible banks.
20 (4-6 TC)	+ pre '64 Ø or + 64-91	1964 - 91 27 years 64-87-91	Appears widened in 64 photos - openings in canopy. ('92 FS stream survey says mostly steep BR channel, transports sediment generated by natural landslides off Red Mtn. Little or no change '91. Riparian veg intact but several open areas. Fresh debris slide off Red Mtn enters at top of segment.
21 (8-20 TC)	+ pre '64 Ø, or + 64-91	27 years	Appears widened in '64 photos - openings in canopy ('92 FS stream survey indicates large natural landslides off Red Mtn - probably experienced debris flow in this segment.) Sparse riparian vegetation (natural); actively eroding.

Figure E-5. Example of Channel Disturbance Worksheet

Interpreting the cause of this channel response provides a good example of extending the analysis beyond the standard method when faced with uncertainty. The cause of this widening and resulting change in channel morphology was uncertain from the standard analysis. The assessment team decided to analyze discharge records for the period covered by aerial photographs. This further analysis supported the interpretation that riparian harvest and direct channel disturbance, followed by several greater than 10-year flow events, resulted in bank erosion, channel widening and eventually braiding in response to the increased supply of coarse sediment remobilized from flood plain deposits.

Current Channel Conditions

Physical features indicative of channel conditions reflect the interaction of many processes that influence transport capacity, bank stability, sediment supply, and availability of flow obstructions. Different types of channels respond differently and there is no single metric for assessing the condition of a stream channel. Nonetheless, impacts resulting from land use can change bed and channel configurations in ways that may affect public resources, perhaps most importantly aquatic life and water quality. Such changes in channel conditions can manifest in a variety of ways in the bed, active channel and flood plain. Some channel characteristics or potential responses are only applicable in certain channel types and establishing direct evidence for such changes is further complicated by the potential for complementary or opposing channel response to contemporaneous changes in discharge and sediment supply. Consequently, we adopt the approach of synthesizing available evidence into a diagnosis of channel conditions. We feel that with enough experience this approach will identify the dominant controls on current channel conditions, but we do not know how good it will prove for more subtle interactions. This approach differs considerably from previous channel assessment methodologies (e.g., Pfankuch, 1975) in that it adopts a process orientation and rejects the temptation to develop a single numerical score for interpretation of current and potential channel conditions. Our philosophy is to design a robust framework within which to analyze channel processes that allows for assessment of both existing conditions and prognosis of potential future conditions. The method more closely resembles medical diagnosis techniques.

The segment categorization is applied from remote data and it simply suggests probable stream conditions. Units mapped in this fashion contain no information about present stream states, although most probable states might be inferred, given knowledge of watershed condition and experience with the segment type. This is important, because at finer spatial scales the structure of channels can be highly variable through time responding to changes in the rates of important processes that determine stream morphology including sediment and discharge regimes and the frequency of channel obstructions (Sullivan et al., 1987). This spatial-temporal variability is an inherent characteristic of a segment type defined by more stable features, although the frequency and magnitude of natural variability is generally unknown.

A major task is to identify and assess relationships between channel characteristics and the volume and quality of sediment and obstructions and to flow regime by segment type for the watershed under assessment. The primary environmental factors determining channel condition within a segment at a point in time are the sediment regime (amount and size), discharge regime (frequency and magnitude), and channel obstructions (substrate, LWD, confinement). Consistent with general systems theory (Orsborn and Anderson, 1986), these are referred to as input variables in that they are factors that are extrinsic to a channel segment.

Geology and climate may strongly influence stream channels by determining both the type and input rate of sediment and the quantity and timing of flows available to transport sediment. Forest management and other land use activities can affect each of the input variables directly or indirectly with resultant effects on stream channels. Forest management may result in accelerated rates of sediment input, altered flow regimes, and depletion or removal of channel obstructions (especially LWD).

The current "state" of a segment may vary over the range of potential channel conditions characteristic of each type depending on current and historic interplay of the input variables, reflecting climatic variability and the history of natural or land-use disturbance influencing each segment. Although the channel characteristics of a segment can also vary over time, the potential state of each segment has finite boundaries. Within a watershed it is feasible that, at any one time, two segments of the same type may be at opposite ends of the scale of potential conditions for that particular segment type.

By classifying channels into segments we can identify general stream properties and responses associated with stream types that occur widely within broad geographic areas. However, an evaluation of stream conditions and probable response to watershed disturbance only can be done by considering each local site within a watershed context. Each watershed has unique combinations of geologic and climatic conditions, as well as a history of storms and past disturbance.

A channel segment will have different characteristics depending on sediment loading, hydrologic conditions and obstruction frequency. Interpretations of channel response for segments of a given gradient/confinement class would necessitate determining the current position on a sediment loading continuum from "sediment poor" to "sediment rich". Channels of a given segment class will respond to an absolute increase in sediment input in a manner related to its present position on the "loading continuum". To develop the relationship between input variables and stream channels, we must identify variables to be measured that respond to changes in the input factors. Response variables are defined as characteristics that change in relation to input variables.

Hypothetically, current input factor levels could be determined by indices of response variables that reflect the prevailing sediment rates, flow regime or obstruction characteristics stratified by segment type. Such indices may be one or more response variables that indicate the general level of an input variable. However, there currently is no scientifically-validated channel condition index available that estimates rates of input factors with quantitative channel measures, although qualitative indices have been used for specific channel interpretations (e.g. Pfankuch, 1975). Until a quantitative method is available, we adopt the approach of using all available evidence to generate a diagnosis of channel conditions.

Our method involves making field observations of key attributes of the stream bed, active channel and flood plain in selected locations and, using geomorphic theory as a basis, diagnosing relative levels of input factors from the weight of the evidence provided by the conditions examined. Interpretations will be guided by the diagnostics of this method but the quality of the interpretations will remain largely dependent on the experience and skills of the analyst. Some interpretations may be augmented at later stages of assessment when geologic and hydrologic history of the watershed are available.

Channel conditions reflect spatial and temporal linkages through the watershed. Causality of potential linkages should guide interpretation of channel conditions and selection of representative reaches for field assessment.

For example, sediment perturbations can be greatly damped with increasing drainage area, and therefore spatial scale is important when predicting sediment impacts to channels (Benda, 1993). In addition, tributary junctions of first and second order channels with third and higher order channels are typically depositional sites of debris flows, and abrupt changes in channel morphology at those locations can be expected (Perkins, 1989; Benda, 1990). Dam-break floods laden with organic debris can affect certain portions of a channel network (Coho and Burgess, 1991).

The current state of a segment has a strong influence on probable response to management activity and is an important starting point for understanding observed trends or predicting probable changes with a management activity. Assessing the current stream channel requires several steps:

- select representative sites for field observations
- make field observations relevant to interpreting aspects of channel processes
- diagnose channel conditions relative to input factors
- interpret potential future conditions based on channel processes.

Selection of Segments for Field Assessment
Remotely sensed information is useful in assessing only certain aspects of channel morphology. Other aspects crucial for evaluation of geomorphic processes (e.g., downcutting or aggradation) and habitat condition (e.g., pool frequency or depth) rely on field observations. Unless unlimited time and resources are available, the analyst will need to focus field assessment on representative reaches and extrapolate conditions to other portions of the channel network.

Sample Size
In order to adequately characterize the watershed, the analyst should sample 15 to 25% of the numbered segments in a basin. Sampling should be stratified and based on the distribution of gradient/confinement classes and an attempt should be made to sample a reach representative of each class. Depending upon the variability of physical factors present in the basin, it also may be necessary to include several segments for each class to collect a representative sample. The channel segment map and worksheet will assist in identifying the mix of response segments in the watershed and the disturbance assessment worksheet may guide selection of channel segments for field examination. Again, it is the most important phase of this module, so an increase in sample size will increase confidence in the overall assessment. If time permits, reconnaissance surveys can be made in the beginning and end of the assessment in order to gain a more qualitative understanding of the similarity and dissimilarity between segments.

Selection Criteria
There are a variety of criteria for selecting sites for field visits. We suggest the following in approximate order of utility:

1. The number of segments of a given type in the watershed (see Form E-1).
2. Segments of known resource importance (consult with fish habitat and hydrology analysts). Candidate segments may include unique combinations of response segment and public resources.

3. Representative physiographic and geologic areas of the watershed.

4. Segments which represent both disturbed and undisturbed conditions.

5. Segments likely to respond to changes in specific input factors (sediment supply, LWD, etc.).

6. Segments likely to respond significantly to changes in independent variables (i.e., 2-4% gradient, moderately confined reaches).

7. Segments subject to inputs from hillslope hazards (consult with mass wasting and surface erosion analysts).

8. Segments that are unique or unusual. (e.g. steep, unconfined reaches)

Selected segments should represent a mix of responses reasonably distributed throughout watershed. Site selection is one of the most important steps in the channel module because if the analyst looks for change in locations where it is unlikely, then resulting information will be misleading. Consequently, recording rationale for site selection is an important component of the channel assessment process. The field site selection worksheet (Form E-3) is provided to briefly document rationale for each segment the analyst will visit.

It will be important to consult with the mass wasting, surface erosion, hydrology, and fisheries analysts for input on critical sites while developing the rationale for site selection, and throughout the field phase of the assessment.

Field Observations

The condition of a stream channel and its flood plain reflect the sediment supply, discharge, and roughness regime of the present, imprinted over any remaining effects of past disturbance (Sullivan et al., 1987). The channel analyst uses key features to identify the occurrence of historic events as well as to diagnose the current regime of key watershed processes. **During this phase of the assessment, the analyst should communicate with individuals conducting the other modules to begin developing working hypotheses on whether the existing conditions are normal for the watershed and reflect geology and climate, or are due to natural or landuse disturbance.** However, causal interpretations are developed during the synthesis stage of the resource assessment using information on erosional and hydrologic history of the watershed.

Fluvial geomorphologists have developed a number of relationships showing patterns of channel characteristics, such as hydraulic geometry, within and between watersheds (Leopold et al., 1964). There has been less progress equating variability of these characteristics within and between watersheds with varying sediment supply, flood hydrographs, and channel roughness. Nevertheless, geomorphologists use key features to qualitatively and, in some recent cases, quantitatively relate specific channel conditions with variations in watershed processes. We draw upon this experience to suggest a diagnostic method that relies on field observations of stream and flood plain features.

Diagnosis of channel condition relies, to a large extent, on qualitative and quantitative field observations of diagnostic characteristics of the channel bed, active channel, and flood plain. These characteristics help indicate the relative magnitude of channel processes, and reflect the style and magnitude of past and potential future responses to changes in sediment supply, discharge, LWD, and large-scale disturbance.

The field component of the channel module is designed to assess, in a simple and repeatable manner, key characteristics of the stream channel that are useful for interpreting channel condition and response potential. The point is to help generate a story. These key features include:

- Channel bed morphology
- Gravel bar characteristics
- Pool characteristics
- Channel dimensions (slope, width and depth)
- Fine sediment deposits
- Roughness elements
- Stream bed material
- Channel pattern
- Bank and riparian conditions
- Flood plain attributes

Unless the analyst justifies the exclusion of features, each should be addressed in some way. Although methods are provided here, the analyst may use discretion in the detail and methods employed to characterize key features. **Although these characteristics are appropriate indicators of channel conditions, not all are relevant and need to be measured in each channel segment.** Table E-3 includes a description of the channel types in which different attributes are most appropriate. (see column in Table E-3 entitled "Applicable to segment type").

The field measurements and observations described below is a list of tools that can be used to interpret stream channel conditions. If other scientific methods are used, they need to be fully explained in the channel methods section of the assessment report. For some of these characteristics, the confidence level of interpretations based on the field assessment can be increased, and uncertainty commensurately decreased, through additional more detailed observations or modeling. The analyst compiles as much information on key channel features as possible, and uses them to diagnose channel condition, as described in a subsequent section of this module.

The following section discusses field methods for collecting observations on each of these channel characteristics. It is not feasible to conduct field observations and measurement of channel features throughout entire channel segments which are long in any kind of reasonable time frame. Rather, field observations should be collected at a characteristic reach within a numbered channel segment. A channel reach may be considered to be on the order of 20 channel widths in length. A longer length can be sampled if 20 channel widths does not capture the variability within a reach. The key is to capture segment variability, which is part of the overall channel variability.

Channel Bed Morphology
Channel bed morphology provides a general indication of the style of potential channel response (Montgomery and Buffington, 1993). The gradient/confinement classes determined from map and aerial photograph analyses should be supplemented on the basis of field observation for each channel reach visited in the field assessments. This classification will provide context to the subsequent channel diagnosis.

The nature and organization of channel bed material defines the channel type in this classification (Montgomery and Buffington, 1993). There are eight general channel types; colluvial, bedrock, braided, regime, pool-riffle, plane-bed, step-pool, and cascade, but intermediate morphologies are common in many watersheds. There are two important issues to consider. Several channel types can exist within a channel segment. Secondly, some channel types can alternate between bed morphologies listed below (Benda, in prep.)

Colluvial channels are recognized by the presence of colluvial deposits in channel banks and the presence of only a thin layer of alluvium overlying colluvium in the valley bottom.

Bedrock channels are floored in bedrock and lack a contiguous bed of alluvial material. The other six channel types are all alluvial channels in which the channel bed and valley fill are composed primarily of material transported by the channel.

Regime channels are often sand-bedded and are recognized by the presence of ripples or dunes on the low-flow channel bed.

Braided channels are those with multiple active channel ways.

Pool-riffle channels may be either free-formed pool and bar sequences or pool and bar sequences by flow obstructions, such as bedrock outcrops, boulders, and LWD. In the latter case the channel has a forced pool-riffle morphology.

Plane-bed channels are those that exhibit a flume-like bed morphology lacking distinct pools.

Step-pool channels are those in which tumbling flow over regularly-spaced accumulations of coarse grains separates channel-spanning pools.

Cascade channels are those characterized by essentially continuous tumbling flow.

At each channel reach visited, the channel morphology is classified according to the above criteria. Intermediate channel morphologies (i.e., plane-bed/step-pool or step-pool/cascade) are acceptable classifications for reaches exhibiting poorly-developed characteristics representative of different channel types. Further descriptions of these channel types are presented elsewhere (Montgomery and Buffington, 1993).

The classification scheme is one way to describe where there is a change in channel bed morphology. It is also important why channel bed morphology changes and what is the process that causes a change within a given reach. For example, if a forced pool-riffle reach goes to a plane bed reach, is it due to a change in gradient or a reduction in the amount of LWD? It is important to note what variables (e.g., gradient, confinement, input factors [wood, sediment], or processes [fluvial v. mass wasting dominated] have changed within a reach. Field form E-4 entitled "**CHANNEL BED** -*Channel Bed Morphology*" gives a recommended format to identify the different channel types, as well as, source, transport and response zones, in a given reach or segment. It includes a comment section to document what and why changes to input factors and processes occur.

Gravel Bar Characteristics

Most of the readily available sediment in moderate to large channels is stored in bars--sediment accumulations within the channel that are one or more channel widths long (Church and Jones, 1982). Bars may lie in the center of the channel, along one side, or across the entire width, thereby forming riffle-pool sequences. Areas of shallow flow over bars are commonly called riffles; deep areas located between bars are pools. Differential patterns of entrainment, transport, and deposition of sediment during floods set up the general morphology of the channel bottom, which then determines the flow characteristics at lesser flows (Sullivan et al., 1987).

Sediment bars may be forced by local flow divergence associated with in-channel obstructions or freely-formed. Bars may be generalized into point, medial, multiple and forced bars. Point bars occur on the inside of meander bends, medial bars are topographic high points in the middle of a channel, multiple bars across the active channel define channel braiding, and forced bars are local sediment storage elements forced by flow divergence imposed by in-channel flow obstructions, such as boulders, bedrock outcrops, or LWD. Bars forced by flow attributes may be due to either direct physical impoundment or result from local hydraulic divergence. The location and area of gravel bars reflects the sediment load of the stream as well as the presence of flow obstructions.

The type of gravel bars present in the segment, their association with obstructions, and their relative proportion of the active channel area should be noted. The size of the riparian opening relative to the active channel width also may be measured during field inspection. Field form entitled "**ACTIVE CHANNEL** -*Gravel Bar Characteristics*" gives a recommended format to help quantify the amount, size and activity level of gravel bars present in a reach. Information on side channels can also be incorporated.

Pool Characteristics

Pools represent the deep topographic depressions between the crests of the gravel bars. They may be formed by a variety of processes involving interactions between discharge and sediment transport, disruption of flow by in-channel obstructions that create local flow convergence and bed scour, and from the focusing of flow into channel banks that causes local scour. Pools may be either hydraulically formed by the interaction of sediment and water movement, or they may be forced by local flow obstructions, such as boulders, bedrock outcrops, and LWD (Lisle, 1986). Increased LWD loading forces creation of additional pools, which contributes to the complexity of in-channel habitat. Although different types of pools have distinctly different habitat values, the pool spacing provides a simple quantitative index of both habitat availability and complexity. Pool spacing is a primary channel attribute that is very sensitive to the loading of in-channel LWD in certain channel types (Montgomery et al., 1993). Different pool spacing typify different channel types, as discussed further in the channel diagnosis portion of the channel module.

Pool frequency should be assessed for each channel segment visited during the field assessment. This involves simply counting the total number of pools within a selected reach. The pool frequency is expressed in terms of the channel length normalized by the channel width divided by the number of pools, yielding an expression for the channel widths per pool. (Channel width/pool=[reach length/channel width]/number of pools). The analyst needs to identify if there is a minimum size pool or criteria which they use to define what pools will be measured. For example, an analyst can measure pools greater than one-half the channel width, or they can measure all pools including small pocket pools on the lee side of obstructions. It is up to the analyst to decide and note their criteria.

The factors controlling pool formation in a channel reach are an important observation for interpreting pool spacing. In each channel reach visited the total number of free and forced pools should be recorded. Forced pools can be subdivided into those controlled by LWD, boulders, and interactions with channel banks. The pool forming factors is often more than one control.

Field form E-4 entitled "**ACTIVE CHANNEL** -*Pool Forming Factors (PFFJ*" is a recommended format to record information on what forms a pool, the pool dimensions, what type of substrate the pool is formed in, and how big of an obstruction is needed to form it. This data gives the analyst basic information on the distribution of pool forming factors and the relationship between obstruction size and residual pool depth (maximum depth - tailout depth). **Empirical information can be derived from such data that can be useful to assess what the role of different pool forming factors and associated obstruction sizes are in the different geomorphic units.**

Subsampling a reach to identify PFF may be a more efficient way to gather this type of information because it takes time and may preclude the analyst from measuring and observing other important parameters.

Channel Dimensions (Slope, Width, and Depth)*.*
Stream channel dimensions are primary channel characteristics related to the channel-forming, or bankfull, discharge. Channel slope, and bankfull width and depth measurements should be taken in the same area where pebble counts are conducted so that they will provide compatible data for subsequent analyses. Slope

Although the approximate valley slope will have already been inferred from topographic maps in the channel segment delineation portion of the channel assessment, channel slope should be field surveyed for channels visited in the field assessment. Accurate measurement of channel slope is necessary for calculations pertaining to the channel condition diagnosis and is especially important if the analyst intends to pursue more detailed analyses involved calculation of sediment transport rates for the watershed.

There are many ways to measure channel slope, but a hand or engineering level should be used to measure channel slope in the field. Although popular among biologists and foresters, clinometers are not an acceptable technique, in low gradient channels (e.g., < 3%), as they are accurate to only $\pm$ 1^{o} in the hands of experienced users. Moreover, they provide little improvement over reach-average estimates derived from topographic maps. In low-gradient channels in particular, differences of less than 0.5^{o} may be significant and errors of 1% are common using clinometers. Channel slope should be measured over a distance of at least 10 channel widths to ensure characterization of the reach-average slope. If a clinometer is used in higher gradient channels, then approximate measures should be taken to ensure accuracy such as tying flagging at eye level and standing at water level to improve accuracy. If a clinometer is used, it should be noted.

Bankfull width

Bankfull stage (Wolman and Leopold, 1957) often is considered to represent the dominant discharge associated with channel-forming events. The recurrence interval of bankfull events varies between channels and regions, but is generally between 0.5 and 2.0 years (Williams, 1978). The bankfull width is the horizontal distance between the channel banks measured directly across the channel.

Bankfull depth

The bankfull depth is the average flow depth across the channel at bankfull stage. The number of bankfull width and depth measurements should be adjusted to capture variability within a channel segment. The bankfull depth may be approximated by dividing the channel cross-sectional area by the bankfull width. This requires surveying a cross-section across the channel. A hand-level, tape, and rod survey capturing major topographic changes along the cross-section is sufficient to portray the cross channel form. The survey should be done at the same locations as pebble counts. Identification of the bankfull flow depth is not always straightforward. Often it coincides with the topographic break-in-slope at the top of the channel banks. In channels that are incised into terrace or debris-flow deposits, however, the bankfull discharge may be significantly lower than this topographic feature. The top of in-channel bars, the limit of vegetation growing along channel margins, and other features may help in estimating the bankfull flow depth.

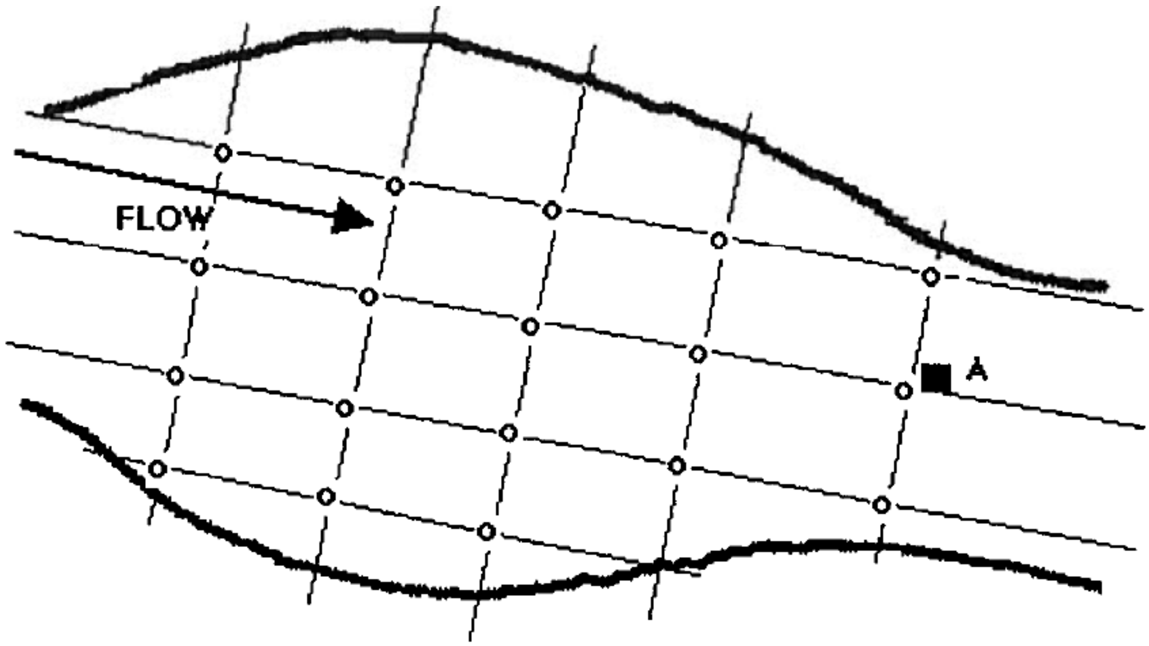

Figure E-6. Longitudinal and Cross-sectional Breakdown of a Pool

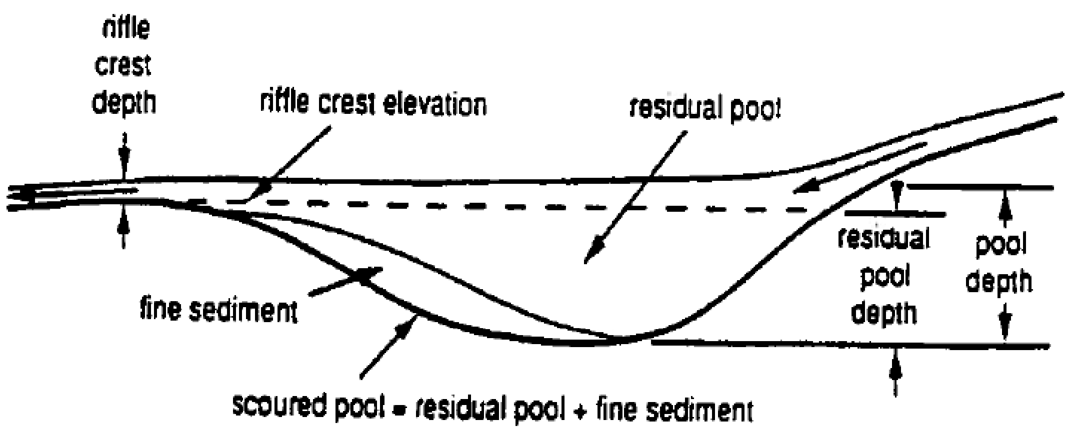

Figure E-7. Longitudinal Profile showing Residual Pool Depth
(From Lisle and Hilton, 1992)

Field forms E-4 entitled "**ACTIVE CHANNEL** - *Long Profile and Cross-Section Data Sheets*" can be used to help gather survey information.

Fine Sediment Deposits

The amount and distribution of fine sediment (e.g., material less than 2mm diameter) on the bed of a channel reflects the combined influences of local hydraulic controls, flow obstructions, and sediment supply. Examination of locations where fine sediment occurs helps to sort out these influences. These locations may be generalized into the following categories: fine sediment occurs 1) locally in pools, 2) in pools and as patches on riffles and bars, and 3) extensively in pools and over riffles. Different additional observations and measurements of fine sediment distribution are appropriate for pools and riffles.

In Pools

The volume of fine sediment overlying coarser channel bed material provides an index of the fine sediment supply to a channel (Lisle and Hilton, 1992). Measuring the volume of fine sediment in a pool involves division of the pool into longitudinal and cross-sectional transects (Figure E-5). The depth of fines is measured using a probe to assess the depth to larger material of the pool bottom at each location where longitudinal and cross-sectional transects intersect. A single point measurement of the fine sediment thickness within a pool is inadequate in all but unusual circumstances because of the variability of sediment depth within the pool. The residual pool depth (Lisle, 1989) also is measured at each sampling location. This is determined as the elevation difference between the pool bottom and the elevation of the pool overflow (Figure E-6). This is readily determined using a hand level and survey rod. The number of points measured within a pool should reflect the size of a pool, but typically at least nine measurement points are necessary to capture the in-pool variability of the fine sediment thickness. Field form E-4 entitled "*V* Data*" is a recommended format to help gather data on the amount of fine sediment in a pool.

Within riffles

The nature and extent of fine sediment distribution over riffles provides an additional observation to record for each channel reach visited in the field assessment. In particular, it should be noted as to whether fine sediment occurs 1) locally within the lee of large clasts and in other hydraulically-sheltered locations; 2) as strands extending downstream from large clasts; 3) over most of the channel bed; or 4) as a thin draping over larger clasts composing the bed surface.

Roughness Elements

Features that provide resistance to flow are an important determination of channel architecture. Energy dissipation results from drag induced as water flows over the bed particles, as well as around the larger scale bedforms including gravel bars meander bends and channel obstructions. In many mountain channels LWD is a dominant source of channel roughness (Sullivan et al., 1987). Wood and alternating obstructions serve as focal points of scour and deposition, ordering the position of gravel bars and sediment storage sites, and intervening scour holes as pools (Lisle, 1986).

The type and distribution of roughness elements can be a major control on channel architecture. The amount of in-channel LWD may be influenced by forest practices while other roughness elements may not. Overall and localized transport capacity of a stream segment is reduced with increased size and numbers of large roughness elements, which could influence the sorting of sediment within the active channel as well as the particle size characteristics of the bed (Buffington, in prep.). Recognizing the role and nature of roughness within a stream segment is important to understanding channel condition and potential sensitivity to land use practices.

Prior to doing field work, the stream channel analyst should meet with the fish habitat and riparian analyst to decide who will count LWD. The stream channel analyst should, regardless of who does the actual wood count, identify the form and function of LWD through the pool-forming factors data, or type and distribution of roughness elements data collection process.

Field forms E-4 entitled "**CHANNEL BED** - *Dominant Roughness Elements (DRE)*" and "**ACTIVE CHANNEL** - *LWD Functions(F)*" are recommended formats which help the stream channel module leader gather qualitative and quantitative information on roughness elements (e.g., boulders bedforms, and LWD), bed surface patterns, fine sediment deposits, LWD functions (e.g., pool scour, stability and sediment storage sites) and the amount of stored sediment behind LWD structures. Such data can be used to derive empirical relationships, at a segment type or geomorphic unit scale, on the role of obstructions in forming and maintaining channel morphology.

Stream Bed Material

Surface Particle Size. The size of particles on and below the channel bed surface are primary channel characteristics that are sensitive to changes in sediment supply, discharge, and in-channel roughness elements (Buffington and Montgomery, 1992). The channel bed typically is coarser than the under-lying substrate. This surface layer of coarser material, often referred to as an armor layer, represents the material providing shear resistance to flow at the channel bed. The characteristics and size of the coarse surface layer control bed mobilization and initiation of sediment transport.

There are many possible sampling techniques and strategies for characterizing channel bed surface textures (c.f. Diplas and Sutherland, 1988) within and between reaches, and several of these techniques are discussed below.

The analyst's choice may reflect a combination of the time allotted and the detail required for characterizing a given reach.

The most common method of grain size sampling is the pebble count technique proposed by Wolman (1954). The basic procedure is to measure the intermediate diameter of 100 grains over a given area of the channel. In order to characterize the full range of grain sizes at a particular location one should conduct a bank-to-bank cross-channel sampling by traversing the channel and measuring for each step the clast immediately in front of one's boot toe. Grain sampling is intended to be random; look away from the bed while advancing across the channel and while reaching for a grain. Measurement locations within a sampling area are determined by either taking random steps or pacing several fixed-interval transects. Accurate representation of the distribution of grain sizes in a reach depends on both the number of sample sites chosen and the area sampled. The analyst should sample enough locations to capture the variability within the channel segment. Any criteria used to establish sampling area size should probably be scaled by the channel width.

Sampling across the active channel may be impossible during high flows or for other dangerous conditions. Two possible strategies can be used in this case. The first is to walk the reach, observing the variability in surface textures, and conduct pebbles counts at several locations that are deemed representative of the general textural conditions of the channel. The second method involves a systematic sampling of a particular morphologic point on several bars within the reach. Typically, high velocity core cross-over locations on point bars (Dietrich and Smith, 1983) is chosen. This technique is attractive, because it is based on systematic sampling of morphologically similar locations in a channel. However, the technique may not accurately represent the full range of grain sizes present in a channel, nor is it recommended for complex LWD-dominated channels, because of the non-systematic nature of barform characteristics and morphogenesis in these streams. For both of these sampling strategies, pebble counts over small areas (order of 1 sq m) can be conducted by point counts using the same techniques discussed above for cross-channel sampling.

A final technique involves identification, sampling, and spatial averaging of discrete textural patches within a channel (c.f. Buffington, in prep.). The analyst first walks the study reach, visually partitioning the bed into distinct textural patches. One or more pebble counts are conducted for each specific textural type and subsequently assumed to be representative for that texture throughout the reach. Textural pebble counts are then spatially averaged based

on areal representation of each texture within the channel. Areal extent can be quantified rigorously through detailed textural mapping or estimated by visual inspection.
A variety of other sampling techniques also exist, such as wax casting, spray painting, and photo inspection (Diplas and Sutherland, 1988). The particular technique employed should be done consistently throughout a watershed, as different methods and strategies are not necessarily comparable.

The pattern of sediment distribution on the bed surface should also be noted. In particular, both the dominant surface texture (i.e., boulder/cobble) and the variance of surface textures should discussed. For example, a channel bed may be composed primarily of cobbles, with gravel bars impounded behind LWD jams. A simple description of the distribution and patterns in the variation of surface grain sizes is an important piece of information regarding channel attributes.

Subsurface Particle Size. The substrate underlying the surface armor of a channel is thought to be representative of the bedload material transported by the channel following disruption of the armor layer (Parker et al., 1980). Thus the percentage of fine sediment in the subsurface reflects the supply of fine sediment to the channel.

Estimating the subsurface particle size is more difficult than the surface sampling methods because of the difficulty of removing surface sediments to the subsurface. The simplest method involves a modification of Wolman's pebble count method. First, the surface armor layer is removed from an approximately $1m^2$ area of a medial or point bar. The surface layer normally extends as deep as the larger clasts exposed on the bar. Second, subsurface material exposed in the excavation is mechanically mixed. Finally, a pebble count is conducted on at least 100 grains randomly selected from the excavation. Subsurface pebble counts should be taken in the same area as surface pebble counts. Care should be taken, however, to avoid sampling in hydraulically sheltered locations, (e.g., in proximity to large woody debris). Because of the modifications resulting from sampling difficulties, the accuracy of this method is likely to be lower than other more intensive methods. Greater certainty in the subsurface particle size analysis may be attained through sieve samples of the channel substrate in order to more accurately assess the grain size distribution, and thus channel sensitivity to changes in sediment supply and transport capacity, or the potential influence of fine sediment on fish populations. The percentage of fine sediment in subsurface gravel should be characterized by any method only after removal of the surface armor layer. Sediment samples for sieve analyses can be collected using a variety of methods including a bucket and shovel and the McNeil sampler used by fisheries biologists (NWIFC, 1993).

Field forms E-4 entitled "*Pebble Count Data*" are example formats to use to collect surface and subsurface particle size distribution data. The data should be plotted up to get information on the median grain size (D50), D84, and to compare the overall surface and subsurface particle size distribution within a given reach. The data will also be useful in identifying the relationship between sediment supply and transport capacity within a given reach (e.g., Q*).

Channel Pattern
Channel pattern refers to the configuration of a river as it would appear from an airplane (Leopold et al., 1964). River patterns represent an additional mechanism of channel adjustment which is tied to channel gradient and cross section. The pattern itself affects reach-scale resistance to flow and is closely related to the amount and character of the available sediment and to the quantity and variability of the transport capacity (Leopold et al. 1964).

Aerial photography generally is used to determine large scale channel pattern, and may record temporal changes at a location, although field observations may confirm interpretations. A measure of channel pattern is channel sinuosity, defined as the ratio of channel length to down-valley distance. Channels may also be described as meandering, straight, braided, and so on. This may best be estimated during the historic photo analysis.

Bank and Riparian Conditions
Bank conditions observable in the field include assessment of bank erodibility, observations of the extent of active bank erosion, and estimation of the proportion of the available shear stress transmitted to channel banks. Bank erodibility primarily reflects bank material composition (% fine or coarse alluvium, colluvium, and bedrock), whereas active bank erosion is influenced by both bank protection offered by roots or LWD and the recent history of flows in the channel. Channel geometry controls the distribution of stress between the channel bed and banks. These factors will help determine the relationship between potential erodibility and how much stress the bank receives.

It is important to note bank material, potential sources of bank reinforcement, and current bank conditions when observing evidence of bank erosion. For example, a bank composed of lacustrine deposits may be highly erodible, but protected by LWD, and thus actual bank erosion may be minor. A bank composed of colluvium overlying bedrock, on the other hand, may not have a high erosion potential, but if there is no bank protection, then concentration of stress on the colluvial portion of the bank may cause slumping. The ratio of bankfull width to depth can help determine the distribution of shear stress between the channel bed and banks during high discharge events.

Bank erosion is both a natural process and a disturbance indicator. Evaluation of the extent and location of bank erosion provides an indication of both average flow conditions and evidence for recent disturbance. Bank erosion should be noted as occurring 1) in local areas along the channel where obstructions force flow into the channel banks; 2) on the outside of meander bends where flow is focused into the banks by the channel geometry; 3) intermittently along channel banks independent of channel geometry; 4) extensively along one side of the channel; and 5) continuously along both channel banks. These qualitative descriptions of bank erosion may be supplemented with an estimate of the percent of the channel banks undergoing active erosion.

Channel-margin landslides are an important bank erosion process contributing sediment to channels and they should be noted during field surveys. Where such features are encountered their size and style of failure should be described. Many of these features are difficult to detect from aerial photographs and thus may elude detection in the mass wasting module. Prior and during the field component of the channel assessment, the analyst should consult with the mass wasting and surface erosion analyst to devise a way to capture the appropriate data on channel-margin landslides.

The focus on bank erosion and bank and riparian conditions also begs two more important questions the stream channel analyst can help answer in the field:

1. What is the role of riparian vegetation in bank protection for a particular segment?

2. And how is LWD recruited into the streamchannel network?

Field forms E-4 entitled "**ACTIVE CHANNEL** - *Bani Erosion Factors (BEF)*" and "**ACTIVE CHANNEL** - *Riparian Composition (RC)* " give a recommended format to gather data that helps answer the preceding questions. Bank erosion factors (e.g., % of bank eroding) and bank dimensions can help quantify the amount of bank erosion occurring in the different segment types and geomorphic units. Sources of bank protection can help identify what the role of riparian vegetation and obstruction are, as well as how and where they are working.

The *Riparian composition* field format asks the analyst to identify what the active riparian recruitment processes (ARRP) are and where they change. This information can be tabulated to identify where and how much of a segment recruits LWD due to bank cutting, log jams, etc. This information can then be compared to riparian composition and bank erosion factors to identify what may occur in the future.

Flood Plain Attributes

Flood plain attributes that should be examined in the field include entrenchment, overbank deposits of sediment and wood, the nature of terrace-forming materials, and out-of-channel evidence for extreme discharge events, or other catastrophic events, such as debris flows or dam-break floods.

Entrenchment

Entrenchment is defined as the vertical containment of a channel and the degree to which it is incised in the valley floor (Kellerhals et al., 1972). Entrenchment reflects the relationship between a channel, its valley, and surrounding hillslope features. Bank and valley bottom disturbance are the most common causes of historic channel entrenchment. Channel entrenchment is defined by the relation of the current channel flood plain, as defined by the bankfull flow depth, and the topographic terrace associated with the valley bottom. The channel is not entrenched when these two features are at least approximately coincident (Figure E-7). Frequent floods would inundate both the flood plain and terrace. A moderately-entrenched channel has a small active flood plain established within a larger trench cut by the channel. The terrace level will be inundated during moderately frequent (i.e., 20-yr) discharge events. An entrenched channel is one where a small active flood plain is effectively isolated from the terrace level during even rare discharge events.

The nature of the material forming the terrace is an important observation to make for interpreting controls on channel entrenchment. Terrace-forming materials should be exposed at least locally along the channel banks in most reaches. While the active flood plain will be composed of alluvial material, it is important to note whether the terrace-forming material is bedrock, colluvium, alluvium, or debris-flow deposits. Alluvium and debris-flow deposits often may be differentiated by examination of clast contacts in channel-bank exposures. Alluvium typically has a clast-supported sedimentary framework. Imbrication, or interbedded layers of sand and gravel also imply an alluvial origin. Debris-flow deposits, on the other hand, typically have a matrix-supported architecture in which large clasts "float" within a finer-grained matrix.

Overbank deposits

A number of other flood plain features are indicative of recent disturbance. In particular, the presence of wood berms on the channel margins, scour damage to channel-margin vegetation, "trash lines" of debris deposited by high flows, and levees or boulder berms are important to note and describe. The approximate age and type (i.e., herbaceous, coniferous, or deciduous) of channel-margin riparian vegetation is also important to note.

Overbank deposits can also help identify historic aggradation. Evidence of flood plain development within larger terrace features normally indicates a historic change in channel condition and sediment supply. Cultural debris exposed in channel banks provides an excellent control on the age of over-bank deposits. Partially-buried trees provide further evidence of active aggradation.

Field form E-4 entitled "**FLOODPLAIN** - *Entrenchment*" gives a format that may be useful in collecting data on terrace materials, entrenchment, and overbank deposits. Sketches or photographs of cross-sections can also be extremely beneficial when trying to identify the relationship between the terrace floodplain and active channel.

Indicators of catastrophic disturbance

Indicators of past catastrophic channel disturbance often are most clearly expressed in flood plain deposits. Floods, debris flows, and dam-break floods, are the primary form of catastrophic channel disturbance in forested mountain drainage basins. They can be dominant and overriding factors to consider when interpreting channel conditions.

Debris flows and dam-break floods are often lumped together in studies of catastrophic stream events in the Pacific Northwest. These two processes, however, have very different rheologies and they affect different parts of the channel network in different ways. It is recommended in watershed analysis that an attempt be made to differentiate between these processes based on field evidence in the mass wasting and channel modules. If they cannot be differentiated, then they are referred to as undifferentiated debris torrents. Note that Pierson and Costa (1987) have recommended abandoning the term debris torrent because it lacks specificity in describing the actual physical process and introduces confusion.

Debris flows are mapped and inventoried as part of the mass wasting module. Debris flows move through and typically erode colluvium stored in first- and second-order channels, or those channels greater than approximately 8 to 10 degrees (Benda and Cundy, 1990). Although debris flows typically do not move long distances down channels studied in the channel module (because of low gradients), debris flow deposits can profoundly effect morphology and habitat of low gradient channels. As a result, recognition of the effects of historic debris flows on the morphology of low-gradient channels maybe critical for appropriate channel interpretation.

Prior to and during the field component of the stream channel assessment, the analyst should consult with the mass wasting analyst to determine if there is a need to identify the historic lengths of debris flow run-out tracks. Such information can be useful in synthesis to determine the direct impact of debris flows.

Dam-break floods can occur when a landslide or debris flow deposit temporarily dams the valley floor. When such a dam fails, the resultant flood wave often entrains large amounts of organic debris which can increase the magnitude of the flood with travel distance. Dam-break floods can occur in much lower-gradient channels than debris flows and they can affect channels that are studied under the channel assessment module. Refer to Coho and Burges (1991) for a discussion of the characteristics of dam-break flood in low-order mountain channels and Johnson (1991) for descriptions of the effects of dam-break floods on channel and valley floor morphology.

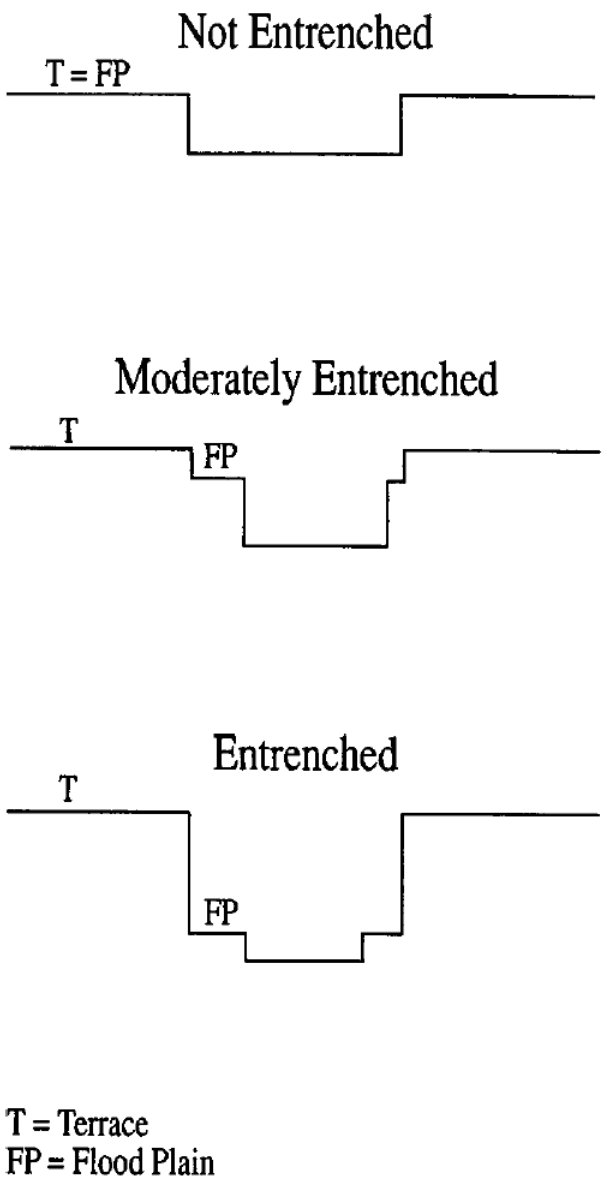

Figure E-8. Entrenchment Types

Additional Observations or Measurements

Additional observations and measurements that relate to specific channel processes or attributes important in the watershed under analysis are encouraged, but such additional analyses should supplement rather than supplant the approach developed here.

Channel Diagnosis Indicators

Conditions of the stream bed, active channel, and flood plain of a stream segment reflect the magnitude of input factors (sediment, discharge, LWD) and the occurrence of catastrophic events (landslides or floods). The manner in which these input factors are processed by a stream are set to some degree by valley characteristics. Consequently channel conditions may be interpreted as indicators of the relative magnitude of input factors.

To date, there is no single quantitative model that can simultaneously and reliably interpret channel condition relative to geomorphic regimes of sediment, water, and imposed obstructions. There are, however, several methods in use that employ channel characteristics as indicators of stream processes. For example, Pfankuch's (1975) channel stability index uses qualitative observations of a variety of stream features to generate a numeric score for channel "stability", although stability is neither explicitly defined, nor interpreted relative to input factors. Kaspesser's RASI index uses particle size characteristics to infer sediment load. We feel that the search for a single quantitative index that characterizes channel condition is misguided.

Streams are complex to diagnose because channel conditions simultaneously reflect a variety of input factors that can be influenced by both natural and land use related disturbance. Furthermore, the impacts of past disturbance may persist for different periods in adjacent portions of the channel network. In the absence of universal quantitative indicators of channel condition, we suggest a diagnostic technique that interprets the stream bed, active channel and flood plain characteristics observed in the field to infer channel condition in relation to channel and hillslope processes. The selected characteristics reflect channel-forming processes, and use quantitative relationships as much as possible. The primary assumption of this approach is that active processes leave a recognizable imprint on key channel features. Even when other processes are active, those characteristics may be evident when the signal is strong enough, and when several processes are active the channel will have a mixture of characteristics that indicate their relative dominance. The diagnostic approach assumes that one indicator is rarely sufficient to determine the input factor regime. Therefore, our approach relies on examining a variety of features, whose collective condition suggest the relative relations between input factors, and which thus govern channel condition. Moreover, by using a variety of features, the analyst can separate, to the extent possible, channel conditions relative to each input factor.

Thus, we rely on observing a number of features and look for the weight of the evidence to interpret channel conditions with confidence. These features may be organized into channel bed, active channel, and flood plain attributes. As the sediment supply changes relative to the transport capacity of the segment, the composition of the bed surface adjusts. Features of the channel bed that can be interpreted relative to input factors are the bed surface particle size distribution, the relation between the median surface and subsurface grain sizes, the distribution of fine sediment on the bed surface, and subsurface proportions of fine sediment. Larger features that characterize the active channel also reflect geomorphic regimes of the reach. These features include characteristics of depositional bars, fine sediment deposits, pool dimensions and locations, and bank conditions. Finally, certain flood plain characteristics may record or reflect past or continuing processes and disturbance. The diagnostic characteristics discussed below, and shown in Tables E-3-a through E-3-c, provide a minimum set of criteria for channel assessment. The approach developed here can be expanded to incorporate new or additional diagnostic attributes as procedures for their analysis and interpretation are developed and tested.

Tables E-3-a (**Stream Bed Attributes and Diagnostics**)**, E-3-b** (**Active Channel Attributes and Diagnostics**) and E-3-c (**Floodplain Attributes and Diagnostics**) lists the attributes, mechanisms for change, qualitative and quantitative interpretive indicators ("dial levels"), and the segment types attributes are most applicable towards. The table, coupled with the proceeding discussion, is meant to help the analyst assess and interpret the different attributes which are measured or observed. The "dial level" is there to help gauge what the attributes, and its observed or measured level, means in the context of the assessment. Again, a weight of evidence approach should be used, thus one dial level for one attribute does not determine whether a channel is high in sediment supply relative to transport capacity. Instead, several attributes together may point to a trend or direction a particular channel is moving towards. Use these and other attributes to determine the current channel conditions for the different segment types.

Channel Bed Attributes

(See table E-3-a **Stream Bed Attributes and Diagnostics**) Channel bed attributes are particularly revealing for interpreting the relative relation between sediment supply and channel transport capacity. The basis for these interpretations is the assumption that the material on the channel bed surface reflects hydraulic sorting of the bedload material to generate a stable alluvial bed and that the amount of fine sediment in transport at low flow can be interpreted from the amount and distribution of fine sediment on the channel bed relative to the distribution of hydraulically-sheltered locations.

Channel Type

The channel type defined by the channel bed morphology provides the context for interpreting channel condition. Different channel types have different potential responses and evidence for previous impacts based on existing conditions need to be interpreted in the context of the channel type. Channel bed morphologies and potential channel responses are discussed in more detail by Montgomery and Buffington (1993). In addition, different channel types (i.e., bedrock v. pool-riffle with the same drainage area gradient) may reflect changes in sediment regime that can be diagnostic (Benda, in prep.).

Median Grain Size

The median grain size on the channel bed reflects a number of influences including discharge, sediment supply, and the hydraulic roughness provided by flow obstructions. An increase in basal shear stress causes winnowing that results in bed-surface coarsening. Increased sediment supply favors bed-surface fining (Dietrich et al., 1989). Limited sediment supply can also lead to bed surface coarsening or bedrock channels. Higher LWD loading provides greater hydraulic roughness which favors bed-surface fining (Buffington and Montgomery, 1992). Lower LWD, in forced pool-riffle channels, can decrease hydraulic roughness and result in bed surface coarsening. As noted in table E-3-a hydraulic roughness and sediment supply v. transport capacity are the two primary mechanisms which affect if a segment is coarser or finer than expected.

Bed Surface Pattern

The spatial variability of grain sizes on the bed surface may reflect channel morphology or interactions with in-channel flow obstructions. For example, sorting of gravel and boulders into pools and steps, respectively, in step-pool channels is a natural consequence of hydraulic channel-forming processes. In contrast, the distribution of gravel-sized substrate on the bed surface in some forced pool-riffle channels is controlled primarily by the distribution of large woody debris. Finer patches of the bed surface in any channel type may reflect hydraulically-sheltered locations. The spatial organization of grain sizes on the channel bed surface can be used to help assess channel condition by considering the channel type and the role, or potential role, of flow obstructions. In particular, the spatial distribution of grain sizes on the bed surface has important implications for interpreting the availability of spawning gravel in some channel reaches.

Particle Size Distribution
Particle size distributions in most channels are approximately log normal. A bimodal surface or subsurface particle size distribution can indicate a high amount of fine sediment in transport either during bed-mobilizing events in the case of the subsurface distribution, or over the gravel bed between armor-mobilizing events in the case of the surface distribution. Plotting up surface and subsurface particle size distribution helps to determine whether there is a strong or weak bimodal distribution.

q* ("qstar")
Surface textures of gravel-bedded rivers respond dynamically to changes in sediment supply. Bed surfaces fine when inundated with sediment and coarsen when deprived of sediment. Dietrich et al. (1989) proposed a dimensionless ratio, q*, which quantifies textural response to sediment supply. The ratio is defined an the transport rate of the bed surface material normalized by that of the load, or subsurface, and quantifies the transport capacity of a channel relative to sediment supply. The dimensionless ratio can be used to assess both current sediment loading conditions and sensitivity to increased sediment supplies.

One conceptually simple equation that expresses the bedload transport rate (q_s) as a function of the difference between the effective basal shear stress and the critical shear stress is given by

$$q_s = k\ (t' - t_c)^{1.5} \qquad \text{eq. 1}$$

where k is a constant, t' is the effective basal shear stress, and t_c is the critical shear stress for incipient motion, and thus the onset of sediment significant bedload transport (Meyer-Peter and Miller, 1948). The ratio of the transport rate for the surface grain sizes and the subsurface, or bedload, grain sizes is q*, which using this general bedload transport expression is given by

$$q^* = (t' - t_{cs})^{1.5} / (t' - t_{css})^{1.5} \qquad \text{eq. 2}$$

where t_{cs} and t_{css} are, respectively, the critical shear stress for the surface armor and subsurface material. The average basal shear stress may be expressed as the product of fluid density (r), gravitational acceleration (g), flow depth (D), and water surface slope (S):

$$t = \ rg\ D\ S \qquad \text{eq. 3}$$

The fraction of the basal shear stress available for sediment transport, defined as the effective boundary shear stress (t'), depends upon the amount of in-channel roughness and energy dissipation. The critical shear stress (t_c) represents the shear stress necessary to mobilize the median grain size (d_{50}) and is expressed as

$$T_c = t_* \ (r_s - r) \ g \ d_{50} \qquad \text{eq. 4}$$

where r_s is the sediment density and t_* is a dimensionless critical shear stress (Shields, 1936), the value of which is controversial, but has recently been estimated at 0.045 (Komar, 1987). Assuming that grain roughness provides the only in-channel roughness implies that t = t' and, thus, q* may be expressed as

$$q^* = \left\{ \frac{[r\ D\ S / t_*\ (r_s - r)\ d_{50s}] - (d_{50s} / d_{50ss})}{[r\ D\ S / t_*\ (r_s - r)\ d_{50ss}] - 1} \right\}^{1.5} \qquad \text{eq. 5}$$

A well-armored bed has low q* values and is interpreted to have the capacity to accommodate an incremental increase in sediment supply through bed surface fining. A poorly-armored channel with a high q*, on the other hand, is vulnerable to other morphologic change in response to altered sediment supply. Channels that have a high q* will have a higher potential to aggrade or lose pool area because the surface has little potential to fine in response to increased sediment loading. A low q* means a channel has a larger potential to react to an increase in sediment load by textural fining. Concurrent morphological change may occur, however, and q* provides only an index of the capacity for the bed surface to fine. Table E-3-a gives approximate q* levels that correspond to the low and high value descriptions.

While q* is a useful assessment tool, we caution that it provides only a "snap-shot" of current sediment loading conditions and care should be taken to interpret q* measures within the context of the fluvial processes occurring in the channel. Analysis of q* made in isolation of other channel processes and diagnostic features can lead to erroneous interpretations of sediment loading (Buffington, in prep.). Furthermore, since q* assumes that grain roughness provides the dominant channel roughness, it is most applicable in obstruction-free sections of gravel-bedded channels (e.g., plane-bed channels or riffles in pool-riffle channels).

% Fines in subsurface

The substrate underlying the surface armor of a channel is thought to be representative of the bedload material transported by the channel (e.g., Parker et al., 1980). Thus the percentage of fine sediment in the subsurface material reflects the supply of fine sediment to the channel. The percentage of fine sediment in the channel subsurface also is an important influence on fish survival to emergence. Preliminary data from subsurface pebble counts in Washington suggests that values of 5 - 15% <2mm defines a typical range in undisturbed basins (Montgomery, unpublished data). The percentage of fine sediment in the subsurface gravel estimated by a subsurface pebble count is less accurate than if measured by techniques such as those recommended by the NWIFC (1993). Because subsurface pebble counts are not expected to be as accurate, data collected in this manner is best interpreted as distributions of values collected in different parts of a watershed. This may reveal areas of the watershed with consistently higher percentages of subsurface fines. Causal mechanisms may be explored when potential sources of fine sediment are identified.

Table E-3-a summarizes the diagnostic attributes for channel bed features. The analyst is encouraged to use additional diagnostic features they find to be useful.

Active channel attributes

A number of active channel attributes reveal aspects of channel condition through the distribution and amount of gravel bars and fine sediment deposits, pool characteristics, channel pattern, and the nature and extent of bank erosion. Most of these indicators involve comparison of existing channel condition with those expected for the channel type. Consequently, both experience and objectivity are crucial for interpreting channel conditions. We believe, however, that consideration of the full suite of channel characteristics examined in this module will lead to a reasonable assessment in most cases.

Gravel Bar Characteristics

Bars can best form where the channel is wide enough to accommodate them (bankfull width/depth ratios greater than about 12; Jaeggi, 1984), and stream gradient is low enough to allow deposition (less than about 2%; Ikeda, 1975). In steeper and narrower channels, bars and small deposits tend to form exclusively around obstructions. Large central bars and braided channels commonly form where valley bottoms and channels widen downstream of steep narrow valleys and canyons. They may also form upstream of channel constrictions due to backwater effects of hydraulic control during storms (Sullivan et al., 1987). Bars usually grow and shrink seasonally because of local imbalances between deposition and erosion; but, other than in braided channels, bars tend to keep the same location as long as channel boundaries remain intact and obstructions in place (Leopold et al., 1964; Lisle, 1986).

Table E-3-a. Stream Bed Attributes and Diagnostics

Channel Attribute	Potential Mechanisms for Change	Dial - Low	Dial - Medium	Dial - High	Applicable to Segment Type:
D50	Sediment supply relative to transport capacity LWD loading	Coarser than expected		Finer than expected	Pool-riffle Plane-bed Forced pool-riffle
Particle Size Distribution	Fine sediment supply	Unimodal	Weakly bimodal, still dominated by larger clasts.	Bimodal, especially high proportions in sand fractions	Pool-riffle Plane-Bed
q *	Sediment supply relative to transport capacity	q* = 0	q* = 0.30	q* approximately = 1	Pool - riffle Plane - bed
Surface fines (<2mm)	Sediment supply	Do not see accumulation of fine sediment on the lee side of obstructions such as boulders and LWD	Do see accumulations of fine sediment on the lee side of obstructions.	Large tails of fine sediment behind boulders and other obstructions	Pool – riffle Plane – bed Forced pool – riffle
Subsurface fines (<2mm)	Sediment supply	Low percentages <10%	Mid-range 10-20%	High Percentages >20%	Should work everywhere, although percentages may vary by type

The size, stability and location of gravel bars can be an indication of changing sediment supply or transport capacity. The presence of medial bars in a channel or deposition occurring on the outside of a meander bend can be an indicator of an increasing sediment supply and decreasing transport capacity in a channel segment. Channel narrowing and evidence for an increase in stable bar features (such as vegetation encroachment) can be an indicator of a low sediment supply relative to previous sediment loads.

Pool Characteristics
The pool spacing in some channel types in forested mountain drainage basins is related to the supply of LWD within the bankfull channel. The size and residual depth of pools; also reflects the influence of LWD. The magnitude of these influences differ for different channel types. The influence of LWD on pool spacing is greatest in pool-riffle and plane-bed channels. A pool spacing on the order of 5-7 channel widths is expected in pool-riffle channels with low LWD loading (Leopold et al., 1964); much higher pool spacing are expected in low LWD loading plane-bed reaches. Pool spacing on the order of 0.5 to 1.0 channel widths characterizes both of these channel types with high LWD loading (Montgomery et al., in press). At such high loading these channel types may be impossible to distinguish except by channel slope (Montgomery and Buffington, 1993), or by reference to nearby reaches with low LWD loading. Preliminary data implies that pool spacing in steeper step-pool channels is related to LWD loading. Imposition of simple numerical standards of pool frequency on all channel types may be inappropriate.

Channel Pattern
Channel pattern to some degree reflects the interaction between sediment supply and transport capacity (Leopold et al., 1964). For example, a downstream change in channel pattern from meandering to braided may reflect an extreme increase in sediment supply (e.g., Smith and Smith, 1984). Downstream channel narrowing and an increase in stable, vegetated bar features can be an indicator of a decrease in sediment supply or flood discharge. Multiple active channels often indicate a high sediment supply. Significant changes in channel sinuosity evident on sequential aerial photographs may indicate change in sediment supply or transport capacity.

Channel braiding and side channel development also may be controlled by flow perturbations induced by LWD. Historical removal of LWD from some large rivers, for example, changed the channel pattern from a complex braided system of channels and side channels to a single thread channel morphology (Sedell and Froggatt, 1984). Consequently, channel pattern must be interpreted in the context of channel processes, especially the complementary and potentially competing effects of sediment supply and LWD loading.

Fine Sediment Deposits in Pools

The distribution of fine sediment on the channel bed can be interpreted in regard to the fine sediment loading of lower-gradient pool-riffle and plane-bed channels. Fine sediment accumulations in local hydraulically-sheltered locations typically do not reflect fine sediment supply. Extensive fine sediment deposits in both pools and riffles, on the other hand, indicate an abundance of fine sediment in all but extremely low-gradient channels. While description of the general distributions of fine sediment deposits within a channel provides a good general indicator of fine sediment supply, the amount and distribution within pools and riffles can be further interpreted separately.

V*

Lisle and Hilton (1992) defined the average ratio of the volume of fines to the residual pool volume for an entire pool as V*. When fine sediment and residual pool depth are measured on transects, this may be expressed quantitatively as

$$V^* = \sum [\, D_s \,/\, (D_r \quad D_s)] \,/\, n \qquad \text{eq. 6}$$

where n is the number of measurement locations, and D_s and D_r are, respectively, the thickness of fine sediment and the residual pool depth at each measurement location. This index provides a measure of the most mobile portion of the channel bed and helps evaluate and detect sediment inputs along the channel on a local scale.

The index correlates with perceived sediment supply and varies in response to local increases in sediment supply (Lisle and Hilton, 1992). $V^* < 0.1$ is considered to reflect low sediment supply, whereas a $V^* > 0.2$ is considered indicative of high sediment supply (Lisle and Hilton, 1992). Local sources of fine sediment should be examined if a channel has a high V* prior to interpreting potential causes. V* is not a reliable indicator of channel disturbance if the local geology causes large spatial variance in sediment supply. Although it is not appropriate to use V* when the channel is bedrock-floored, it can still be used if there is limited bedrock exposure. In massively aggraded channels, V* is not an appropriate index of channel condition. V* is most useful in pool-riffle and forced pool-riffle segment types.

Fine Sediment Deposits Within Riffles

The distribution of fine sediment on the channel bed may reflect the supply of fine sediment to the channel. In many gravel-bed channels, some sand-size material moves over the channel bed at discharges insufficient to break the gravel pavement, or armor, and initiate significant bedload transport (Jackson and Beschta, 1982). Observation of the distribution of fine sediment over the low-flow bed surface in a riffle thus provides an indication of the fine sediment supply of the channel. At a low supply of fine sediment, sand and fine gravel exposed on the bed surface occur only locally in sheltered locations behind flow obstructions or large clasts. As the amount of fine sediment moving over the bed increases, these local depositional sites tend to expand downstream into elongated sand stripes (Figure E-9). At extremely high fine sediment loading, the entire channel be may become buried by a blanket of fine sediment overlying a coarser armor layer. This style of channel response to increased sediment supply is unlikely in steep step-pool or cascade channels that have a high transport capacity. Thus, this type of response is most relevant to lower-gradient pool-riffle and plane-bed channel.

Bank erosion
Bank erosion should be interpreted in the context of channel-forming processes. Erosion on the outside of meander bends, even large channel-margin landslides, is to be expected in many situations. Extensive erosion on both channel banks, however, typically is uncommon, but is to be expected in some situations, as in the case of a high-gradient channel deeply incised through unconsolidated sediments. The nature and extent of bank erosion must be interpreted in the context of the channel geometry and patterns and the nature of the bank-forming materials. Increases in channel bed elevation, occurrences of dam-break floods, and increases in discharge can all cause bank erosion.

Table E-3-b summarizes the diagnostic attributes for active channel features. The analysts are encouraged to use additional diagnostic features found useful in the past.

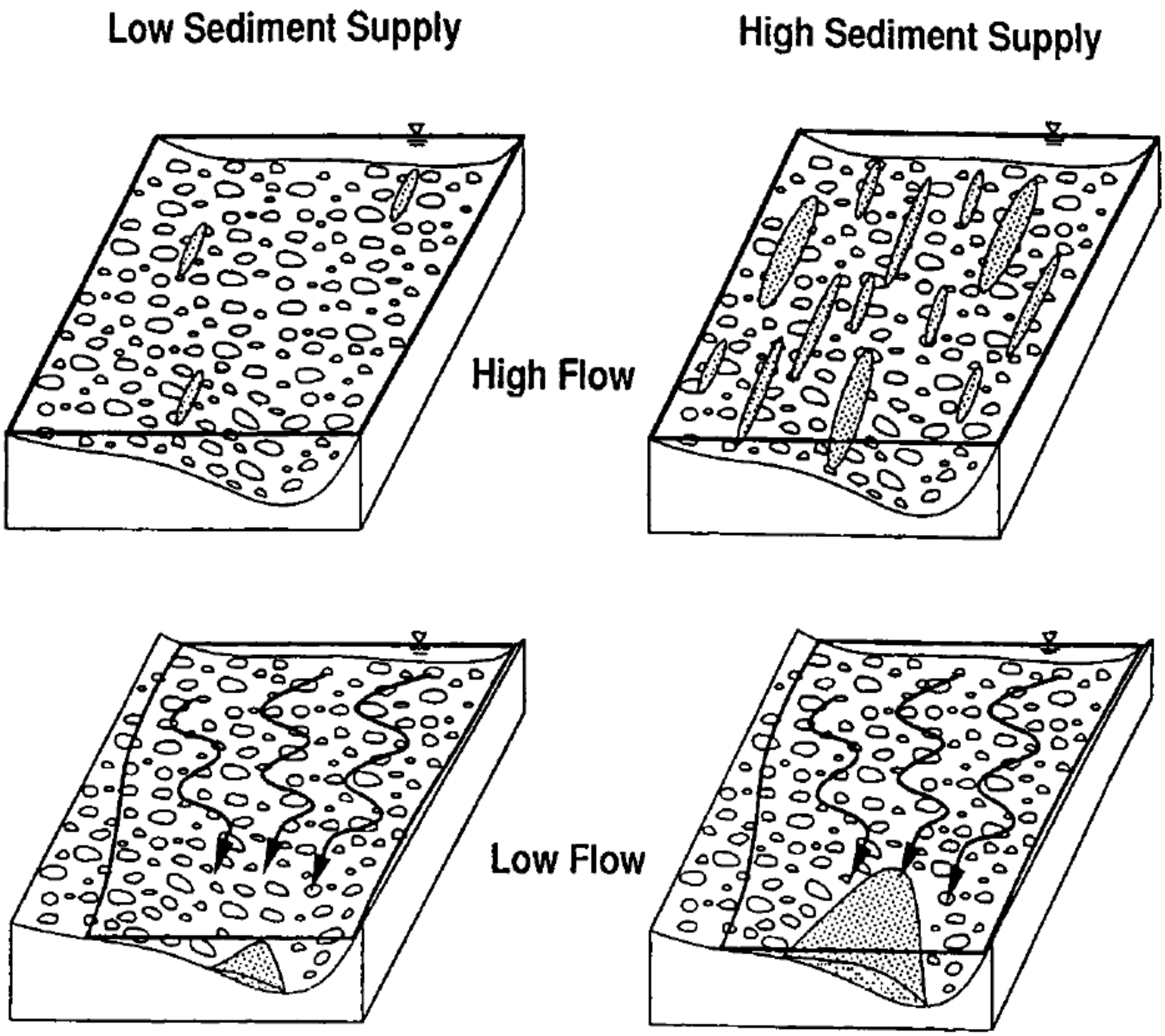

Figure E-9. Pool Filling with Fine Sediment

(Conceptual model of filling of pools with fine sediment during waning stages in gravel-bed channels with high and low sediment supplies. At high stages, fine sediment, as well as coarse gravel (arrows), are transported over much of the channel. At low flow, the flow over riffles (curved lines), converges into pools and carries fine sediment winnowed from the bed surface. From Lisle and Hilton, 1992.

Table E-3b. Active Channel Attributes and Diagnostics

Channel Attribute	***Potential Mechanisms for Change***	***Dial - Low***	***Dial - Medium***	***Dial - High***	***Applicable to Segment Type:***
V*	Local source of fine sediment	Gravel bottom pools, little difference between pool bottom and riffles. V* <0.1	Small amount of fine deposits on pool bottoms 0.1<V*<0.20	Large amount of fine sediment (sand) at pool bottom. V*>0.20	Pool-riffle Forced pool-riffle
Channel Pattern - Sinuosity	Sediment Supply	Single thread, meandering	Multiple stable channels	Braided	Pool-riffle
Channel Pattern-side channels	• Riparian Condition • LWD Loading	No side channels, single channel	Multiple minor side channels	Significant side channels	Pool-riffle Forced pool-riffle Plane-bed
Gravel Bars	Sediment supply	Small point bars isolated along the edge of the channel	Point bars take up greater portion of the active channel. Deposition in some places are not expected.	• Medial bars • Bars on the outside of meander bends	Pool-riffle Forced pool-riffle
Pool dimension	• Sediment supply	Pools span channels		Pools diminish in size and become isolated	Pool-riffle Forced pool-riffle
% Pool formed by LWD	LWD	Nearly all free pools		Nearly all forced pools	Pool-riffle Forced pool-riffle Plane-bed
Channel width/pools	LWD	Infrequent pools (>4 CW per pool)	Between 1 to 4 CW/ per pool	High pool frequency, less than 1 CW per pool	Different for each channel type
Pool dimension	LWD loading	Small pools		Large pools	Forced pool-riffle Place-bed
Pool dimension	• Sediment supply	Large in volume and depth	Shallower than expected	Small, often not fully spanning, shallow.	Forced pool-riffle Plane-bed Step-pool
Bank Condition and Erodibility	• Loss of bank strength • Dambreak flood or debris flow • Peak flows	Eroded and raw banks on outside of bends	Eroded and raw banks on the inside of meander bends and in straight reaches	Nearly all banks eroded and raw	Anywhere

Flood plain Attributes

Interpreting flood plain conditions typically is more straightforward than interpreting in-channel conditions. Log berms, levees, and boulder deposits generally indicate recent catastrophic impacts. The age and condition of the near-channel riparian vegetation can corroborate such interpretations. Direct evidence for aggradation also is relatively simple to interpret.

Channel entrenchment is somewhat more difficult to interpret because it reflects different processes in different portions of a watershed. In low-gradient portions of a watershed where terraces are formed primarily by fluvial processes, the flood plain and terrace should be coincident (Figure E-8), unless there has been a relatively recent change in either one of the channel input factors, or in external boundary conditions, such as base level. In steeper portions of a watershed in which debris-flow processes are active, the stream terrace may be composed of debris-flow deposits through which the channel has re-incised. In these portions of the channel network entrenchment may not reflect recent channel disturbance. Thus, evidence for channel entrenchment must be interpreted in the context of the dominant channel-forming processes for a given reach.

Table E-3-c summarizes the diagnostic attributes for flood plain features. Again the analyst is encouraged to use additional diagnostic features found useful in the past.

Table E-3-c. Floodplain Attributes and Diagnostics

Channel Attribute	*Potential Mechanisms for Change*	*Dial - Low*	*Dial - Medium*	*Dial - High*	*Applicable to Segment Type:*
Entrenchment	• Bank disturbance • Change in historic condition	Flood plain coincident with terrace	Flood plain inset within terrace	Flood plain deeply inset within, and isolated from terrace	Anywhere, but does require a spatial context
Overbank sediment deposits	• Sediment supply • Large flood event • Debris flow or dambreak flood.	Normal flood plain stratigraphy	Scattered lenses of fine and coarse sediment	Deposits with depth of coarse and fine sediment	Any type of channel and defined flood plain
Wood deposits	Debris flow or dambreak flood	Deposits on front ends of gravel bars and along margin		Nearly all wood thrown from channel onto flood plain	Any type of channel with defined flood plain
Boulder berms	Debris flow	No boulder berms	Vegetated boulder berms on channel	Fresh boulder berms on channel margins	Colluvial Cascade Step-pool Plane-bed Forced pool-riffle

Channel Segment Diagnosis
The goal, of the channel segment diagnosis is to help the analyst identify which processes and input factors are most important for a segment that was visited.

Systematically diagnosing channel condition requires compiling key observations relative to the bed, active channel and flood plain into a summary of characteristics related to relative channel condition. Once the data is complied and displayed, the analyst weighs the evidence for channel condition relative to each of the input variables, noting both patterns and inconsistencies. For example, several attributes of both the bed and active channel indicating a high supply of fine sediment, provide strong evidence. If only one attribute suggests high sediment loads, the evidence may be weak, depending on the nature of the feature showing symptoms. Like a medical diagnosis, the analyst must weigh the suite of characteristics, using data and professional judgment to arrive at an interpretation of channel condition. We expect the objectivity of this assessment to improve as researchers develop more quantitative relationships between these diagnostic features and input variables. Furthermore, critical additional information is found in the other modules, which can be used to help aid in the interpretation of channel condition.

Each of the input variables is operative in every stream segment and each can currently experience any combination of levels of input variables. Some segments may have one dominant process which strongly influences channel condition, whereas other channel segments may have several interacting factors controlling channel morphology conditions.

A worksheet is provided offering a format for compiling this information (Form E-5). The analyst may use alternative forms for compiling the information although the format should be followed reasonably closely. The analyst should provide a brief narrative describing channel condition interpretations. The second page of the form encourages the analyst to bring results from the historic photo assessment to bear on the channel interpretation. This portion of the assessment may support conclusions based on current channel features.

Sensitivity to Input Factors

Segment Clustering and Geomorphic Units
At this point in the assessment procedure, the channel network has been divided into discrete valley segments, of which a representative sampling has been observed in the field. Channel characteristics of these representative stream segments have been interpreted with respect to local regimes of sediment, water and wood. Results from what are usually a limited number of observed segments must now be extrapolated to other segments. We term this scaling up step "segment clustering" and the result is delineation of the

watershed into "geomorphic units," areas encompassing portions of the channel network that are representative of similar fluvial processes. Recognizing the dominant channel-forming processes, and their magnitude, frequency, and distribution, operating in each area with commensurate channel conditions is the primary objective.

The goal for the stream channel analyst is to describe the clusters of segments that relate to a geomorphic unit. The basic assumption behind identifying geomorphic units is that segments within the unit will look similar and will respond similarly to external forcing (i.e. forest practices, urbanization, grazing, climate change and so on). The sensitivity of particular streams to changes in watershed processes occurring as a result of natural or land use effects is likely to reflect the relative importance of fluvial processes acting on materials in the area. The current condition and likely response of similar segment types is likely to differ throughout the watershed depending on local influences of terrain, geology, past disturbance and drainage position.

Geomorphic unit delineation uses assessment of both channel conditions and sensitivity. Channel conditions are considered in relation to the regime of each input factor based on the integration of field observations into a channel diagnosis. Channel sensitivity is an assessment of the degree to which a unit change in any input factor results in a significant change in channel morphology or processes. While channel sensitivity depends on current channel conditions, it reflects the potential for future changes.

Stream channel conditions are likely to be related to the land form/geology associations within the watershed. These will, reflect, among other things, lithology, soils, slope gradients, and hydrologic input. The analyst may already have formed hypotheses associating channel conditions and sensitivity with land form and geology in the watershed, having used these criteria for field site selection (see criteria for site selection). Field observations and diagnostic characteristics may confirm original ideas or suggest new interpretations.

The analyst defines boundaries separating stream segments into areas with similar geomorphic response. "Geomorphic units," so defined include both the stream segments and any landforms associated with them. **In drawing these units, the channel analyst uses judgment and may wish to consult with analysts performing mass wasting and surface erosion assessments who should have developed an understanding of the landforms in the watershed.** Although the geomorphic units are likely to be related to landforms, their delineation is not restricted to this criteria.

Analysts may identify any part of the stream system that they believe has significantly different responses or sensitivities from other units in the watershed.

Clustering channels into geomorphic units composed of segments with similar channel conditions, response potential and sensitivity provides a way to organize information gathered in the channel assessment with information gathered by other modules to describe causal linkages and appropriate land management prescriptions. Identification of geomorphic units so defined may involve generalization and some segments that do not share the same response or sensitivity may be incorporated into the same unit. Such is the price we pay for developing a functional method that is likely to facilitate rather than paralyze the decision-making process.

Channel Sensitivity Interpretation

An understanding of the factors presently controlling and likely to influence channel morphology and process is crucial to the synthesis side of watershed analysis. Consequently, analysts should describe for each geomorphic unit channel conditions and interpretations of channel-forming processes. Each input factor should be considered. It is helpful to record key observations for each unit that form the basis for the analyst's interpretations. Form E-6 is provided to facilitate note-taking. These observations form the basis for the sensitivity interpretation, which is a subjective assessment of likely response to each input factor. To determine channel sensitivity, the analyst should consider the relative effectiveness of each input factor (LWD, sediment, discharge, and catastrophic events) on channel morphology and processes. The analyst should provide a brief narrative providing the scientific basis and justification for the interpretation of sensitivity, observations which back the interpretation, and relative potential rating of channel response. The analyst needs to consider the magnitude, frequency, and distribution of the processes that effect each input factor when coming up with the potential ratings for channel response. This will help link past to current channel conditions.

In essence, the analyst customizes the interpretation of response originally based on the response matrix (Table E-2) for the particular watershed location in question. This step is crucial if the analyst is to develop an interpretation of channel processes tailored to the watershed under study. Performing this step relies on the analyst's experience and expertise. Although the generalized response table provides a good starting point for the assessment, simply parroting its interpretations as conclusions of the analysis yields no insight into the watershed under study since the table cannot account for geologic materials and local situations. Failure to adjust the response table for the geomorphic unit in question will result in low confidence in the analysis.

The channel analyst's response rating is a first approximation based on the findings of the previous sections of the channel assessment. These interpretations may be refined during the synthesis stage when additional information regarding watershed processes is available from the other module assessments.

Aggregating discrete channel segments into areas of similar watershed conditions and response potential will also greatly facilitate the next steps of the watershed analysis resource assessment. During the synthesis stage, the full resource assessment team further develops a watershed-scale perspective of the linkages between sources of inputs, channel response and habitat or water quality conditions that builds on existing working hypotheses developed earlier in the assessment. They will systematically work their way through the watershed, building a story of local and watershed scale connections based on their collective observations. Performing this analysis for segments grouped into larger representative areas will reveal dominant watershed and biological processes operating at a scale appropriate for hypothesis-testing and decision-making in Watershed analysis. To perform this linking exercise for each mapped channel segment would be exceptionally time-consuming and yield little interpretive benefit, since only rarely will the cause and effect relationships between hillslope and channel processes or the management actions prescribed for them be relevant to just one segment.

The geomorphic units are delineated on a mylar overlay of the official base map and numbered as Map E-2. The analyst should provide a brief narrative describing the geomorphic unit and justification for why it was identified.

An Example From the Tolt River

The Tolt River WAU contains 166 segments. After visiting 22 segments and assessing them for channel and valley conditions, the stream channel team determined that for the purpose of making generalized descriptions of channel condition and sensitivity, the 166 segments could be collapsed into 14 geomorphic units. In this case, the channels in each area currently look alike, although in several units channels were noted as either already responding to input variables or potentially responsive. (That is, they would look like those streams already responding if changes in the input factor occurred.) Each of the units was judged sufficiently distinctive such that differences in both channel-forming processes and sensitivity to input variables was evident. Most geomorphic units were closely related to landforms in the watershed, although the team identified a variety of units that did not always relate to a land form. Figure E-10 shows the geomorphic unit map for the Tolt River. The channel assessment team adopted a convention of naming units descriptively to reflect the dominant channel-forming processes that caused them to distinguish them initially. Some of the units represented tributary streams on similar landforms (e.g., steep tributaries draining convergent topography), several related to specific river segments experiencing certain conditions (e.g., the North and South Fork braided sections) and two units of similar segment clusters were distinguished because of the influence of beaver activity.

For the most part, geomorphic units and interpretations were judged to be applicable only to the type location in the watershed and there was little carryover of a mapped unit to other parts of the basin. The exception was the North Fork Braided Reaches located primarily on the North Fork of the Tolt, where one similar unit was identified on a segment of the South Fork Tolt River.

The sensitivity interpretation for the North Fork Braided Reaches demonstrates the tailoring of the interpretations of channel-forming processes and sensitivity to input variables based on the channel's segment type, position in landscape, and current condition. Note that this interpretation would not have been reached by using the response matrix (Table E-2) alone.

Fourteen geomorphic units were identified in the Tolt River WAU. Segment field observations were qualitatively matched to terrain and land forms to identify areas of similar condition and response to input factors. Following is a brief description and the key observations produced by the team for a geomorphic unit along the valley of the main river.

North Fork of the Tolt River Canyon

Featurest This is a deep, tightly confined canyon incised into bedrock and glacial till deposits. Stream gradients average 2-6%, with a short segment of approximately 10% which includes a waterfall that blocks upstream fish passage.

Transport Zone

Characteristics: There has been very little change in these segments throughout the photographic record (1942-1990).

Coarse Sediment: Response rating = LOW

- Stream energy appears to be sufficient to carry the sediment load (which is relatively large considering the braided reaches upstream).
- q* = 0.13-0.16, highly armored

Fine Sediment: Response rating = LOW

- High stream energy due to gradient!confinement, capable of flushing fines
- Very few fines observed
- V*: pools too deep to measure, estimated 0.1

- Localized area of higher V*, upstream end of Segment 4 at mouth of tighter canyon

Peak Flows: Response Rating = MODERATE
- Till valley walls can be eroded, channel could widen in places during high flows
- relatively large substrate makes significant scour unlikely
- No evidence of existing damage, but moderate potential for damage in future

LWD: Response Rating = MODERATE
- Slight reduction in number of pieces per channel width
- Function as bank protection in alluvial/till segments, and some sediment trapping
- Bedrock!compact till creates bank protection where present

Catastrophic Damage: Response Rating = HIGH
- Dambreak floods could occur (evidence of jam that spanned channel in upper end of Segment 6)
- Lower end of scour!transport gradient, but high stream energy due to canyon 4th order stream.

Applies to: Segment 6 (field verified), and Segments 4, 7, 8, 9, 10.

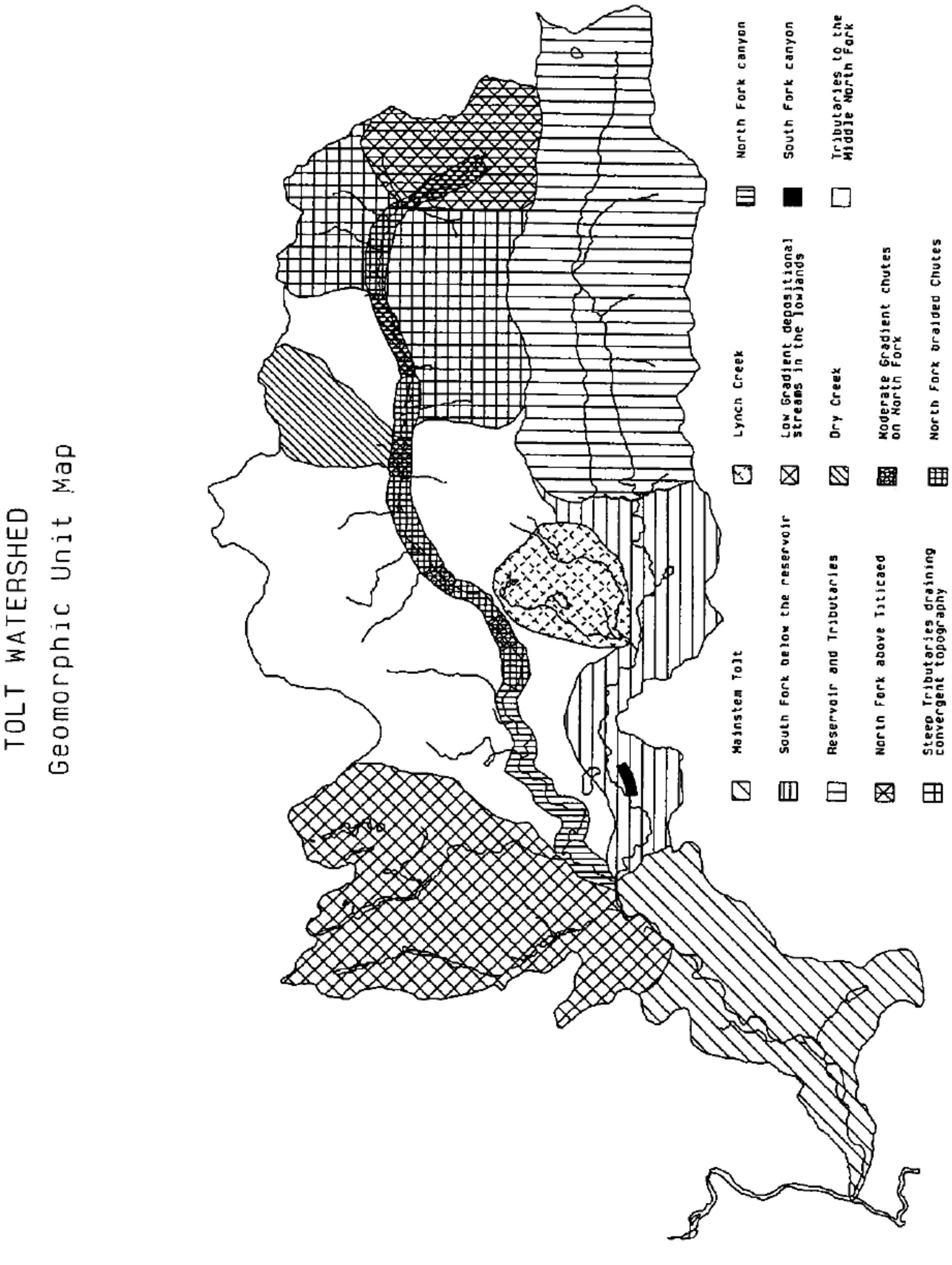

Figure E-10. Tolt Watershed Geomorphic Unit Map

Habitat-Forming Processes

The final task in the channel module is to describe the geomorphic processes controlling channel morphology relevant to the creation of fish habitat. Previous steps in the assessment yield conclusions regarding the sensitivity of the channel to changes in hillslope input factors. This portion of the assessment assists in translating those effects into fish habitat conditions. The channel analyst does not attempt to inventory habitat conditions. Rather, the channel analyst describes the origins and channel controls on the environments associated with key components of the life cycle of fish.

These life history stages include (1) upstream anadromous migration, (2) spawning and incubation, (3) rearing, and (4) over-wintering. The channel analyst is not expected to interpret channel condition relative to each life-history stage, rather the channel analyst interprets processes controlling key habitat elements determined by the fish biologist to be important for one or more life-history stage. These attributes include; deep pools, undercut banks, areal extent and size characteristics of gravel to small cobbles, pool characteristics and the nature of pool-forming agents, and the availability and access to slow water and off-channel areas.

The channel analyst's interpretation of the factors controlling the local physical environment in a segment will assist the fisheries analyst to interpret the vulnerability of fish to forest practices during the synthesis stage of the resource assessment. This procedure is enhanced when the channel analyst works closely with the fish habitat analyst, particularly in the field portions of the assessment.

The fish analyst may pose a more refined set of conditions for the channel analyst to address. The fish analyst may request a number of more specific interpretations...for example, they may ask the channel analyst to focus interpretation for stream segments, specific life-history environments rather than all four, or habitat conditions specifically defined for a particular fish species that may occur in the reach. This is why it is important for the fish habitat and stream channel analyst to spend some time in the beginning of the process to focus their efforts on the fish-habitat issues of concern. This may be best accomplished by having a preliminary meeting or doing a reconnaissance survey together. The advantages of this approach are several. Field data collection would be focused on the important issues, and coordination between the fish and channel module analysts could make data collection more efficient. The issues identified by the analysts could then be investigated based on subsequent data collection.

The channel analyst briefly describes the geomorphic factors influencing the four life-history environments in narrative form. If the fish analyst does not provide guidance for focusing discussion towards specific features in a given segment, the channel analyst describes the channel features for each of the characteristics in a general way.

If there is significant uncertainty in this analysis, the channel analyst may recommend further steps to reduce that uncertainty to a level acceptable to both the fish and channel groups.

Channel Assessment Report

The Channel Assessment Report organizes and presents results of the channel assessment. The report is a compilation of key work products, maps and narrative summarizing interpretations. Narrative may be on the order of only several pages long and provide a concise discussion summarizing results of each section of the analysis module. While the Channel Assessment Report should be concise, it should be complete enough so that, together with the other module products, it provides the input necessary for the synthesis and prescription phases of Watershed analysis where the information developed in the analysis modules is incorporated into land use decision making.

Realistically, there will not always be the type of data or information available that the analyst would desire for high confidence in the analyses and interpretations. Assessment of the confidence level possible based on available information thus may be important for decision-making based on these analyses. The degree of confidence that can be assigned to the products of this analysis depends upon a number of factors. Considering the amount, type, and quality of available information, analysts should determine their relative confidence in the interpretation based on each work product. Other factors to consider in this evaluation may include, but are not limited to, extent of field work, experience of the analyst, complexity of the geology and terrain, aerial photographs and map quality, and multiple lines of evidence for inferred changes.

Where a Level 2 team chooses not to use the recommended forms, they must follow the stream channel assessment outline (see below). Additional methods employed need to be fully explained and justified in the channel assessment report.

Channel Condition Assessment Report

I. **Title page** with name of watershed analysis, name of module, level of analysis, signature of qualified analyst(s), and date

II. **Table of contents**

III. **Maps**

- Channel-response segment map (map E-1)
- Geomorphic unit map (map E-2)

IV. **Summary Data**

- Distribution of segments worksheet (form E-1)
- Basic trend information - channel disturbance worksheet (form E-2)
- Field site selection worksheet (form E-3)
- Channel assessment field forms (forms E-4) or equivalent
- Channel segment summary sheet (form E-5)
- Geomorphic unit description and sensitivity justification (form E-6)

V. **Summary Text**

- Watershed overview; network-wide influences
- Historic trends in channel changes
- Summary of current channel conditions and justification for interpretation
- Description of geomorphic map units (GMUs) and justification for interpretation
- Discussion of habitat-forming processes
- Study methods
- Descriptions of any deviations from the standard methods and why the changes were necessary
- Recommendations for Level 2 (at Level 1 only)
- Statement of the author's confidence level in the analysis and results
- Does module report address all critical questions?

VI. **Other Information (optional)**

- Monitoring strategies and design and implementation suggestions
- Learning resources (a.k.a., references, bibliography) section
- Acknowledgments section

All module work products should be archived for use during the Synthesis of this assessment and in future years.

Table E-4. Channel Assessment Task Checklist

Below is the channel assessment checklist, which helps guide the channel analyst through the watershed analysis.

Review	Task	Schedule	Complete
	Analysis materials in place		
	Startup meeting--brief team on process and intent Schedule module tasks		
	Map segments--Complete Response Segment worksheet (Form E-1)		
	Produce channel segment map on mylar overlay (Map E-1)		
	Provide map to fish and hydrology analyst		
	Meet with fish and hydrology analysts for input on analysis sites		
	Perform aerial photo interpretation; complete the channel disturbance worksheet (Form E-2)		
√	Review products and checkoff with team:		
	Select field sites and complete field site selection worksheet (Form E-3)		
	Complete field work-- (Field forms E-4)		
	Derive diagnostic variables and assess channel condition—complete channel diagnostic worksheet (Form E-5)		
√	Team meeting: review results of field work and channel interpretations		
	Cluster segments and determine channel sensitivity Complete Geomorphic Unit worksheet (Form E-6)		
	Complete the geomorphic unit map (Map E-2)		
	Interpret habitat-forming processes by geomorphic unit. Complete narrative		
	Produce module report		
√	Review module report		

Summary

The channel assessment module is intended to organize collection and presentation of the information necessary to make informed decisions about potential watershed management impacts on stream channels. The module relies on trained specialists to conduct and interpret analyses in order to provide effective information. The general approach is oriented around answering questions critical for developing a sufficient understanding of watershed processes to allow decision makers to weigh the benefits and potential risks of land management activity and to develop effective management prescriptions to avoid adverse impacts, enhance resource conditions and values, and accelerate recovery from past disturbance. The underlying philosophy is that only through incorporation of high quality information into the decision-making process can potential adversaries agree on a common decision-making framework. Recognition of when, where, and how to undertake more detailed analyses necessary to adequately understand watershed processes is a crucial component of Watershed analysis that must not be constrained prior to conducting the standard analysis.

Acknowledgments

This module represents the results of many people over the course of many years. This version was written by Kate Sullivan, Dave Montgomery, George Pess, and John Buffington. Mary Raines and Peter Whiting drafted the first version of this module based, in part, on a draft manuscript of report TFW-SH10-93-002. Development of the channel diagnostic procedure also benefited from discussions with Walt Megahan, Bill Dietrich, Lee MacDonald, Lee Benda, Matt O'Conner, Larry Schmidt, and JoAnn Metzler. This version of the module incorporates field forms that were aided in development by JoAnn Metzler.

The current module represents a work in progress on a complex issue completed under a statutory time table. Further revision of the manual and methods are required to maintain the technical viability and credibility of the channel assessment procedure. Periodic revision and incorporation of new methods and insight is a fundamental assumption of the diagnostic approach upon which this module relies.

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Form E-1. Channel Segment Identification Worksheet

FORM E-1. SEGMENT IDENTIFICATION WORKSHEET

SEDIMENT

FS – Fine Sediment Deposition
CS - Coarse Sediment Deposition

DISCHARGE

SC - Scour Depth
SF - Scour Frequency
BE - Bank Erosion

WOOD

WL - Wood Loss
WA - Wood Accumulation

CATASTROPHIC EVENTS

DFS - Debris Flow Scour
DFD - Debris Flow Deposition
DB - Dam Break Flood

VW > 4CW UNCONFINED						
2CW < VW < 4CW MODERATELY CONFINED						
VW < 2CW CONFINED						
	<1.0 Pool-Riffle	1.0 - 2.0 Pool-Riffle, Plane-Bed	2.0 - 4.0 Plane-Bed, Forced Pool-Riffle	4.0 - 8.0 Step-Pool	8.0 - 20.0 Cascade	> 20.0 Colluvial

VALLEY GRADIENT AND TYPICAL CHANNEL BED MORPHOLOGY

Form E-2. Channel Disturbance Worksheet

Channel Response Segment Number	Change in Channel Width (+ or -)	Time Interval (years)	Disturbance Indicators: Channel pattern change, alluvial fans, adjacent catastrophic damage

Form E-3. Field Site Selection Worksheet

SEGMENT CHOSEN	RATIONALE

Form E-4: Channel Assessment Field

Stream____________________________ WAU_____________ Observers________________
Segment No.___________ Response Type___________ Date____________
Length Sampled________ Total Segment Length_________ Flow: high mod low

Channel Dimensions
Mean bkfl width:_________________________ Wetted width:___________
Mean bkfl depth:_________________________ Wetted depth:___________
Valley bottom width:______________________ Channel slope:__________

Bed Conditions
Morphology: colluvial bedrock regime braded pool-riffle forced pool-riffle plan-bed step-pool cascade

Gravel Bars: point medial multiple forced
___________% active area in bars
Riparian opening wider than active channel?

Channel Pattern: meandering sinuous straight braided Sinuosity:________

Pool spacing: Free	POOL TALLY (approx. width X length X mas depth) LWD Forced	Bldr Forced	Banks Forced
Total:	Pool spacing = (reach length/channel width)/number of pools =		

Primary LOD Function(s): pool scour bank stability
Bar stability sediment trap step former
Describe:____
____

LWD Tally (> “)

Fine Sediment Deposits:
In pools: avg V* and range (see V* forms): ________________
____

In riffles:
1) Locally in sheltered locations 3) over most of bed
2) Strands extending downstream 4) thin draping over larger clasts

Stream Bed Material:
Surface Texture: ____________________________
Distribution & patterns: ____________________________
____

D50 (see pebble count forms):

Other Comments:

Bank Conditions

Bank Material:

Texture: ____

Source: ____

Sources of protection: ________________________________

____

Bank erosion: % of reach

Location: 1) locally where forced by obstructions
2) outside of bends
3) intermittent; independent of channel geometry
4) extensively along one side
5) continuously along both banks

Mass Wasting (record approx. length and height; mark on map)

Floodplain Conditions

Entrenchment:____________________ Cross-Section Sketch

Terrace material, source and size:

____

____

Overbank Deposits:

1) Wood berms
2) Debris trash lines
3) Boulder berms
4) Other, ______________

Channel margin vegetation:_______________________________________

____

Riparian condition: _______________________________________

____

Other Comments:

____

____

____

____

____

Migration:

Spawning (gravel presence & stability):

Rearing (pool formation):

Overwinter (off-channel):

Stream Channel Assessment Forms E-4

Date:
Stream:
Segment #:
Weather:
(air temp & visibility)
General Flow condition:
(flow level & visibility)

Observers:
Length Sampled:
Total Segment Length:
Mean bankfull width:
Mean bankfull depth:
Wetted width:
Wetted depth:

CHANNEL BED

Channel Bed Morphology

1=colluvial, 2=bedrock, 3=cascade, 4=step-pool, 5=plane bed, 6=forced pool/riffle, 7=free pool/riffle, 8=regime, 9=braided (depositional channels include 5-8; transport include 4-2; source includes 1. Note where this is not the case and note the primary depositional, transport and source channels.)

Distance (ft or M)	**Type**	**Slope (Clino or level)**	**Comments**

ACTIVE CHANNEL

Gravel Bar Characteristics

1=Point; 2=Lateral; 3=Medial; 4=Tranverse; (controlled by bed obstructions such as boulder); 5=Single Obstruction (e.g., LWD or Boulder); 5=LWD (a=bar apex; b=meander bend/channel cutoff or avulsion).

Activity Level (AL)

1=Active (all within floodplain & no evidence of vegetation); 2= Semi-active (>50% in floodplain and non-vegetated, or side channel around outside end of bar active during high flow events); 3=Not active (bar is above floodplain, part of terrace, or entire bar is vegetated except for banks)

Side Channel (SC[W]) – give width of side channel.
Side Channel (SC[L]) – give width of side channel.

Note – Measure bar dimensions as a function of activity level within bar. One bar can have several activity levels.

Distance (ft or M)	**#**	**Type**	**Lgth (ft or M)**	**Wdth (ft or M)**	**Hght (ft or M)**	**AL**	**SC (W) (ft/m)**	**SC (L) (ft/m)**

ACTIVE CHANNEL

Pool Forming Factors (PFF)

PFF key

1=Channel meander (free) or bedform, 2=Bank, 3=Log, 4=Log jam, 5=Rootwad, 6=Roots of standing tree or stump, 7=Boulder, 8=Bedrock (indicate type), 9=Beaver dam, 10=Manmade (artificial bank, culvert, bridge, etc.), 11=Gravel bar (for backwater & side channel pools). Can be more than one element. (Please refer to Ambient Monitoring Manual for definition of pool forming factors).

Substrate (Dominant [dom] and subdominant [sub])

1=Bedrock; 2= Boulder; 3=Cobble; 4=Gravel; 5=Sand; 6=Organics; 7=Silt

Obstruction size (size of obstruction creating pool) Can be more than one element. Record length and width of structure that creates the pool.

Start Dist (ft or M)	End Dist Ft or M	PFF	L FT or M	W Ft or M	MaxDpth Ft or M	TIDepth Ft or M	Subste Dom & sub	Obs Size W) ft or M	Obs Size (L) Ft or M

ACTIVE CHANNEL

Long Profile Data Sheets

Date: Watershed: Stream:

Segment#: Surveyors:

Unit #	**Dist (ft or M)**	**Backsight (ft or M)**	**Foresight (ft or M)**	**Comments (Benchmark, turning point, pool, riffle, etc.)**

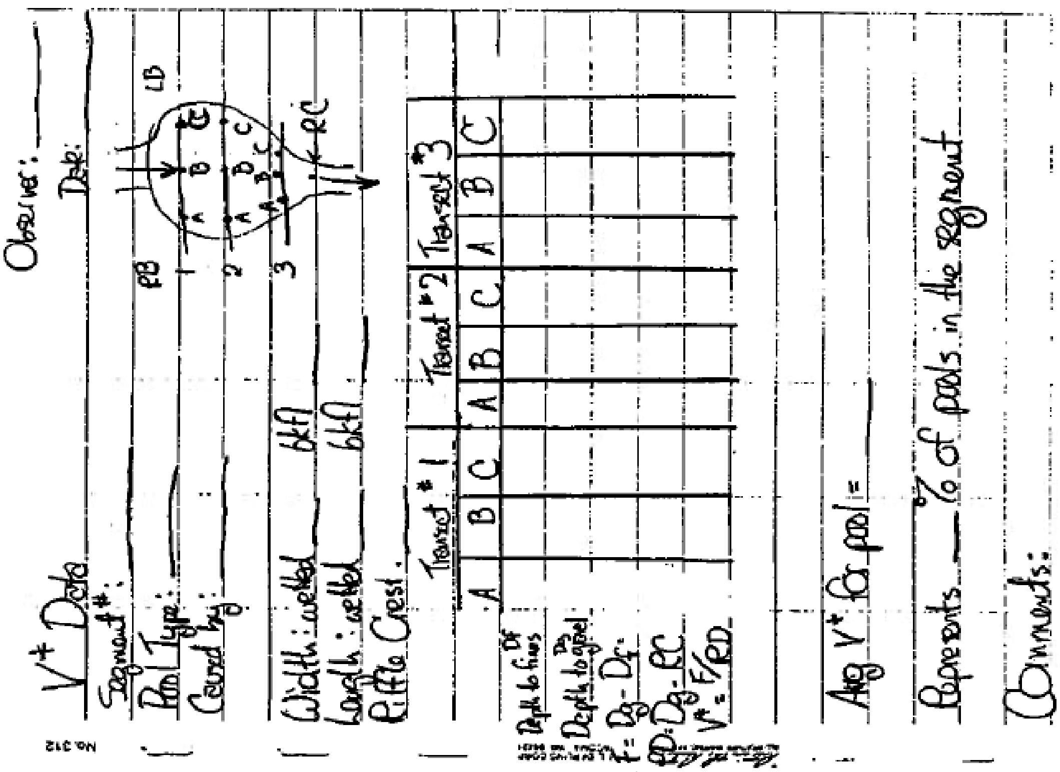
ACTIVE CHANNEL

Cross Section Data Sheets

Date: Watershed: Stream:

Segment#: Surveyors:

Dist (ft or M)	Type	Distance (ft or M)	Depth (ft or M)	Comments



V* Data

Observer:

Date:

Segment #:

Pool Type:

Censused by:

Width: wetted ___ bkf

Length: wetted ___ bkf

Riffle Crest.

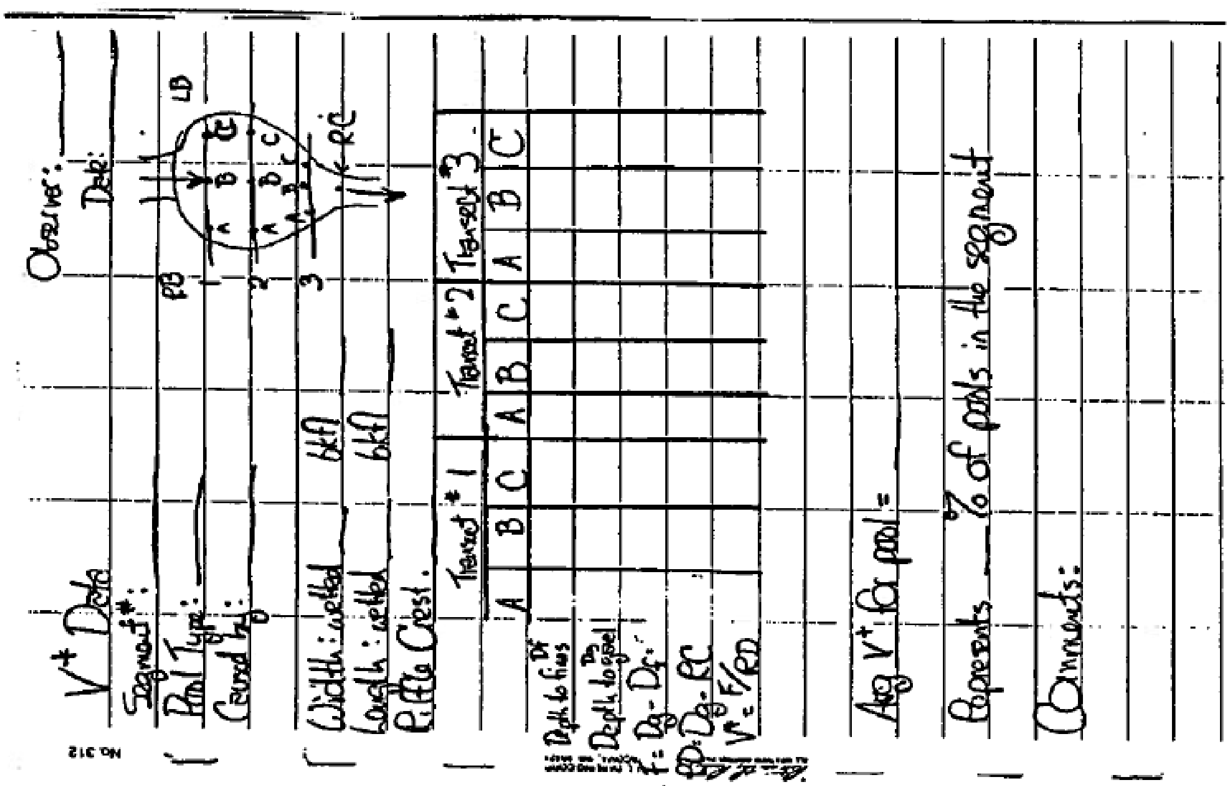
RB LB RC

	Transect # 1			Transect # 2			Transect # 3		
	A	B	C	A	B	C	A	B	C
Depth to fines D_F									
Depth to gravel D_G									
$F = D_G - D_F$									
$RD = D_G - RC$									
$V^* = F/RD$									

Avg V* for pool =

Represents ___ % of pools in the segment

Comments:



V* Data

Observer:

Date:

Segment #:

Pool Type:

Censused by:

Width: wetted ___ bkf

Length: wetted ___ bkf

Riffle Crest.

RB LB RC

	Transect # 1			Transect # 2			Transect # 3		
	A	B	C	A	B	C	A	B	C
Depth to fines D_F									
Depth to gravel D_G									
$F = D_G - D_F$									
$RD = D_G - RC$									
$V^* = F/RD$									

Avg V* for pool =

Represents ___ % of pools in the segment

Comments:

CHANNEL BED

(For particle size distribution (surface and subsurface see pebble count form)

Dominant Roughness Elements (DRE)

1= structure controlled (steps & obstructions), 2= Particles (a=bedrock, b=boulder, c= cobble, d=gravel), 3= bed form (bars, pools, riffles), 4= LWD, 5= sinuosity, 6=banks

Bed Surface Pattern (BSP)

1= Glide; 2=Riffle; 3=Rapid; 4=Side Channel

Substrate (Subste) (Dominant [dom] and subdominant [sub])

1=Bedrock; 2=Boulder; 3=Cobble; 4=Gravel; 5=Sand; 6=0rganics; 7=Silt

Fine Sediment Deposits

In Pools (also see V form) (FSD-p)*

1 = local accumulation behind obstructions and in slackwater; 2= accumulation local and in patches; 3= widespread accumulation.

In Riffles (FSD-r)

1= locally in sheltered locations; 2= strand extending downstream of obstructions; 3= over most of the bed; 4= thin draping over large clasts

Dist (ft or M)	DRE	BSP	Subste (dom& sub)	FSD-p	FSD-r	Comments

ACTIVE C HANNEL

LWD

Functions(F)

1=pool scour; 2=bank stability (a=single piece, b=debris), 3=bar stability (a=single, b=bar apex jam, c=meander bend, d=channel cutoff jam), 4= sediment storage, 5=step or terracette former, 6= channel creator. Note - function can be more than one at any given time. Record channel width at various points to compare to LWD size. For jams estimate number of pieces and rough size distribution.

#pieces - scale number of pieces to appropriate size based on bankfull width.

Log Jam or Channel Stored Sediment (LJ/CSS) (Only applies to LWD that create log jam or exhibits sediment storage as a primary function) Measure Height (Upstream bed v. Downstream of obstruction bed elevation), Length (Upstream end of obstruction to Upstream end of log jam or sediment accumulation), and Width. Minimum dimensions should be .2Mx.3Mx.6M long. Volume=(H/2)LW

Distance (ft or M)	**F**	**#pieces (> cm)**	**#pieces (> cm)**	**LJ or CSS L (ft or M)**	**LJ or CSS W (ft or M)**	**LJ or CSS H (ft or M)**	**Comments**

Segment # ___ Pebble Count Data Observer: ___

Location of Count: ___ Date: ___

Surface

D_{16} = D_{50} = D_{84} =

Unit of measure: ___

Subsurface

D_{16} = D_{50} = D_{84} =

(Sketch channel banks, thalweg, patches of substrate sizes + location of sample on back)

Segment # ___ Pebble Count Data Observer: ___

Location of Count: ___ Date: ___

Surface

D_{16} = D_{50} = D_{84} =

Unit of measure: ___

Subsurface

D_{16} = D_{50} = D_{84} =

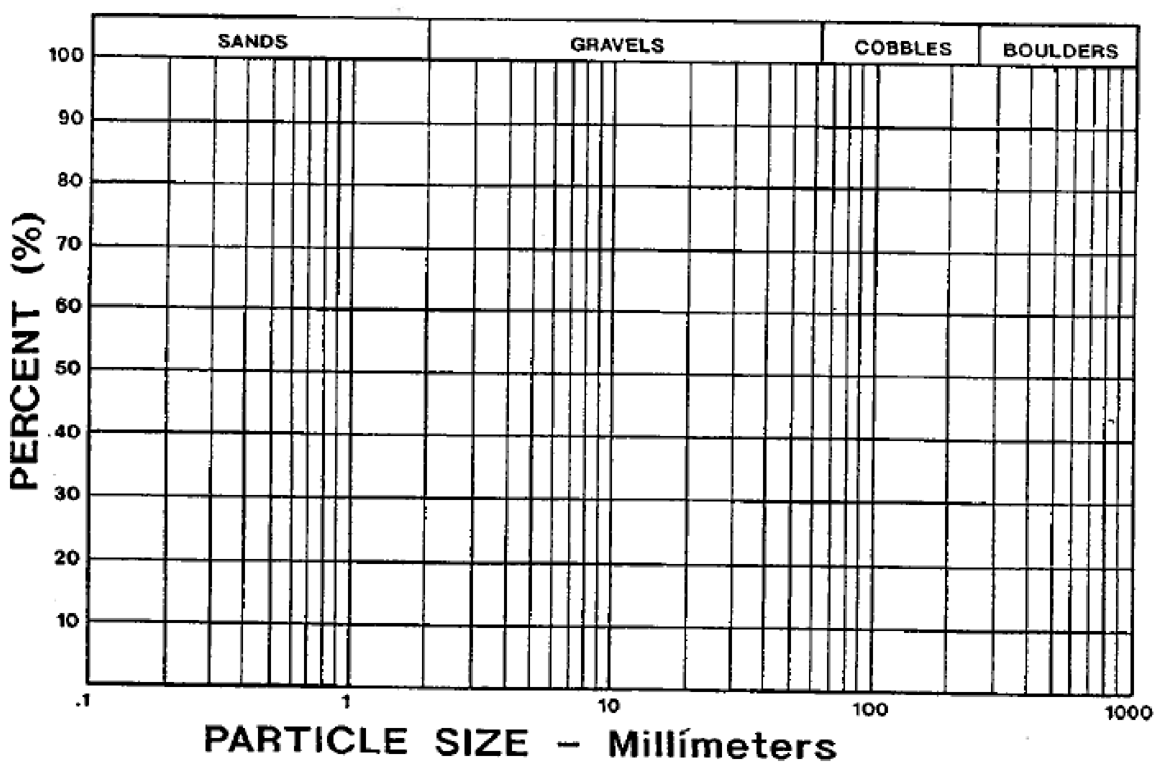
PEBBLE COUNT

Watershed Name: Date:

Party: Reach:

					PEBBLE COUNT			PEBBLE COUNT		
					DATE:			DATE:		
					REACH:			REACH:		

Inches	PARTICLE	Millimeters		Particle Count	TOT #	ITEM %	% CUM	TOT #	ITEM %	% CUM	TOT #	ITEM %	% CUM
	SILT/CLAY	< .062	S/C										
	Very Fine	.062 - .125	S										
	Fine	.125 - .25	A										
	Medium	.25 - .50	N										
	Coarse	.50 - 1.0	D										
.04 - .08	Vry Coarse	1.0 - 2	S										
.08 - .16	Very Fine	2 - 4											
.16 - .24	Fine	4 - 6	G										
.24 - .31	Fine	6 - 8	R										
.31 - .47	Medium	8 - 12	A										
.47 - .63	Medium	12 - 16	V										
.63 - .94	Coarse	16 - 24	E										
.94 - 1.26	Coarse	24 - 32	L										
1.26 - 1.9	Vry Coarse	32 - 48	S										
1.9 - 2.5	Vry Coarse	48 - 64											
2.5 - 3.8	Small	64 - 96	C										
3.8 - 5.0	Small	96 - 128	O										
5.0 - 7.6	Large	128 - 192	B										
7.6 - 10	Large	192 - 256	L										
10 - 15	Small	256 - 384	B										
15 - 20	Small	384 - 512	L										
20 - 40	Medium	512 - 1024	D										
40 - 160	Lrg-Vry Lrg	1024 - 4096	R										
	BEDROCK		[illegible]										
				TOTALS									



D_{16} = D_{50} = D_{84} =

ACTIVE CHANNEL

Bank Erosion Factors
1=locally where forced by obstructions; 2=outside of bends; 3=intermittent, independent of channel geometry; 4= extensively, along one bank; 5=continuously along both banks.
Bank & vegetation
1=80% covered, 2=50 to 80% covered. 3=25 to 50% covered. 4=<25% covered
Bank material composition:
Texture (alluvium, colluvium, bedrock, etc.):
D50 observed:
Source:
Sources of protection:

Dist (ft|M)	BEF (LB)	BEF (RB)	BV (LB)	BV (RB)	Lgth (ft|M)	LBHght (ft|M)	RBHght (ft|M)	%Bank Eroding	Com

ACTIVE CHANNEL

Riparian Composition (RC)

1=mixed; 2=coniferous; 3=deciduous; 4=herbaceous; FP=floodplain. Note % of each and cross-sectional or longitudinal change in vegetation.

Riparian Age (RA)

a=Young (<40yrs), b=Mature(between 40-80yrs), c=Old (120 for coniferous, 80 for mixed or deciduous). Note whether sparse or dense.

Active Riparian Recruitment Processes (ARRP)

l=bankcutting; 2=windthrow; 3=floodplain; 4=jams; 5=upstream sources

Distance (ft or M)	RC (LB)	RC (RB)	RA (LB)	RA (RB)	ARRP (LB)	ARRP (RB)	Comments

FLOODPLAIN

Entrenchment (Ent)

1= Not entrenched (floodplain & terrace connected); 2= Moderately entrenched (small active floodplain in a larger trench that may be inundated during 20 yr event); 3= entrenched (small floodplain, isolated terrace).

Terrace material (TM)

Note % of each terrace forming material (e.g. bedrock, alluvium, colluvium, and debris flow deposit) and D50 (observed). There may be more than one terrace, please note each terrace material source, and estimate terrace D50 of each.

Overbank deposits (OD)

1= wood berms; 2= debris trash lines; 3= boulder berms; 4= other

Terrace observed D50

Overbank deposit observed D50:

Dist (ft or M)	**Ent**	**TM**	**OD**	**Comments**

Form E-5 Segment Summary Sheet

page 1 of 2

Segment:__________________________ WAU:______________________

Attributes		**Sediment Supply**	**Transport Capacity**	**LWD Function**	**Catastrophic**
Channel Bed	Channel type				
	Median grain size				
	Bed surface pattern				
	Particle Size Distribution				
	q*				
	% fines in Subsurface				
	Roughness elements				
Active Channel	Gravel bar characteristics				
	Pool characteristics				
	Channel Pattern				
	Fines in pools				
	V*				
	Fines in riffles				
	Bank Erosion				
Flood-plain	Overbank deposits				
	Entrenchment				
	Riparian vegetation				

Form E-5 Segment Summary Sheet

page 2 of 2

Input Factor	Existing Condition	Change from Historic	Response
Coarse Sediment			
Fine Sediment			
Peak Flow			
Large Woody Debris			
Catastrophic Damage			
Geomorphic Unit			

Form E-6. Geomorphic Unit Description and Sensitivity Justification

Geomorphic Unit: ____

Description: ____
(including ____
gradient & ____
confinement) ____

Input Factor	Conditions	Response Potential	Relative Sensitivity
Coarse Sediment			
Fine Sediment			
Peak Flow			
Large Woody Debris			
Catastrophic Damage			

	Field-verified	Extrapolated
Segments in Geomorphic Unit		