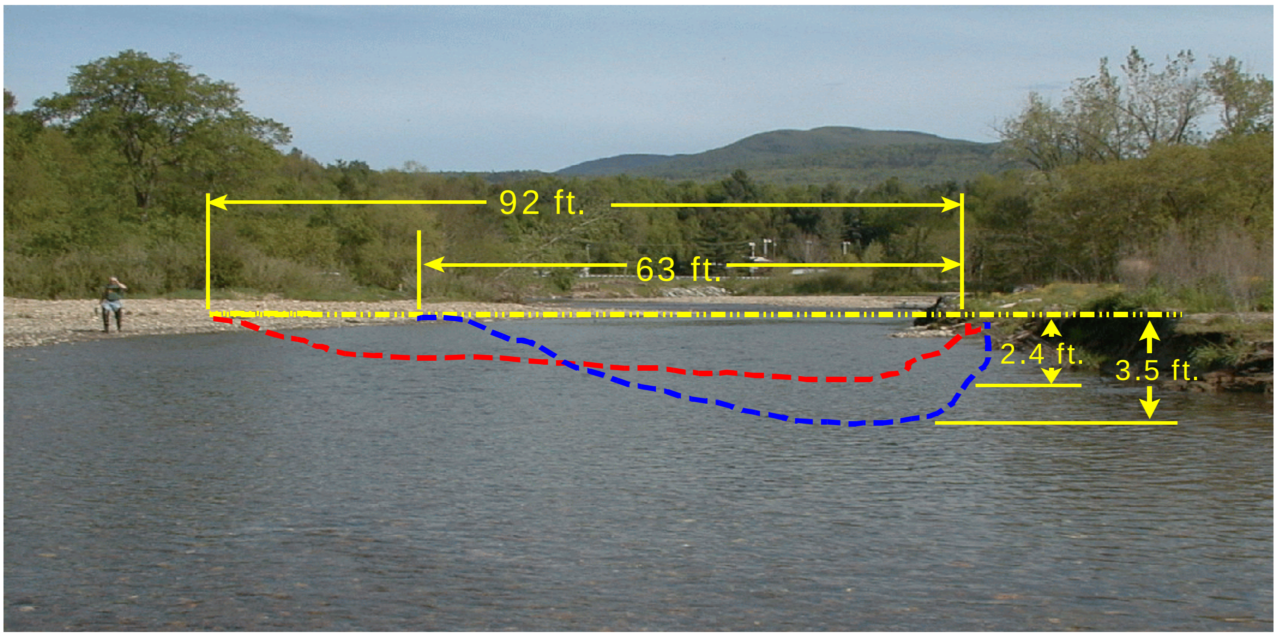
Vermont Stream Geomorphic Assessment
Phase 3 Handbook

SURVEY ASSESSMENT



FIELD AND DATA ANALYSIS PROTOCOLS

Vermont Agency of Natural Resources

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The Phase 3 Handbook, Spreadsheet, and Database may be downloaded from the River Corridor Management, Geomorphic Assessment internet web page at: **www.vtwaterquality.org**

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PHASE 3 INTRODUCTION

The Phase 3 Survey Assessment is a detailed protocol for gathering scientifically sound information that can be used for watershed planning and detailed characterization of aquatic habitat, erosion, and flood hazards. References used to develop the Phase 3 protocols are listed after the field data collection and analysis sections (Steps 1-7). The Phase 3 Survey Assessments are composed of observations, measurements, and survey data and are conducted on "reference" equilibrium reaches and selected degraded sites to quantify physical channel form and processes in detail. Phase 3 assessments can be used to verify Phase 1 and Phase 2 data and compare stream reaches and segments to each other and to regional reference conditions.

Where to complete a Phase 3 Survey Assessment

Whether just completing a Watershed Assessment (Phase 1) or responding to a specific concern, an assessment team may decide on a set of priority reaches to conduct Survey Assessments. Basin planning and project-related reach selection processes are described in the Introduction section of the Phase 2 Rapid Stream Assessment Handbook. Conduct Phase 3 quantitative survey-level assessments at sites within Phase 2 selected reaches to verify the stream condition and adjustment process conclusions made using the Rapid Assessment protocols.

While these protocols do not provide guidance on corridor protection and stream restoration project designs, the Agency highly recommends the use of these methods for field collection and analysis of survey data at sites that are candidates for these types of projects and for which an alternatives analysis will be completed. Good project planning and design also involves the identification and assessment of reference reaches to more fully understand the type and degree of adjustments present at the project site. Undisturbed areas may become priorities for corridor protection projects and serve as "reference reaches" for the impacted or adjusting reaches of the same stream type.

Methods and Skills

The information and data collected in a Survey Assessment comes from field observations and measurements, as well as spreadsheet analysis. The completion of a Phase 3 assessment can take up to 3 to 4 days depending on the size of the stream.

The Phase 3 Survey Assessment is divided into two basic parts. In Steps 1-3, field surveys are conducted to describe, measure, and photograph the stream and its setting. Steps 4 involves the plotting and reduction of geomorphic and habitat data using computer spreadsheets. Step 5 includes the Stream Survey and Habitat Assessments where the condition and sensitivity of each site is summarized.

The skills needed to complete a Survey Assessment are:

- Reading topographic maps
- Measuring distances and compass headings in and around streams
- Surveying skills (requiring training in the use of transit, laser, or total station survey equipment)
- Calculating some basic mathematical equations (examples are provided in the text)
- Estimating quantities and evaluating stream conditions

These skills, especially the transit or laser level surveying, require training. If a team is being assembled to complete a Survey Assessment, consider finding the assistance of someone who has experience with interpreting survey data. The involvement and technical assistance of specialists in the fields of geology, aquatic ecology, and fluvial geomorphology is also highly recommended. Contact the DEC River Management Program, the Fish and Wildlife Department, or the Vermont Geological Survey about the availability of professionals in these fields and/or to learn about opportunities and requirements for technical training to complete Phase 3 Assessments. A glossary of technical terms is contained in Appendix Q.

Materials Needed

Prior to getting started you will need the following materials and equipment for the Survey Stream Assessment:

Transit, surveyor's level, or laser level survey equipment
Team-mate(s)
Data sheets, topographic map(s), pencils, and clipboard
Measuring tape (100 ft or longer in 1/10 ft increments) and range finder (optional)
Bank pins to secure measuring tape on the left and right stream banks
Waders, wading shoes (old sneakers) or wading sandals
Equipment for weight sieving and bulk weighing bar sediment samples
Benchmark pins and colored flagging
Measuring rod (8 ft. – optional if using survey rod)
Metric ruler, clinometer or protractor
Metal detector – to locate existing survey and benchmark pins
Shovel and trowel for examining bank stratigraphy
Compass
Camera/film

Final Products of the Phase 3 Survey Assessment

Products of a Survey Assessment include:

1. "**Existing Stream Typing"** which involves classifying reaches based on physical parameters such as valley landform, floodplain, channel dimensions, sediment sizes, bed forms, and slope. The Stream Type gives the overall existing physical condition of the channel and helps predict the reference or equilibrium condition of the reach. Phase 3 stream typing provides an opportunity to verify the Phase 2 stream type assessments and whether the existing stream type is the same as the reference stream type predicted using maps and aerial photos during the Phase 1 Watershed Assessment.

2. A **"Stream Geomorphic Assessment"** for each reach assessed that includes:

    - **stream condition** given the land use, channel and floodplain modifications documented at the assessment sites, the current degree of change or departure of the channel, floodplain, and valley conditions from the reference condition for parameters such as dimension, pattern, profile, sediment regime, and vegetation;
    - **adjustment process** or type of change that may be underway due to natural causes or human activity that has or may result in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel plan form adjustment processes); and
    - **sensitivity** of the valley, floodplain and/or channel condition to change due to natural causes and/or anticipated human activity.

The Stream Geomorphic Assessment is an appropriate tool for setting priorities and problem solving in a watershed context, because it will not only tell you the proximity of adjusting reaches to one another but you will be able to ascertain how one reach may be affecting the condition of another. At the end of the Survey Assessment, direct measurements will have been used to evaluate different channel adjustment processes at each site. The physical "stream condition" is largely a function of type and magnitude of channel adjustments that are happening in response to the channel and floodplain modifications documented at sites and in the watershed.

3. A **"Stream Habitat Evaluation"** of the assessed sites based on evaluation of physical habitat parameters. (Under development)

Appendix A provides field data collection forms and Appendix B includes a set of instructions for entering data into the Phase 3 Data Management System (DMS).

Getting Starting

Read the Handbook: Each member of the assessment team should be encouraged to read the Phase 3 Handbook before getting started. Understanding the entire protocol and the rationale behind it can save a lot of questions that will undoubtedly arise otherwise.

Protocol Steps: This handbook is organized by parameter number. For example, questions on the survey of channel cross-sections can be answered by turning to Step 2.5 of this handbook that includes instructions on how to conduct a cross-section survey.

Landowner Permission: Make sure landowner permission has been obtained to conduct assessments on private property. If assessments are being carrying out under the auspices of a town or other entity, obtaining a "generic letter" explaining the purpose of the study is recommended. This can be mailed or handed to landowners with whom the assessment team will come into contact.

Computer Tools & Outputs: The Vermont Agency of Natural Resources has developed a spreadsheet and data base computer program to support the Phase 3 Stream Geomorphic Assessment. Both spreadsheet and database programs are in Microsoft software. This handbook is accompanied by a computer disk that contains the DMS spreadsheet that can be used with the Excel software. Appendix B shows examples of the input workbooks and describes the spreadsheet summary tables and database reports used to complete Phase 3 products. Sending electronic copies of data (entered into the computer spreadsheet) to the DEC River Management Section to include in the state geomorphic database will provide several benefits:

- ensuring that a duplicate copy of the data exists in an alternate location;
- building a statewide database that will result in a more powerful problem solving tool; and
- receiving assistance from other geomorphic assessment professionals for data interpretation.

Assessment Sites: Ideally, survey assessment sites are at least 12-20 bankfull widths in length (two stream meander wavelengths), and begin or end at the head of riffles, steps, or at grade control. If the assessment is part of a river protection, management, or restoration project, the assessment site boundaries should extend beyond both the upstream and downstream boundaries of the project area to at least the next riffle or grade control.

Selecting sites to complete reference surveys should avoid river segments influenced by bridges, culverts, or other channel/floodplain constrictions that would significantly modify the hydraulics and sediment transport characteristics of the reach.

Previous Assessments: Review all Phase 1 and Phase 2 data summary reports available for your reach and its watershed before you begin a Phase 3 Survey Assessment. Ideally, you should have Watershed Assessment and Rapid Assessment data summaries with you in the field while you are conducting a Survey Assessment.

Reminder: The right bank and left bank are defined looking downstream. If you have any questions about the definitions of any terms, please refer to the glossary in Appendix Q.

Field forms: Paper field forms (Appendix A) are organized by step and parameter number and have a heading for the following information:

> **Stream Name:** As printed on the USGS topographic map. It is also helpful to note the name of the receiving water in parentheses.
>
> **Assessor Assigned ID:** A Site ID that is assigned by the assessor. This ID is to allow for the assigning of a reach ID that may have more meaning to the assessing organization than the state-wide unique Site ID has.
>
> **Location:** The site location description should help someone unfamiliar with the area to locate the site. Try to provide as much detail to your description as you can; for example, give a distance and compass heading from a named landmark, road crossing, or road mile marker to the upstream end of the site. All sites should be marked on a topographic map and labeled with Phase 1 reach numbers (if available).
>
> > **Example:** Off Rt. 100, 2 miles up from Rt.100 / Bridge St. intersection in Granville. Upstream end of site begins NE approximately 1/2 mile off Rt.100 just above tributary entering on the east bank.
>
> **Date Established:** Date of Survey Assessment.
>
> **Town:** Town(s) where site is located.
>
> **Elevation:** Elevation above sea level of the upstream extent of the study reach recorded from the U.S.G.S. topographic map.
>
> **Observers:** First and last initial of each field observer.
>
> **Organization/Agency:** Three (or more)-letter acronym(s) of the organizations and agencies represented in the assessment crew.
>
> **Latitude and Longitude**: Latitude (N/S) and Longitude (E/W) of the most upstream end of the study reach, recorded from GIS, GPS, or similar mapping software as degrees, minutes, and seconds in the Vermont state plane coordinate system based upon the 1983 North American Datum (NAD).
>
> **U.S.G.S. Map Name:** USGS (1:24,000 and 1:25000) topographic quadrangle map name(s) on which the watershed is located.
>
> **Drainage Area:** If this has not already been determined from a Phase 1 Assessment, or from a published source, use a planimeter to measure the drainage area in square miles from U.S.G.S. topographic map or record the watershed surface area calculated from GIS or other mapping software, as described in the Step 2.7 of the Phase 1 Watershed Assessment Handbook.

Site Length: Recorded in feet as the distance along the channel from the upstream to the downstream extent of the reach. Site length is calculated as part of the longitudinal profile analysis performed by the Phase 3 spreadsheet. Entering the value here is for convenience of referencing site length during the review of field data forms.

Benchmark Elevation and Location: Elevations are recorded in feet and coordinates are recorded in degree minutes and seconds in the Vermont state plane coordinate system based upon the North American Datum (NAD) of 1983. Benchmarks should be established at elevations identified in FEMA flood studies or other published engineering studies where available. In remote locations where flood studies have not been completed, establish a new benchmark elevation on a durable location (e.g., bedrock) that can be located in the future.

Heavy Rain in Last Seven Days: Answer yes or no based on whether the channel has carried flows from a large rain storm in the seven days prior to your field assessment.

Flood history: Use the check box to indicate whether you are familiar with the last occurrence(s) of major flood(s) in your assessment reach (recurrence interval $\geq$ 10 yrs). Appendix K contains long-term flood history graphs for 33 U.S.G.S. Gage Stations around Vermont. Refer to the station data nearest to the reach you are assessing and/or use additional local sources and recent knowledge where possible. This may be important because the small stream being assessed may have experienced a major flood, while the larger river reach downstream where the gage located did not flood during the same storm or runoff event. Record additional flood history sources in the Notes (Step 1.7) section of the Site Location and Description field form.

Site Number: A unique state-wide identification number is assigned to the site for inclusion into the State geomorphic database. The State site number is made up of the 10-digit HUC number plus a 4-digit number sequentially assigned by the RMP when the data is entered into the DMS and a ".3" to indicate that it is a phase 3 site.

Watershed: In the DMS spreadsheet, use the drop down menu to select the appropriate HUC-10 watershed in which the assessment was conducted. The HUC 10 number will be combined with the 4 digit ID described below to form a state-wide unique site ID.

4-Digit Site Number: This 4-digit number will be assigned by the RMP as sites are entered into the DMS. This number will be combined with the HUC 10 number to form the state-wide unique site number.

Site Sketch: The first thing that should be completed upon arriving at the site is to walk the extent of the reach to determine the beginning and end of the assessment site and to sketch the planform of the stream. It is helpful to have a base map of the reach as this will help to scale the sketch and accurately depict the planform of the reach. Base maps can be generated either electronically or more simply by tracing the reach from a topo map or orthophoto and enlarging the trace on a photo-copier. Ideally the site will be 20 bankfull widths or two meander wavelengths in length, beginning and ending at the same morphological bed feature type (i.e., riffle head to riffle head). The reach may be shorter than 20 bankfull widths if there exists a dramatic change in stream morphology within this standard length. Use the Site Sketch field form or a number a blank pages (taped together on match lines), if a larger scale is desired, to draw the chosen study reach. If possible, have one field-crew member walk the centerline of the stream to note the approximate location of bed features (i.e., riffles, runs, pools, and glides).

Working in one direction, sketch the meanders (using right and left top-of-bank), bed features, floodplains, terrace, and land uses. With a range finder (if available) indicate the lengths of the various bed features, this will help to improve the accuracy of the sketch and provide useful information when locating cross section locations and verifying computer-generated planform plots. Coming back in the opposite direction, flag the location of bankfull indicators and the places where benchmarks will be established and where cross-sections, pebble counts, bank erodibility assessments, and bar samples will be completed (see appropriate Phase 3 Steps for guidance on selecting locations for these investigations). Indicate these locations on the sketch. Using the topo map or compass, orient the paper and place a North arrow on the sketch.

In looking for bankfull indicators avoid areas of bedrock, rip rap, bridge footings or other control points when identifying bankfull features. Naturally developed flood plain on the inside of meanders and developing point bars should be considered good indicators and weighted more heavily than erosion or scour features along the outside of meander bends. For extensive discussion on the identification of bankfull indicators and the processes that create these indicators see Appendix K.

With landowner permission, establish a permanent benchmark using either four-foot rebar, survey spikes or other features of stable elevation that will reference the survey to a point of known elevation. Use the codes listed in the Map and Sketch Codes table in Appendix A to indicate certain features in the sketch.

The plan form sketch provides an opportunity to see both the vertical and lateral constraints on the stream system. These constraints may be beneficial to the stability of the stream (i.e., natural grade control provide vertical stability) or they may substantially increase the hazard potential of the stream. Take special note of hazardous planform alignments on the sketch (e.g., the stream entering a culvert or bridge at acute or right angles or a house located at the outside downstream end of a meander bend).

Once the cross-section and profile surveys have been completed, be ready to select the stream banks where you intend to complete erosion studies. After these assessments have been completed, note on the sketch where any bank and bed pins and scour chains may have been placed.

Height Of Bankfull Features: At each bankfull indicator identified during the site sketch walk, record the height of each bankfull feature above the current water surface in the spaces provided on the Site Sketch field form. Calculate the height using survey rod and level or stretch a level tape out from the bankfull indicator across the water surface and use a measuring rod to determine the height (see Figure I.1). Once this exercise has been completed at each indicator, make a decision as to which subset of indicators best represent the bankfull stage. Place the selected bankfull height above current water surface in the box on the right hand side of the Site Sketch form. This value can be used to determine or verify bankfull stage at your cross-sections and along the longitudinal profile.

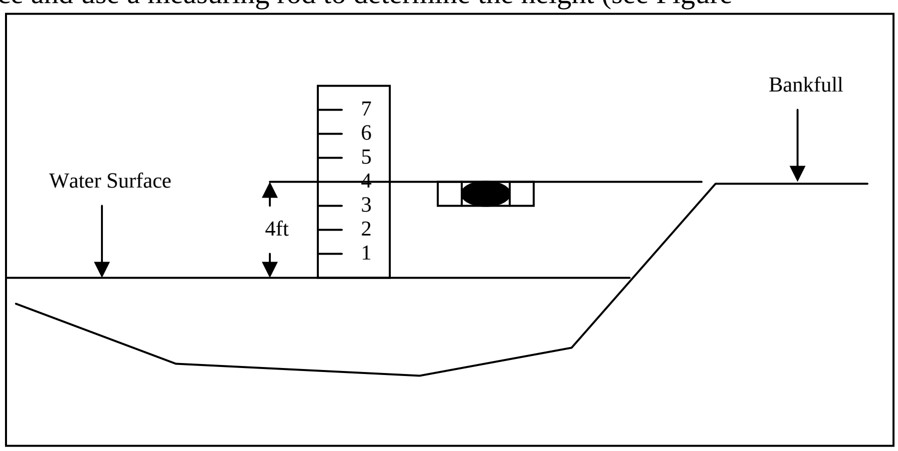

Figure I.1 Measuring height of bankfull above current water surface using a tape, line level and survey rod.

Taking Pictures: Use either the Standard or Database - Photo Log form (Appendix A) to document the picture you have taken. It is important to record the roll and photo number and description of each photo. A photo database has been developed by the River Management Program to record photo information. Recording the information required to fill out the Database – Photo Log form (Appendix A) will enable digital photos storage in the State Geomorphic Database and significantly enhance the accessibility of assessment photos.

Phase 3 Quality Assurance Program

Field teams should consist of a minimum of 2 people, with 3 to 4 people as optimal. At least one person on the team must commit to a training in the protocols, including field assessment and data analysis techniques. This person would be responsible for the completeness and accuracy of the data collected. Other members of the team may have less extensive training, but would be able to assist in the assessment at some level. Establishing the roles of different team members at the start of an assessment will insure that the team works efficiently and collects meaningful data.

To insure consistent data collection, general guidelines need to be followed. Teams should walk the entire reach before conducting a survey assessment. This is done to determine if different conditions exist along the length of the reach that may affect the interpretation of results at the survey site. If a team is unable to walk the entire reach due to time constraints then the team needs to document on their map and field sheets the portion of reach that was walked and assessed, so that at a later date, the rest of the reach can be assessed. The survey assessment teams should be made aware that it may take more than two days to complete an assessment on a site. If the team is not able to go back to a site in consecutive days, they should return during conditions similar to that of their first field visit if possible. Mark on the Reach Location form any comments about changes in conditions between days.

At the start of the assessment it is important to establish a Quality Assurance (QA) Officer. This person will be responsible for reviewing the data collected. The QA Officer should be a person who is well versed in the protocols, has had training in the assessments, and is familiar with project-level use of the survey assessment data. Training can be obtained from the DEC River Management Program (RMP) or other trainers certified by the Agency or Natural Resources.

Once data has been collected and entered into the spread sheet and database, the standard reports and tables can be generated and reviewed by the QA Officer to determine if there is information that is missing, inconsistent with the protocols, or needs further evaluation. Methods for correcting or completing the information should be established. If Phase 3 data would change data collected in a Phase 1 assessment, the QA Officer should identify those parameters to be updated in the Phase 1 database.

The QA Officer should establish a filing system for keeping track of paper copies of the data and maps in a notebook for each year's data. The paper copies are very important to keep, especially the maps, for future reference. Notes and location data on the maps are important to refer to if work is to be done on the site in the future. Groups that have access to GIS software may choose to make a digital map of the different data that is shown on the field maps. A digital map can be updated each year and is useful for displaying information in a watershed, reach and segment context.

Everyone attempting to use Phase 3 data will appreciate efforts made to document its quality, including its deficiencies. If problems are encountered with incomplete data for certain parameters, make both hard copy and data base notes that can be found and considered later. It is amazing what just a few months (let alone years) can do to the collective memories of the assessment team.

After the assessment is complete and the QA team has reviewed the data, a QA data sheet (Appendix A) should be completed to indicate the extent of assessment that has been completed. In the future, if data is updated or changed the same process of data review will need to be completed. The QA data sheet can then be updated to indicate changes.

For those groups who would like to have their data entered into the State database, the assessor completed portions of the QA sheet will assist in incorporating the data into the State database. As the data is brought into the State database, RMP will review the data, and the QA process and QA sheet will be completed. This process will be done each time data is updated or changed and resubmitted by a group.

Step 1: Site Location And Description

A Survey Assessment should begin with a windshield survey along the stream corridor (see Watershed Orientation Survey guidance in Appendix A) and a walk up and back along the segment to become familiar with the stream and its environs. Many site attributes can be missed if you stay within the immediate site or stream segment where the survey will be completed.

FIELD FORM: SITE LOCATION AND DESCRIPTION

1.1 LOCATION MAP

Draw a picture of how someone else would find the study reach five years from the date the site was established. Schematically show the river reach, roads, and at least one village center. Provide a distance in miles from the point where one would access the river back to a bridge or intersection that can be easily identified on a map. Indicate which direction is North.

1.2 ASSESSMENT TYPE

Menu:

DEG	Degraded site which may be the focus of management efforts.
HGC	Gage site for a hydraulic geometry curve study.
NCD	Natural channel design restoration project monitoring.
REF	Reference site.
MGS	Limited assessment of meander geometry.
HMS	Habitat Monitoring Site.

Circle the initials of the appropriate assessment type. Indicating the type of assessment conducted will be useful when comparing current data with data collected for the same purpose at other sites. For instance, a survey completed on a certain date as a reference assessment can be compared with other reference assessment data on different streams of the same stream type. If the type of assessment being conducted is not represented in the menu, contact the Vermont River Management Program to have additional assessment types added to the menu.

1.3 VALLEY AND STREAM TYPE

Record the existing valley and stream type of the Phase 3 site determined during a Phase 2 assessment (Step 1.5) of the segment or reach. If a Phase 2 assessment has not been completed, measure the valley and channel widths with a tape measure, range finder, or scaled from a field map. Then determine the ratio of valley width / channel width. Use this ratio and the menu below to determine a valley type.

Menu:

Valley Type	Valley Description	Confinement Ratio
1-NC	Narrowly Confined	≥1 and < 2
1-SC	Semi-confined	≥2 and <4
2-NW	Narrow	≥4 and <6
3-BD	Broad	≤6 and <10
3-VB	Very Broad	≤10 –may have abandoned terraces on one or both sides

Again, if a Phase 2 assessment has not been completed, use the stream type spaces on the field form to record a preliminary ocular evaluation of the existing stream type using the Stream Classification tables in Appendix I. Evaluate the Stream Type using the Rosgen classification system (1996) and the Bed Type using the Montgomery-Buffington (1997) classification system. The existing stream type will be determined and/or verified in Step 5 based on Step 2 and Step 3 data. The Stream and Bed types determined here (Step 1.3) are used to aid that determination. If weeks go by between the collection and evaluation of quantitative data, this preliminary evaluation may be a useful reference

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1.4 SURFICIAL GEOLOGY

Menu:

Material	**Description**	**Erodibility**
1-Alluvium	alluvial - river sediments	High
1-Ice-Contact	glacio-fluvial – glacial river deposits	High
2-Glacial Lake	glacio-lacustrine – glacial lake deposits	Moderate - High
2-Glacial Sea	glacio-marine – glacial sea	Moderate - High
2-Till	Till – glacially deposited sediments	Moderate - High
3-Colluvium	Rock fall and landslide deposits	Variable
3-Bedrock	bedrock	Low
Other		

Record the dominant surficial geologic material type found within the river or stream corridor. The information for this section is determined primarily from the boundary conditions analysis (Step 3.1) or the Surficial Geologic Map of Vermont. Descriptions of geologic materials and sources of maps and other publications are provided in Appendix F.

1.5 NEAREST GAUGING STATION & LOCATION

Provide the U.S.G.S. number for the gage nearest the assessment site. Look first for a gage within the same watershed and then to adjacent basins. Place a check next to the location that best describes where the gage is in relation to your study reach (see Figure 1.1).

on tributary	____
on assessment stream	____
on receiving above confluence	_X_
on receiving below confluence	____
other, within basin	____
adjacent basin	____

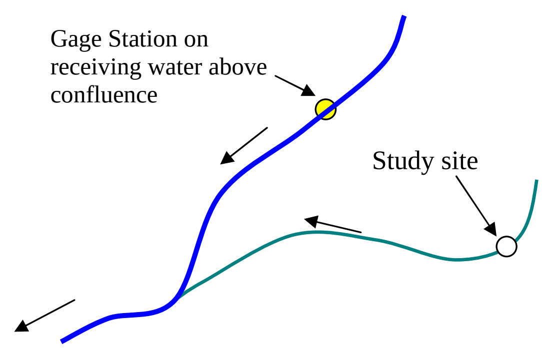


Figure 1.1 Example of describing the location of the nearest Gage Station.

1.6 UPSTREAM CORRIDOR

Menu:

Paved roads, buildings	H / M / L / N
Dirt Roads	H / M / L / N
Bank Erosion	H / M / L / N
Agricultural runoff	H / M / L / N
Channelized, rip-rapped	H / M / L / N
Forested, vegetated buffer	H / M / L / N
Armored Banks	H / M / L / N
Channelized	H / M / L / N

Circle one of the initials "H / M / L / N" representing "High / Medium / Low / None" to indicate the presence or prevalence of each of the land use / land cover categories and channel modifications listed. This information is readily available if Phase 1 and/or Phase 2 Stream Geomorphic Assessment of upstream reaches have been completed. If remote or rapid assessments have not been completed upstream, use maps, ortho photos, and field surveillance to characterize the land use/land cover in the upstream riparian corridor and floodplain.

1.7 NOTES

Take note of any unique field observations, for example: how access was granted; flood occurrences; landowner interests; recent weather or runoff events; etc.

1.8 SURVEY EQUIPMENT USED

Record the type of survey equipment used, for example:

- Laser level with direct read rod
- Total station system
- Transit level

1.9 REACH CONDITION

To complete the Stream Geomorphic and Habitat Assessment (Step 5), the stream types, impacts, and conditions determined during the Phase 1 and Phase 2 Assessments may be used as the basis for stream adjustment and condition departure analyses. Phase 3 quantitative data can be used to confirm your hypothesis regarding stream condition and stage of channel evolution that you developed using results of the Phase 2 Rapid Assessment. If you have not already determined a reference stream type using Phase 1 (Step 2) protocols or conducted the Phase 2 Rapid Assessment, you should do so now before leaving the field and analyzing your Phase 3 Survey Assessment data.

Step 2: Channel Geometry, Sediments and Vegetation

Streams in different settings have predictable flow and sediment characteristics, which in turn result in predictable combinations of channel and floodplain characteristics. Step 2 involves measuring the dimensions of the channel and its sediments to help understand whether the type of channel and floodplain present is what would be expected to exist given the stream's setting. For instance, a relatively straight channel with little or no access to a floodplain during high water is a stream type found in nature, but not typically in unconfined valleys where gravel is the dominant sediment size in the stream bed and banks. Finding such an inconsistency at a site may explain the channel adjustments observed.

Detailed discussions of channel geometry measurement techniques are found in Harrelson and others (1994), Rosgen (1996), and Dunne and Leopold (1978). Starting with the longitudinal profile provides an opportunity to review the location of cross sections and to change these locations if there is good reason to do so. It also gives one more look at bankfull elevations.

FIELD FORM: LONGITUDINAL PROFILE

2.1 LONGITUDINAL PROFILE

Starting at the upstream most riffle or step (where present), survey the longitudinal profile of the site, surveying the head and tail of each bed feature and point of maximum depth within each pool. At each bed feature record the feature number, type, downstream distance, compass bearing (azimuth) and elevation of the thalweg, water surface, bankfull stage, and the right and left tops of bank as shown in Figure 2.1. Record the locations of established cross section sites and survey the water surface at the cross-section locations to relate the cross-section surveys to the longitudinal profile surveys. Bed features are not always easily discerned so it will be up to the field crew-member walking in the river along the thalweg to delineate the extent of individual features. For guidance on feature identification see Appendix M. Also record in the Feature column the location and number of each meander apex. Record all elevation data to the nearest 0.01 ft. and horizontal distance data to the nearest 0.5 ft.

#	Feature		Dist.	Azim.	Elevations					XS	Notes
					Thalweg	Water Surface	LBank	RBank	Bkf		
1	(XS1)	RiH1	0	-	16.15	18.24	21.24	23.55	19.54	1	Good Crossover Riffle
2	RiT1	PH1	25	245	13.56	15.55	19.78	21.92	17.24		
3	(MA1)	PM1	35	240	8.50	15.55	19.89	21.87	17.45		Very strong Bkf indicator on LBank.
4	PT1	GlH1	50	234	12.51	15.47	18.55	20.56	16.52		
5	GlT1	RiH2	72	242	12.82	13.99	17.76	19.57	15.23		End of surveyed reach

Figure 2.1 Longitudinal Profile Field Form (feature codes on Profile Field Form in Appendix A).

The importance of the longitudinal profile is twofold. Both longitudinal and aerial plots of the data can be generated. The longitudinal profile data (distances and depths) are entered into a spreadsheet, programmed to generate a profile drawing for thalweg, water surface, bankfull stage, and top of bank. The longitudinal plot as shown in Figure 2.2 allows one to examine the distribution of slope or energy grade throughout the overall reach. The data also allows one to determine the mean slope of different bed features which is very useful in stream condition assessments and restoration designs. The aerial plot will be useful in analyzing meander geometry.

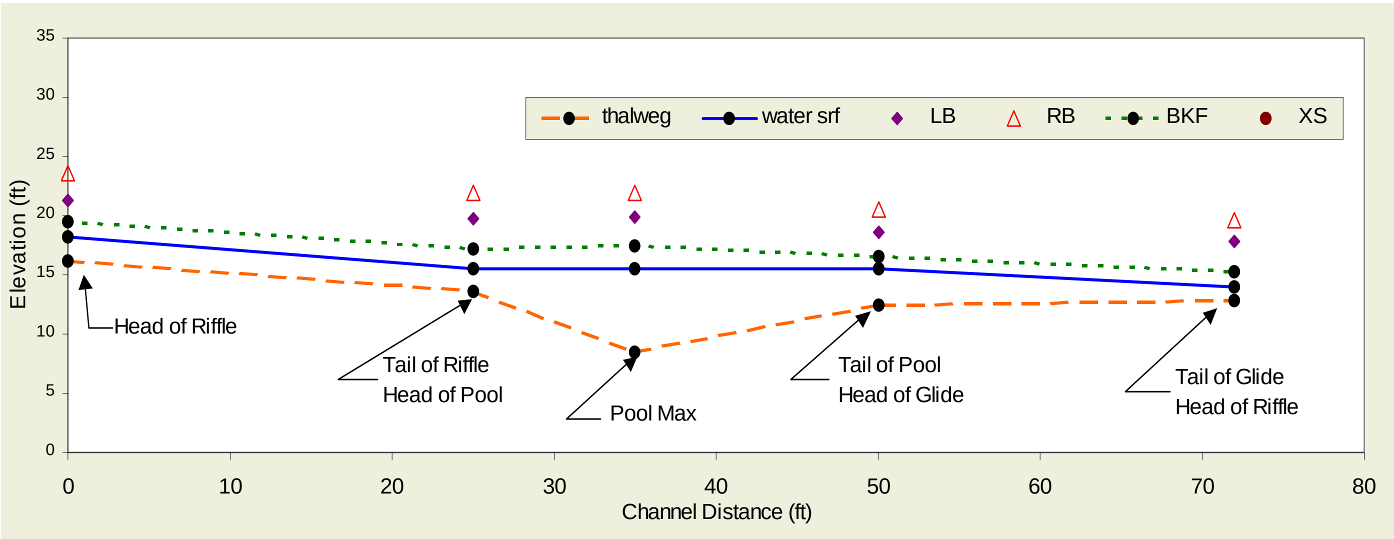


Figure 2.2 Longitudinal Profile Plot

At the bottom of the Longitudinal Profile Field Form is a box containing standard feature labeling codes (e.g., PH = Pool Head). It is important to carefully label each feature using these codes, especially when entering data into the spreadsheet for data analysis.

Slope is always a function of the vertical drop divided by the horizontal distance traveled. Therefore, to know the slope of a riffle, the elevation at the head and tail of the riffle must be known (to calculate the vertical drop) and distance between those points must be determined (to determine the horizontal distance). To simplify the data collection along the profile consider the head (upstream point) of each feature to be the tail (downstream point) of the preceding feature (see Figure 22.1). For instance the head of a run is often the tail of the preceding riffle.

Always try to collect data at the deepest part of the pools. This may not always be possible on larger rivers. Data at the mid-point of longer riffles, runs, and glides may also be collected. These data points are not used in slope calculations but may help to confirm the bed feature profiles at a later date.

At each station along the profile, the field crew will be collecting elevations on the bed at the thalweg, the water surface, the bankfull stage, and the right and left tops of the bank. The elevation of the thalweg is recorded at the deepest point along the cross-section of the channel. The elevation of the water surface is recorded at the current water stage along the left or right bank which ever is closest to the thalweg. At a meander crossover, the water surface elevation may be recorded on either the left or right side of the stream. The elevation of bankfull stage is recorded at good bankfull indicators, typically on the inside bank of the meanders. If there is uncertainty at bed features and a bankfull indicator is not observed, do not invent one, leave the space on the form blank. The elevation of the top of bank is recorded along the left and right banks.

FIELD FORM: CROSS-SECTION

The first task in selecting cross-sections is to address the specific goals of the survey. If the goals do not dictate the selection of cross-sections, use the following guidance. Ideally, one cross section for each bed feature type identified should be chosen. For example, if a riffle-pool stream contains riffles, runs, pools, and glides, locate at least one cross-section at each of these bed features. Beyond representation of each bed feature type, it is beneficial to select multiple riffle locations as many empirically derived relationships are based on riffle dimensions.

2.2 CROSS-SECTION

Cross-Section Number

The cross-sections located during the site walk should be numbered starting No.1.0 at the upstream-most cross-section. The numbering convention should include one decimal place (1.0, 2.0, 3.0, etc.) to allow additional cross-sections to be added in between. For instance, a later decision to complete a cross-section at a run might be placed between a riffle cross-section (1.0) and a pool cross-section (2.0) previously surveyed and be numbered 1.5. A field form should be filled out for each new cross-section.

Feature

Circle the bed feature where the cross-section is located. Also circle the approximate location of the cross-section within the feature: the **head** or upstream end of the feature; in the **mid-**portion of the feature; the place of **max**imum depth within the feature; or at the **tail** or downstream end of the feature.

Reference

Circle **yes** or **no** to indicate whether the cross-section should be considered a reference cross-section during analysis. A reference cross-section might be where the dimensions are very close to those predicted by the Vermont Hydraulic Geometry Curves (see Appendix J) for the stream type being worked on. Reference cross-sections characteristically have a low width-to-depth ratio (except D-type braided channels), little or no erosion, boundary conditions that are resistant to erosion (i.e., vegetated with woody plant species), and little or no sign of incision or mid-channel deposition.

L/R Monument Heading

Once the cross sections have been monumented, indicate whether the monument is on the left or right bank and the compass heading of the cross section (method further described below). When recording compass heading remember to adjust for west declination (subtract 15 degrees from the compass reading).

Cross-Section Survey

After selecting the location to conduct your cross-section measurements (Figure 2.3), place bank pins on either side of the stream so that the line between them will be perpendicular to the bankfull flow line. At each riffle cross section, the flood prone area should be surveyed, thereby making it important to place the bank pins above the flood prone elevation. To determine the flood prone elevation at riffles, survey the thalweg and bankfull elevations at the cross-section. Next, subtract the thalweg elevation from the bankfull elevation to determine the maximum bankfull depth. Multiply the maximum bankfull depth by two and add this value to the elevation of the thalweg. This new value is the flood prone elevation. Place the pins on the bank or valley floor just above this elevation. At all other cross sections, survey as much of the valley bottom as is reasonable keeping in mind the objective of depicting as complete a representation of the valley and channel morphology as possible given the time available.

Clamp the cam line or measuring tape between the bank pins. If using a measuring stick to record depth then make sure the line is level across the stream. This is most accurately done by clamping the line on both sides and moving one end up or down until both sides are at the same elevation as determined by the survey level. If you are using a survey level to measure elevations along the line you will only be using the cam line or tape for measuring horizontal distances and it will only need to be approximately level across the stream.

After setting up the cam line or measuring tape choose a location along the cross section to install a four foot length of rebar to serve as a monument. Select a location that is amenable to the landowner and is not susceptible to erosion or deposition or other processes that will result in a change in grade elevation at the base of the rebar. Once the appropriate site has been selected, drive the rebar 3 feet into the ground and mark with flagging ribbon. Standing at the rebar, site the compass heading of the cross section. Be sure to subtract 15 degrees from the compass reading in order to compensate for magnetic declination.

Starting at the left bank pin, record the depths or elevations at all significant breaks in slope across the stream until reaching the right bank pin. Also, record depths or elevations at the current left and right edge of water. By carefully measuring at all significant breaks in slope, important features such as top of bank, bankfull stage, bar formations, edge of water, and the maximum depth or thalweg will be surveyed. Remember to survey and record the base of the rebar monument. Figure 2.3 shows an example of a well conducted cross section profile.

Generally on larger streams, at least ten measurements within the active channel (below bankfull stage) would have been taken. If long distances are traversed with little or no change in slope, take one or more additional depth measurements in between obvious breaks in slope. At each location where a measurement is taken, record the distance along the tape and the depth or elevation, and note the channel, floodplain, or terrace feature. Record all elevation and horizontal distance data to the nearest 0.01 ft.

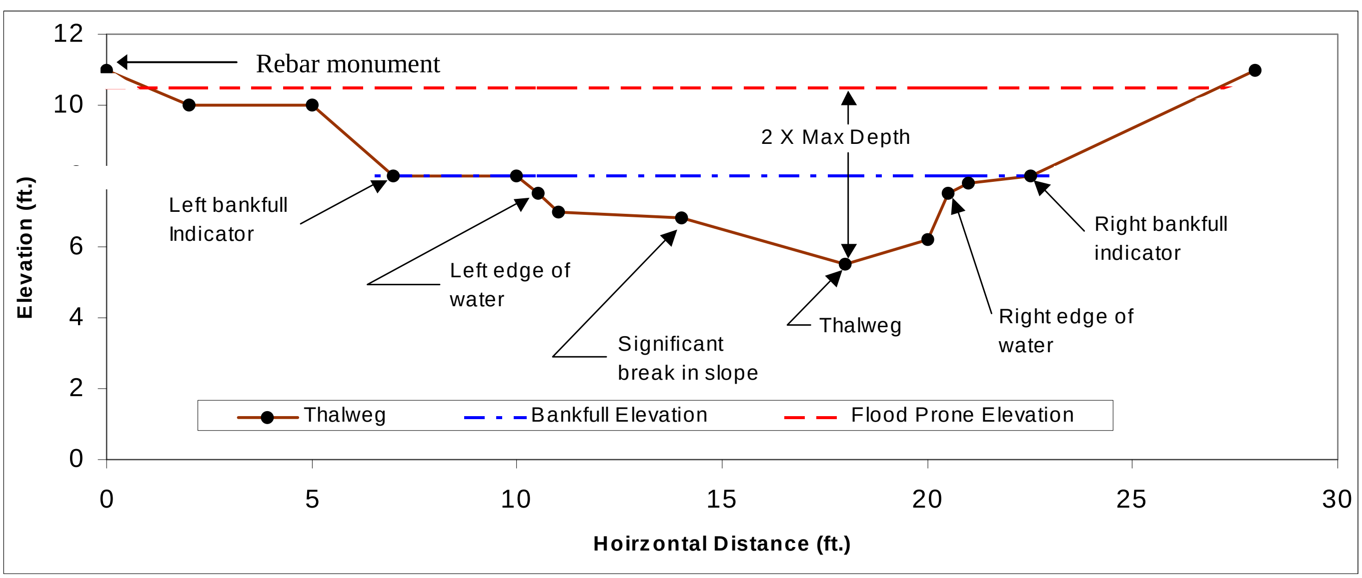


Figure 2.3 Example Cross Section Plot

2.3 WIDTH OF FLOOD PRONE AREA (Wfpa)

The distance across the channel (and floodplain, if present) at an elevation that is 2 times the maximum depth (dmbkf) as shown in Figure 2.3 above. Flood prone area is a measure of the ability of the channel to utilize the floodplain to dissipate energy during high flows. Measuring the flood prone area consists of determining the flood prone elevation as discussed in Step 2.2 (Cross Section Survey) above and measuring the width of the channel or floodplain at this elevation. Often times the width of the flood prone area is so great or vegetation in the floodplain is so dense that field measurement is not feasible. In these circumstances the extent of flood prone area should be estimated in the field and associated with physical landmarks or geographic coordinates. After returning to the office locate the landmarks on an orthophoto or topographic map and measure the distance between the two points.

2.4 BANK VEGETATION

With each cross section serving as the center of a length of stream corridor equal to 2 bankfull widths (see Figure 2.4), evaluate the composition and density of the riparian over-story, under-story, and ground cover vegetation and percentage of the bare soil near the left and right banks within 30 feet of the bankfull location. Over-story / under-story and ground cover vegetation types are provided on the field form.

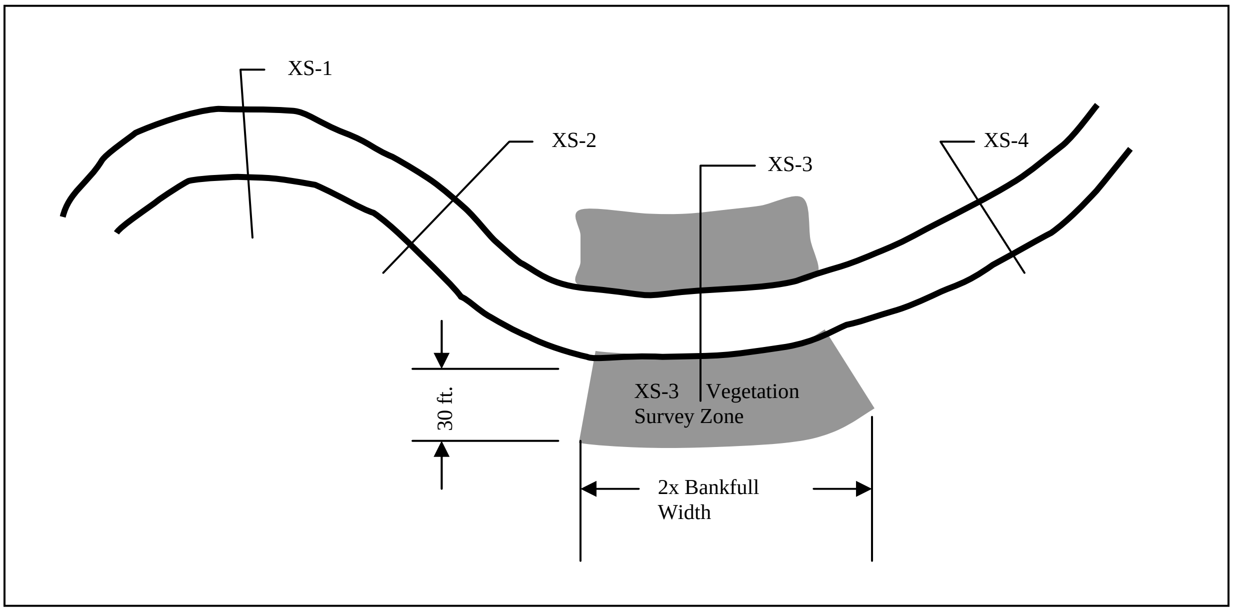


Figure 2.4 Plan View of Vegetation Survey Zone for XS-3

2.5 VALLEY CROSS-SECTION DRAWING

Complete a rough sketch of the entire valley floor. Indicate relative extent of the valley floor, terraces, floodplains, the active channel, woody vegetation, and land uses (Figure 2.5). Also indicate the floodprone area (Wfpa).

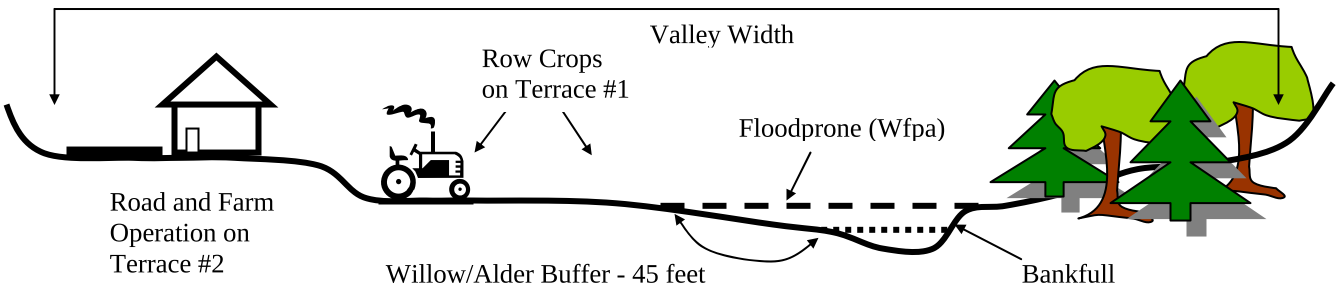


Figure 2.5 Example of valley cross-section drawing

FIELD FORM: PEBBLE COUNT

Pebble counts can supply critical data for determining the sediment regime (size and quantity of sediments) and the equilibrium conditions of a channel. A detailed discussion of sampling and analysis of pebble count data is given in Bunte and Abt (2001). Conduct a pebble count (modified from Wolman, 1954) throughout the study site to determine the sediment size distribution at cross-sections; for each bed feature type; and for the site as a whole. Collect a bulk bar sample to determine the sediment size distribution on the bars to determine the sediment size distribution of bed load at bankfull flow.

2.6 PEBBLE COUNT

Cross-section

For each cross section or bed feature, begin at the bankfull stage of either bank and measure the size of at least 80 equidistantly spaced particles across the stream. To reach the target of 80 particles more than one pass may be necessary. For example; if the bankfull width of the channel is 80 feet, a single traverse of the cross section measuring particle size at approximately every foot may be completed, or two traverses measuring particle size at approximately every two feet may be desirable. Once the observation interval has been determined, begin making measurements.

To keep the selection of particles objective, reach down to the channel bed with one finger extended and select the first particle touched off the tip of a boot without gazing at the channel bed. If the particle can be removed from the bed, measure the median axis of the particle (Figure 2.6). If the particle cannot be removed from the channel bed, try to determine and measure the median axis where it sits in the bed. Sand particles, too small to measure, are estimated by size class (i.e., fine, medium, coarse). Silt and clay particles are also noted. Those sediment particles collected from the bank (from bankfull elevation to the toe of the bank) should be distinguished from those collected from the bed of the channel.

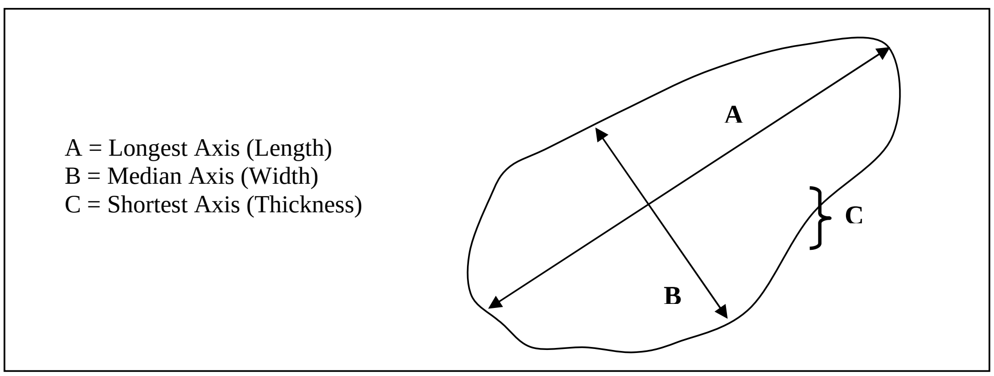
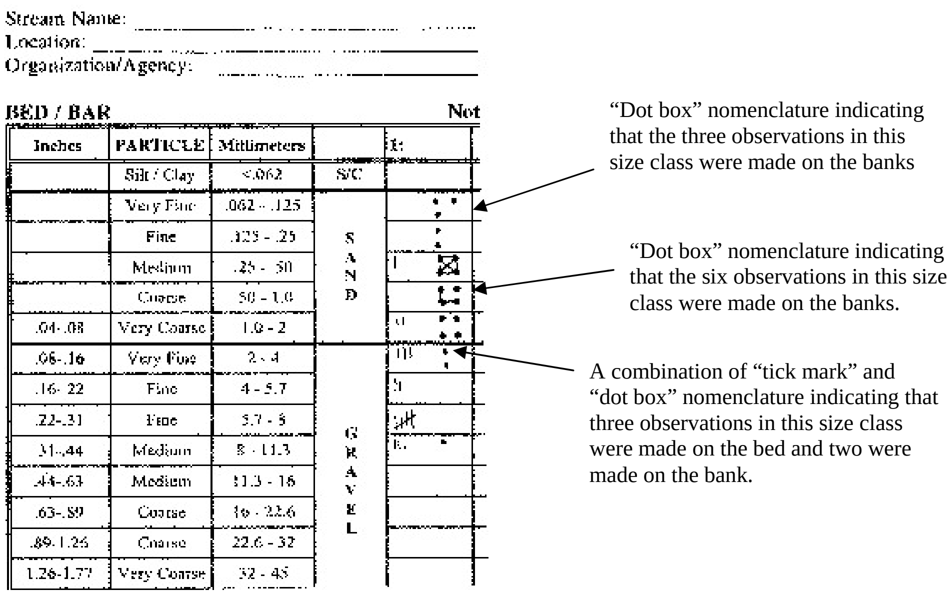


Figure 2.6 Median axis of sediment particle

Channel Bed

Determine the particle distribution of the bed at riffles adjacent to the point bars from which bulk bar samples are collected (Step 2.7). This can be done by conducting a Wolman pebble count as described above. In order to determine particle distributions for both the cross section as a whole and the bed as a unit, distinguish between particles collected on the bank from those collected on the bed. An easy method for doing this is to record those particles from the bank using the “dot box” nomenclature, and those collected from the bed using “tick mark” nomenclature (see Figure 2.7). Also be sure to make enough observations to assure that even after bank particles are removed from the data that there are still more than 80 observations of particles collected from the bed.



Stream Name:
Location:
Organization/Agency:

BED / BAR Not

Inches	PARTICLE	Millimeters		
	Silt / Clay	<.062	S/C	
	Very Fine	.062 - .125	SAND	
	Fine	.125 - .25	SAND	
	Medium	.25 - .50	SAND	
	Coarse	.50 - 1.0	SAND	
.04-.08	Very Coarse	1.0 - 2	SAND	
.08-.16	Very Fine	2 - 4	GRAVEL	
.16-.22	Fine	4 - 5.7	GRAVEL	
.22-.31	Fine	5.7 - 8	GRAVEL	
.31-.44	Medium	8 - 11.3	GRAVEL	
.44-.63	Medium	11.3 - 16	GRAVEL	
.63-.89	Coarse	16 - 22.6	GRAVEL	
.89-1.26	Coarse	22.6 - 32	GRAVEL	
1.26-1.77	Very Coarse	32 - 45	GRAVEL	

Figure 2.7 Sample pebble count form demonstrating the use of dot box and tick mark nomenclature to differentiate between particle collected from the bed and banks.

FIELD FORM: POINT/SIDE BAR – BULK MATERIALS SAMPLE

2.7 BAR PEBBLE COUNT

Particle samples taken from well-graded point bars of riffle-pool stream types have been found to display particle sizes similar to bed load samples collected at bankfull flow (Rosgen, 1996). These data can be used in calculation of the shear stress necessary to mobilize bed sediments. Further discussion of bed load transport, critical shear stress, and methodologies for its calculation can be found in Appendix O. When selecting sampling locations care should be taken to sample that portion of the site with stable cross-sections and bars that exhibit good sediment continuity and particle size distribution. If appropriate bars are not available for sampling, sub-surface bed sediments also display a gradation similar to the bed-load during bankfull flow. See Bunt and Abt (2001) for protocols on sampling the bed sub-surface.

The bar particle sample is collected using a bottomless five gallon bucket. The diameter of the bucket establishes the size of the sampling area. Divide any bendway having a point bar into three sections as illustrated in Figure 2.8. These sections represent the upper, middle and lower thirds. In the lower third measure the difference between the elevation of the bankfull stage on the inside of the bendway and the thalweg elevation (between points A and B in Figure 2.8). The sampling region is located between C and D on a radius concentric with the radius of the bendway half the vertical distance between A and B.

Place the bottomless bucket in the sampling region to define and enclose a bar sampling area. Remove the two largest particles on the surface of the bar sampling area, weigh them, and measure the median axis (if the surface area of the largest particle is greater than 15% of the of the size of the bucket opening, use a bucket or other template with a larger opening). Within the circle defined by the bucket, remove and place in the sample container all of the particles within a depth that is equal to twice the diameter of the largest particle. For fine material systems (largest particles average less than 10 mm) remove the two largest particles and set aside, then excavate materials from bucket to a depth of six inches.

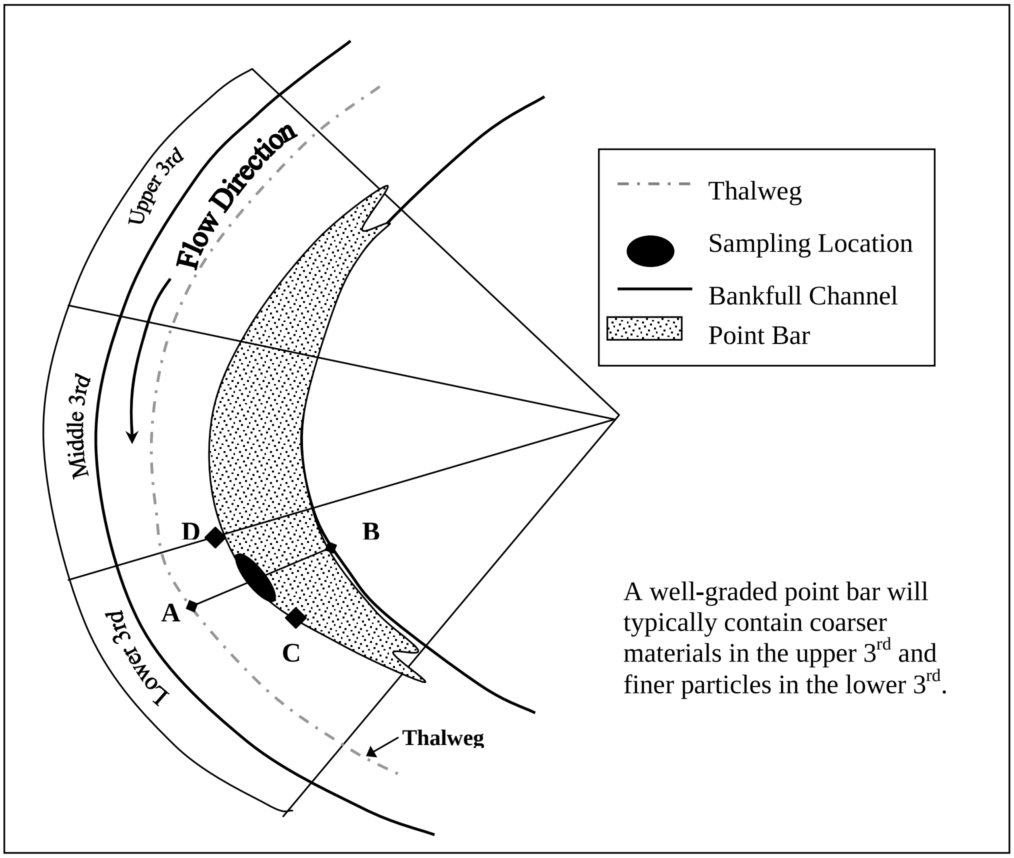


Figure 2.8 Location of Point Bar Sampling

Sieve and weigh samples by "wet sieving" the collected channel materials with water and a standard sieve set (2 1/2": 2 1/4": 5/8": 5/16": No. 5: No. 10: No. 16). Weigh sieved materials and record weights (less tare wt.) by size class. Include weights and mean diameters of the two largest particles collected. Determine a material size class distribution for all of the collected materials. These data represent the range of channel materials subject to movement or transport as "bedload" sediment materials (Rosgen 1996). Plot data; determine size-class indices, i.e. D16, D35, D50, D84, and D95.

FIELD FORM: PLANFORM GEOMETRY

Planform geometry refers to the curvilinear measurements of a stream or river channel: the wavelength, bend length, belt width, and radius of curvature (Figure 2.10). Planform geometry values may be measured from aerial or ortho photographs or field generated maps. Planform parameters may be accurately measured in the field; however, vegetation and other obstacles can make direct measurement difficult. Measurement from aerial or ortho photos can be an easier exercise; however, the large scale at which the photos are taken can make it difficult to accurately measure features. Another problem with the use of aerial photography is that it is not possible to accurately measure present planform geometry of a river that migrated since the date of the photo.

Field generated maps are good sources of planform information in that they are current and generated at a small scale. Field generated maps developed with total station survey equipment (horizontal as well as vertical surveying) are the most preferred source of meander geometry information. Compass and tape generated maps are less accurate than total station maps, but the error may be less than that incurred when using aerial photography. It is recommended that when using compass and tape maps as your basis for measurement that you verify the results with measurements taken from aerial or ortho photographs where possible. Indicate which method(s) were used to generate the meander geometry values recorded.

2.8 PLANFORM GEOMETRY

Planform Plot

A planform plot is generated from the longitudinal profile and planform data (Figure 2.9) and is used to measure planform. If each meander apex has been identified and properly labeled in your data, the spreadsheet will automatically calculate both bend lengths and wavelengths. Belt width and radius of curvature may be measured using a scaled ruler and protractor from a printed version of the planform plot. Belt width and meander wavelength may also be accurately measured from recent ortho photos using the methods described in Steps 6.5 and 6.6 of the Phase 1 Handbook. Regardless of the type of map used, the methods for measuring meander geometry generated by DMS Spreadsheets are identical (Figures 2.9 and 2.10). See Appendix B for instructions on using the Vermont Phase 3 Stream Geomorphic Assessment Spreadsheets to measure meander geometry.

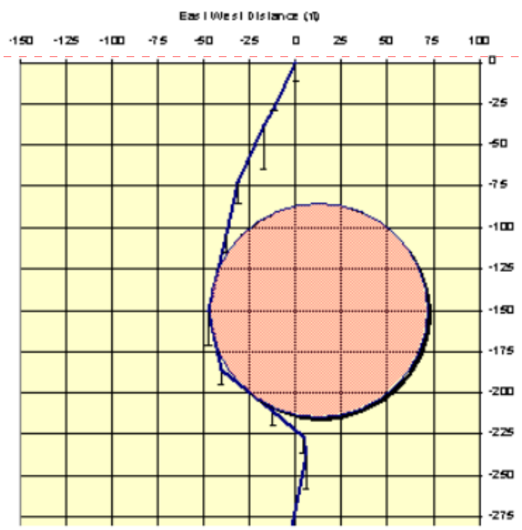


Figure 2.9 Planform Plot Created by DMS Spreadsheets (plots show bankfull depths as vertical bars at each survey point along the longitudinal profile).

Comment [SJ1]: Using compass and tape measure we now have a plot of planform, this will be more accurate than a hand drawn sketch. Agreed, but I think a hand scketch is a good QAQC measure to make sure large errors were not made using the compass. This should be explained in the text.

Meander Wavelength (L_m)

Meander wavelength is measured as the distance in feet between two lines typically drawn perpendicular with the fall line of the valley, one drawn at the beginning and one at the end of the meander wavelength. The end points of the meander wavelength are located at thalweg inflection or cross-over points. Alternatively, the beginning and end points may (Figure 2.10) be set at the apex of bendway curves. A meander wavelength consists of two bendways and is typically 10-14 bankfull widths in unconfined, alluvial channels.

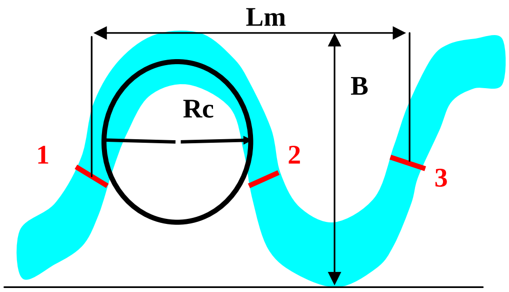


Figure 2.10 Planform geometry parameters

Variable		Definition
Lb1	Bend length 1	Centerline channel distance 1 to 2
Lb2	Bend length 2	Centerline channel distance 2 to 3
Lb	Average Bend length	(Lb1+Lb2)/2
Lm	Meander Wavelength	Down valley straight-line distance 1 to 3
B	Belt Width	Straight-line distance (measured from parallel down-valley lines drawn at the outside lateral extent of the channel bendways)
Rc	Radius of Curvature	Radius of the circle (measured to centerline of channel)

Belt Width (B)

Belt width is measured as the distance in feet between two lines drawn at the lateral outside extent of the stream's meander bends, drawn parallel with the down valley direction of the stream (Figure 2.10). The belt width may be defined by the lateral confinement of the channel and is measured from outside bend to outside bend. The belt width is typically 6 times the bankfull width in unconfined channels (Williams, 1986) and represents that portion of the valley in which alluvial streams have adjusted their slope in a manner consistent with the size and quantity of sediment being transported by the stream.

Channel Bend Length (L_b)

Channel bend length is measured as the average length in feet of the two channel bend lengths within one meander wavelength (Figure 2.10). If inflection points are chosen to delineate the wavelength, then each channel bend length runs from inflection point to inflection point . If apexes are chosen to delineate the wavelength, then each sub-length is measured from apex to apex .

Radius of Curvature (R_c)

Radius of curvature is measured from a circle that is fitted into the meander bend. Fit the circle to the centerline of the meander for the length of channel for which the radius is constant (see Figure 2.10). If the meander being measured is tangential to the adjacent meander bend, then the circle may extend to or just include the inflection point (cross over). If the meander being measured is connected to the adjacent meander bend by a straight section of channel, then the circle may not include the inflection point (cross over).

Step 3: Boundary and Reach Conditions

This section describes how to characterize the materials making up a streambank and to analyze signs of slope instability. The stream banks also serve as a major source of the sediment carried by a stream. One of the primary factors affecting channel equilibrium and adjustment is the differential resistance of the stream bed and banks to the erosive power of the stream. For instance, if the bed materials of a stream are more resistant to erosion than the bank materials, the stream may widen rather than degrade its bed. The relative erodibility of these materials is largely a function of their geologic make-up.

A wide variety of surficial deposits are encountered in Vermont streambanks. Some are the result of glacial processes that operated during the Pleistocene Epoch more than 10,000 years ago while others may be stream deposits formed less than a decade ago. A careful description of these materials is critical to understanding the history of how the stream has behaved in the past, how the system is operating today, and how it can be expected to operate in the future.

FIELD FORM: STREAM BANK AND BOUNDARY CONDITIONS

The assessment of stream bank materials requires a certain amount of geologic expertise. If you have not done stratigraphic or soil profile descriptions before, you may want to have an experienced person come along to assist with your initial efforts. For a general overview of geologic mapping techniques see Compton (1985).

As you conduct the site walk as described in Step 1, identify units of bank that are characterized by similarity of the bank erodibility parameters listed below. For each bank section identified there should be a corresponding cross-section. When surveying meandering riffle-pool systems you need to select the high banks on the outside of the bendway (typically subject to the highest erosion rates) and not the inside of the bendway or point bars. When assessing banks at riffle cross-sections, choose a section of bank from either side that is representative of the bank erosion conditions.

After completing your site walk, return to the bank section and use a shovel or sharp trowel to cut away the bank surface exposing fresh material that is representative of the section. Ideally the cut will be 2 to 6 feet wide, although this will vary a lot from site to site. Sometimes several short cuts will need to be staggered across the bank to expose all of the stratigraphic units. At each bank assessment site draw a sketch showing a schematic geologic cross section (use the space provided on the Stream Bank and Boundary Conditions Field Form).

Several different tools can be used for digging out and scraping the bank. A long-handled, round-pointed shovel is good for moving lots of earth and digging pits in areas without stream cuts. An entrenching tool can be very handy if the handle is longer than 16 inches or so. With the blade set at right angles to the handle it can be used as a hoe and a scraper. A wide-bladed, heavy duty hoe also works well, especially if the handle is cut off to about 3 feet (the shortened handle allows it to be used for sideways scraping without running into the sides of the excavation). A small mason’s trowel is good for fine work.

3.1 BANK AND BOUNDARY CONDITIONS

In the first section of the Stream Bank Field Form, you will take some basic measurements and describe several parameters of the bank as a whole. The presence of bedrock, revetments, and the type of bank vegetation may play a critical role in bank stability and should be carefully noted. Characterize the following parameters.

Length of Bank: Total length in feet of bank being examined.

Bankfull height: The height measured from the toe of the bank to the bankfull elevation. See Appendix K for identification of the bankfull stage or elevation.

Bedrock present at site: Describe any bedrock outcrops in the vicinity as they can be critical to evaluating the condition of the stream and the bank in question.

Bank revetments: Describe any bank revetments at the site, including graded rip-rap, rock walls, or other materials placed on the bank with the intention to stop erosion.

Surface protection: Estimate percentage of bank surface that is protected by collapsed sod, intact vegetated slump blocks, large woody debris, masses of roots, etc.

Bank vegetation: Use the over-story, under-story, and ground cover characterizations described in Phase 3, Section 2.4 and on the Phase 3 cross-section field form.

Land use above bank: Refer to the corridor land use menu provided in Phase 2, Section 3.3 to characterize the land use above the bank.

Concentration of stormwater onto the bank: Fully describe any stormwater discharges in the vicinity of the bank.

3.2 BANK FAILURE

For those stream banks that are not eroding and appear intact, you should choose “none” under the type of failure and proceed to Step 3.3. Where banks are failing or in situations where the stream is adjacent to or causing a landslide, characterize the following:

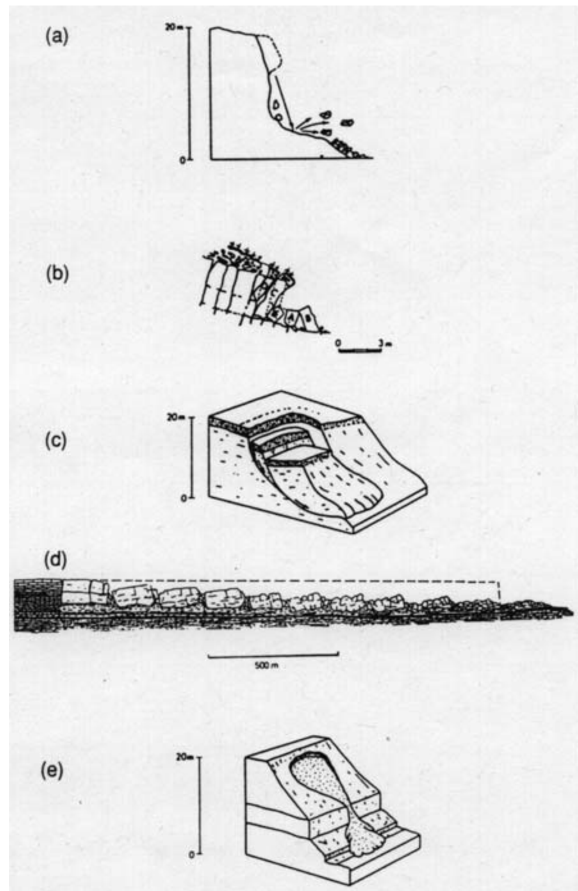
Type of Failure: If there is little or no exposed soil but there are signs of slow soil creep (such as those convexly curved down-slope), choose soil creep. If there are signs of old, healed landslide scars, choose “landslide/inactive”. If there are large areas of bare soil on the bank or other signs of fresh landslide activity, choose “landslide/active”.

Landslide Type

Menu:

a	**Fall**
b	**Topple**
c	**Slide**
d	**Spread**
e	**Flow**
f	**Slide-Flow**

The classification is modified from Cruden and Varnes (1996) (Figure 3.1). Following Cruden (1991) the



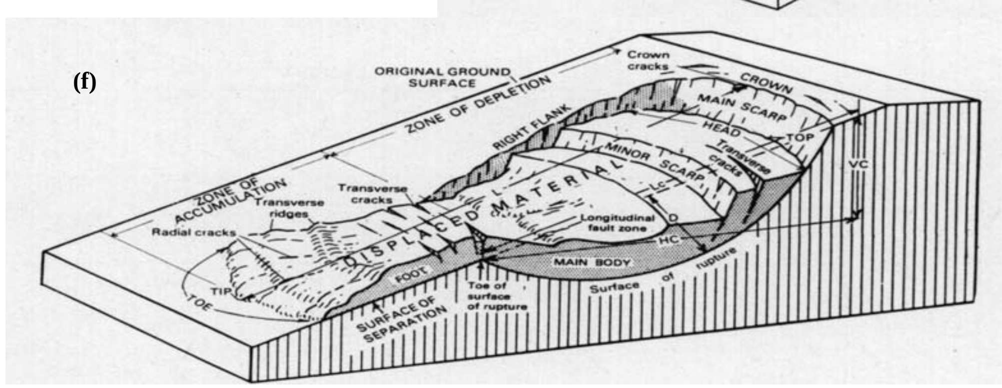


Figure 3.1 Landslide Classification modified from Cruden and Varnes, 1996

term landslide is used in the broad sense to include "the movement of a mass of rock, debris, or earth down a slope." As the landslides encountered near streams in Vermont occur mostly in fine grained materials, rock falls and debris falls are not discussed further.

Length of bank failure: Length of the failure as measured along the streambank. This may be equal to or less than the total length of the bank being evaluated.

Height of bank failure: Greatest height of the failure. Rarely this may be less than the total bank height determined in 3.1.

Condition of landslide toe: If a landslide is present, is the material that has moved still present as an intact mass or block or has it been partly or entirely eroded away.

Damage resulting from the slide: Is there known impact to human structures or facilities? If so, describe in comment section on reverse side of field form.

3.3. SKETCH

The sketch can either show the face-on view of the section or a cross-section. In any case, it should be roughly to scale and should include indicators of scale and orientation. Show units, the nature of boundaries between units, internal structures, rooting, zones of seepage, zones of piping, sample locations, etc. If new fractures are developing on or in back of the bank, indicate them.

3.4 STRATIGRAPHIC DESCRIPTION

Stratification, or the layering sequence of the surficial materials, is another factor that will affect the erodibility of the bank. Two banks containing the same materials may have different erodibility characteristics depending on how erodible materials are stratified within the profile of the bank. Points of contact between different material layers are weak features.

This may be the most important part of the worksheet. Make thickness measurements in feet and determine the elevation of the top of the section through use of a topographic map or other source. If you are not sure of the datum used for the elevations, say so in the comments section. For each stratigraphic unit describe the following:

Depth: Measure the depth from the top of the bank down to the top of each unit or horizon.

Thickness: Measure the thickness of each unit using the survey rod, a tape, or a folding ruler. For the purposes of this publication we'll assume that the layers are approximately horizontal. If they are not, see Compton (1985) for instructions on measuring the thickness of dipping layers. If possible, measure the thickness on a vertical face. On a low, eroding streambank this may be easy to produce using the shovel or trowel. However, on a bank that is more than a few feet high you will need to measure the thicknesses on an inclined slope. The simplest way is to walk your way up the slope with a survey rod or folding ruler and a hand level or clinometer. Stand at the base of the slope (this will usually be the edge of water in a stream survey) with the rod held vertically in front of you with its base at your feet. Sight across with the hand level and move it up or down the rod until it matches with the top of the lowest layer. If the top of the lowest unit is higher than your eye height, use the level to sight across to the slope to find a point that corresponds to your eye height. Record the rod value and walk up slope to the point you sighted to. Repeat the procedure to determine each of the successive thicknesses until you reach the top of the exposure. Measure the thickness of each unit.

USCS Classification: The Unified Soil Classification System is a standard method used by soils engineers to describe unconsolidated deposits. A field version of this is given in Appendix N from Koler (1994). See U.S. Army Corps of Engineers (2001) for a description of the procedure for examining samples. A chart to estimate percentages developed by NRCS (1998) has also been provided in Appendix N. The No. 4 U.S. Standard sieve has openings of 4.76 mm, No. 40 has 0.42mm openings, and No.200 has 0.074mm openings.

Soil Horizons: Soil horizons form through the interaction of several factors, typically characterized as climate , relief, parent material, organisms, and time (Birkeland, 1984). Crudely speaking, the horizons can be described as forming in one of two ways: horizons that form in an existing body due to alteration (in Vermont this is often due to downward movement of water and materials from overlying layers) or horizons formed through accumulation of material as it builds up (as in the accumulation of peat). Note that the soil profile development seen in Vermont does not usually extend deeper than 40 to 60 inches and thus high stream banks would often be made up of mostly what a soil scientist would characterize as one or more C horizons, despite the fact that this may be composed of several distinct geologic materials.

Describe soil horizons in the upper 40 inches using standard NRCS nomenclature. For the purposes of this manual it is not necessary to use NRCS nomenclature for the horizons below the start of the highest C horizon. Lists of abbreviations as provided by Schoeneberger et.al. (1998) are included in Appendix N. For details on field description of soils see Birkeland (1984), Schoeneberger et.al. (1998), and Waters (1992).

Root Quantity and Size: Describe both quantity and size of live roots following a modification of the system of Schoeneberger et al., 1998. Unit area to be assessed varies with root size as described in Appendix N.

Quantity of live roots, menu:

1	**Few**	less than one per unit area
2	**Common**	≥ 1 to < 5 per unit area
3	**Many**	≥ 5 per unit area

Root size, menu:

F	**Fine**	< 2mm (1 square cm unit area)
M	**Medium**	≥ 2mm to <5 mm (100 square cm unit area)
C	**Coarse**	≥ 5mm to <10mm (100 square cm unit area)
VC	**Very Coarse**	≥ 10mm (1 square meter unit area)

Color: The color of a soil or surficial material is helpful in interpreting the environment of deposition and drainage of a material. The standard technique is to use a Munsell color chart (Schoeneberger et.al., 1998) . Soils are compared to this standard chart while in a moist state and in direct sunlight and the hue, value, and chroma of the sample are recorded.

Moisture: Wet or moist horizons in a bank may be less cohesive than surrounding layers due to such causes as coarser overall grain size and/or lower clay content and they may sometimes serve as failure surfaces for landslides. Be careful to determine that water is saturating the layer as a whole rather than just wetting the outer surface as it runs down from higher up on the bank.

Menu:

Dry	moisture absent
Moist	damp, no visible water
Wet	visible water

Plasticity: Modified from Schoeneberger and others (1998).

Menu:

N	**Non-plastic**	will not support a 6mm diameter roll if held by one end
L	**Low plasticity**	6mm diameter roll can be repeatedly rolled and supports itself, 4mm diameter roll does not
M	**Medium plasticity**	4mm diameter roll can be repeatedly rolled and supports itself, 2mm dia. roll does not
H	**High plasticity**	2mm diameter roll can be repeatedly rolled and supports itself

Cohesiveness: Characterize the cohesiveness.

Menu:

Non	**Noncohesive**	6mm diameter roll cannot be formed
Coh	**Cohesive**	6mm diameter roll can be formed

Clasts: Clasts are large fragments of rock set in a finer matrix. If present, these probably serve as one of the sources for the coarse particles transported by the stream. Describe large clast percentages, sizes, and lithologies. **Menu:**

Trace	< 5%
Little	5-15%
Few	16-30%
Some	31-45%

Structure and Bedding: Describe the sedimentary bedding and structure.

Bedding menu:

Massive	Uniform unit without internal layering
Thickly bedded	beds > 30 cm
Bedded	beds > 3 cm to 30 cm
Thinly bedded	beds 0.5 cm to 3 cm
Laminated	beds < 0.5 cm

Soil structure involves the extent to which individual particles bond together to form aggregates known as peds (Birkeland, 1984).

Structure menu (modified from Waters, 1992):

M	**Massive**	individual soil particles entirely bound together into one aggregate
SG	**Single-grain**	individual soil particles not bound to one another at all
GR	**Granular**	spheroidal peds or granules usually packed loosely
BK	**Blocky**	irregular, roughly cubelike peds with planar faces (angular or subangular)
PL	**Platy**	flat peds, usually roughly horizontal
PR	**Prismatic**	vertical, pillarlike peds with flat tops

Lower Contact: Describe the contact of this unit with the one that underlays it.

Menu:

Not exposed	not visible in this section
Sharp	≤ 2cm thick
Gradational	> 2cm (note thickness of transition interval)

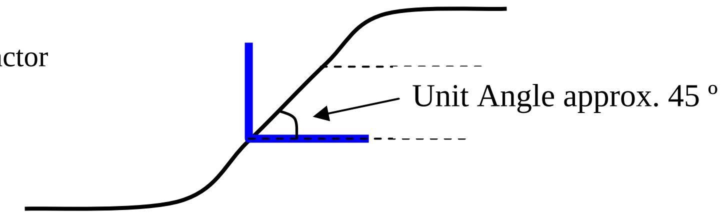
Interpretation: The various types of surficial material found in Vermont and their relative erodibility are described in Appendix F – Geologic Material. First determine the general depositional setting for the unit in question and then describe the type of facies present. Overall landform interpretations will be made in Section 3.7. Keep in mind that some deposits are of composite origin.

General depositional environment of the sedimentary unit in question: glacial (includes ice-contact), lacustrine, marine, mass-wasting, eolian, or fluvial. Interpretation:

> Several varieties of **glacial deposits** are encountered. All of these are generally unsorted and unstratified. Lodgement till was deposited in the lower parts of an ice sheet and . Ablation till forms as the upper, more debris-poor portions of an ice-sheet melt and collapse. This type of till often contains lenses of crudely sorted sands and gravels. Flowtill is a term for debris flow deposits that formed from glacial till.
>
> **Ice-contact deposits** are materials that have been sorted to some extent by the action of flowing waters. They are characterized by having evidence of post-depositional collapse due to the melting of ice below, or beside them. Esker deposits formed as stream-channel deposits on, under, or within the ice sheet during it's waning phases. Today they are winding ridges. Kame terraces are deposits of stratified sand and gravel formed on the margin between an ice sheet and a valley wall. It is important to recognize that ice-contact deposits can grade into lacustrine deposits.
>
> In the **lacustrine** setting, material may range from coarse-grained shoreline beach deposits and deltas at stream inlets to fine-grained deposits laid down far from the inlet streams. The material may have come into the lake directly off of a melting ice sheet or be due to streams flowing off of the land. Delta deposits can be divided into topset, foreset, and bottomset deposits. Lake-bottom deposits can, in places, contain extensive amounts of ice-rafted sediment, forming what is called waterlain till.
>
> **Marine** deposits formed in the Champlain Sea include beach gravels and sands, deltas, and both coarse and fine lake-bottom deposits.
>
> **Landslide or mass-wasting deposits** are sometimes encountered in stratigraphic sections. These can include deposits resulting from block falls, planar slides, rotational slumps (all moving as units) or from grain-by-grain flow, spread, or soil creep.
>
> **Eolian deposits** are relatively uncommon in most of Vermont but can range from thin sheets of wind-blown sand to small dunes. Most formed in the distant past when post-glacial lakes drained, leaving, at least for brief intervals, large unvegetated lake plains. Some, however, formed due to poor soil erosion control practices in the 19th and early 20th centuries.
>
> In the **fluvial** setting, material may be range from alluvial fan deposits to channel, bar, and overbank deposits. Their age may range for Late Pleistocene to modern.

Often, the materials we see in a stream bank are a composite of many processes, some of which may be operating today but many of which took place during the Pleistocene Epoch or the early part of the Holocene Epoch. A common scenario in many of Vermont's valleys at the end of the last glaciation was for a subglacial stream to flow out into an ice-proximal lake, discharging sediment laden water at high velocities into the lake. As the stream waters slowed, gravels dropped out, then further out an extensive blanket of sands was deposited. At still greater distances from the inlet (a few miles perhaps), fine silts and clays settled out. As the glacier retreated, the earlier ice-proximal gravels were buried by sands that were in turn buried by fine lacustrine silts and clays. After the lake drained, fluvial deposits may have washed out over the lake plain. Subsequent post-glacial stream erosion may expose all of these materials in a single streambank.

Angle: Use a clinometer to measure or a protractor to estimate the angle of the unit, for example:



Consistency: Classify consistency using the consistency ratings shown in the menu below. This is a semi-quantitative rating based on the Standard Penetration Test used by engineers. The ranges of numbers are the results of Standard Penetration Tests involving measuring how many blows it takes to drive a 2 3/8 inch outside diameter sampling tube one foot by means of a 140 lb weight dropping 30 inches. This is a standard test done during hollow-stem auger boring for engineering projects. Approximate midpoint N values have been chosen to use in this rating scheme.

Coarse-grained deposits, N value menu:

2	0-4 very loose
7	5-10 loose
20	11-29 medium dense
35	30-49 dense
50	> 50 very dense

Fine-grained deposits, N value menu:

1	0-2 very soft
3	3-4 soft
6	5-8 medium
12	9-15 stiff
23	16-30 very stiff
30	> 30 hard

3.5 BANK EROSION FACTORS

The contribution of sediment to streams through the process of streambank erosion has been largely underestimated (Rosgen, 1996). While bank erosion is a natural river process, lateral migration rates can be accelerated when variables controlling bank stability are altered. By assessing variables that affect detachment of bank material and flow stresses along the bank it is possible to develop an index of erodibility. The following factors are used in the Vermont DMS spreadsheet to calculate a Bank Erosion Hazard Index (see Appendix N for BEHI calculation methodology).

Total bank height / Bankfull Height (ΣT / Bkf Ht): Ratio of the total bank height (measured from the toe of bank) to the bankfull height.

Overall thickness of exposure above bankfull: The height of that portion of the bank from the bankfull elevation to the top of the bank.

Root Depth / Total Bank Height: Ratio of the depth of root zone (measured from the top of bank) to the total bank height. Measure the depth of the root network that is affectively contributing structural integrity to the bank and divide by the total height of the bank.

Weighted Root Quantity (ΣR / ΣT): If the bank can be broken into sections of varying root quantities, evaluate the root quantity and vertical distance of each section. Calculate weighted root quantity, weighting the root quantity values for each section based upon the vertical distance of the section. Use Appendix N for guidance in making this estimation.

Overall weighted bank angle ($\Sigma A / \Sigma T$): Use a clinometer to measure or a protractor to estimate the angle of the bank. If the bank can be broken into sections of varying angles measure the angle and vertical distance of each section. Calculate weighted bank angle weighting the angle values for each section based upon the vertical distance of the section.

Bank angle up to bankfull height: Use the same procedure for calculating a weighted bank angle from the toe of the bank up the bankfull elevation

Weighted Consistency Rating (WCR) = Σ(Cu x Tu)/ΣT: Multiply the thickness of each unit by its consistency rating in Step 3.4 (Cu x Tu) and record the product for each unit. Sum up the weighted values for each of the units and divide by the total thickness (ΣT). Record this value as the weighted consistency rating (WCR) for the bank.

Modified Weighted Consistency Rating (MCR): Evaluate the position of units with values lower than 10. If there is any material with a Cu rating less than 10, below bankfull height, divide the sum for the entire bank by 2 and record as the modified weighted consistency rating (MCR) for the bank. The higher the sum, the greater the overall compressive strength of the bank.

3.6 DOCUMENTATION

Samples of Bank Materials: Samples need not be taken at all sites, but they can be of great help in determining environments of deposition and understanding the history of a stream and its surroundings. If samples are taken, it is important for them to be properly documented, labeled, and stored. The date, site number, and depth below the top of the section should be recorded on the container. Sample locations should be recorded on the sketch. Be very careful that you understand where your sample came from. Most stream banks (even the steep, eroding ones) have slumped material covering much if not all of the outer surface. Samples should usually be from the undisturbed material that lies behind the slump. If you do sample slumped material, note this on the sample and realize that such samples are usually of little value for interpreting the environment of deposition or geol

In order to characterize the grain size of a fine-grained deposit such as lacustrine silty clay, one quart plastic freezer bags will be adequate. For sands, gallon size plastic freezer bags are better. When sampling glacial till, sample size is very important. A gallon plastic bag is probably only at best adequate for sampling the till matrix and is not large enough to sample the large clasts. Bunte and Abt (2001) is focused on bar and channel sampling but provides useful guidance for coarse bank materials as well. Section 2.7 of this handbook provides bar sampling procedures.

Photographs: Always include a scale and, if possible, a chalkboard or wipe-board with the site number, date, etc. A sketch showing the key features of the area photographed is very helpful. Carefully specify the location and orientation of the photo.

3.7 GEOLOGIC ORIGIN AND PROCESS

The Discussion Section can include additional information on penetration measurements, paleocurrents, pH measurements, as well as interpretations.

Interpretation and Age of Adjacent Landforms: This section on interpretation is listed near the end of the form because it is more important to objectively describe the characteristics of the layers than it is to make an interpretation of geologic origin. If the documentation of the exposure is adequate, other investigators can make their own evaluations of the origin of the deposit at a later date. Although not the primary focus of this data form, an accurate understanding of the origin of the layer can help one to make extremely useful inferences about its lateral extent and to infer the ages of terraces, etc. If you don't feel confident that you understand the origin of a particular unit or landform, refrain from speculating and just describe it carefully. The following are common landforms that may be on or near stream exposures in Vermont: ground moraine, moraine, kame, kame terrace, esker, subaqueous fan, lake bottom, beach, delta, stream terrace, abandoned channel or flood chute, bar, levee, overbank or floodplain deposit, alluvial fan, landslide, talus pile, artificial cut, artificial fill, artificial berm, other.

Although it is often impossible to determine the age of a landform or the deposits that make it up, it is worth attempting. If a stream terrace can be determined to have been formed out of 19th century alluvium, then inferences can be made about rates of change.

Erosion mechanism and cause of slope failure: It is important to realize that a slope failure may be due to a combination of causes. Stream adjustment will commonly serve as a trigger but the other factors will need to be considered as well. The following list is modified from one in Cruden and Varnes (1996, p. 70). Note that the list contains both internal and external factors.

Internal factors:

Weak or sensitive materials
Weathered materials
Surfaces of weakness such as sedimentary bedding planes and joints or faults
Material properties such as unconfined compressive strength, bulk density, angle of internal friction, consistency, permeability, soil moisture
Contrasts in material properties
Height of bank and surface slope

External factors:

Intense rainfall or rapid snowmelt
Rapidly falling stream stage after a flood
Removal of material due to high bank shear stress or bed shear stress during floods
Earthquakes
Excavation of slope or toe
Loading of slope or crest by buildings, roads, earth fill, etc.
Stream adjustment from human causes: downcutting, widening, or planform adjustment
Water from irrigation, leaking pipes or ditches, etc.
Removal of vegetation
Mining
Artificial vibrations
Drawdown of reservoirs

Confining layer present: Answer yes or no. This is a layer that strongly impedes the flow of water. This is typically a fine-grained unit, but a coarse unit with fines mixed in or a coarse unit which has cements filling its pores may also serve as a confining layer. If free soil water is present above the confining layer it will often concentrate at the top of the confining layer and be seen in a bank face as a line of seepage or springs.

Comments: Include any general observations.

Step 4: Spreadsheet Plotting and Geomorphic Data

Overview

Management and analysis of the Phase 3 data is facilitated by the Stream Geomorphic Assessment Data Management System (DMS). The components of the DMS that are applicable to Phase 3 data include a spreadsheet and database. Field data from each site is entered into an individual spreadsheet. The spreadsheet will reduce the data and format it for export to the database. In summary, the Phase 3 spreadsheet will conduct an analysis of an individual site and the database will allow for comparison of the spreadsheet results between sites.

The Phase 3 spreadsheet is a Microsoft Excel workbook designed to:

1. accept field data collected using the Phase 3 field protocols,
2. reduce the data to meaningful measures of channel geometry and hydraulics; and
3. format the reduced data for export to a database for permanent storage and further analysis.

The Phase 3 database is a Microsoft Access database that is designed to:

1. accept and store data from phase 3 spreadsheets,
2. facilitate inter-reach analyses; and
3. print reports on the results of various analyses.

Geomorphic Data

The Vermont DMS spreadsheet is set up to receive data directly from the Phase 3 field forms. Tutorials on data entry can be accessed in the comment fields established for many of the data fields in the spreadsheet. Detailed instructions for use of the Phase 3 spreadsheet can be found in Appendix B. Inquire about opportunities for DMS training sessions through the DEC River Management Program.

The Phase 3 spreadsheet contains five worksheets that correspond to the various Phase 3 field forms. The seven worksheets include:

1. Reach Location and Description,
2. Longitudinal Profile and Pattern,
3. Pebble Count,
4. Cross Section,
5. Meander Geometry,
6. Boundary Conditions, and
7. Data Quality Assurance.

Other worksheets contain tables where data is stored to facilitate database entry. Completed spreadsheets can be mailed on disk or e-mailed to the River Management Program. Submitted data will be entered into the State stream geomorphic database. Contact the RMP about using the State database to enhance the power of current stream geomorphic assessments (see Appendix P).

After returning from the field, enter data into the Phase 3 spreadsheet. By following the steps below, the spreadsheet will provide information necessary for subsequent calculations. For instance by entering pebble count information in Step 4.3, the spreadsheet will insert the D84 sediment size for your river into the cross-section worksheet needed to calculate a roughness coefficient and conduct hydraulic calculations described in Step 4.4.

4.1 SITE LOCATION AND DESCRIPTION

This worksheet does not perform any data plotting and analysis. It merely stores the site location and description data from the field forms and the geomorphic assessment evaluations (condition, adjustment, and sensitivity) derived at the end of Step 6 for later entry into the database with the rest of the data entered and/or generated. The following sections show examples of these plots and explain some of the derived data that will be used later in the geomorphic and habitat assessments (Step 5).

4.2 LONGITUDINAL PROFILE AND PATTERN

Longitudinal profile data entered into the spreadsheet will be plotted as shown in Figure 4.1. This plot shows the bed features (i.e., riffles, runs, pools, and glides) surveyed in the field. Remember that the vertical scale on the plot is exaggerated.

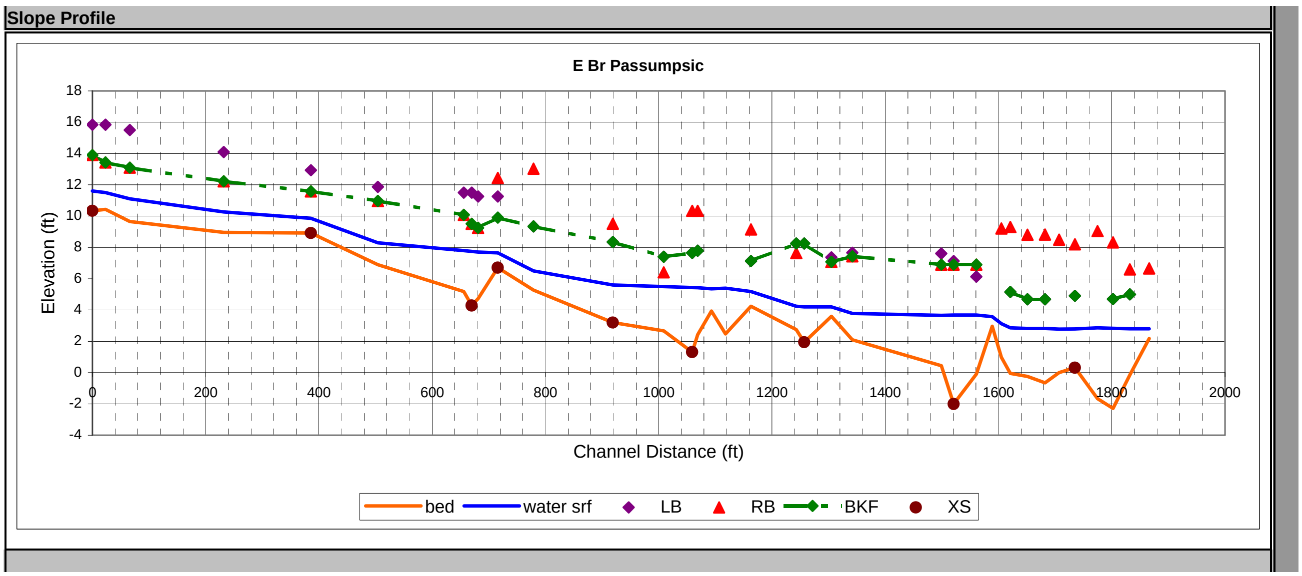


Figure 4.1 Longitudinal Profile of the East Branch, Passumpsic River in Burke, VT

After plotting the profile data, enter distance and water surface elevation data into the valley and channel slope calculator boxes. From this data, the spreadsheet calculates sinuosity using the following formula:

$$\text{Sinuosity (K)} = \frac{\text{Channel Length (CL)}}{\text{Valley Length (VL)}} = \frac{\text{Valley Slope (VS)}}{\text{Channel Slope (CS)}}$$

Valley slope, channel slope, and sinuosity are important values for defining or verifying which type of reference stream to use in evaluating the condition of the assessment site. The channel slope of the assessment site is used in a number of hydraulic calculations in Step 4.4 and as a ratio with bed feature slopes to compare bed feature characteristics between streams.

With care in using the bed feature identification codes to identify stations along the longitudinal profile, the spreadsheet will automatically calculate the mean length and slope of each bed feature and a summary table of calculated values and ratios associated with each bed feature located below the Length and Slope Calculator boxes (Figure 4.2).

Mean Riffle Length (ft.)	
Mean Riffle %Slope	
Riffle Slope Ratio	
Total Length of Riffles (ft)	
Riffle Aerial Extent (%)	
Riffle to Riffle Spacing	

Figure 4.2 Example table of bed feature values calculated in the Longitudinal Profile Worksheet.

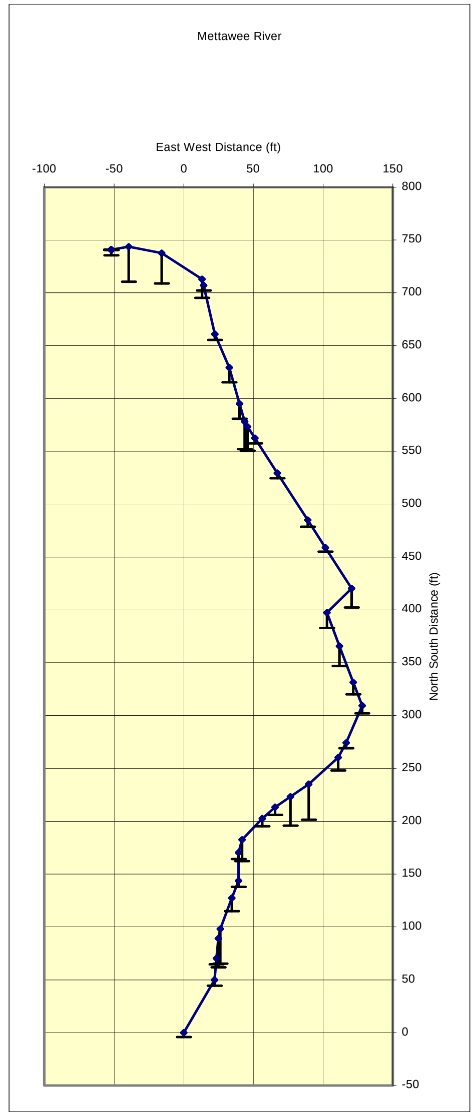


Figure 4.3 DMS Plan form plot from distance and azimuth data.

In the example table shown in Figure 4.2, the riffle slope ratio is calculated by dividing the mean riffle slope by the channel slope of the entire reach. The slope ratios and spacing values are important for evaluating the condition of your stream by comparing the values to those derived from reference stream(s) of the same stream type. The length and areal extent of each bed feature is useful in evaluating physical habitats. The spreadsheet derives these values for each bed feature identified in the profile which are valuable in describing current and future desired conditions as part of restoration projects.

The Longitudinal Profile and Pattern worksheet uses the distance, azimuth, and apex data to plot the channel planform and calculate the bendlengths and wavelengths within the assessment site (Figure 4.3). As discussed in Step 2 of this handbook, there are several methods for measuring and determining meander geometry values depending on equipment, field measurement constraints, the availability of current and accurate orthophotos. When data generated for bendlengths and wavelengths in the Profile and Pattern worksheet is the most accurate representation of meander geometry, enter the calculated values into the corresponding table fields of the Meanders worksheet to further reduce the planform data. The planform plot can be printed out and used as a map from which you can measure radius of curvature and belt width. Again use the planform plot for these purposes only when it provides the highest degree of accuracy.

4.3 PEBBLE COUNT

Particle size measurements are entered into Pebble Count tables set up for each bed feature type (i.e., riffle/steps, runs, pools, and glides), for bar samples, and particles measured from the bed of riffles. The following pebble count plots are made from these data:

Riffle/Step Pebble Count Run Pebble Count Pool Pebble Count Glide Pebble Count Other Feature PC →	Data taken at each cross-section is entered into the corresponding bed feature pebble count table which plots the cumulative percent of each particle size class at each cross-section count for inter-site comparisons.
Total Pebble Count -	Takes the all particles measured throughout the site and makes a separate plot for each bed feature type for inter-bed feature comparisons.

Weighted Pebble Count -	Looks at the total length of each bed feature as a percentage of the reach length and uses these percentages to plot a weighted pebble count of all of the particles measured (excluding those taken at bed features labeled as "other"). Particle sizes calculated on the weighted plot are used to classify the stream and make hydraulic calculations.
Bar Pebble Count -	Plots the cumulative percent of each particle size class corresponding to sieve sizes used to conduct the bar sample. Where bar samples are collected at reference cross-section (see Step 2.7), the bar count represents the size classes entrained as bed load during bankfull flows.
BED Pebble Count -	Plots the particles measured on the bed of the riffles, omitting those particles measured at the riffle cross-section between the toe of the slope and the bankfull elevation. BED particles size distributions are used in entrainment calculations.

The cumulative percent of each particle size class is plotted for each bed feature in the Total Pebble Count shown in Figure 4.4. From this plot the D16, D35, D50, D84, and D95 for the bed feature are calculated by the spreadsheet (Figure 4.5). These values represent the sediment sizes at different levels of the cumulative percent plot. For instance, if the D84 calculated from the Pebble Count is approximately 90 mm (or 3.5 inches), this means that 84% of the particles in the reach are smaller than 90 mm. Notice in the example below that a comparison of bed feature particle size distribution is possible. The D50 of the riffles and runs are higher than those calculated for pools and glides. This may be explained by the higher velocities measured at pools during bankfull flows that scour the larger particles into the riffles and the subsequent filling of pools with fines during lower flow periods.

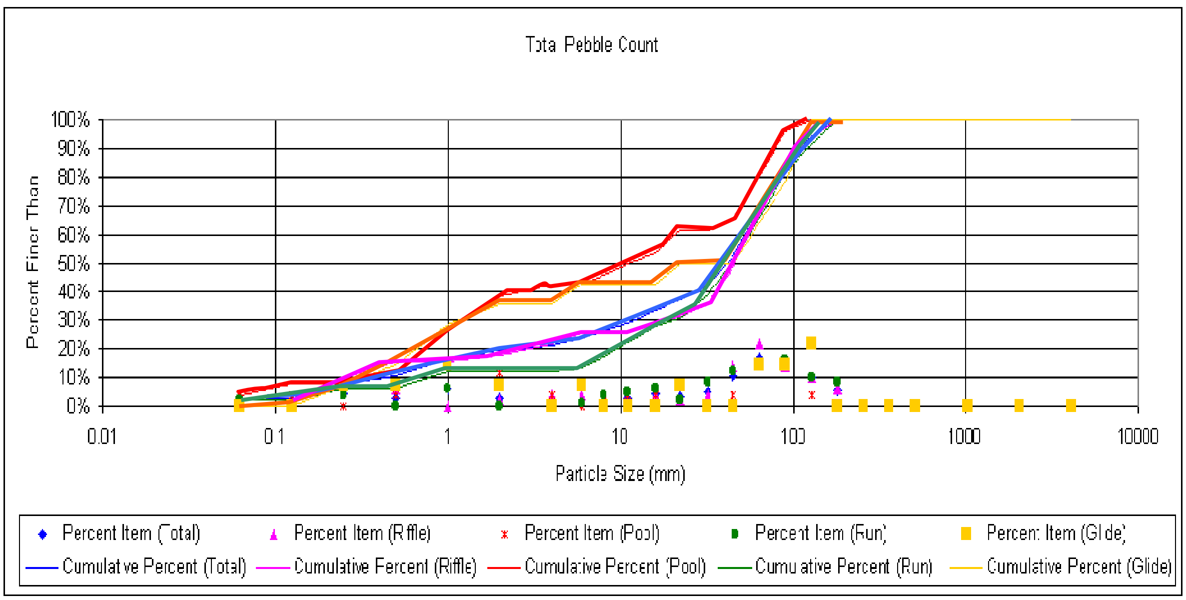


Figure 4.4 Gradation analysis plot

Pebble Count information is essential for understanding the sediment transport characteristics of a stream and how they relate to the geometry of channels in regime. One characteristic of a stream in dynamic equilibrium is when the power produced, as a function of its channel dimension, slope, and velocity, is in balance with the resistance of the channel boundary particles to erosion. On the bed of the channel, this resistance is largely a function of particle size and distribution.

The spreadsheet performs a number of calculations related to sediment entrainment. The D50 values calculated from the Bar and Riffle Bed Pebble Counts are used to calculate a critical dimensionless shear stress value for the channel (Appendix O). This ratio is then used to calculate the mean depth necessary to move the theoretical largest particle of the bed load or that measured on the surface of the Bar Pebble Count area. At cross-sections and bars, that exhibit good sediment continuity and particle size distribution, the sediment sizes encountered within the Bar Pebble Count area are those that largely make up the sediment load in transport along the bed of the channel during bankfull flows (referred to as the bed load). The ratio of the measured mean depth (at the riffle) with the calculated mean depth can be used to determine whether the stream's power is in balance with the sediment load it must move to remain in regime. For instance, when the actual depth is less than the depth calculated to move the largest particle on the bar (ratio < 1.0), the stream may be aggrading - unable to move its bed load during bankfull flows.

	Size percent less than (mm)				
	D16	**D35**	**D50**	**D84**	**D95**
Total	0.920	18.319	41.323	89.201	134.029
Riffle	1.117	31.113	45.726	89.301	134.716
Run	7.353	26.819	43.492	97.766	147.418
Pool	0.611	1.625	11.000	68.750	87.728
Glide	0.543	1.866	22.000	98.400	117.901

Figure 4.5 Total Pebble Count showing particle size distributions at different bed features for the East Branch of the Passumpsic River.

4.4 CROSS-SECTION

The worksheet plots cross-section data, calculates channel dimensions and hydraulics at each cross-section, and summarizes data by bed feature. Cross-channel distances and depths are plotted by the Cross-Section worksheet as shown in 4.6. The plot also includes lines indicating the elevations of bankfull flow (blue line) and the flood prone area (red line). From your field notes, and verified by the plotted cross-section, provide the spread sheet table with the bankfull elevation, the "top of bank" elevation (for the low bank), and the width of the flood prone area. These values are used by the spreadsheet to perform calculations and populate a Dimensions Table with bankfull channel values for :

Cross-Sectional Area (ft^2)
Width (ft)
Mean Depth (ft)
Maximum Depth (ft)
Wetted Perimeter (ft)
Hydraulic Radius (ft)
Bank Height (ft)
Width/Depth Ratio
Flood Prone Area Width (ft)
Entrenchment Ratio

.

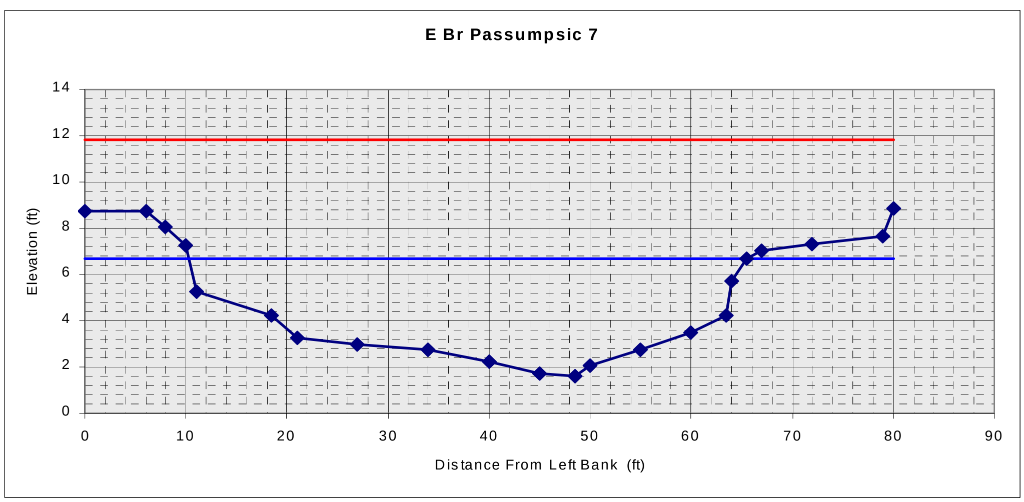


Figure 4.6 Cross-Section plot of the East Branch of the Passumpsic River.

The worksheet calculates the following bankfull hydraulic information for each cross-section using channel dimensions, the channel slope calculated in the Profile worksheet, and a Manning's roughness coefficient.

Velocity (ft/sec)	Stream Power (lbs/ft/sec)
Discharge - Q Manning's (cfs)	Friction Factor (u/u*)
Shear Stress (lbs/ft sq)	Threshold Grain Size (mm)
Shear Velocity (ft/sec)	

A roughness coefficient (**n**) is calculated using Manning's equation in the "Check from channel material" portion of the worksheet that uses a ratio of the mean depth at bankfull and the D84 sediment size calculated from the weighted Pebble Count. The equations used to calculate relative roughness, channel friction factor, and bankfull velocity can be reviewed in the comment boxes created for each calculation box. The worksheet will not calculate a discharge (Q) for the cross-section until a Manning's "n" value is entered into the worksheet cell located above the Dimensions box. The "n" value calculated from relative roughness can be used, or a roughness coefficient may be calculated using other published methods. In natural stream systems, bankfull velocity may be affected by the roughness associated with factors, such as vegetation (e.g., large woody debris) or planform features, that a roughness value based on sediment size may not adequately represent.

The bankfull shear stress value is used in conjunction with Shield's curve (Leopold, 1994) to determine threshold grain size. This calculation is useful for evaluating, at a particular cross-section, what sediments will be at the "threshold of motion" when the stream is at bankfull discharge.

The cross-section worksheet provides a place to record the composition and density of vegetation observed on the left and right banks in the vicinity of the cross-section as described in Step 2.8.

In addition to indicating at what bed feature the cross-section survey was made, indicate whether the cross-section should be considered a reference cross-section, and whether the cross-section should be included in the mean dimensions calculations. These "yes/no" decisions provide the opportunity to store all collected data into the spreadsheet workbook for the assessment site while deciding that certain data should not be included in summaries of reference data or other values calculated to represent the site.

The worksheet summarizes dimension and hydraulic data for all surveyed cross-sections into a table that precedes the cross-section plots (from left to right in the worksheet). If enough cross-sections have been surveyed to represent the longitudinal profile, the summary table can be useful in examining the continuity of hydraulic data through the site. Looking at the variability of shear stress, stream power, and threshold grain size from the top to the bottom of the assessment site may indicate where significant changes in sediment transport are occurring. Use river modeling programs such as HEC-RAS that factor planform and backwater effects if there is interest in further analyzing sediment transport continuity.

Dimension and hydraulic data are also summarized by bed feature type. For instance, the range and means of dimension data collected at riffle, run, pool and glide cross-sections are calculated. Mean entrenchment values have been included for riffles and runs. The data base will use the entrenchment value calculated for runs only where no riffles have been surveyed. Ratios comparing the width, depth, maximum depth, and cross-sectional area of run, pool, and glide cross-sections to riffle cross-sections are not presented in the worksheet but have been calculated for reporting through of the stream geomorphic data base.

4.5 PLANFORM GEOMETRY

The worksheet calculates the mean and range of values for wavelength, bend length, belt width, and radius of curvature (Figure 4.7). As discussed in Step 2, the source of planform data varies depending on the type of field equipment used; the field constraint encountered; and the availability of current and accurate ortho-photos. Use the Notes box of the worksheet to indicate the source or sources of data. The worksheet provides space to enter values for up to ten bendways.

Planform Dimensions (ft)	
Curve#	
Wavelength	Lm
Bend Length 1	Lb1
Bend Length 2	Lb2
Bend Length Average	Lb
Belt Width	B
Radius of Curvature	Rc
Wavelength Sinuosity	K

Figure 4.7 Planform dimensions entered into the DMS spreadsheet

The average bend length, calculated for the 2 bend lengths measured within each wavelength, is used in a ratio with wavelength to look at the sinuosity for each individual wavelength. This "wavelength sinuosity" should not be confused with the channel sinuosity calculated in the Profile and Planform worksheet for the entire assessment site.

The Meander worksheet imports the mean bankfull width of the riffle and run cross-sections from the Cross-Section worksheet for use in developing a series of dimensionless ratios for your reach. The mean bankfull width of the run cross-sections will be used to develop planform-related ratios only when riffle data is not available. Leopold (1994) and others have reported the following ratios for unconfined, low slope streams:

Lm:W = Wavelength / Width	**=**	**10 to 14**
Lb:W = Bend Length / Width	**=**	**5 to 7**
B:W = Belt Width / Width	**=**	**6**
Rc:W = Radius of Curvature / Width	**=**	**2.5 to 3.2**

Step 5 of the Phase 3 Stream Geomorphic Handbook will discuss the use of dimensionless ratios and other data to assess whether the stream is undergoing an adjustment processes and to what degree it has departed from a reference condition as determined for the type of stream being assessed.

4.6 STREAM BANK AND BOUNDARY CONDITIONS

The worksheet stores bank and boundary condition data collected on the Stream Bank Field Form (Steps 3.1 – 3.7). A Bank Erosion Hazard Index (BEHI) is calculated using bank erosion factors as described in Appendix N. The spreadsheet copies the BEHI value to the cross-section worksheet for reference with other dimension and hydraulic information.

Step 5: Stream Geomorphic Assessment

The stream geomorphic assessment is comprised of three separate yet interrelated evaluations of the assessment site, including stream condition, sensitivity, and adjustment process.

The Phase 3 geomorphic condition assessment starts with analyzing the data to further understand what type of equilibrium stream would exist in the geographic, geologic, and climatic setting as a reference to compare with the type of stream measured in the field. The type and degree of departure of the existing from the reference type is due to current and previous channel adjustments and defines the stream condition. An assessment of the stream's likelihood to further adjust will describe sensitivity. And finally, the information of condition and sensitivity in combination with channel evolution models provide the basis for explaining the future adjustment process and condition of the assessment site.

When the power produced by the stream becomes out of balance with the flow, sediment, and debris produced in its watershed it is said to become geomorphically unstable and begins to adjust its dimension (width and depth), its pattern, and its profile (slope) to come back into balance with its current regime (Figure 5.1).

Stream Stability

The ability of a stream, over time and in the present climate, to transport the flow, sediment, and debris of its watershed in such a manner that it maintains its dimension, pattern, and profile without aggrading or degrading. (Rosgen, 1996)

A geomorphic assessment will essentially help answer the questions:

Stream Condition –**What is the shape and form of the stream** compared with those conditions that would exist in the absence of human watershed disturbance?

Sensitivity – **What is the likelihood that or how readily will the stream respond** to watershed or local disturbance.

Adjustment Process –**How will the stream respond** to watershed disturbance as it reaches equilibrium and how long might that take?

Figure 5.1 Channel adjustment. Cross-section is ineffective at sediment transport.

Stream Typing: As part of making these assessments, define the existing stream type for the assessment site. This involves describing the current set of channel and floodplain characteristics. The site condition may then be determined by analyzing the departure of the existing stream type from the reference steam type. Stream typing involves classifying reaches based on physical parameters such as valley landform, channel dimensions, slope, sediment supply, and bed forms. Vermont ANR uses both the Rosgen (1994) and the Montgomery-Buffington (1997) stream classifications systems (Appendix I) to summarize many of the physical parameters thought to be important in typing streams, including the following **stream setting (independent) and channel response (dependent)** characteristics.

Independent "Stream Setting" Characteristics

Drainage Area and Watershed Zone - measured as the square miles of land area draining into the downstream most point of the site, drainage area indicates the relative size and location of the stream within the watershed. Watershed zone refers to one of the three zones (source, transfer, and response) depicted in **Figure** 5.2. The watershed zone within which a channel lies as well as the spatial sequence in which the zones occur determines the effect that watershed and channel disturbances have on a particular channel reach (Montgomery and Buffington, 1997).

- Source streams: Transport limited, sediment storage reaches. Although transport limited, source reaches are primarily where non-alluvium sediments (colluvial material) enter into the stream system. The primary mode of transport is intermittent and infrequent during large flow events when landslides occur and debris and sediments are scoured from source streams.
- Transfer streams: Morphologically resilient with high sediment transport capacity to supply ratio. These streams rapidly convey increased sediment loads.
- Response streams: Storage streams in which significant morphologic adjustment occurs in response to changes in sediment supply. Zones of transition from transport to response reaches are locations where impacts from increased sediment supply may be both pronounced and persistent.

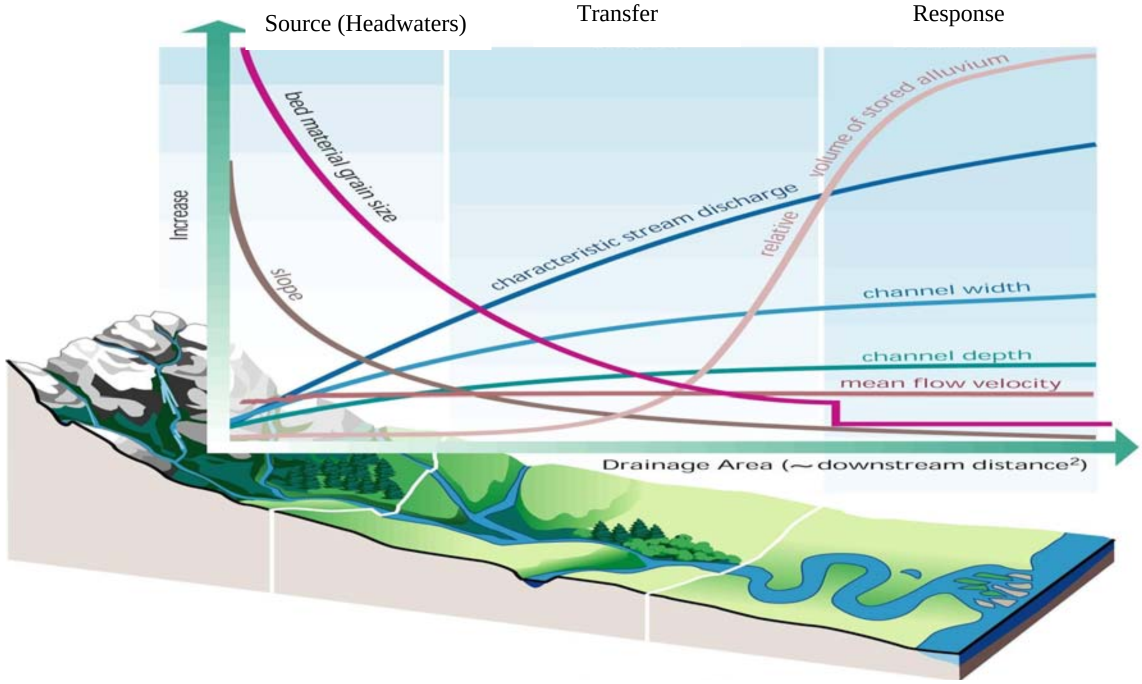


Figure 5.2 Slope and bed material grain size changes from headwaters to unconfined valley settings (adapted from the Stream Corridor Restoration Manual, Federal Interagency Stream Restoration Working Group, 1998).

While there are many important exceptions, the size and location of the stream correlates with the headwater to valley trends of the characteristics described below.

Flow Regime – an evaluation of whether the stream is subject to flow regulation from diversion or dams, and/or has been affected by storm water through changes in land use/land cover. The hydrology, whether natural or altered, can have significant effect on sediment regime and channel geometry. Because consideration of historic changes is critical in assessing morphologic condition and flow regulation was at one time very prevalent in Vermont it is important to know the history of the hydrologic regime.

Valley Slope and Confinement - represented respectively as ratios of the valley rise/valley run and the valley width/channel width. While the channel slope is used as a key parameter in stream typing, valley slope is an independent variable that helps to describe the setting of the stream. The lateral confinement of the stream imposed by the valley walls confers the type and range of channel adjustments that may occur. For instance, a confined or naturally entrenched stream with a moderate water surface slope has little opportunity to adjust its planform and develop a floodplain in response to increased flows or sediment supply. In this example the stream may increase its cross-sectional area or width-to-depth ratio to bring its erosive power in balance with its changed flow and sediment regime.

Sediment Regime – measured as bed load or evaluated by examining surficial geology of the watershed, the amount of upstream erosion and deposition, tributary inputs, and the size and quantity of in-stream sediment and depositional features. High bed load systems will display significant deposition in the form of bars. These bars result in a distribution of shear stresses on the channel bed and banks that leads to the formation of well developed pools and riffles and lateral migration (Bunte and Abt, 2001). Low gradient streams with high sediment supplies and low transport capacity are very sensitive and may undergo adjustment following minor changes in channel geometry or boundary conditions.

Channel Boundaries – describing bed and bank materials and their erodibility including characteristics of the local geology, bank stratigraphy, the influence of large woody debris, and riparian vegetation characteristics. Similar to the discussion above for valley confinement, the resistance of the channel boundaries to the erosive power produced by the stream will explain whether the meandering (planform) of the channel is "passive" or "active" as well as the type and range of adjustment process that might be observed.

Dependent Channel "Response" Characteristics

Entrenchment - represented as a ratio of the width of the floodprone area to the bankfull width of the stream (W_{fpa} / W) (Rosgen, 1994). Entrenchment can most easily be thought of as a measure which describes floodplain access of a stream at discharges greater than bankfull. Entrenchment maximizes channel response to increased discharge by limiting overbank flow. Unconfined, response streams that have lost or are losing access to floodplain will generally erode their bed and banks until the boundary materials can withstand the powerful flood discharge or a new flood plain has been created at a lower elevation (as per Schumm, 1984 and Simon, 1989)

Width/Depth Ratio – represented as a ratio of the bankfull width to the mean bankfull depth (W / d). The capacity of a channel to handle flow or water discharge is a function of width, depth, and velocity. While flow capacity would not be significantly affected by a change in depth (owing to the corresponding change in width and/or velocity), sediment transport capacity is sensitive to changes in depth (Leopold et. al., 1964). The width to depth ratio is often used as an indicator of sediment transport capacity, stream aggradation, and aquatic habitat (Rosgen, 1996).

Sinuosity – represented by ratios of the channel length to the valley length (CL / VL) or the valley slope to the channel slope (VS / CS). Changes in sinuosity indicate the adjustment of channel planform and slope that generally take place so that the power of the stream is maintained in balance with the sediment size and load produced in the stream watershed. For instance if the measured sinuosity of a channel is very low (i.e., the channel slope is nearly the same as the valley slope) in a wide, alluvial valley setting, a channel degradation process may be predicted (Stage II of the channel evolution process). After much erosion, the stream in this example would decrease its slope to be in balance with its sediment regime, thereby increasing its sinuosity.

Water Surface Slope – represented as a ratio of the vertical drop of the water over the length the water travels in the reach. Stream channel hydraulics is largely influenced by the slope of the water surface which correlates strongly with bed material grain size from the upstream (headwaters) to downstream (depositional) zones.

D50 Sediment Size – 50 % of the particles measured are smaller than the D50 sediment size calculated for the stream. The D50 bed material size represents the most prevalent size particle and is used as a standard for comparison between streams.

D84 Sediment Size - 84 % of the particles measured are smaller than the D84 sediment size calculated for the stream. The D84 bed material or grain size represents the larger particle sizes of the channel that are likely to become mobile during the annual high water events (Q1.5) (Leopold, 1994). Comparing the D84 particle size with the grain size that a given cross-section is capable of entraining (as a function of the shear stress generated) gives some indication of channel adjustment and condition.

Bed Feature Type – described as a series of rhythmic bed features within the channel profile such as step-pool or riffle-pool. Bed feature type conveys information pertaining to the sediment transport-supply ratio, hydraulic processes and habitat characteristics (Montgomery and Buffington, 1997).

Stream Type Classification – A combination of descriptors including the relative drainage size, sediment regime, confinement, channel geometry, prevalent sediment size, and bed morphology (see Phase 1: Step 2; Phase 2: Step 2; and Appendix I for further description). Examples of how a stream might be generally described or typed would be as follows:

> A large (drainage area), high sediment supply, actively-meandering, C4 riffle-pool stream in a very broad valley; or
>
> A small, low sediment supply, passively meandering, C3b plane bed stream in a narrow valley.

Because of the length of descriptors, fluvial geomorphologists often use the abbreviated description established by different classification systems. While this generally works due to the correlative nature of these parameters, there are enough exceptions that one should use caution when a channel is described as simply a "C4" or a "riffle-pool" stream type.

Step 5.4 is a summary of the conclusions made in the Step 5 Stream Geomorphic Assessment. A table has been developed in the DMS spreadsheet and Phase 3 data base to enter the reference and existing stream types, geomorphic condition, reach sensitivity, and adjustments processes determined for the assessment site (Figure 5.11).

5.1 SITE CONDITION (stream type departure analysis)

This Step provides for an assessment of how much a stream has departed from the reference condition. For instance, a stream may be actively aggrading or degrading to the point where its condition is represented as a completely different stream type then what would exist naturally. In another case (as shown in Table 5.2), the existing condition may have departed from the reference but not, at the time of survey, to the extent that it represents a different stream type. Use the descriptions of “reference,” “good,” “fair,” and “poor” provided on page 8 of the Program Introduction and in Step 8.6 of the Phase 2 Handbook (RGA: geomorphic condition evaluation) to decide which condition best describe the degree of departure supported by the site survey (Phase 3) data.

On the Site Location and Description worksheet of the DMS, an area has been set aside to complete the Stream Geomorphic Assessment. Existing and reference stream types are recorded here and are based on an evaluation of Phase 1, Phase 2 and Phase 3 data (see Step 5.4).

The existing stream type is determined by the survey results and either verifies or alters the Phase 2 existing stream type determination. The measured stream type is not necessarily the stream type that would exist if the stream were in equilibrium and/or unaffected by human modifications. Figuring out the type of reference condition that did exist or is likely to exist serves as a basis for understanding how far the stream has departed and what adjustments are underway as the stream equilibrates to a regime condition.

Choosing a Reference: A reference stream should share the following characteristics with the assessment site (variables that are more independent of channel adjustments):

Drainage Size and Watershed Location
Natural Flow Regime
Valley Slope and Confinement
Sediment Regime (size, storage and supply) as influenced by watershed geology and soils
Channel Boundary Materials and meander passivity

This list of geographic, geologic, and climatic parameters defines the **stream setting**. A Phase 1 assessment, using maps and existing data, provides information on many of these stream settings parameters. Also, if there is a reference stream in the same or neighboring watershed with the same setting, use survey data collected there to define the remaining "dependent" reference parameters. Pay particular attention to choosing a reference stream with the floodplain connection (entrenchment) and width/depth ratio expected in that particular stream setting. If a nearby reference is not available for comparison, it may be possible to query the State database to find the stream types and range of reference data from streams with similar settings. Table 5.1 provides a guide for selecting probable reference stream types based on several setting parameters.

Table 5.1 Guide for selecting probable reference stream types, based on Phase 1 stream setting parameters. (Note: G and F stream types are typically ascribed to degraded reaches but do exist as reference channels in certain naturally confined settings such as gorges)

Watershed Zone or Sediment Regime	**Valley Confinement (See Step 1.3 Menu)**	**Valley Slope**	**Sediment Size: Storage and Supply**	**Reference Stream Type**
Source	Narrowly confined (NC)	Steep (> 4 %)	Boulder-Cobble-Gravel-Sand	**A** Colluvial/Step-pool
	Confined on Narrow (NC, SC, NW)	Mod. - Steep (2 - 4 %)	Boulder-Cobble-Gravel-Sand	**B or G** Colluvial/Step-pool
Transfer (Transport)	Confined, Narrow, or Unconfined (Any Valley Type)	Steep - Low (any)	Bedrock-Boulder	**A, B, C, G or F** Cascade, Step-pool, or Plane Bed
	Semi-Confined or Narrow (SC, NW)	Mod.- Steep (2 - 4 %)	Cobble	**B** Plane bed or Step-pool
	Narrow or Unconfined (NW, BD, VB)	Mod.- Low (< 2 %)	Cobble-Gravel-Sand	**E** Pool-riffle or Dune-ripple
Response	Semi-confined or Narrow (SC, NW)	Mod.- Low (2 - 4 %)	Cobble-Gravel-Sand	**B or G** Riffle-Pool or Plain bed
	Narrow or Unconfined (NW, BD, VB)	Mod.- Low (< 2 %)	Cobble-Gravel-Sand	**C, E or F** Pool-riffle or Dune-ripple
	Semi-confined, Narrow or Unconfined (SC, NW, BD, VB)	Mod.- Low (< 2 %)	Cobble-Gravel-Sand	**D** Braided

The Vermont Department of Environmental Conservation has a reference reach program that collects data on geomorphic reference streams statewide. Reports containing reference data from Vermont and other regions by stream type have been drafted (Appendix B). As the State reference database becomes more robust, predicting and affirming reference condition will be enhanced. Reference data, especially for larger, alluvial streams are very hard to come by in Vermont and the ANR reference reports offer only limited data at this time. Also note that individual reports may contain data from a wider range of conditions than might be applicable as a reference for the assessment site. The Phase 3 database is available for making custom queries to try and find reference information for the streams that have been assessed. Also consider published regime relations for Northeast and North American streams.

Phase 2 and Phase 3 stream type assessment and measurements are used to define the reference stream bank and boundary conditions and specify stream type variables:

Entrenchment	Width/depth	Sinuosity
Slope	D50 particle size	Bed morphology

In a Phase 3 Stream Type Report, example shown in Table 5.2, the reference stream type is summarized using data queried from the DMS data base from an adjacent reach. The existing stream type differs from the reference, but in this case not enough to result in a different stream type.

Table 5.2 Example Stream Type Report produced from the Phase 3 data base. Independent variables represented by shaded parameters. An iterative process may be used to determine a reference stream type.

Stream Parameter	Existing Stream Type		Reference Stream Type	
Drainage Area and Watershed Location	**Square miles:** **Relative size:** **Location:**	43 Medium Transf.-Response	**Square miles:** **Relative size:** **Location:**	43 Medium Transf.-Response
Flow Regime	**Regulation:** **Impoundment:**	None None	**Regulation:** **Impoundment:**	None None
Valley Slope & Confinement	**Slope:** **Confine. Type:** **Ratio:**	0.006 Very Broad 12	**Slope:** **Confine. Type:** **Ratio:**	0.006 Very Broad 12
Sediment Regime	**Supply:** **Storage:**	High Large	**Supply:** **Storage:**	High Large
Channel Boundaries	**Morphology:** **Bank Materials:** **Erodibility:**	Actively formed Alluvium High	**Morphology:** **Bank Materials:** **Erodibility:**	Actively formed Alluvium Moderate
Entrenchment	**Degree:** **Ratio:**	Slight 4.5	**Degree:** **Ratio:**	Slight 4.5
Width/depth	**Degree:** **Ratio:**	Moderate – High 35	**Degree:** **Ratio:**	Moderate 18-25
Sinuosity	**Degree:** **Ratio:**	Low – Moderate 1.15	**Degree:** **Ratio:**	Moderate 1.2-1.5
Water Surface Slope	**Degree:** **Ratio:**	Low 0.0045	**Degree:** **Ratio:**	Low 0.005
D50 Sediment Size	**Class:** **Size (mm):**	Medium Gravel 16	**Class:** **Size (mm):**	Coarse Gravel 20
D84 Sediment Size	**Class:** **Size (mm):**	V. Coarse Gravel 45	**Class:** **Size (mm):**	V. Coarse Gravel 55
Stream Type Classification	**Rosgen:** **M-B Bed Type:**	C4 Pool-Riffle	**Rosgen:** **M-B Bed Type:**	C4 Pool-Riffle
Summary Condition	A medium-sized, actively-formed, high sediment supply, pool-riffle C4 stream at the transfer zone into a very broad valley		A medium-sized, actively-formed, high sediment supply, pool-riffle C4 stream at the transfer zone into a very broad valley	

Using Phase 1 and Phase 2 assessments of the independent and dependent stream and valley parameters, decide the most likely reference or modified reference stream type for a given setting (see definitions in Program Introduction). Then, comparing this data and/or reference data collected from other similar streams with the measured (existing) conditions of the site, determine if the type and magnitude of channel adjustment processes that have and may still be occurring in the channel (Step 5.3), verify your selection of reference. Be sure the adjustment process describes a plausible channel evolution from the reference to the existing condition, given the watershed and channel impacts assessed in Phase I and Phase II. When thorough examination of the data in Step 5.3 does not support the a plausible channel evolution, revisit the question of "what is reference condition?" and repeat the process.

5.2 SENSITIVITY

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance. Table 5.3 has been set up to help identify the sensitivity of assessment site based on stream type. Use the table and the discussion that follows to note the sensitivity of the reach in its existing condition in the Stream Geomorphic Assessment area of the Site Location and Description worksheet of the DMS.

Streams are a metaphor for "change." Every stream changes in time. The exercise of assigning a sensitivity rating to a stream is done in the context that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the setting characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially degradation or aggradation, may become acutely sensitive.

The following parameter list is offered to both further describe those variables that largely contribute to a streams natural sensitivity as well as infer which human activities increase a stream's sensitivity by triggering adjustment and channel evolution within the watershed.

Boundary Conditions

Bedrock: Bed and banks comprised of bedrock drastically reduce a streams sensitivity to vertical and lateral adjustment.

Bed and Bank Sediments and Stratigraphy: The erodibility of the channel will have a strong influence on sensitivity and mode of channel adjustment in response to disturbance. Erodibility is affected by: size, gradation, cohesivity and stratification of bank sediments; bank height and angle relative to bankfull stage; the root network associated with riparian vegetation; and large woody debris within the channel. Bed armoring with large cobbles and boulders; bank vegetation with deep roots; and bank materials that are cohesive, non-stratified, or non-alluvial in nature are all characteristics of stream boundary conditions more resistant to lateral or vertical adjustment. The most sensitive streams tend to be those with sands, gravels, and/or small cobbles as the dominant materials within the bankfull channel. The erodibility of the banks relative to the bed is important as it will influence whether a response to disturbance occurs as channel widening or channel incision.

Alluvial fans: Zones of transition from transport to response reaches are locations where change from increased sediment supply may be both pronounced and persistent.

Colluvial Processes: Streams in close contact with valley walls, especially where hill slope failures are prevalent, often fill with fine colluvial material. These streams also tend to have steeper channels where fine grained sediments are subject to higher erosive power and undergo frequent adjustment. Streams with slope values greater than 4% with sand, gravel or cobble beds (Stream types: A3, A4, and A5) are commonly described as "Source" streams subject to colluvial

processes. Streams with lower slope values ("G" and to a lesser extent "B" type streams) may also be sensitive to colluvial-related adjustment processes.
Vegetation: The role of vegetation in establishing boundary conditions and increasing a stream's resistivity to adjustment is critical for stream types in narrow and unconfined valley types with smaller sediments sizes. Bank height and rooting depth relative to bankfull stage are also important factors.

Table 5.3 Stream Type Sensitivity (based on Rosgen, 1996; Montgomery and Buffington, 1997)

Sensitivity	Valley Type	Stream Type		
High to Extreme ***d50** ≤ gravel size except: A3, G3 } steep & entrenched F3 - entrenched D3 - braided **** very high sediment supply	**Confined** Slope >4%	**A3**	Colluvial / Step-Pool **(Source)**	Highly Entrenched
		A4		
		A5		
	Semi-Confined To Narrow Slope 2-4%	**G3**	Step-Pool / Plane Bed **(Source, Response)**	
		G4		
		G5		
	Narrow To Unconfined Slope <2%	**F3**	Plane Bed / Riffle-Pool / Ripple-Dune **(Response)**	
		F4		
		F5		
		B4c	Riffle-Pool/Ripple-Dune (**Response)**	Not Entrenched
		B5c		
		C4		
		C5		
		C6		
		E4	Riffle-Pool / Plane Bed **(Transport, Response)**	
		E5		
		E6		
		D3	Braided **(Response)**	
		D4		
		D5		
Moderate	**Semi-Confined To Narrow** Slope 2-4%	**B3**	Step-Pool **(Source, Transport, Response)**	Moderately Entrenched
		B4	Plane Bed / Riffle-Pool **(Response)**	
		B5		
	Narrow To Unconfined Slope <2%	**C3**	Riffle-Pool **(Response)**	Not Entrenched
		E3	Riffle-Pool / Plane Bed **(Transport, Response)**	
Very Low to Low *** d50** ≥ boulder size except B3 **** low sediment supply	**Confined** Slope >4%	**A1**	Bedrock / Cascade / Step-Pool **(Transport)**	Highly Entrenched
		A2		
	Semi-Confined To Narrow Slope 2-4%	**B1**	Bedrock / Step-Pool **(Transport)**	Moderately Entrenched
		B2		
		G1		
		G2		
	Narrow To Unconfined Slope <2%	**F1**	Bedrock / Plane Bed **(Transport)**	Highly Entrenched
		F2		
		C1	Bedrock / Riffle-Pool	Not Entrenched

		C2	**(Transport, Response)**	

Sediment and Flow Regimes

Sediment Regime: After boundary conditions, the bed load of a stream is perhaps one of the most important factors influencing stream sensitivity.

- Source streams are highly sensitive to increases in discharge and hill slope processes because of their steep slopes and close proximity to valley walls.
- Transport (transfer) streams are morphologically resilient with high sediment transport capacity to supply ratio. These streams rapidly convey increased sediment loads.
- Response streams are storage streams in which significant morphologic adjustment occurs in response to changes in sediment supply. Low gradient streams with high sediment supplies and low transport capacity are very sensitive and may undergo adjustment following minor changes in channel geometry or boundary conditions. Because these streams typically contain larger discharges, an increase in channel slope will result in a dramatic increase in stream power (Montgomery and Buffington, 1997).

Flow Regime: Highly variable "flashy" systems may display more erosion due to: wetting and drying that prepares materials for transport; and a higher incidence of flooding that may lead to widening. A decline in magnitude of flood flows may result in vegetation becoming more effective at stabilizing the channel margins (Knighton, 1984). Changes in land use and land cover that increase impervious cover, peak discharges, and/or the frequency of high flows will heightened a stream's sensitivity to change and adjustment.

Floods: Streams that experience flooding of high magnitude, frequency and/or duration are sensitive to change. Floods are high discharge events that exceed the bankfull stage of a stream and produce tremendous power, energizing the stream system with flows of both water and sediment. Streams that seem relatively insensitive to adjustment over long periods of time (i.e., decades), oftentimes despite previous disturbance, may become very active after a large flood or series of high flow events.

Confinement

Valley Width / Channel Width: The confinement ratio does not, in itself, explain the sensitivity of a stream to adjustment. Unconfined streams tend to be more sensitive, except when natural confinement co-occurs with bed loads comprised of finer sediments (i.e., source streams).

Encroachment and Floodplain Modification: Confinement becomes a significant sensitivity concern when structures such as roads, railroads, and berms significantly change the confinement ratio, reduce or restrict a stream's access to floodplain, and result in higher stream power during flood stage.

Channel Evolution: Adjustments in Dimension, Pattern, and Profile

Existing Channel Geometry: The departure analysis completed in Step 5.2 to describe the stream's current condition is also useful in evaluating its sensitivity to future change. Where the stream has departed from reference and is a completely different stream type (e.g., B3 to a G4) it may be dramatically more sensitive to future change.

- Vertical adjustment is indicated by bank height and entrenchment ratios that are out of the expected range for a given stream classification. Vertical adjustment and the channel evolution that follows is the most severe adjustment. Imposed changes in planform geometry (channel straightening) often lead to head-cutting and incision. Local degradation can lead to system-wide channel adjustments when available stream power, as an indicator of the flow energy available to perform work, exceeds the critical or resisting power of the particular boundary sediments (Simon, 1995). Sediment competency measures can be used to compare the existing channel geometry and shear stress to those necessary to move the bed material during bankfull flow events.

- Lateral adjustment is indicated by sinuosity and meander geometry. Stream sensitivity may increase where lateral adjustments, accelerated by human activities, lead to bed degradation.

- Dimensional Adjustment is indicated by width to depth ratios that have departed significantly from reference, affect sediment competency, and result in vertical adjustment.

Upstream or Downstream Adjustments: Upstream and downstream adjustments are likely to impact the reach through increased sediment supply or headward migration of incision processes.

5.3 CHANNEL ADJUSTMENT PROCESS

The channel adjustment process is identified to evaluate the type of change that is underway due to natural causes or human activity that has or will result in a change to the floodplain and/or channel condition and in some cases even the valley setting of the stream. An analysis of channel adjustment involves looking at the departure of existing conditions from those of reference and gaining an understanding of the physical processes at work as the stream becomes in balance with the flow and sediment regimes of its watershed. Channel evolution models developed and verified by researchers studying channel adjustment in North America and Europe have shown to be useful in Vermont in understanding why and how streams are responding to various watershed, flood plain, and channel modifications (Appendix C).

The time required for a stream to adjust to a given disturbance is difficult to predict owing to the fact that they are influenced by boundary conditions, climate and history and persistence of disturbance. Prediction of adjustment time may be enhanced by dividing those features subject to adjustment into three categories, each of a distinct temporal and spatial scale (Center for Watershed Protection, 1999b).

- **Macroforms**: features at the floodplain width scale such as longitudinal channel slope, meander radius of curvature, pool-riffle spacing, sinuosity, and meander amplitude and wavelength. Channel slope adjusts over periods in centuries before slope; width, depth and roughness are back into mutual agreement.
- **Mesoforms**: features at the scale of the width of the active channel. These features include bankfull parameters and bar forms such as point, medial, and diagonal bars. Modification of channel width occurs over a period of 10 to 20 years until width, depth and roughness are mutually adjusted.
- **Microforms**: features measured at the scale of eddies below boulders and other flow obstructions. These features include the spatial distribution of bar form sediments (transverse, longitudinal and vertical axis) and sediment structures such as imbricated sediment forms. Roughness and depth adjust rapidly over a period of one to 10 years to a change in the independent variables.

The amount of data produced in a Phase 3 assessment can be overwhelming to river managers trying to understand the fluvial geomorphic processes at work. The discussion that follows will help organize the analysis and key in on certain data to test hypotheses that were formed about what the river is doing at the assessment site. Phase 3 data will be used to verify or alter the conclusions made at the end of a Phase 2 Rapid Assessment about the channel adjustment processes and stages of evolution the assessment site may be going through to achieve equilibrium. Phase 3 adjustment and stage of channel evolution are recorded in the Stream Geomorphic Assessment area of the Site Location and Description worksheet of the DMS.

When a stream is in adjustment, we say that it is evolving toward equilibrium or working to get in balance with its watershed inputs. Using the fundamental equation offered by Lane (Figure 5.3) an understanding may be gained as to how different land uses or management activities “tip the balance.”

In the Lane equation the watershed input or source variables of water discharge (Qw) and sediment discharge (Qs) are on opposite sides of the balance. This model has the advantage of demonstrating how degradation and aggradation result from changes to the source variables. Schumm (1969) offers another equilibrium equation that puts the source variables together on one side of the equation and the response variables on the other.

Qs, Qw ~ S, d50, D, W

Where S=slope, d50=median diameter of bed material, D=flow depth, and W=flow width. The advantage of this model is the inclusion of width and depth as response variables, that together with channel slope define the amount of power the stream has to move its sediment load. In either case, the changes that occur on one side of the equation result in a variable response on the other side of the equation (sometimes back and forth) until balance is achieved.

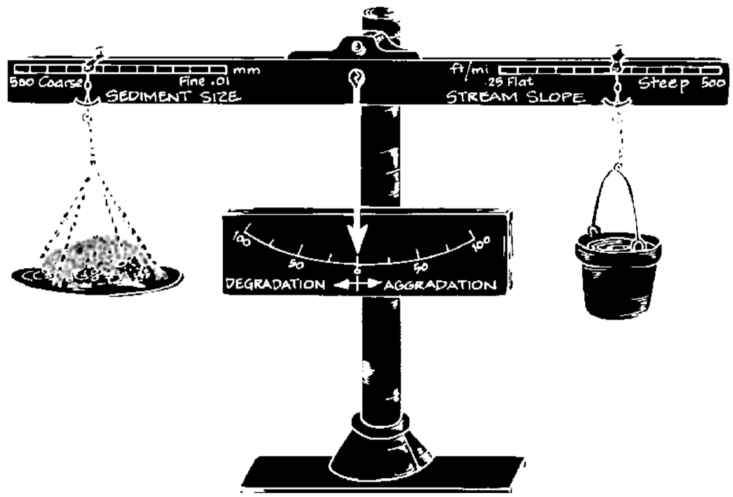


Figure 5.3 Lane's Balance (1955) demonstrating a balance between Sediment Supply (Qs) & Sediment Size (D) % Slope (S) & Discharge (Q)

Equilibrium equations offered by Lane and Schumm are both useful in identifying channel adjustments as stages within a channel evolution process. Here is an example: When excess erosion has occurred upstream increasing the sediment supply to the assessment site (Qs on the left side of the Lane Balance), the physical process operating within the site may be observed as it adjusts its slope (S on the right side of the balance) to eventually come back into equilibrium. Depending on when the survey is conducted, in relation to the adjustment process, different conclusions may be made about the adjustment process at work. Initially, there may be signs of **aggradation** and a localized decrease in slope as sediment builds up in the reach. This is typically followed by a channel avulsion that shortens the reach length resulting in what may be a dramatic increase in slope. At this step in the process, the data may strongly indicate channel **degradation.** Depending on the severity of the degradation process, the balance may have swung too far, and some decrease in slope will occur before equilibrium is achieved. If surveys are completed at this time, the processes observed may be either channel **widening** or **planform adjustment**.

Typical adjustment sequences have been observed and documented that may help to explain why Rapid or Survey level assessments reveal signs of more than one process going on, as well as those adjustments that are likely to occur before the river is in equilibrium. Some types of adjustment, particularly degradation and aggradation, may be predicted in part by analyzing those Phase 3 data related to channel dimension, pattern, and profile that serve to quantify the critical stream power necessary to achieve sediment continuity (Figure 5.4). These macro scale adjustments of aggradation and degradation represent instabilities of a significant scale with respect to management decisions. That said, it is important to remember that macro scale adjustments are typically preceded by micro and meso adjustments. One product of this step in the protocol is the selection of a channel evolution model that best explains the set of responses the reach has made and is likely to make as it comes into balance with observed changes to watershed inputs and/or imposed channel conditions.

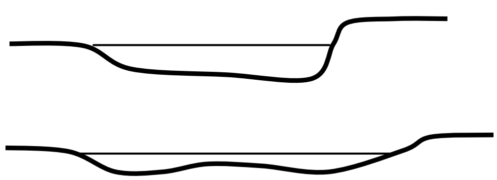
The following pages are offered as guides to the adjustment and channel evolution processes that typically occur in the different stream types and settings in Vermont. In a format similar to that laid out in Step 7 of the Phase 2 handbook, each of the four adjustment processes are defined in terms of the imposed source/response variable changes and some of the typical management activities that trigger the adjustment. These definitions are largely centered on the changes that occur in low gradient, unconfined, response reaches. Some common exceptions are laid out in these generalized definitions and others are described in further detail in Appendix C where several typical channel evolution models are explored. Management implications are made throughout these guides where appropriate.

There will be situations where a stream is encountered in the early stages of channel evolution, where only one of the adjustment processes, typically degradation or aggradation, may be observed in isolation. More commonly, a stream will be observed in later stages of channel evolution, where observations and data indicate that several adjustments have either recently occurred (i.e., within the last 30 years) or are currently in process. Where a stream is in Stage IV of channel evolution, the data may suggest that all four adjustments processes have occurred and are still influencing the hydrology and sediment regime of the stream. In summarizing the interpretations in Step 5.4, indicate previous vs. current adjustment processes as supported by the Phase2/Phase 3 data.

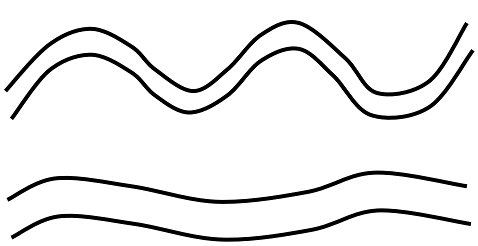
Each adjustment process page includes a table of "Parameter Changes" indicative of the adjustment process. These changes are represented as thresholds (as documented in the literature); as increases (+) or decreases (-); or as present or absent. Remember, these parameter changes are offered as a guide to how the channel geometry may change when an adjustment processes has occurred as the **initial** response to an imposed watershed or reach level change. The magnitude or direction of change may be affected or moderated when different adjustments are occurring at the same time.

DEPTH, SLOPE & FLOODPLAIN ARE CRITICAL FACTORS IN:

DIMENSION



PATTERN & PROFILE



SEDIMENT CONTINUITY

- **Stable streams are in dynamic equilibrium**
- **Dynamic equilibrium is achieved over time through sediment continuity**
- **Sediment continuity is achieved when the stream has the power to move the size and quantity of sediment delivered from upstream**
- **Stream power is a function of channel slope and discharge**
- **Stream discharge is a function of climate, geology, and land cover**
- **Channel slope is a function of valley slope, floodplain width and meander pattern**
- **Flow velocity and channel area are functions of discharge and are determined by channel and floodplain dimensions (width and depth)**

Figure 5.4. "How Streams Work" to achieve sediment continuity and dynamic equilibrium.

Degradation

Imposed Changes: The following watershed and local changes, and their subsequent effects on watershed input (source) variables and stream power factors, often lead to channel degradation as the first, or primary channel adjustment response (Figure 5.4, Table 5.4).

Table 5.4 Imposed Changes Leading to Degradation

Imposed Changes	Source Inputs/ Boundary Condition	Stream Power Variables
Watershed Scale		
Climate (dry period)	Qs (-)	
Stormwater (hydrology)	Q (+)	D (+)
Dams/Diversions (upstrm)	Qs (-)	
Bridges/Culverts (upstrm)	Qs (-)	
Reach or Local Scale		
Channel Realignment		S (+)
Dredging/Mining		D (+)
Berming/FP Encroachment		D (+)
Bed and/or Bank Armoring	Resistance of bank/bed (+)	

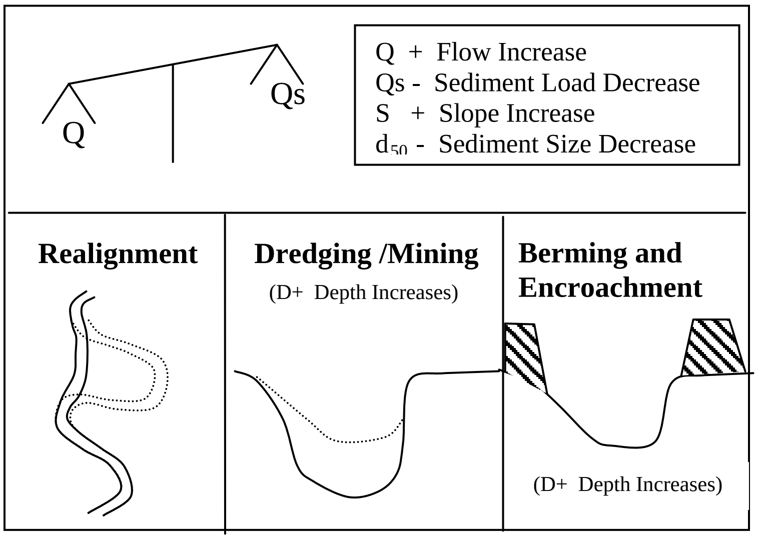


Figure 5.5 Reach scale changes leading to degradation

Indicators of Degradation: The above table gives a list of parameters and the specific response changes in those parameters that are indicative of channel degradation. Where management activities have changed reach-level planform and profile geometry see the Parameter Table (5.10) on the Planform Change sheet under the increased slope scenario. The changes in channel geometry, sediment, and fluvial process anticipated as a result of channel degradation are listed in Table 5.5 and illustrated in Figure 5.6.

Table 5.5 Parameter Changes Indicative of Degradation

Cross-Section Response	Change	Reference
Entrenchment Ratio	Approaches 1	Rosgen (1996)
Bank Height Ratio	+	Rosgen
Area	+	VT HGC
Depth	+	VT HGC
d50surface/d50subsurface	Approaches 3	Bunte and Abt
Entrainment Depth Ratio	< 1	
$d_{threshold}$ / $d84_{reference}$	+	
d50	+	
BEHI (Bank Erosion Index)	(+)	
Profile - Local Response	**Change**	**Reference**
Slope	+	
Nickpoints / Headcuts	Present	

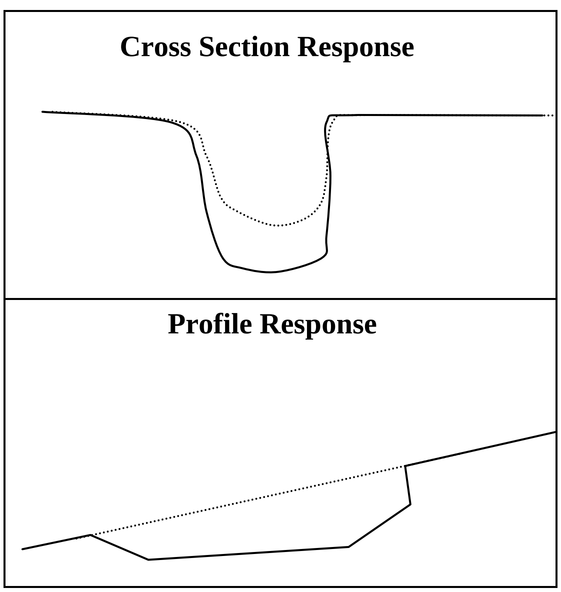


Figure 5.6 Degradation as Primary Response

Probable Secondary Adjustments: The degraded channel is capable of containing larger discharges. The channel experiences greater erosive forces and down-cuts until the bed materials are coarser and/or more resistant to erosion than the bank materials. When bank materials are less resistant to erosion as compared to the bed materials, channel widening initiates as the most common adjustment to immediately follow degradation (see widening).

Aggradation

Imposed Changes: The following changes and their subsequent effects on source variables and stream power factors often lead to channel aggradation as the first, or primary channel adjustment process (Figure 5.6, Table 5.6).

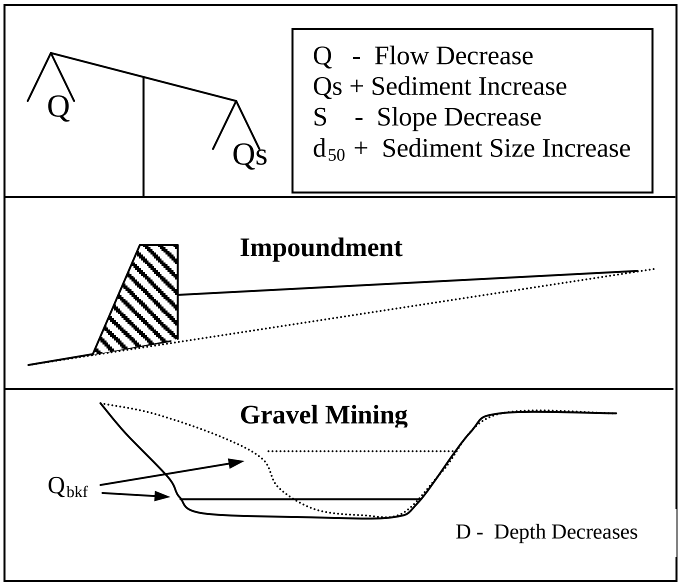


Table 5.6 Imposed Changes Leading to Aggradation

Imposed Changes	Source Inputs/Boundary Condition	Stream Power Variables
Watershed Scale		
Watershed Denudation	Qs (+)	
Flow Diversion	Q (-)	Q (-)
Reach or Local Scale		
Impoundment (dnstrm)		S (-)
Debris Jam (dnstrm)		S (-)
Dredging/Gravel Mining		D (-)

Figure 5.7 Changes leading to aggradation

Indicators of Aggradation: Table 5.7 lists the parameters and the specific changes in those parameters that are indicative of channel aggradation. The changes in channel geometry, sediment, and fluvial process anticipated as a result of channel aggradation are listed in Table 5.7 and illustrated in Figure 5.8.

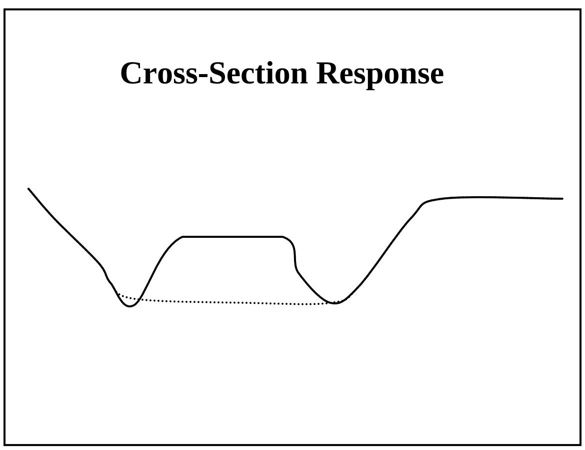


Figure 5.8 Aggradation as primary response

Table 5.7 Parameter Changes Indicative of Aggradation

Cross Section Response	Change	Reference
W/D Ratio	>24	Rosgen (1996)
D by D.A.	(-)	VT HGC (2001)
XS Area	(-)	VT HGC (2001)
d50surf/d50sub	Approaches 1	Bunte and Abt (2001)
Entrainment Depth Ratio	> 1	
$d_{threshold}$ /$d84_{reference}$	(-)	
d50	(-)	
BEHI (Bank Erosion Index)	(+)	
Profile Response	**Change**	**Reference**
Local Slope	(-)	

Probable Secondary Adjustments: Depending on the resistance to erosion of the channel banks and floodplain the most probable adjustments to follow aggradation are channel widening, meander extension and channel avulsion (see widening and planform change). Where the build-up of sediment occurs in the mid-channel area, flows are split and concentrated against both banks. Channel widening results from the erosion caused by increases of near-bank shear stress against both banks. The build-up of sediment on point bars can result in an increase in shear against the opposite bank and an accelerated rate of bank erosion, meander extension and planform adjustment.

Widening

Imposed Changes: The following watershed and local changes and their subsequent effects on source variables and stream power factors often lead to channel widening (Figure 5.9, Table 5.8). Typically, widening occurs as an adjustment process that follows degradation or aggradation. Widening can, however, be seen as an initial response to imposed changes. Widening can occur in the absence of degradation, for instance, when a) flows are increased or b) the sediment supply is decreased, and the bed is composed of materials that are more resistant to erosion than the sediments and materials in the point bars and stream banks.

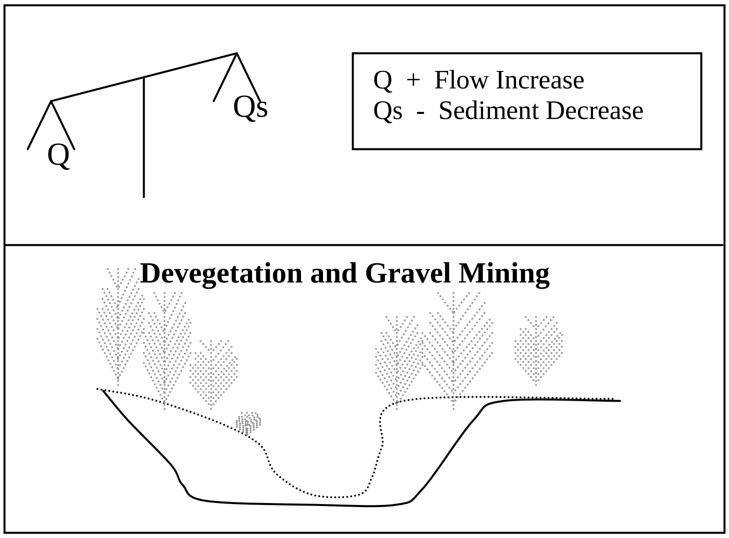


Figure 5.9 Changes leading to widening

Table 5.8 Imposed Changes Leading to Widening

Imposed Changes	Change in Source Inputs/Boundary Condition	Stream Power Variables
Watershed Scale		
Climate	Q (+/-)	
Stormwater	Q (+)	
Dams/Diversions (upstrm)	Qs (-)	
Bridges/Culverts (upstrm)	Qs (-)	
Reach or Local Scale		
Devegetation of channel banks	Bank Resist. (-)	
Dredging/Gravel Mining		D (-)

Indicators of Widening: Table 5.9 lists parameters and the specific changes in those parameters that are indicative of channel widening. The changes in channel geometry, sediment, and fluvial process anticipated as a result of channel aggradation are listed in Table 5.9 and illustrated in Figure 5.10.

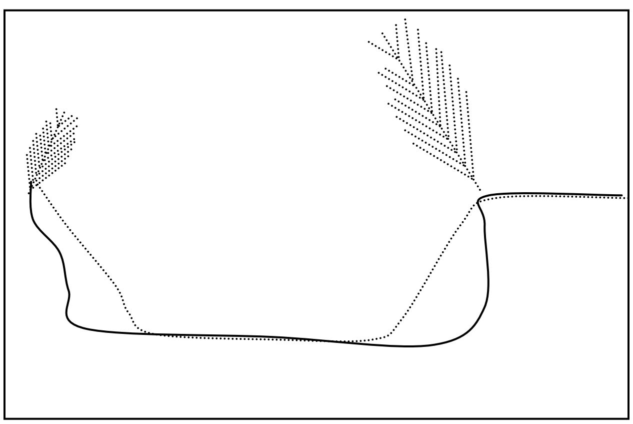


Figure 5.10 Widening as primary adjustment

Table 5.9 Parameter Changes Indicative of Widening

Cross Section Response	Change	Reference
W/D Ratio	(+) beyond 24	Rosgen (1996)
Width by DA	(+)	VT HGC (2001)
Area by DA	(+)	VT HGC (2001)
Sinuosity	(-)	
BEHI (Bank Erosion Index)	(+)	

Probable Secondary Adjustment: The affect of widening is a decrease in stream power at the cross section for all flows. Where the sediment supply has not been significantly reduced, channel aggradation is the most common adjustment to follow widening (see aggradation). Sediments may begin to build up in the channel in a pattern quite different than what existed prior to the widening process, possibly leading to planform adjustments (see planform).

Planform Change or Adjustment

Imposed Change vs Adjustment: Planform changes are often directly imposed during management activities such as channel re-alignment and dredging. Planform adjustments may occur as secondary or tertiary responses to degradation, aggradation and widening. For instance, planform changes may be an observed secondary response in a reach that is aggrading. Whether planform change is imposed or is the response to another adjustment process, the consequent increase or decrease in channel slope and its affects on stream power are primary considerations.

Imposed Planform Changes: Channel planform changes are often imposed to accommodate land use or flood flows and most commonly result in an increase in channel slope**.**

- **Re-alignment, Channelization and Mining (a slope increase):** Management activities that alter planform usually involve straightening and armoring the path of the stream. Bank armoring prevents planform adjustment back to the original channel geometry, leading to adjustments in cross section such as aggradation or degradation. Eventually these adjustments compromise the armoring, and planform adjustment will ensue. Table 5.10 lists the values of planform parameters that result from imposed changes that have increased channel slope.

Planform Adjustment: A planform adjustment that comes about in response to a preceding adjustment or disturbance is an indication of a decrease or increase in sediment transport capacity. Such a change of transport capacity can result from changes in slope and/or dimension, an increase in sediment load, or a combination of the two. Regardless of the cause, the planform adjustment process can generally be described as follows.

- **Meander Extension (a slope decrease):** A deficiency in transport capacity or competency will lead to aggradation. Often this aggradation occurs in the form of point bar growth, which subsequently triggers meander extension. As the meander migrates laterally the slope of the reach is decreased which further decreases transport competency.
- **Chute or Neck-Cutoffs and Channel Avulsions (a slope increase):** At some point during lateral meander migration, sediment deposition leads to a damming or back water effect, and a planform adjustment occurs in the form of a channel avulsion. The result of a channel avulsion is typically increased stream slope.

Indicators of Planform Change or Adjustment: Table 5.10 gives expected adjustment direction and ranges of values for various planform parameters and processes (illustrated in Figure 5.11). Comparing the existing values of planform parameters with reference conditions and the ranges presented here will help determine if a planform change has occurred.

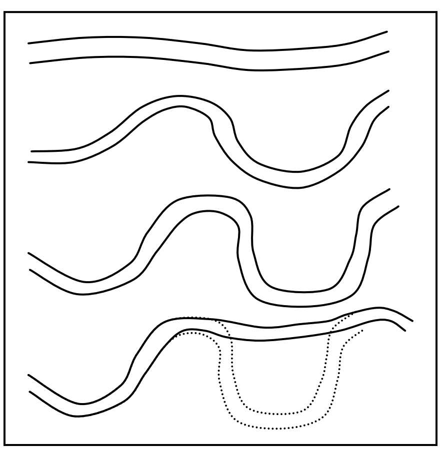


Figure 5.11 Common planform adjustment sequence

Table 5.10 Parameter Changes Indicative of Planform Change/Adjustment

Planform Parameters	Slope Increase	Slope Decrease	Reference
Bend Length	(-)	(+)	
Radius of Curvature	(+)	(-)	
Wavelength	(+)	(-)	
Belt Width	(-)	(+)	
Sinuosity	(-)	(+)	
Belt Width/W_{bkf}	<6	>6	Williams
Wavelength/W_{bkf}	>10-14	<10-14	Williams
Radius/W_{bkf} Ratio	<2.5-3.2	>2.5-3.2	Williams

Succeeding Adjustments: The adjustments to follow a planform change depend upon the preceding adjustment and the result of the planform change. If the planform change results in a channel slope that does not create the stream power necessary to transport the bed load the succeeding cross sectional adjustment will be aggradation. If the Planform adjustment results in a channel slope that creates an excess of stream power in the reach the succeeding cross sectional adjustment will be degradation, widening, or both.

5.4 STREAM GEOMORPHIC ASSESSMENT SUMMARY

Based on the Phase 2 assessment and the analysis of Phase 3, Steps 5.1 through 5.3 data, summarize in the Stream Geomorphic Assessment area of the River Location and Description worksheet of the River Morphology DMS spreadsheet and database:

- Reference stream type – Rosgen and Montgomery-Buffington classifications (see Appendix I);
- Existing stream type – Rosgen and Montgomery-Buffington classifications (see Appendix I);
- Site condition rating – the degree to which the existing condition of the site has departed from its reference condition (see definitions of reference, good, fair, or poor in Program Introduction);
- Site sensitivity – whether the site has low, moderate, high, or extreme sensitivity to further disturbance;
- Site channel adjustment processes – how the channel may be adjusting to achieve equilibrium through the processes of degradation, aggradation, widening, or planform; and
- Stage of channel evolution – through what stages of channel evolution are these adjustments occurring (F Stage and D Stage Models described in Appendix C)

A table titled "verification remarks" is also provided in the Stream Geomorphic Assessment Section of the DMS worksheet for the assessor to record why the Phase 3 survey results either confirmed or altered the Phase 2 stream geomorphic assessment results.

Phase 3 Quality Assurance Protocol

After completing all or parts of Steps 1 through 7 of the Phase 3 Stream Geomorphic Assessment Handbook, you should complete the Quality Assurance Data Sheet in Appendix A and enter the information in the Phase 3 database. Use the following protocols in completing the QA Data Sheet.

QUALITY ASSURANCE WORKSHEET

QA Officer: The name of the project quality assurance officer.

ANR QA Reviewer: The ANR Stream Geomorphic Assessment Program member serving as the quality assurance reviewer for project data will conduct the State QA review.

Training: Indicate whether an ANR sponsored training was received by one or more members of the assessment team:

Field Survey Protocols – Training on the completion of Steps 1 – 3.
Data Analysis Protocols – Training on the use of the Phase 3 Data Management System and the Phase 3 database.
Quality Assurance (QA) – Specialized training to complete quality assurance reviews.

Phase 1 Assessment: Indicate whether a Phase 1 assessment of the watershed was completed and used in the geomorphic assessment of the Phase 3 site.

Phase 2 Rapid Assessment Completed: Indicate whether a Phase 2 Rapid Assessment (Field Notes and RGA) were completed on the Phase 3 survey site.

Exclusive Use of Protocols and Database: The Vermont ANR Handbooks are one of many different geomorphic assessment protocols that have been published by agencies, organizations and private companies. Indicate whether the ANR protocols were used exclusively, and if not, what other protocols were used. If the protocols are sufficiently divergent from the ANR protocols, data will not be entered into the State Stream Geomorphic Database.

Tools Used to Collect Data: Transcribe the information about the tools and survey equipment and other tools used to complete the survey assessment from the field forms.

Confidence Level: Using the following definitions, circle the level that best describes the confidence that the assessment team has in the Phase 3 data collected for each Step in the protocols:

Low to Moderate – Unsure of field and data analysis protocols and/or used field equipment for which there was little prior experience.
Moderate – Understood and followed Phase 3 Protocols; some prior experience with river survey equipment and techniques; some experience with use of survey data analysis techniques in reach-scale problem solving for river management projects.
Moderate to High – Understood and followed Phase 3 Protocols; frequent prior experience with river survey equipment and techniques, frequent experience with use of survey data analysis techniques in reach-scale problem solving for river management projects.
High – Understood and followed Phase 3 Protocols; extensive prior experience with river survey equipment and techniques, extensive experience with use of survey data analysis techniques in reach-scale problem solving for river management projects.

Data Completed – Date the Protocol Step was initially completed.

Data Updated – Date the Phase 3 data for a Protocol Step was revised based on new or additional field assessments.

Date of Local QA Team Review - Date a quality assurance review of the Phase 3 data for a Protocol Step was completed by the local QA team leader.

Date of State QA Team Review - Date a quality assurance review of the Phase 3 data for a Protocol Step was completed by the State QA team member.

Comments – Any comments relaying details about the tools and materials that were used or why a confidence level was selected.

References:

1. Birkeland, P.W. 1984. Soils and geomorphology: Oxford University Press, New York, 372p.

2. Bunte, K. and S.R. Abt. 2001. Sampling surface and sub-surface particle-size distributions in wadable gravel- and cobble-bed streams for analysis in sediment transport, hydraulics, and stream bed monitoring. Gem. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

3. Center for Watershed Protection *et. Al.* 1999a. Impact Assessment of Instream Management Practices on Channel Morphology, Prepared for Vermont Geological Survey. Vermont Agency of Natural Resources. Waterbury, VT.

4. Center for Watershed Protection et.al. 1999b. Watershed Hydrology Protection and Flood Mitigation Project Phase II-Technical Analysis. Stream Geomorphic Assessment. Prepared for Vermont Geological Survey. Vermont Agency of Natural Resources. Waterbury, VT.

5. Center for Watershed Protection. 2000. Memo No 6; Results of Biomonitoring/Watershed Imperviousness Assessment. Prepared for Vermont Geological Survey.

6. Compton, R.R., 1985, Geology in the Field: Wiley, 398 p.

7. Cruden, D.M., and D.J. Varnes. 1996. Landslide types and processes: pp.36-75 *in* Turner, A.K., and Schuster, R.L., eds., Landslides: Investigation and mitigation: National Research Council, Transportation Research Board Special Publication 247, 673p.

8. Dunne, T., and L. Leopold. 1978. Water in Environmental Planning, W. H. Freeman and Co.

9. Environmental Protection Agency. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers 841-B-99-002.

10. Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration Manual: Principles, Processes, and Practices.

11. Fishenich, C., and H. Allen. 2000. Stream Management, Water Operations Technical Support Program, US Army Corps of Engineers, Environmental Laboratory.

12. Fishenich, C. 2000. Glossary of Stream Restoration Terms. USACE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg, MS 39180

13. Harrelson, Cheryl C., C.L. Rawlins, John P. Potyondy. 1994. Stream Channel Reference Sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

14. Hornbeck, J. W., M. Adams, et.al. 1993. Long-term Impacts of Forest Treatments on Water Yield: A summary for Northeastern USA. Journal of Hydrology, V150 p. 323-344.

15. Koler, T.E. 1994. Soil and rock classification for engineering analysis and design: Figure 3.B.2 *in* Hall, D.E., Long, M.T., and Remboldt, Slope stability reference guide for National Forests in the United States: U.S. Department of Agriculture, Forest Service, EM-7170-13, v.1, 321p.

16. Lane, E.W. 1955. The Importance of Fluvial Morphology in Hydraulic Engineering, American Society of Civil Engineering, Proceedings, 81, paper 745: 1-17.

17. Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Company. San Fransisco.

18. Montgomery, D., and J. Buffington. 1997. Channel-reach Morphology in Mountain Drainage Basins. Geological Society of America Bulletin; v. 109; no. 5; pp 596-611

19. Rosgen D. 1996. Applied Fluvial Morphology. Wildland Hydrology Books, Pagosa Springs, Co

20. Schoeneberger, P.J. 1998. Field book for describing and sampling soils: Natural Resources Conservation Service: Lincoln, Nebraska, Version 1.1.

21. Schumm, S. 1984. The Fluvial System, John Wiley and Sons, New York.

22. Simon, A. 1989. The Discharge of Sediment in Channelized Alluvial Streams. American Water Resources Association. Water Resources Bulletin; Vol. 25, No. 6.

23. Waters, M.R. Principles of geoarchaeology: a North American perspective: University of Arizona Press, Tucson, 398p.

24. Williams, G.P. 1986. River Meanders and Channel Size. Journal of Hydrology 88:147-164.

25. Wolman, M.G. 1954. A Method of sampling coarse bed material. American geophysical Union, Transactions, 35:951-956.

Notes