New Hampshire Geological Survey
New Hampshire Department of Environmental Services
Implementation of Phase 2 Geomorphology Assessments
Version 1.0
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The Phase 2 portion of the fluvial geomorphology assessment program is designed to collect field data on river reaches that have been deemed important for survey through the screening process in the Phase 1 portion of the assessment. Ultimately, the purpose of these assessments is to obtain reliable data regarding the present state of river channel physical condition, enabling the delineation of Fluvial Erosion Hazard (FEH) zones, and an overall greater understanding of the existing physical condition of the river under study. The New Hampshire implementation of Phase 2 fluvial geomorphology assessments are based upon multiple versions of the Phase 2 protocols developed by the River Management Program at the Vermont Agency of Natural Resources (for example, their latest version dates to 2009). Small amendments have been made to these protocols to adopt them for use in the conductance of fluvial geomorphology assessments in New Hampshire. Hence, Phase 2 assessments in New Hampshire are typically referred to as the New Hampshire implementation of the Vermont Phase 2 fluvial geomorphology assessment protocol. The purpose of this framework guidance is to document, and provide brief instructions on, these modifications.

Phase 2 assessments provide a level of detail necessary to more accurately identify public safety risks from adjusting rivers through the delineation of river erosion hazard zone corridors, while simultaneously identifying less disturbed reaches, than is able to be achieved during the Phase 1 assessment. As rapid geomorphology assessments, one mile of river or stream can typically be evaluated using these protocols in about one day.

The Phase 2 procedure involves the identification of both naturally occurring and anthropogenically induced features in rivers and lands directly adjacent to them; stream channel form and condition; condition of riparian banks and buffers; and, overall potential for channel adjustments, as provided in the published Vermont Phase 2 protocols (Vermont Agency of Natural Resources, 2007, 2009). Some revisions and modifications have been made, and we have designed a couple of optional add-ons to the protocol, which are available based upon the specific needs of a project, and are provided here.

Vermont expanded upon their protocols in the 2009 version, by adding additional measurement components to the stream channel (Section 2); riparian banks, buffers and corridors (Section 3); and the rapid habitat assessment (Section 6). While these expanded versions of the protocols are available and can be used for assessments in New Hampshire, in general, New Hampshire has adopted the expanded 2009 version modifications of Section 2 (with minor comments as provided below), while continuing use of the 2007 versions of Sections 3 and 6 (remainder of the protocol remains as is). A document is available that collates the forms from these two versions into one for this purpose. All further comments below are provided under this assumption.

Equipment and materials to be used in New Hampshire Phase 2 assessments

Measuring tape
This is a flexible form of ruler that is made of a non-stretchable material, preferably fiberglass or steel, with linear measurement capability of no less than 100 feet, incremented in tenths ***and hundredths*** of feet, ***not*** inches.

Rangefinder
This allows the user to measure the distance to an object of interest using a laser beam with the measurement reported on an electronic readout display, that is capable of measuring accurate distances up to 165 feet away.

Digital Camera
This should be a unit that takes photographs as digital images and stores them on a data card for later download to other electronic media, and that is capable of zooming into features of interest. The digital camera shall also be GPS-enabled and capable of collecting and storing the latitude/longitude point at which a photograph is collected, and for download of points to an electronic medium.

Measuring rod
A survey grade leveling rod that contains a measuring ruler scale that is capable of extending up to 18 feet in height, with scale increments in tenths ***and hundredths*** of feet, ***not*** inches.

GPS unit
This should be capable of collecting accurate latitude/longitude information to a horizontal accuracy equal to or less than 2 meters. A separate GPS unit can be used as a supplement to the use of a GPS-enabled digital camera to improve precision where necessary.

Compass
This provides a reading of the direction in a frame of reference in relation to the surface of the Earth. Such a unit displays cardinal directions and azimuth direction and may be in either non-digital or digital form.

MODIFICATIONS AND CLARIFICATIONS TO EXISTING VERMONT PHASE 2 PROTOCOLS FOR USE IN NEW HAMPSHIRE

Segment I.D. parameter – top of field forms
When using paper forms, the Segment I.D. parameter should be filled in with the reach number of the reach that is being assessed. For those reaches that have been divided into segments, the reach number and the segment letter (i.e., Reach 5B) should be written in the space.

Flood history known – top of field forms
Indicate (yes or no) whether you are familiar with the last occurrence(s) of major flood(s) in your assessment reach. If you circle "yes," then use a small section of the space provided for site sketches to specify when the last flood occurred. Alternatively, if you feel sufficient space is available near to this parameter on the front page of the forms, then it may be written there.

Segment length – top of field forms
The reach lengths should be available from the Phase I GIS information. If the assessment that is underway is for a segmented section of a reach, then the segment breaks will be placed into GIS later in the office. In this case, the segment length value may be filled in later in the office once segments determined in the field are placed into GIS and the segment lengths determined.

Sketches and Photographs
For the purposes of the New Hampshire implementation of the Phase 2 protocols, the use of sketches is optional, and is at the discretion of those conducting the assessment. Any sketches that are made during a Phase 2 assessment should be made in accordance with the descriptions provided in the Vermont Phase 2 protocols.

For performance of Phase 2 data collection in New Hampshire, a digital photographic log of the river being assessed will be collected. The Standard Photo Log form used to document pictures in the Vermont Phase 2 protocols is not required in New Hampshire, unless the digital camera is at a location where a GPS point is not able to be obtained, in which case the feature shall be documented in writing and the location noted. Collect photographs at each cross-section, including individual views upstream, downstream, at the right bank and at the left bank, while ensuring that the cross-section with measuring tape stretched across the channel is incorporated into at least two photographs. Collect photographs at all river features identified as components of the Feature Indexing Tool (FIT) within the Vermont Phase 2 protocols, and any features added to FIT within the New Hampshire implementation of the protocols. Any such additions are described below.

Directionality of photographs
If the digital camera used possesses the capability to record the compass directionality of photographs, then use this functionality for all photos. If the digital camera does not possess the capability to record the compass directionality of collected photographs, then for photographs solely of cross-sections, document the picture number and appropriate view for each photograph collected.

Use of GPS units
Use a GPS unit to capture the spatial location of all features that are components of FIT and locations of cross-sections.

Vermont Protocol Step 1.3 – River Corridor Encroachments
To identify encroachments within the river corridor under this section, consider the area of land within the valley walls to be the corridor of interest, as opposed to an area of land equal to 8 times the channel width.

Vermont Protocol Step 1.5 – Confinement
If it is impractical to measure the valley width at a location, GPS points can be collected that adequately location the valley wall. Later, using GIS, the valley width can be estimated using the field-collected GPS points that delineate each side of the valley wall and recorded on the field form.

Recording of Vermont Protocol Step 2 Data
The cross-section data collected in Step 2 will be entered into the Vermont Phase 2 Survey Datasheet, as modified by the Vermont Department of Environmental Conservation. Values for ratios determined for incision, width/depth and entrenchment for each reach shall be those output from the automatic calculations incorporated into the datasheet. GPS points will be collected at the location of all cross-sections. If at all possible, two cross-sections should be collected per river reach or segment. If a reach or segment is encountered in which an additional third cross-section will allow refinement of the ability to type the stream within a reach or segment, then the addition of such a cross-section can be incorporated. In the event that a river reach or segment is too deep for wading, collection of cross-section data within the bankfull channel from a boat or canoe can be an option. If a decision is made to collect data in a non-wadeable reach using a boat (or canoe), it should be affixed to a tagline set across the channel at the desired cross-section. Measuring rod readings can then be collected along the cross-section from the boat (or canoe) affixed to the established tagline.

Additionally, in those situations where more than one cross-section is collected in a reach or segment, the specific cross-section that is ultimately used for typing of the reach or segment should be noted on the field form to the right of the grey box entitled “2. Stream Channel.”

Vermont Protocol Step 2.3 – Bankfull Mean Depth
Once the measuring tape is stretched across the bankfull channel at a cross-section, a minimum of 10 bankfull depths should be collected evenly spaced intervals across the channel, as described in the Vermont Phase 2 protocols. Bankfull depths should also be measured at additional locations on the established cross-section where a change in the cross-section profile occurs that would otherwise not be captured using the 10 measurements. Such changes observed in the cross-section profile at which additional bankfull depth measurements should be collected include when the character of the bed material changes from one dominant size class to another, based upon experienced field observation, and where change in bed elevation is not gradual, such as a sharp drop or rise in bed elevation on the cross-section. Where a cross-section traverses a major feature, such as a bar or exposed bed, measurements shall also be taken of the start, middle and end of such feature.

Vermont Protocol Step 2.9 – Sinuosity
The channel stream centerline delineation combined with the valley length information from the Phase I portion of these protocols can be used to determine sinuosity.

Vermont Protocol Step 2.12 – Bed Substrate Composition
The procedure employed will be as indicated in the Vermont Phase 2 protocols. In the event that the river reach is too deep for wading, a sampler can be operated from a boat or canoe in straight reaches of the channel away from the influence of meander bends and the dominant bed particle size can be estimated based upon the visual assessment of the collected sample.

In the vast majority of reaches, one pebble count to be able to characterize the overall bed sediment type in a reach should be sufficient. Collect a pebble count at more than one cross-section within a reach if the substrate on the bed is considerably different than the first pebble count that is collected, and if there is no other reason to break a reach into additional segments.

In order to support the fact that the finer scale data achieved can be used to construct more accurate sediment gradation curves, all pebbles collected on the bed should be measured and placed within the pebble count categories provided in the "SGA Phase 2 Survey Datasheet," modified by the Vermont Department of Environmental Conservation. The ranges are also provided in Table 1 at the end of this document. A separate worksheet is available for field tally of this information, which is included in the set of field forms for the New Hampshire implementation of the protocols.

For the embeddedness section of this step, the measurement of individual particles to allow completion of this task is not required. The percent embeddedness for the channel and the margin may be visually estimated. Substrates that are dominated by sand or finer particle sizes should be counted as 100% embedded.

Vermont Protocol Step 2.13 – Average Largest Particle
It may be difficult, or not possible, to obtain this information in reaches or segments where the dominant bed particle size is sand or finer, or the reach is impounded. In these cases, this step may need to be omitted. If this step needs to be omitted, mention this in the notes section with a two or three phrase descriptor as to the nature of the omission.

Vermont Protocol Step 5.1 – Depositional Features (bars)
As encountered in the field while walking a reach or segment, mid, point, side, diagonal, delta and island bars should be tallied and their tallies recorded on the Phase 2 tally sheet. However, the presence of bars should be recorded as a FIT feature, in a manner commensurate with how the other FIT features in the protocol are recorded.

Valley Wall Field Verifications
Before field survey for a reach, those who will be conducting the survey should examine the delineated valley walls for a project and identify those sections of wall in which discrepancies between the delineation and the real location may exist. Such locations

should be targeted for field-based identification of the actual location of the valley wall. It is critical that the locations of valley walls be verified in the field during the assessment, as these locations frequently bound the final FEH zones. The locations of valley walls should be verified using GPS at all locations for which cross-sections are collected in each reach. Those conducting a Phase 2 assessment should have a hardcopy or digital GIS map of the valley walls available while in the field, so that while walking the reach, visual evaluations of the match between the locations of the valley wall in the field compared to the map can be made.

There are a couple of ways in which the locations of the valley walls may be verified. GPS points can be collected at the location of the valley wall in the field. However, tree coverage issues in New Hampshire, particularly in summer, can limit the accuracy of GPS units at those locations in which the valley walls are typically found. Alternatively, a GPS point can be collected at the streambank and the distance and compass bearing to the valley wall can be measured and recorded. These valley wall verifications should be collected not only at locations where discrepancies between the delineated and actual valley walls are found to exist, but periodically throughout the walk of a reach or segment as well.

OPTIONAL ADD-ON COMPONENTS TO EXISTING VERMONT PHASE 2 PROTOCOLS

Depending on the circumstances and goals of a particular project, the following procedures can be added, or be a supplement, to the existing Vermont Phase 2 protocols. These optional add-ons are not designed to be used with every assessment as they are not modifications intended to be universally applied to every Phase 2 assessment conducted in New Hampshire. However, some rivers present situations in which alternatives are sometimes required. These add-ons can be used, therefore, on a case-by-case basis.

More detailed protocol for cross-section collection where coupling of bed morphology readings to established datum is required

In most circumstances for these rapid Phase 2 assessments, the collection of bed elevation information coupled to the bankfull elevation is sufficient. However, if it is desired to couple the bed elevations to an established datum, the procedure outlined below may be used. This procedure may also be used if it is desired to establish a cross-section for return to the cross-section at a later date for resurvey to allow documentation of change over time. A local benchmark with arbitrary elevation can be assigned to a benchmark placed for this purpose. This add-on does not have to be used for the entire project in which an assessment is conducted, and can be applied to any river reach for which this more detailed data is desired.

Within a reach or segment for assessment, for the cross-sections assessed, an automatic level can be used for survey of each cross-section, and elevations recorded on each cross-section are tied to an established datum of known elevation which has been established in an area. If the cross-section for survey on a river is placed such that no proximal benchmark of known elevation already exists, the elevation will need to be transferred

from a nearby or temporary benchmark that is established near the cross-section, which serves as the base elevation for conduct of the cross-section survey. Along the cross-section, collect elevation readings using the automatic level and measuring rod at 0.5 foot intervals across the channel. In between each 0.5 foot interval, if the character of the bed material changes from one dominant size class to another, or where a change in bed elevation is not gradual, such as a sharp drop or rise in bed elevation, then a reading at such a feature should be collected. Documentation of these features is important if the purpose of the survey is to return in the future to evaluate small-scale changes in the bed morphology. With this add-on, this level of measurement applies to the floodplain and adjacent terraces on the cross-section within the spatial extent that is defined on a river or stream to received this more detailed survey.

Large woody debris (LWD) assessment and Rapid Habitat Assessment (RHA)
For a particular project, a situation may arise in which it is desired to not only count the number of pieces of LWD found within a reach or segment, but to collect additional information sufficient so that the density of LWD within a reach or segment may be calculated later after the field visit is completed. Calculation of the total density of LWD for a reach or segment may be completed through summation of the individual densities (calculated for each piece of LWD) for a reach/segment or other spatially defined extent of river.

When using this add-on, those conducting a reach assessment should use the latest version of the RHA in the Vermont Phase 2 protocols. The large woody debris and jams section of this assessment procedure are omitted with this add-on, and are replaced with the instructions provided here. In this add-on, those conducting the assessment measure the diameter of each end of each piece of large woody debris, in addition to the length of each piece of debris that is encountered during the assessment within a defined reach or segment. For a piece of LWD to qualify for measurement, it should meet the following characteristics:

- be positioned in, or suspended over, the bankfull width of the channel;
- have a minimum length of 6 feet;
- a minimum diameter at the wider end of 12 inches;
- and minimum diameter at 6 feet out from the wide end of 6 inches.

Record the position of each piece of large woody debris with a GPS unit, and code as a large woody debris feature. Classify accumulations of ten (10) or more pieces of large woody debris found in the same location as a debris jam and tally accordingly. In these cases, the sizes of the individual pieces should only be estimated given the practical limitation of seeing within such jams. Record the position of each debris jam so measured with a GPS unit, and code as a debris jam feature. The diameter at each end and the length of each piece should be recorded, either electronically on a field tablet, or though the field assessment form designed for this exercise (Appendix A). For any large woody debris piece that has a length longer than the bankfull width, the checkbox for this should be selected beside the recorded length. At each piece of large woody debris encountered, the vicinity should be quickly checked for the presence of root mats, whether there is an

upstream sediment deposit, any burial of debris in the streambed or protruding rocks, as such features can act to keep wood anchored into the channel for a longer period of time. If any such features are present, the appropriate checkbox should be selected on the field form for this exercise. If an electronic tablet is chosen for the recording of field data, then it should be designed to enable the incorporation of all the parameters described here and on the field form in Appendix A.

When the survey is complete, the data can be placed into a GIS shapefile of the points that correspond to the pieces of LWD or debris jam assessed, including the data associated with each piece of LWD or debris jam. Given that the measurements and GPS locations are available, the LWD data can still be tallied and placed into the appropriate ranking categories as provided in the Vermont Phase 2 protocols. If an electronic tablet has not been used for the collection of this data, collected data can be entered manually into a worksheet which has been developed for this purpose (NH FEH Appendix A Worksheet.xls) for the automated calculation of volumes.

Calculation of density of each piece of wood assessed
For each piece of wood assessed, using the values of the diameters at each end, the volume of the piece may be calculated using the equation for the frustrum of a paraboloid (Lienkaemper and Swanson, 1987):

$$Volume = \frac{\pi(D_1^2 + D_2^2)L}{8}$$

Where

π = 3.14
D_1, D_2 = Diameter at each end of piece
L = Length

These calculations can be performed automatically in the field if the data is recorded digitally and a device, such as a personal data assistant, is programmed to perform the calculation directly. Alternatively, the diameters at each end of the piece may be recorded manually for later calculation in a spreadsheet for input or appending to the LWD GIS shapefile.

Table 1. Pebble count particle size classification gradations for use in Step 2 pebble counts.

Pebble Size Class	Size Range (mm)		Size Range (inches)	
	Low	High	Low	High
Silt/Clay	0	0.062	0	0.002
Very Fine Sand	0.062	0.125	0.002	0.005
Fine Sand	0.125	0.25	0.005	0.010
Medium Sand	0.25	0.5	0.010	0.020
Coarse Sand	0.5	1	0.020	0.039
Very Coarse Sand	1	2	0.039	0.079
Very Fine Gravel	2	4	0.079	0.157
Fine Gravel	4	6	0.157	0.236
Fine Gravel	6	8	0.236	0.315
Medium Gravel	8	11	0.315	0.433
Medium Gravel	11	16	0.433	0.630
Coarse Gravel	16	22	0.630	0.866
Coarse Gravel	22	32	0.866	1.260
Very Coarse Gravel	32	45	1.260	1.772
Very Coarse Gravel	45	64	1.772	2.520
Small Cobble	64	90	2.520	3.543
Medium Cobble	90	128	3.543	5.039
Large Cobble	128	180	5.039	7.087
Very Large Cobble	180	256	7.087	10.079
Small Boulder	256	362	10.079	14.252
Small Boulder	362	512	14.252	20.157
Medium Boulder	512	1024	20.157	40.315
Large Boulder	1024	2048	40.315	80.630
Very Large Boulder	2048	4096	80.630	161.260
Bedrock				

References

Lienkaemper, G.W., Swanson, F.J. 1987. Dynamics of large woody debris in streams in old-growth Douglas-fir forests. *Canadian Journal of Forestry Research,* 17:150-156.

Vermont Agency of Natural Resources. 2007. Vermont Stream Geomorphic Assessment Phase 2 Handbook: Rapid Stream Assessment. Waterbury, Vermont.

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