Step 5: Channel Bed and Planform Changes

When disturbed, streams go through a series of adjustments to regain equilibrium with the flow and sediment supply of their watersheds. These adjustments often involve a change in planform (or meander geometry) to achieve a change in channel slope (or steepness). Some planform changes, such as channel avulsions and flood chutes, are easy to spot in the field, while others are more easily observed through an analysis of an air photo time series. Several Step 5 parameters involve looking for signs that the stream bed sediments are building up (aggradation) or being eroded away (degradation). These two adjustment processes occur when changes in channel dimension or slope are imposed on the channel or in response to changes in stream flow or sediment load.

5.1 BED SEDIMENT STORAGE AND BAR TYPES

Background

Sediment deposition and storage in stream channels is a part of the equilibrium condition of many stream types. The sorting and distribution of sediment into the bars of the equilibrium channel, concentrates flow, enhances sediment transport, and results in a diversity of habitat types. When a stream is out of balance, sediment accumulation may raise the elevation of the stream bed and result in the formation of point bars, mid-channel bars, or islands that accentuate vertical and lateral channel adjustments.

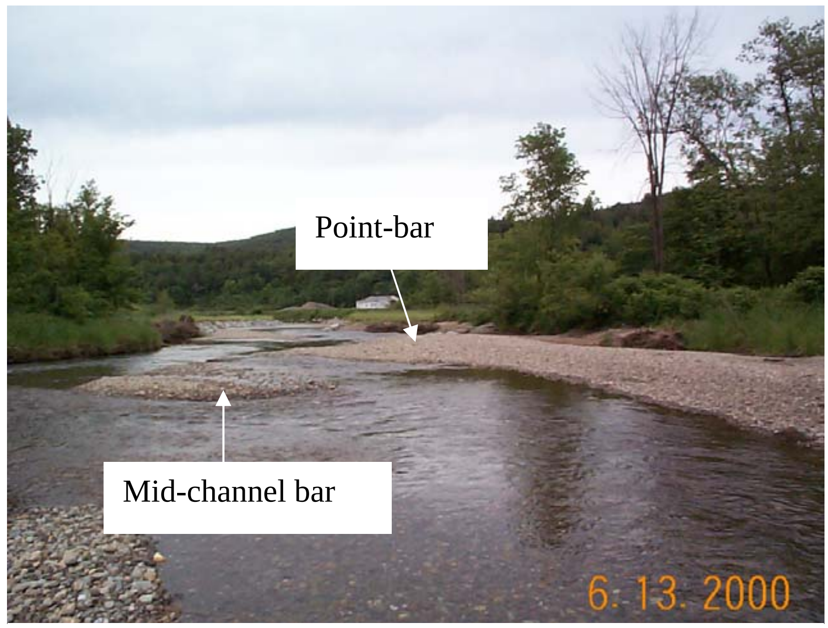


Figure 5.1 Mid-channel and point bars

Mid-channel bars are not attached to the banks and are generally found in straight reaches (Figure 5.1). They form as a result of the flow divergence that occurs around obstructions such as large boulders or rock outcrops or due to an over-widening of the channel. Unvegetated mid-channel bars indicate the bar has recently been formed and may be enlarging. The sediment source for these bars may be from bank failures, downcutting of the channel bed, or from upland sources, such as construction sites or road washouts.

Note there is one situation where the occurrence of a mid-channel bar(s) may not indicate problematic sediment deposition. Often a mid-channel bar will develop just downstream from where a tributary enters the channel as a result of sediments being delivered to the channel from the tributary. This is usually a localized deposition and may not indicate large-scale sediment deposition problems. If this is the only mid-channel bar or similar depositional feature you observe in the segment (or reach), then the segment is not likely being negatively affected by sediment deposition (see *Delta Bars* below).

Point bars are attached to a bank and are usually located on the inside curve of a channel bendway. Point bars are either devoid of vegetation or have only sparse non-woody vegetation usually covering less than 25 % of the bar surface area. Equal size, alternating point bars in a pool-riffle system may be a sign of equilibrium, while unequal size alternating bars and steep-faced bars may indicate channel adjustment.

Side (Lateral) bars are attached to a bank and are usually located on straighter segments of meandering streams or on stream types with very little sinuosity. Side bars are either devoid of vegetation or have only sparse non-woody vegetation usually covering less than 25 % of the bar surface area.

Diagonal (Transverse) bars are usually observed immediately upstream of meander bends that have been armored and/or truncated. The current running off the steep face of a diagonal bar flows towards the bank at an angle that is almost perpendicular to the bank, often causing excessive bank erosion.

Delta bars form where a tributary enters a mainstem river and deposits a load of sediment (Figure 5.2). Very large delta bars are indicators of the size, stability, and/or sediment load (natural or unnatural) of the tributary entering the mainstem. Large delta bars are not necessarily a sign of instability in the tributary, and may not necessarily cause channel adjustment in the receiving water. High gradient tributaries are usually important sources of coarse sediment for receiving waters.

Figure 5.2 Delta bar formed at the confluence of the First Branch of the White River and a small tributary.

Islands form as mid-channel features that remain stable at an elevation above normal high water such that they become vegetated. Islands are mid-channel features that have flow on either side during all but the very lowest flow conditions. They should not be confused with the vegetated lands that have the channel on one side and a flood chute on the other, the latter of which only carries flow during flood conditions. Islands may form and persist for different reason, including:

- They form as part of the deposition-erosion process associated with a braiding. "D" channels consist of many vegetated islands;
- They form as chute cut-offs, deepen, and persist in river systems that went through a dramatic shift in sediment supply. Many watersheds in Vermont have islands that formed as flood chutes when the rivers were clogged with sediment during severe deforestation at the end of the 19th century. In some systems, especially those where large dams were built, the sediment source was reduced dramatically over a short period of time leaving the islands in place

when stream power (and erosion) and sediment deposition were reduced. In other systems, the islands disappeared as deposition and erosion continued.

Evaluation

Indicate the number of each category of depositional feature types are present in the segment (or reach) based on the descriptions below. Very small and localized depositional features, such as a collection of fine gravels downstream of a large boulder, *should not* be considered in evaluating this parameter.

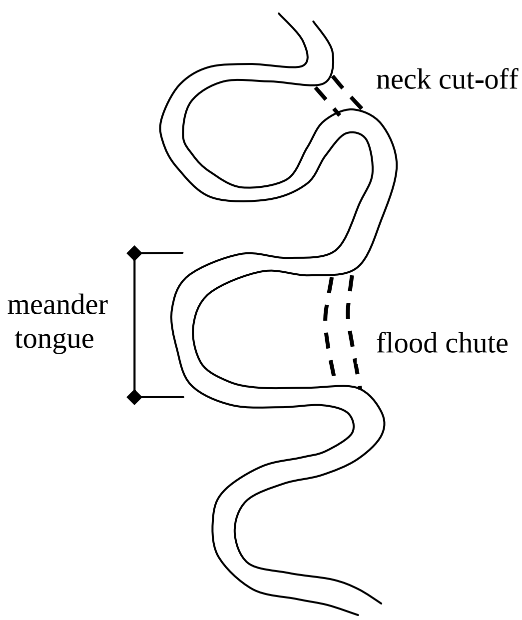
Menu

Mid-Channel	Sediment deposits in middle of channel with split flow
Point	Unvegetated sediment deposits located on inside of channel meander bend
Side (Lateral)	Unvegetated sediment deposits located along the margins of the channel in locations other than the inside of channel meander bends
Diagonal	Bars that cross the channel at sharp oblique angles, associated with transverse riffles
Delta	Sediment deposits where tributary enters mainstem channel, often fan-shaped
Islands	Well-vegetated mid-channel deposits of sediment
None	No deposits of sediment evident

5.2 FLOOD CHUTES, NECK CUT-OFFS, CHANNEL AVULSIONS, MIGRATION AND BRAIDING (FIT)

Background

Flood chutes, cut-offs, channel avulsions, major lateral migration and braiding (or bifurcation) are deposition-related features that strongly indicate the fluvial processes typical of response type stream reaches. Depending on the location and sediment regime of the reach within the watershed, these planform adjustments may be part of the equilibrium condition or associated with vertical adjustments and channel instability.



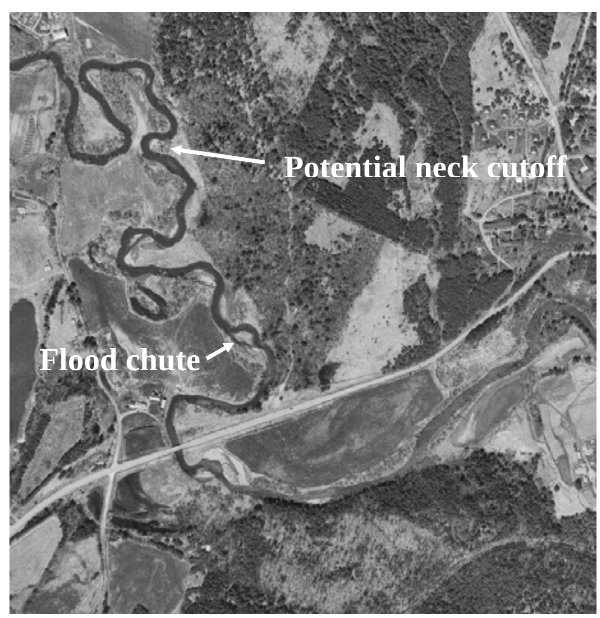


Figure 5.3 Aerial view of neck cut-offs and flood chutes that have or are about to result in channel avulsion.

A neck cutoff forms as two meanders migrate towards one-another and the neck of land between them is *about* to be cut off (Figure 5.3). Flood chutes occur when high flows form a channel across the base of the meander tongue (Pielou, 1998). An avulsion occurs when flood chutes and neck cutoffs become the main channel, completely abandoning the old channel. Sometimes a channel will avulse suddenly, without a neck cutoff or flood chute precursor. These sudden changes in stream channel locations are called channel avulsions. The old channels abandoned after the avulsion takes place look like dry rivers, or long, narrow wetlands, called oxbows.

Braided or bifurcated channels occur where the sediment supply is far in excess of the stream's ability to transport it. Braided channels may occur naturally where a stream transitions rapidly from a high to low gradient channel or where a channel has an extremely high sediment load due to natural erosion processes. They may also occur where human-induced erosion introduces a sediment load to a downstream location where the stream lacks the power to keep the sediment moving downstream. A high degree of sediment deposition may lead to multiple channels persisting even during low flow periods.

Evaluation
Indicate the number of flood chutes, neck cutoffs, channel avulsions, areas of major lateral migration or braiding / bifurcation within the segment (or reach).

Use the Feature Indexing Tool (FIT) in SGAT to document the downstream location of flood chutes, neck cut-offs, channel avulsions and braiding. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where flood chutes, neck cut-offs, channel avulsions and braining are noted.

5.3 STEEP RIFFLES OR HEAD CUTS (FIT)

Background
Steep riffles, as defined in these protocols, are typically associated with aggradation processes where a wedge of sediment drops out at some point along the channel (often at the head of bendways) and forms a steep face of sediment on the downstream side.

Head cuts are a sign of incision, or bed degradation, a lowering of the channel bed elevation through scour of bed material (Figure 5.4). As the water flows over a nick point in the channel bed, the water speeds up. The water that is falling down this steep slope has extra energy, and thus it digs away at the bed like a backhoe scooping its way upstream. The upstream movement of a headcut is stopped when it meets a grade control (i.e. bedrock, dam), or when the channel has re-established a gentler slope. Incision can

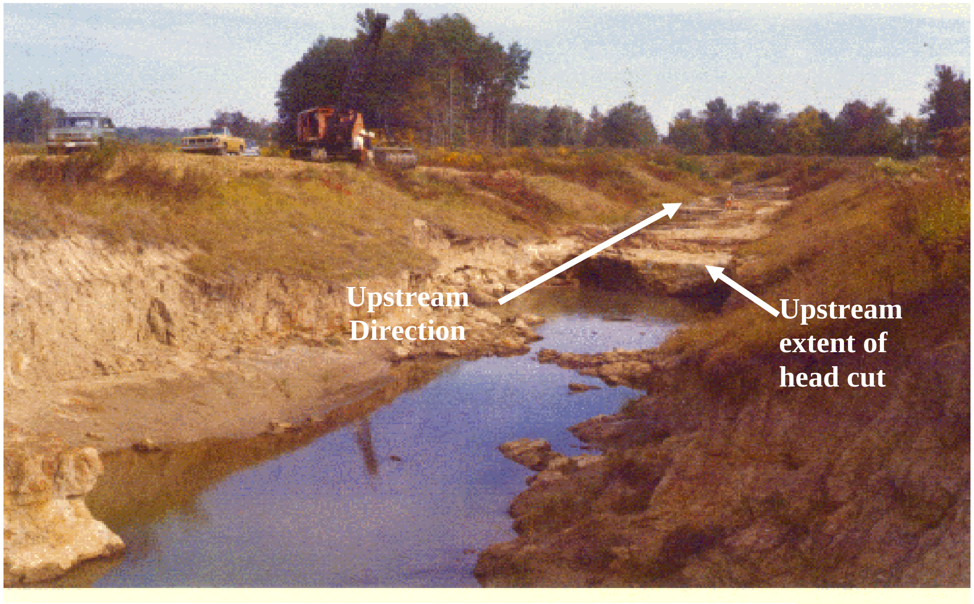


Figure 5.4 A head cut is a steep area in the streambed.

result in catastrophic (mass) bank failures and undermining of infrastructure near the channel, as streambeds have been known to lower tens of vertical feet along a mile length of stream. When a stream is incising in its valley, tributaries will also be affected. As the bed of the mainstem is lowered, headcuts will begin at the mouth of the tributary stream and move upstream "rejuvenating" the tributary stream and the valley through which it flows.

Evaluation
Record the number of head cuts and/or steep riffles, those features that are uncharacteristically steep (2-3 times greater slope than the average riffle within the segment or reach). Indicate "yes" or "no" as to whether headcuts are observed at the mouth of tributary streams that are likely to initiate tributary rejuvenation.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of head cuts and steep riffles. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where head cuts and steep riffles are noted.

5.4 STREAM FORD OR ANIMAL CROSSING (FIT)

Background
Vehicle or animal crossings (Figure 5.5) at the wrong location in the meander geometry of the stream may increase the chance that a stream will avulse, or cut a new channel during a storm event.

Evaluation
Note whether a ford is present in the segment (or reach), and *mark its location on the field map.*

Menu

Yes	A vehicle or animal crossing is evident at the stream site.
No	A vehicle or animal crossing is not evident at the stream site.

Figure 5.5 Cows crossing the river at a stream ford.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of stream fords or animal crossings. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where stream fords or animal crossings are noted.

5.5 CHANNEL ALTERATIONS (FIT)

Background
Activities defined as channel alteration include dredging, straightening, and bar scalping / gravel mining.

Dredging is the removal of sediments and other material from the channel. Though often done with the intention of releasing a "blocked" channel or containing floodwaters in the channel rather than the floodplain, dredging actually mobilizes more sediment in the long run. Channels are shaped over time to carry their water *and* sediment. When sediment is removed the channel slope increases, the stream power increases, and "hungry water" results. This hungry water removes sediment from the channel bed and banks. The resulting degradation and downstream aggradation may result in compromised stream habitat and/or erosion hazards.

Straightening is the process of changing the natural path of the river. It is the removal of meander bends, often done in village centers and along roadways, railroads, and agricultural fields. Straightening increases both the downstream and upstream hazard potential. When the stream is straightened the channel slope increases and there is a corresponding increase in flow velocity and stream power. Increased stream power often results in the erosion of the channel bed and banks, mobilizing sediment that was previously stable. In the eroded area the mobilization of these sediments may result in direct mortality of fish, amphibians, and reptiles, especially incubating eggs and young. Fish, amphibians, and aquatic insects are typically carried downstream, and population recovery may be slow if bed sediments remain highly mobile. The stream often loses access to the floodplain, and bed armor is disturbed. This extra force causes the river to degrade in the upstream direction, initiating head-cuts. Often the channel downstream of a straightened stretch aggrades as the sediment that used to be in the bottom of the river is re-deposited.

Bar Scalping / Gravel Mining: Evidence of gravel mining can be obtained from: a) historical information; b) the landowner; c) heavy equipment tracks on a gravel bar; and d) gravel berms pushed up on side of channel (Figure 5.6).

Both the "re-arranging" and/or removal of gravel can impact the morphology of the river. For example, where gravel is bermed up and bars removed to improve channel capacity, major damage may result from the changed morphology of the river. Damages may include widening and bank erosion, headcuts, and significant changes in the meander geometry and slope of the stream.

Figure 5.6 Gravel mining

Evaluation
A review of aerial photos is helpful in identifying where channels have been straightened, as former (now abandoned) channels are often evident on aerial photos. If in doubt as to whether or not the stream has been straightened, look for evidence, either on the ground or in an aerial photo, of the former course of the channel. In some cases, evidence of straightening can be found on soil maps as well. On the ground, look for oxbow wetlands or similar depressions in the river corridor that may indicate where the old channel meanders used to be.

Dredging Menu

Dredging	Evidence of removal of sediments and other material from the channel
gravel mining	Bar scalping: gravel has been removed from the top of bars Gravel mining: gravel has been removed from bars or bed of river
Commercial Mining	Historic (pre-1988) large-scale commercial extraction of gravel from channel.
None	No evidence of channel alterations

Use the Feature Indexing Tool (FIT) in SGAT to document the location of dredging, gravel mining and commercial mining. Dredging, gravlel mining and commercial mining are indexed as a point in the FIT. Please note whether the point is the exact location or the general location of the dredging. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where channel alterations are noted.

Straightening Menu

Straightening	Evidence that there has been the removal of meander bends and re-alignment of channel. Historically done in village centers and along roadways, railroads, and agricultural fields.
With Windrowing	Pushing gravel up from the stream bed onto the top of either bank as a part of the straightening of the river.

Straightening is indexed as a line in the FIT. When the FIT data is uploaded into the DMS the data will automatically be populated for each reach where straightening is noted. Record the length of straightening seen along the segment / reach on the Field Form to assist with confirming values calculated with the FIT.

COMMENTS

This space provides an opportunity to note observations about the site that have not been captured by the other parameters. It is critically important to provide a narrative description of the indicators you used to decide upon the bankfull elevation. See Appendix K for a list of indicators. You may also want to qualify any of the decisions that you made in choosing from the menus offered under each parameter. Finally, if any protocol described in the handbook is unclear given the conditions at your site, make note of this to inform the ANR River management Program on how this protocol can serve you better.

Step 6: Rapid Habitat Assessment (RHA)

Background

Physical processes, combined with chemical constituents and biological interactions, are what determine biological productivity and diversity; and, in essence, drive any given ecosystem. "Habitat", in the truest sense, is composed of all three of these components: physical, chemical, and biological. When evaluating the condition of an aquatic system, assessing the biota will give a good measure of how a system is doing; but once the status of the biota is determined, it is also important to understand why the system is supporting biota well, or why it is not, in order to make good management decisions. Looking closely at the physical processes and the resulting physical conditions that determine aquatic habitat, and thus the biota that inhabit it, and by comparing healthy systems to unhealthy systems, we can understand how fluvial processes impact aquatic habitat and biota.

Simply put, by assessing aquatic biota we can tell whether the system has a problem, and we may even be able to tell what type of problem we have (i.e. there is too much sediment or the water is too hot); but what we cannot answer by assessing biota alone is WHY do we have this problem. What happened in the stream system or watershed that resulted in too much sediment or water that is too warm? That is where understanding the physical processes that drive the stream or river system become necessary.

The U.S. Environmental Protection Agency (EPA) has developed and published Rapid Bioassessment Protocols (RBPs) which contain Rapid Habitat Assessment (RHA) protocols used to:

- Determine if a stream is supporting or not supporting aquatic life
- Characterize the existence and severity of habitat degradation
- Help to identify sources and causes of habitat degradation
- Evaluate the effectiveness of control actions and restoration activities

Evaluation

The parameters listed in the RHA evaluate the physical components of a stream (the channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The results can be used to compare physical habitat condition between sites, streams, or watersheds, and also serve as a management tool in watershed planning or similar land-use planning. Each parameter is scored on a scale of 0 (poor) to 20 (excellent). Parameter scores are totaled, and the total score is compared to a reference condition score. The reference condition is most useful if it is specific to the stream type being evaluated. References can be identified locally within the watershed or area of study, or regional references can be used.

It is important to learn these protocols well and practice them in the field before collecting data. This will improve your ability to gather data consistently.

Each of the parameters is described in detail in the following sections.

Field Form: Rapid Habitat Assessment

Defining High and Low Gradient Streams: There are two different RHA field forms; one to use for high gradient streams and one to use for low gradient streams. Before starting the RHAs determine whether you are surveying a high or low gradient stream**.**

> ***High gradient streams*** typically appear as steep cascading streams, step/pool streams, or streams that exhibit riffle/pool sequences (usually stream types A, B, and C). *Most of the streams in Vermont are high gradient streams.*

Low gradient streams typically appear slow moving and sinuous, and have less clearly defined riffles and pools and may even exhibit ripple-dune bed features (usually stream types E and sometimes C). These streams are often found in the large valley bottoms of the Champlain Valley and occasionally in high elevation meadows. The lower reaches of the Otter Creek, Lewis Creek, and Poultney River are all examples of areas you are likely to find low gradient streams. In choosing whether to use the high gradient or low gradient RHA field form, consider the following:

When to use high gradient RHA field form	When to use low gradient RHA field form
- reference stream type is A or B - reference stream type is C characterized by riffle/pool bed features and a dominant substrate size of gravel or larger	- reference stream type is E - reference stream type is C with ripple/dune or riffle/pool bed features and dominant substrate size is fine gravel, sand or smaller

Be sure to use the RHA field form that is appropriate for the **reference** stream type of the segment (or reach), as determined in Phase 1 and verified in Phase 2 Step 2.

In the RHAs you will evaluate 10 parameters. Three of these parameters have two versions, an (a) and a (b), which correspond to the two gradient categories, high and low, respectively. If you are surveying a high gradient stream always use option (a), and use option (b) when surveying low gradient streams.

Scoring Guidance: Begin by determining which condition category (reference to poor) matches the conditions you are observing in the stream segment (or reach). For every habitat parameter there are values, ranges, and descriptive text for each condition category that will help you determine the appropriate condition category (i.e. 0-25% embedded). Be sure to read each category completely before determining the condition category.

Once you have chosen the appropriate category, consider the text within the category box more closely to determine which of the 5 score values in the category best matches the condition you are observing in the field. The range of scores within each condition category gives you flexibility in “describing” what you observe in the field. For example, when there is a range of percentages or values presented in the category description, i.e. 0-25% embedded, and your observations indicate that the parameter condition is more towards the optimal end of that range, i.e. 0% embedded, you should choose the highest score within that category to indicate that the habitat parameter was in the highest potential condition for that category. Similarly, if the condition category lists several components that should be present, but you observe that some of these components are missing or scarce, you should score at the low end of the score values within that condition category. Some of the habitat parameters have scoring guidance written into each condition category box, which you should use to determine parameter scores.

Please do not skip parameters, as this will skew the score totals. If you are unsure about how to score a parameter use your best judgment and make a note in the Comments section on the Field Notes form of any questions, concerns, or reasons you had trouble evaluating a parameter.

6.1 EPIFAUNAL SUBSTRATE / AVAILABLE COVER

	Reference	Good	Fair	Poor
Epifaunal Substrate/ Available Cover	Greater than 70% (50% for low gradient streams) of stream bed and lower banks covered with **mix** of substrates favorable for epifaunal colonization and fish cover; substrates include snags, submerged logs, undercut banks, and unembedded cobbles and boulders (for high gradient)	40-70% (30-50% for low gradient streams) of stream bed and lower banks covered with a **mix** of substrates favorable for epifaunal colonization and fish cover	20-40% (10-30% for low gradient streams) of stream bed and lower banks covered with substrates favorable for epifaunal colonization and fish cover; few substrate types present	Less than 20% (10% for low gradient streams) of stream bed and lower banks covered with substrates favorable for epifaunal colonization and fish cover; few substrate types present

Definitions:
Epifaunal – "epi" means surface, and "fauna" means animals. Thus, "epifaunal substrate" is structures on the streambed that provide surfaces on which animals can live. In this case, the animals are aquatic invertebrates (such as aquatic insects and other "bugs"). These bugs live on or under cobbles, boulders, logs, and snags, and the many cracks and crevices found within these structures. In general, older decaying logs are better suited for bugs to live on/in than newly fallen "green" logs and trees.

Cover – "cover" is the general term used to describe any structure that provides refugia for fish, reptiles or amphibians. These animals seek cover to hide from predators, to avoid warm water temperatures, and to rest, by avoiding high velocity water. These animals come in all sizes, so even cobbles on the stream bottom that are not embedded with fine sands and silt can serve as cover for small fish and salamanders. Larger fish and reptiles often use large boulders, undercut banks, submerged logs, and snags for cover.

Figure 6.1A Reference epifaunal substrate and cover.

Evaluation:
When evaluating epifaunal substrate and available cover look at the relative **quantity** and **variety** of natural structures **in the stream**. In general, consider the entire bankfull area of the channel, but give greater weight to the area of the channel that remains wetted during lower flow conditions (such as those during late summer). A wide variety and/or abundance of submerged structures in the stream provide bugs and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for fish and bug populations to recover following disturbance decreases. **The greater the abundance and variety of structures serving as epifaunal substrate and cover, the higher the score.**

Figure 6.1B Poor epifaunal substrate and cover.

In ***high gradient*** streams look to see that there are riffles and runs with a wide variety of particle sizes (gravels to boulders). Riffles and runs are critical for maintaining a variety and abundance of invertebrates in most high gradient streams, and they serve as spawning and feeding habitat for many fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition in high gradient streams. Riffles and runs offer a diversity of habitat through variety of particle sizes, and, in many small high gradient streams, will provide the most stable habitat. In ***low gradient*** streams, snags and submerged logs are among the most productive habitat structures for bug colonization and fish cover. Low gradient streams typically do not have the larger rock substrates found in high gradient streams, but often contain more and larger woody material such as whole fallen trees and log jams.

6.2a EMBEDDEDNESS (high gradient)

	Reference	Good	Fair	Poor
Embeddedness (high gradient)	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment. Little open space between particles.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. Almost no open space between particles.

Definition:
Embeddedness: is a measure of the amount of surface area of cobbles, boulders, snags and other stream bottom structures that is covered with sand and silt. An embedded streambed may be packed hard with sand and silt such that rocks in the stream bottom are difficult or impossible to pick up. The spaces between the rocks are filled with fine sediments, leaving little room for fish, amphibians, and bugs to use the structures for cover, resting, spawning, and feeding. A streambed that is **not** embedded has loose rocks that are easily removed from the stream bottom, and may even "roll" on one another when you walk on them.

Evaluation:
Embeddedness is a result of large-scale sediment movement and deposition, and is a parameter evaluated in the riffles and runs of high-gradient streams. The rating of this parameter may be variable depending on where the observations are taken. To avoid confusion with sediment deposition (another habitat parameter), make observations of embeddedness in the upstream and central portions of riffles in an area containing cobble substrates. Pick up several rocks of at least softball size, up to volleyball size. As you lift the rock from the stream bottom look down through the water to see if a plume of fine sediment is released from around the rock as you dislodge it from the stream bottom. If so, the rock is embedded. In fast flowing water it may be difficult to see through the water to observe the sediment plume. If the rock is difficult to extract from the stream bottom, it is likely embedded.

To estimate the **percent embeddedness**, observe the surface of the rocks you dislodge from the streambed. If a rock is embedded the surface of the rock that was in contact with the streambed will be "clean", compared to the upper surface of the rock that was exposed to the water. This upper surface will be slimy and often dark in color, due to a covering of algae. If this clean surface extends over the bottom of the rock and up the sides, then the rock was embedded. The algae cannot colonize the surface area of the rock that is covered with silt and sand. Estimate the percent of the total surface area of the rock that is "clean" (embedded). Do this for several rocks and take the average percent embeddedness. Determine into which quartile your average percent embeddedness value falls (0-25%, 25-50%, 50-75%, or 75-100%). Score embeddedness values at the lower end of a quartile with a higher score within the range of scores available for that quartile. The lower the percent embeddedness the higher the rating.

Figure 6.2A Reference embeddedness

Figure 6.2B Poor embeddedness

6.2b POOL SUBSTRATE CHARACTERIZATION (low gradient)

	Reference	Good	Fair	Poor
Pool Substrate Characterization (low gradient)	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.

Since low gradient streams are naturally depositional areas, i.e. they accumulate fine sediments, it is not appropriate to evaluate embeddedness in these streams. The bed of a low gradient stream is usually composed largely of gravel, sand and silt. These sediment types often favor the establishment of aquatic vegetation, which provides surface area for aquatic invertebrates and cover for fish.

Evaluate the **type** and **variety** of bottom substrates found in pools. Firmer sediment types (i.e. gravel, sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants. In addition, a stream that has a uniform substrate in its pools will support fewer types of organisms that a stream that has a variety of substrate types.

Figure 6.3A Reference pool substrate condition

Figure 6.3B Poor pool substrate condition

6.3a VELOCITY/DEPTH PATTERNS (high gradient)

	Reference	Good	Fair	Poor
Velocity/Depth Patterns (high gradient)	All 4 velocity/depth patterns present: slow-deep, slow-shallow, fast-deep, fast-shallow. Slow is < 1 ft/s. (0.3 m/s), deep is > 1.5 ft (0.5 m).	Only 3 of the 4 patterns present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 patterns present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth pattern (usually slow-deep).

Definitions:
Patterns of water velocity and depth are important features of habitat diversity in high gradient streams. Fish, amphibians, and aquatic invertebrates use different velocities and depths at different life stages, for different daily activities, or may specialize in using a particular velocity/depth pattern all their lives. The four patterns are: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow. “Deep” is considered to be 1.5ft (0.5 m) or greater. “Fast” is defined as 1 ft/s (0.3 m/s) or greater. The occurrence of these 4 patterns relates to the stream’s ability to provide and maintain a stable aquatic environment. It is closely tied to the distribution of bed features and the overall geomorphic condition of the stream. Bed

features are defined and relate to velocity/depth patterns as follows:

<u>Step</u>**:** A step is a **fast-shallow** bed feature common in high gradient streams (> 2%). Steps are composed of large boulders and cobbles lined up across the stream that result in a near-vertical drop in the streambed. Steps are important for providing grade-control, and for dissipating energy. As water flows over a step it takes various flow paths, thus dissipating stream energy through turbulence and vertical drop.

<u>Riffle</u>**:** A riffle is a **fast-shallow** bed feature common in moderate gradient streams (< 2%). A riffle has relatively shallow depths, coarser bed material and a steeper gradient when compared to the rest of the channel. Riffles are usually found between pools and in straight reaches. The **fast-shallow** water flowing over the coarse bed material introduces a lot of oxygen into the water. These are the critical areas where the bugs (benthic macro-invertebrates) live.

<u>Run</u>: Runs are **fast-deep** bed features common in high and moderate gradient streams (>1 %). Runs are often located just downstream of riffles, leading into pools in stable pool-riffle streams. They are also found along straight sections of channel and gentle meanders. Runs may be the dominant bed feature in disturbed stream channels.

<u>Pool</u>: Pools are **slow-deep** bed features, generally found at the outside of meander bends in riffle-pool streams, and between steps in step-pool streams. Pools are also commonly associated with large woody debris, large boulders and bedrock, and similar channel obstructions that result in scour of the channel bed. Typically pool bed material is finer than the material found in riffles.

<u>Glide</u>: Glides are **slow-shallow** water that form where the bed of the channel rises from the deep scour of the pool to the head of a riffle. A glide is often called a "pool tail".

Evaluation:

The best habitat will have all 4 velocity/depth patterns present. You may find one of these patterns represented in an entire riffle, step, or pool, or, more commonly, you may find several of these patterns within one riffle or pool. For example, a pool usually has **slow-deep** water at its center or focused to one side of the pool, with **slow-shallow** water in the surrounding pool edges. In high gradient streams characterized by cascades and abundant boulders you are likely to find different velocity/depth patterns within several feet of each other, as water pushes between boulders, eddies back behind them, and tumbles over them.

Figure 6.4A Reference velocity/depth patterns. Arrows indicate different patterns.

Figure 6.4B Poor velocity/depth. Only slow-shallow pattern present.

6.3b POOL VARIABILITY (low gradient)

	Reference	Good	Fair	Poor
Pool Variability (low gradient)	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.

Definition:
This parameter rates the overall mixture of pool types found in streams, according to **size** and **depth**. The 4 pool types are: (1) large-shallow, (2) large- deep, (3) small-shallow, (4) small-deep. Large pools are wider and longer than ½ the average bankfull channel width. Deep pools are >3' deep.

Evaluation:
A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and variety of habitat to support a diverse aquatic community. **An even mix of all pool types is most desirable.** In the absence of some pool types, it is better to have deep pools over shallow pools. All small-shallow pools or lack of pools entirely are the least desirable conditions.

Figure 6.5A Reference pool variability

Figure 6.5B Poor pool variability

6.4 SEDIMENT DEPOSITION

	Reference	Good	Fair	Poor
Sediment Deposition	Little or no enlargement of mid-channel bars or point bars and < 5% (20% in low gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% in low gradient streams) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% in low gradient streams) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; > 50% (80% in low gradient streams) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.

Definitions:
Sediment deposition is the accumulation of sediments on the streambed that raises the bed elevation. Sediment deposition may result in the formation of point bars, mid-channel bars, or islands.

<u>Point Bars</u> **-** unvegetated deposits of sediment located on the inside of a channel bendway, adjacent to the stream bank, typically higher than the average water level.

Mid-channel Bars: unvegetated deposits of sediment located in the middle of the channel away from the banks that split the channel flow, except under very low flow conditions; typically higher than the average water level; generally found in areas where the channel runs straight.

Islands – mid-channel bars that are above the average water level and often above the bankfull elevation; vegetated with well-established woody vegetation.

Evaluation:
This parameter evaluates the amount of sediment deposition that has accumulated in pools and the changes that have occurred to the streambed as a result of the deposition. Deposition occurs from large-scale movement of sediment. It results in the formation of bars and islands and the filling-in of runs and pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow velocity decreases, such as on the inside of bends.

High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many aquatic organisms. While point bars are typical of a healthy stream system, if they are not excessively large or steep, mid-channel bars are indicative of channel instability, and usually occur when the channel is over-widened and thus does not have enough stream power to move the sediment through the channel. The channel may appear braided. While this is a natural condition in parts of the country (i.e. in glacial-fed rivers), it is not naturally common in Vermont.

Look for the presence of unvegetated mid-channel bars, filling-in of pools with fine sediments, and overly steep and large point bars (compared to other point bars in the system) as signs of sediment deposition. Refer to section 5.1 on the Field Notes form. Note there is one situation where the occurrence of a mid-channel bar(s) may not indicate problematic sediment deposition. Often a mid-channel bar will develop just downstream from where a tributary enters the channel as a result of sediments being delivered to the channel from the tributary. This is usually a localized deposition and does not indicate large-scale sediment deposition problems. If this is the only mid-channel bar or similar depositional feature you observe in the segment (or reach), then the segment is not likely being negatively affected by sediment deposition.

Figure 6.6A Reference sediment deposition

Figure 6.6B Poor sediment deposition

6.5 CHANNEL FLOW STATUS

	Reference	Good	Fair	Poor
Channel Flow Status	Water reaches base of both lower banks, and <10% of channel bed substrate is exposed.	Water fills >75% of the available channel; or <25% of channel bed substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

This parameter evaluates the degree to which the channel is filled with water. It includes evaluation of whether a system is being affected by 1) water withdrawals and/or 2) stream adjustments in response to changes in land use, but can also consider naturally occurring low flow conditions due to a channel's underlying geology. The flow status will change as the channel enlarges (e.g., aggrading stream beds with actively widening channels) or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed the amount of suitable substrate for aquatic organisms is limited. In high-gradient streams, cobble and gravel substrates in riffles are exposed; in low-gradient streams, the decrease in water level exposes logs and snags, thereby reducing available habitat.

When measuring this parameter you should consider the area from the toe of streambank to the opposite streambank. Whether due to natural runoff patterns or human-induced impacts, streams have different flow characteristics ranging from intermittent, to variable, to uniform. A stream that is naturally variable or intermittent is more likely to exhibit poorer channel flow status condition than a uniform stage stream. Be sure to evaluate only what you observe on the day of survey; however, if you have knowledge that the stream flow is high due to a recent storm or goes dry on a regular basis, or similar knowledge due to your familiarity with the stream, be sure to include these as a comment on the bottom of the field form.

Flows are decreased if large quantities of water are withdrawn or impounded for:

$ hydropower
$ irrigation
$ public water supplies
$ snowmaking
$ recreation and flood control reservoirs

Figure 6.7B Poor channel flow status

Figure 6.7A Reference channel flow status

6.6 CHANNEL ALTERATION

	Reference	Good	Fair	Poor
Channel Alteration	Channelization in the form of dredging, straightening, berms or streambank armoring absent; stream with natural pattern.	Some channel alterations present along 10-20% of segment, usually in areas of bridge abutments; evidence of past channelization, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization along 20-80% of stream segment ; riprap or armoring present on both banks.	Over 80% of the stream segment channelized and disrupted. Instream habitat greatly altered or removed entirely.

Definitions:
Activities defined as channel alteration include: berms (Section 1.3), dredging (5.4), straightening (5.4), and streambank armoring (3.1, bank revetments).

Evaluation:
This parameter is a measure of large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control, irrigation, or other property protection purposes. Such streams have far fewer natural habitats for fish, aquatic invertebrates, and plants than do naturally meandering streams. Channel alteration is present when armoring or berms are present; when the stream is straight for long distances, or when dredging has occurred. Evidence of past dredging may be difficult to determine in the field; look for excavation scars or spoil piles. Local knowledge of nearby residents or town/state officials may also help. (You may have acquired information in Phase 1 and Section 5.4 of Phase 2 that will help you assess channel alterations.) In general, channel alteration that occurred several decades ago from which the stream is in the process of recovering rates higher than **recent** channelization of similar magnitude.

Figure 6.8A Reference condition: channel alteration absent.

Figure 6.8B Poor condition: excessive channel straightening.

Figure 6.8C Example of berm and streambank armoring with stone wall. Dirt on top of stone wall is an old berm; note large tree growing in berm that was present before berm was constructed. Saplings on top of berm have grown up since berm was built several decades ago. Berm height above average water level is approximately 10 feet.

6.7a FREQUENCY OF RIFFLES / STEPS (MORPHOLOGICAL DIVERSITY) (high gradient)

	Reference	Good	Fair	Poor
Frequency of Riffles/Steps **(high gradient)**	Occurrence of riffles/steps relatively frequent; ratio of distance between riffles is 5-7 times (steps 3-5 times) stream width; variety of habitat is key. In streams where riffles/steps are continuous, presence of boulders or other large, natural obstruction is important.	Occurrence of riffles/steps infrequent; distance between riffles is 7-15 times (steps 5-15 times) stream width.	Occasional riffle/step or bend; bottom contours provide some habitat; distance between riffles/steps is 15 to 25 stream widths.	Generally all flat water or shallow riffles/steps; poor habitat; distance between riffles/steps is >25 stream widths. Mostly runs.

Definition:
Frequency of Riffles/Steps is the ratio of the distance between riffles or steps to the stream width. For high gradient streams and/or streams that are confined by their valleys, where distinct riffles are uncommon, step frequency can be used as a measure of meandering, or sinuosity (see Section 6.7b). Typically these streams have low sinuosity, but may exhibit good step frequency due to the presence of boulder "steps" and cascades that serve to absorb the stream energy much like meanders do in a sinuous, low gradient, unconfined river. This is particularly true in headwater streams.

Evaluation:
This parameter measures the spacing of riffles, and thus the heterogeneity of habitat, or "morphological diversity", in a stream. Riffles and steps are usually separated by pools and/or runs. Frequent riffles means there will also be frequent pool and runs, ensuring a diversity of channel morphologies and thus a diversity of habitat. Refer to the data you recorded in section 2.11 and Table 1 below to determine the riffle/step spacing for the segment you are evaluating.

Figure 6.9A Reference frequency of riffles

In unconfined streams that are able to meander back and forth within their valley it is helpful to also consider the sinuosity of the channel when evaluating riffle/step spacing. Typically the greater the sinuosity the lower the riffle/step spacing will be in a stable system. A moderate to high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to absorb surges when the stream flow fluctuates as a result of storms. The absorption of increased stream energy by bends in the stream protects the channel from excessive erosion during flooding and provides refugia for fish and aquatic invertebrates.

In some streams, you may need to refer to topographic maps and orthophotos in gain an appreciation of the stream's riffle frequency (or sinuosity). You may also need to look at a stretch of stream longer than your sampling site.

Table 6.1: Typical riffle / step spacing by stream type.

Stream Type	Spacing	Feature
A	1-3 times Wbkf	cascade / step
B	3-5 times Wbkf	step / riffle
C & E	5-7 times Wbkf	riffle

Figure 6.9B Poor frequency of riffles / steps

6.7b CHANNEL SINUOSITY (low gradient)

	Reference	Good	Fair	Poor
Channel Sinuosity (low gradient)	The bends in the stream increase the stream length 2.5 to 4 times longer than the straight down-valley length.	The bends in the stream increase the stream length 1.5 to 2.5 times longer than the straight down-valley length.	The bends in the stream increase the stream length 1 to 1.5 times longer than the straight down-valley length.	Channel straight; waterway has been channelized for a long distance.

Definition:
Sinuosity is the ratio of channel length to direct down-valley length. Sinuosity may also be expressed as the ratio of down-valley slope to channel slope (see Section 2.9). It is used to evaluate the "curviness" of the stream. Curves, or meanders, help to absorb and dissipate stream energy. Those streams with a high sinuosity have many meanders, while straighter streams will have a low sinuosity. Sinuosity is in part a reflection of the slope of the channel, and the slope of the valley. Steep streams in steep valleys have low sinuosity, while low gradient streams meandering through broad valleys can be highly sinuous.

Evaluation:
This parameter evaluates the meandering, or sinuosity, of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by meanders protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events. To gain an appreciation of this parameter in low gradient streams, a longer segment or reach than that designated for sampling may be incorporated into the evaluation. In some situations, this parameter may be rated from viewing accurate topographical maps or recent aerial or orthophotos. Refer to your evaluation of sinuosity in Section 2.9 on the Field Notes form when scoring this parameter.

The "sequencing" pattern of the stream morphology is important in rating this parameter. In "oxbow" streams meanders are highly exaggerated and transient. Natural conditions in these streams are shifting channels and bends, and alteration is usually in the form of flow regulation and diversion. A stable channel is one that does not exhibit progressive changes in slope, shape, or dimensions, although short-term variations may occur during floods (Gordon et al. 1992).

Figure 6.10A Reference sinuosity

Figure 6.10B Poor sinuosity

6.8 BANK STABILITY

	Reference	Good	Fair	Poor
Bank Stability (score each bank) *Note: determine left or right side by facing downstream.*	Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly re-vegetated. 5-30% of bank in segment (or reach) has areas of erosion.	Moderately unstable; 30-60% of bank in segment (or reach) has areas of erosion; high erosion potential from crumbling, unvegetated banks during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.

This parameter measures whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks, and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, freshly exposed tree roots, and exposed soil. Refer to Section 3.1 on the Field Notes form.

Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Figure 6.11A Reference bank stability

Figure 6.11B Poor bank stability

6.9 BANK VEGETATIVE PROTECTION

	Reference	Good	Fair	Poor
Bank Vegetative Protection **(score each bank)** *Note: determine left or right side by facing downstream.*	More than 90% of the streambank surfaces and <u>immediate riparian zone</u> covered by native vegetation, including trees, understory shrubs, or herbaceous vegetation; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.

Definitions:

<u>Immediate Riparian Zone</u>**:** This is the area where the root binding capacity of the vegetation serves to stabilize the streambank. This is a function of bank height. Grasses cannot stabilize banks that are over ½ meter high (~1.5 ft.), and shrubs and woody vegetation cannot stabilize banks that are over 1.5 meters (~4.5 ft.). Banks that are higher than 1.5 meters are beyond the root-binding capacity of the vegetation.

<u>Potential plant height</u>**:** the height to which a plant, shrub or tree would grow if undisturbed.

Evaluation:

This parameter measures the amount of vegetative protection afforded to the streambank and the near-stream portion of the riparian zone. Refer to Section 3.1 on the Field Notes form. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and aquatic macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap. This parameter is made more effective by defining the native vegetation for the region and stream type (i.e., shrubs, trees).

Figure 6.12A Reference riparian

In some regions, the introduction of exotics has virtually replaced all native vegetation. The value of exotic vegetation to the quality of the habitat structure and contribution to the stream ecosystem must be considered in this parameter. In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded and can extend to the bank vegetative protection zone. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Figure 6.12B Poor riparian buffer

Riparian buffers provide structure to the banks of a stream. The roots of the vegetation hold the soil in place, and the grass, shrubs or trees provide friction to slow down the floodwaters. Vermont ANR has developed guidance on the width of riparian zones for stream stability, habitat, and removal of nutrients, sediment and bacteria.

6.10 RIPARIAN VEGETATIVE ZONE WIDTH

	Reference	Good	Fair	Poor
Riparian Vegetative Zone Width (score each side of channel)	Width of **naturally vegetated** riparian zone >100 feet; human activities, (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) and grazing have not impacted zone.	Width of riparian zone 50 - 100 ft; human activities and grazing have impacted zone only minimally.	Width of riparian zone 25 - 50 ft.; human activities and grazing have impacted zone a great deal.	Width of riparian zone < 25 feet: little or no riparian vegetation due to human activities.

Evaluation:

This parameter measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. Refer to section 3.2 on your Field Notes form. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and organic input to the stream. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, animal pasture, bare soil, rocks, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and animal pasture are the common causes of anthropogenic degradation of the riparian zone. Conversely, the presence of "old field" (i.e., a previously developed field not currently in use and in the process of growing up to shrubs and trees), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone and may be given relatively high scores. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

6.11 RAPID HABITAT ASSESSMENT SCORE

Add up the scores circled for the ten habitat parameters (remembering that parameters 8, 9, and 10 have left and right bank scores to add) and divide by 200, which is the total possible score for the RHA.

Use the following table to evaluate the habitat condition of the stream site.

Table 6.2: Phase II Assessment Score Ranges

0.85 – 1.00	Reference Condition
0.65 – 0.84	Good Condition
0.35 – 0.64	Fair Condition
0.00 – 0.34	Poor Condition

Step 7: Rapid Geomorphic Assessment (RGA)

Background
The Rapid Geomorphic Assessment evaluates degradation, aggradation, widening, and planform adjustment processes on the RGA field form (Steps 7.1 to 7.4). The RGA provides a method to document the current adjustment processes occurring in a segment (or reach) and to determine the stage of channel evolution that best describes the set of current and historic adjustment processes observed (Step 7.5). Finally, in Step 7.6 and 7.7, you can use the RGA scores and existing stream type to develop an overall condition score and sensitivity rating for your reach.

A channel adjustment process occurs 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 characteristics. An analysis of channel adjustment involves determining the departure of the stream's existing conditions from those of a reference stream of the same type, and understanding the physical processes at work in the stream as it comes into 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 been found to be useful in Vermont in understanding why and how streams are responding to various watershed, floodplain, and channel modifications (Appendix C).

In a Phase 2 assessment, stream condition is based on the magnitude of adjustment processes underway and the degree to which the stream has departed from the reference, or equilibrium condition. If a stream changes such that it becomes ineffective, or conversely, too effective, at transporting the flow, sediment, and debris produced in its watershed, adjustments occur in the dimension (width and depth), pattern (meandering), and profile (slope) of the channel as the energy grade of the stream (affected by parameters such as channel slope, depth, and velocity) comes back into balance with the current watershed inputs.

Evaluation
Three separate RGA forms have been prepared for streams in different settings; one for streams in narrowly confined and semi-confined valley types (confinement ratio < 4), a second for streams in narrow, broad, or very broad valley types (confinement ratio $\geq$ 4, typically riffle-pool or ripple-dune stream types), and a third for plane bed stream types in semi-confined to narrow valley types (confinement ratio $\geq$ 3 and $\leq$ 5). The descriptions of adjustment processes differ between these forms and attempt to capture the different erosion and depositional processes that occur in these different confinement and slope settings. The greater channel depths and slopes that are present in confined channels under flood conditions, as compared to unconfined stream systems, affect the type of bed forms and depositional features formed, as well as the erosion processes that occur. Be sure to use the appropriate RGA field form based on the **reference** stream type and confinement, and not necessarily the existing confinement type circled in Step 1.5 of the Field Notes form. If the stream is plane bed **by reference**, then use the plane bed RGA form.

Selecting a Reference Stream Type: Start the RGA by assigning the **reference** stream type that would exist in the geographic, geologic, and climatic setting you are working in, and compare the characteristics of this stream type to those of the **existing** stream type you observe in the field. Use the reference stream type assigned in the Phase 1 assessment and confirmed in the Phase 2 assessment. Reference stream type is evaluated on the basis of watershed zone, confinement, and valley slope in Phase 1, in addition to entrenchment, width/depth ratio, sinuosity, channel slope, substrate d50, and bed form determined in Phase 2. Any change in the existing stream type characteristics from those of the reference stream type may explain the adjustment process and condition you observe in the segment (or reach). For example, a stream assessed in Phase 2 as an "F Plane Bed" stream type that exists in a physical setting determined in Phase 1 to be more consistent with a "C Riffle-Pool" stream type may have become more entrenched in its valley. In this scenario the channel would likely exhibit characteristics of a channel that has gone through the degradation process, which you would confirm in completing Step 7.1 of the RGA field form. In this case, the major adjustment that took place describes a plausible evolution of the channel from the selected reference condition to the existing stream condition observed in the field.

Understanding the reference condition is important in understanding past channel adjustments, predicting future adjustments, and most importantly, deciding what management alternatives should be pursued. Both natural and human-caused changes to a stream channel may complicate the selection of the appropriate reference stream type. ***Assigning a Modified Reference Stream Type****:* Watershed land use conversion, alone or in combination with channel, valley, floodplain and/or flow modifications, may prohibit the evolution of the channel back to the natural reference stream type. In this case, management towards an equilibrium state that is different than the natural reference stream type that historically existed may be more consistent with the river corridor conservation goals of ecological and economic sustainability in both the short and long term. Typically the assignment of a modified reference stream type is limited to situations were historic watershed and river corridor development is so predominant that relief of the stressors associated with such development (which in many cases would require removal of substantial amounts of infrastructure) is impractical. If you decide to assign a modified reference stream type to a segment (or reach), check the "Modified" box in the header on the RGA field form. In these cases, evaluate the stream adjustment and stream type departure, channel evolution stage, stream condition, and stream sensitivity on the comparison of existing conditions to those equilibrium conditions that are typical of the modified stream type. Typical situations for which one might choose a modified reference stream type include:

> ***Streams with dams*** that create various types of impoundments. For large impoundments, where the reservoir is significantly wider than the channel bankfull width, do not complete an RGA. For riverine impoundments, where the impoundment is not significantly wider than the river itself, there may be segments for which completing an RGA makes sense. For instance, a segment located at the upstream end of an impoundment may be aggrading and widening, and thus evaluated as "in adjustment." If you have checked the modified reference box in the RGA heading, write "(impounded)" next to the stream type, and then do not identify the adjustments you see as "stream type departures" under steps 7.1 (degradation) and step 7.2 (aggradation). In impounded segments you may elect to forego the completion of Steps 7.1 through 7.6 and use the reference stream type of the segment as the basis of a sensitivity rating.
>
> ***Streams in urban areas*** may have little or no chance to adjust back to reference conditions. For instance, some Vermont villages were built on alluvial fans. The braided "D" channels that existed there historically were channelized, encroached upon, and hydrologically modified to such a degree as to preclude the adjustment of the stream back to the pre-settlement condition. In this example, you might choose to assign a "B type" channel as a modified reference stream type, due to the greater entrenchment and slope of the channelized stream, which is a stream type that could likely be maintained in equilibrium in the village setting.

Departure From Reference: The Rapid Geomorphic Assessment determines stream geomorphic condition based on the degree of departure of the channel from its reference stream type, which is evaluated by the magnitude and combination of adjustments that are underway in the stream channel. The degree of departure from reference is assessed as *not significant, minor, major, or extreme* and correlated with *reference, good, fair, or poor condition*. With respect to stream equilibrium and natural variability, the degree of departure is captured by the following three terms:

In Regime: A stream reach in *reference and good* condition that is in dynamic equilibrium which may involve localized, *insignificant to minimal change* to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability.

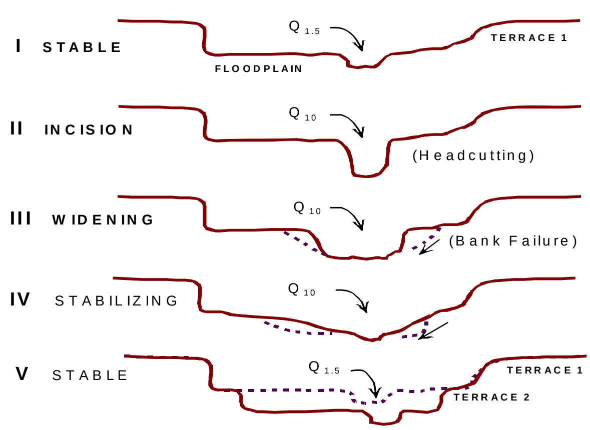
In Adjustment: A stream reach in *fair* condition that has experienced *major change* in channel form and fluvial processes outside the expected range of natural variability; and may be poised for additional adjustment with future flooding or changes in watershed inputs that could change the stream type.

Active Adjustment and Stream Type Departure: A stream reach in *poor* condition that is experiencing extreme adjustment outside the expected range of natural variability for the reference stream type; likely exhibiting a new stream type; and is expected to continue to adjust, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs and boundary conditions.

Natural Exceptions: Some stream types do not respond or adjust to the stressors identified in the assessment protocols, while others are in a state of ongoing adjustment where management of watershed, channel, and floodplain stressors may have little consequence. Three scenarios where this may occur are described below.

> ***Streams in bedrock controlled gorges*** are changing and adjusting at a geologic time scale and are very unlikely to exhibit the adjustment processes described in the RGA. If your segment is confined within a bedrock gorge, you should forego the completion of Steps 7.1 through 7.6 and assess the segment or reach as having a "Low" sensitivity.
>
> ***Streams impounded by beaver dams*** may be going through aggradation, widening and planform adjustments, but may not be good candidates for evaluation. Streams that have considerable beaver influence over a long period of time may function more as wetlands than fluvial systems. These areas usually have extensive, intact dams impounding large ponds within the stream valley. It is recommended to create separate segments out of these areas and not conduct Phase 2 assessments on them. In other situations streams may have temporary or minimal beaver influence that induces localized channel adjustments but does not trigger long-term or extensive overall channel adjustments in the segment. These areas usually have small dams, or a series of small dams, that wash out regularly and through which the stream still flows in a largely riverine state. In these situations it is recommended that you include the beaver-influenced area within the larger segment, but disregard the localized beaver influence when evaluating stream condition and rather focus on the overall condition of the segment
>
> ***Alluvial fans, extreme deposition zones, and braided "D type" streams,*** typically found at major breaks in valley slope (from steep to gentle), are extremely high deposition zones, where the sediment load exceeds the stream's capacity to move it. While you should complete all the evaluations under the four adjustment processes (because many human-caused alterations may have occurred in these zones), take into consideration that these streams may be wide, full of depositional features, braided, and in an ongoing state of planform adjustment due to the natural setting in which they occur. You should not rate naturally braided streams (or those located on alluvial fans) as in fair or poor condition, based solely on those adjustments that would be expected to occur (i.e., no human-caused stressor involved), unless there has been a management decision to establish a "modified" reference stream type for the segment or reach (see discussion below).

***Channel Evolution Sequence*:** Depending on when you complete your survey relative to where in the channel evolution stage a channel is, you may come to different conclusions about the adjustment process occurring in the channel.



In regime, reference to good condition, insignificant to minimal adjustment.

Fair to poor condition, major to extreme channel degradation.

Fair to poor condition, major to extreme widening and aggradation.

Fair to good condition, major reducing to minor aggradation, widening, and planform adjustments

In regime, reference to good condition, insignificant to minimal adjustment.

Figure 7.1 Five Stages of Channel Evolution (Schumm, 1977 and 1984), the channel condition and adjustment processes often observed during each stage

For example, a reach adjusting to a large influx of sediment from erosion sources upstream may display signs of one adjustment process over others depending on which stage of channel evolution the channel is in. Initially, there may be signs of **aggradation** and a localized decrease in slope as sediment builds up in the reach. This may be followed by a channel avulsion that significantly shortens the reach length resulting in what may be a dramatic increase in slope. At this step in the process, an assessment may strongly indicate channel **degradation.** Depending on the severity of the degradation process, the balance may have swung too far, and some decrease in channel slope will occur before equilibrium is achieved. If you survey at this time, you may conclude that the dominant processes are either channel **widening** or **planform adjustment** (Figure 7.1). Typical adjustment, or channel evolution, sequences have been observed and documented that may help to explain why your Rapid Geomorphic Assessment reveals signs of more then one type of adjustment process going on at the same time, as well as those adjustments that are likely to occur before the river regains equilibrium with its watershed inputs (Appendix C).

Field Form: Rapid Geomorphic Assessment

Complete the RGA field form header in the same manner of the Field Notes form header, including the reference stream type for the reach based on Phase 1 and/or Phase 2 data .

Selecting Condition Category: The assessment of degradation, aggradation, widening, and planform adjustment processes is set up as a series of 4 to 6 evaluations. In large part, the evaluations are based on the values determined for parameters assessed in Steps 1 through 5 and recorded on the Field Notes form. For each parameter, a separate description is provided under each of the four geomorphic condition headings (reference, good, fair, and poor). You will work down through each evaluation and put a check in the box next to the condition that best describes your segment or reach. Make sure you check one of the four condition boxes in each row. After you have worked through all 4 to 6 evaluations under an adjustment category, look at the array of checks and decide *which of the four condition categories* best captures the stream condition with respect to that adjustment process.

Selecting a Score: Once you have chosen the appropriate category, consider the array of checks and the text within the evaluation boxes of the category more closely to determine *which of the 5 score values* in the category best matches the condition you are observing in the field. The range of scores within each condition category gives you flexibility in "describing" what you observe in the field. Give greater weight to the actual channel and floodplain geometry changes (evaluated in the top 2-4 rows under each adjustment type) than to the human-related modifications (evaluated in the lower 2-3 rows under each adjustment type). When there is a range of percentages or values presented in the category description (i.e. Width/depth is $> 30 \leq 40$) and your observations indicate, for instance, that the parameter condition is more towards the optimal end of that range, i.e. 30 W/d, you should factor this into selecting a higher score within that category.

Some of the evaluations under each adjustment process include descriptions of <u>when</u> a modification or channel change occurred (i.e. using the terms "historic," "recent," or "existing"). Recognizing adjustment processes in both space **and** time is essential to your prediction of channel evolution and selecting an appropriate management response. For instance, a channel may have incised decades ago in response to a dredging operation and is still moderately entrenched. However, aggradation and planform change are assessed as the current adjustment processes. The river manager, in trying to resolve conflicts associated with erosion due to these current adjustments, may be particularly concerned about channel degradation and widening processes that may still be active upstream, generating all the sediments that are aggrading in the reach. In the lower left corner of each adjustment process box, next to the adjustment scores, is a **"Historic"** check box to indicate that while the channel is not actively or currently undergoing the adjustment process, the adjustment did occur in the past.

The evaluation of degradation, aggradation, channel widening, and planform adjustments and the stage of channel evolution are discussed in Steps 7.1 through 7.4. Stream condition, based on a rating derived from the adjustment scores, is assessed in Step 7.6. Stream sensitivity, based on the existing stream type, adjustment processes, and whether the existing stream type represents a stream type departure, is assessed in Step 7.7.

7.1 DEGREE OF CHANNEL DEGRADATION (INCISION)

"Incision", "downcutting", and "degradation" are all words used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Some streams incise so deeply they become entrenched stream types (i.e. when a C type stream incises to an F type stream, Table 2.3). Other streams, in more confined valleys, are naturally entrenched and should not be characterized as degraded unless evidence of the downcutting process is observed. Channel degradation may occur when there has been a significant increase in flows, a significant decrease in sediment supply, or a significant increase in slope due to a loss of channel sinuosity or floodplain. Incision occurs during periods of high runoff. Indicators of degradation or incision (noted in the left hand column on the RGA Form) include:

- Exposed till or fresh substrate in the stream bed and exposed infrastructure (bridge footings);
- New terraces or recently abandoned floodplains or flood prone areas along the banks of the stream;
- Headcuts, or nickpoints, in channel. Headcuts look like riffles that are 2-3 times steeper than a typical riffle;
- Freshly eroded, vertical-faced banks (Figure 7.2);
- Old stream channel deposits that are imbricated (stacked like dominoes) high in the bank, indicating that the channel bed used to be at a higher elevation and has since cut down;
- Tributary rejuvenation, sometimes observed through the presence of nickpoints at or upstream of the mouth of a tributary where the tributary enters a river (when the main channel degrades, the tributaries that flow into it respond by degrading and lowering their channel beds to meet the lower main channel bed); and
- bars with steep faces, which usually occur on the downstream end of a bar.

Refer to your Field Notes for the following signs or conditions that may provide evidence of channel incision:

1.3 = berm, road, and railroad encroachments present
1.5 = human-caused change in valley type
1.6 = no grade controls
2.7 = increased incision ratio
2.8 = decrease in entrenchment ratio
2.10 = incomplete riffles or runs only
2.14 = F or G stream types (B in unconfined valleys)
4.5 = impoundments present
4.6 = stormwater inputs present
4.7 = flow regulated (> flows or < sediments)
4.8 = constrictions with scour problems below
5.2 = flood chutes and avulsions present
5.3 = headcuts and nickpoints present
5.5 = gravel mining, dredging or channelization

Figure 7.2 Degraded Channel

Major Degradation and Stream Type Departures: In the upper right hand corner of the degradation section of the RGA form, evaluations concerning head cuts and entrenchment ratio are set apart with darker border lines. If one **or** both of these parameters are checked in the poor condition category, then rate the segment (or reach) as "poor" in the degradation adjustment process regardless of how the other four evaluations within step 7.1 were made. Checking that the stream has exceeded the stated thresholds for incision ratio and entrenchment means that, depending on the reference or modified reference you are comparing to, a "stream type departure" has occurred. You should use the check boxes in the lower left hand corner of the degradation section to indicate the stream type departure that best describes what you are seeing in the field.

7.2 DEGREE OF CHANNEL AGGRADATION

Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. Channel aggradation may occur when there has been a significant decrease in flows, a significant increase in sediment supply, or a significant decrease in slope due to irregular meander migrations. Depending on upstream processes and the boundary conditions of your reach, channel widening (Step 7.3) may occur in association with channel aggradation. Indicators of aggradation (noted in the left hand column on the RGA Form) include:

- Shallow pool depths;
- Abundant sediment deposition on side bars and unvegetated mid-channel bars and extensive sediment deposition at obstructions, channel constrictions, and at the upstream end of tight meander bends (Figure 7.3);
- Most of the channel bed is exposed during typical low flow periods;
- High frequency of debris jams; and
- Coarse gravels, cobbles, and boulders may be embedded with sand/silt and fine gravel.
- Lateral migration of thalweg (deepest thread of flow).

Refer to your Field Notes for the following signs or conditions that may be evidence of channel aggradation:

1.6 = downstream grade controls present
2.6 = high width/depth ratio (> 30)
2.10 = transverse bars or runs only
2.12 = homogenous gravel/sand substrates
2.14 = plane bed stream type (in unconfined valley)
3.1 = significant bank erosion
4.7 = flow regulated (< flows or > sediments)
4.8-4.9 = constrictions with deposition above or below
5.1 = unvegetated mid-channel or diagonal bars
5.2 = flood chutes, neck cutoffs, channel avulsions, and/or braiding present
5.3 = steep riffles present

Figure 7.3 Aggradation

Major Aggradation and Stream Type Departures: In the upper right hand corner of the aggradation section of the RGA form, evaluations concerning loss of bed features and unvegetated deposition features are set apart with a darker border lines. If both of these parameters are assessed in the poor condition category, then rate the segment (or reach) as “poor” in the aggradation process regardless of how the other four evaluations within Step 7.2 were made. The exception being where the reference condition is characterized as extremely depositional. Checking that the stream has experienced these extreme changes in deposition means that, depending on the reference or modified reference you are comparing to, a “stream type departure” has been observed. You should use the check boxes in the lower left hand corner of the aggradation section to indicate the stream type departure that best describes what you are seeing in the field.

7.3 WIDENING CHANNEL

Channel widening usually follows the channel degradation process (Step 7.1). The containment of higher flows within an incised channel typically leads to erosion of both banks. Alternating stages of widening and aggradation occur as the stream forms a floodplain at a lower elevation. An over-widened channel is also an outcome of the sediment aggradation process described in Step 7.2. When the stream becomes incapable of transporting its sediment load, sediments collect on the stream bed, forming mid-channel bars that concentrate flows into both banks, and lead to a wider channel. Streams that score poorly under channel aggradation (7.2) may also score poorly for the channel widening parameter, but in such cases you want to record aggradation as the dominant adjustment process. Channels also become over-widened due to an increase in flows or to a decrease in sediment supply, which is not necessarily related to bed aggradation but may be seen in association with degradation. In these cases widening is the dominant process. Indicators of widening (noted in the left hand column on the RGA Form) include:

- Active undermining of bank vegetation on both sides of the channel; many unstable bank overhangs that have little vegetation holding soils together;
- Erosion on both right and left banks in riffle sections;
- Recently exposed tree roots;
- Fracture lines at the top of the bank that appear as cracks parallel to the river; evidence of land slides and mass failures;
- Deposition of mid-channel bars and shoals (Figure 7.4); and
- Urbanization and stormwater outfalls leading to higher rate and duration of runoff and channel enlargement typically in smaller watershed with a high percentage (>10%) of impervious surface (urban land use).

Refer to your Field Notes for the following signs or conditions that may be evidence of channel over-widening:

2.6 = high width/depth ratio (> 30) (Figure 7.4)
2.7 = increased incision ratio
2.8 = decrease in entrenchment ratio
2.8 = moderately channel entrenchment (<2.0)
3.1 = significant bank erosion or revetments on <u>both</u> banks, overhanging banks
4.6 = stormwater outfalls present
4.7 = flow regulated (> sediments or > flows)
5.1 = mid-channel, side, or diagonal bars present
5.2 = flood chutes, neck cutoffs, channel avulsions, and/or braiding present
5.3 = steep riffles may be present
5.5 = channel alterations present

Figure 7.4 Widening related to aggradation and the formation of a mid-channel bar.

Major Channel Over-Widening: In the upper right hand corner of the over-widening section of the RGA form, evaluations concerning width to depth ratio (W/d) and the active lateral erosion of both banks are set apart with a darker border lines. If both of these parameters are assessed in the poor condition category, then rate the segment (or reach) as "poor" in the widening process regardless of how the other three evaluations (within Step 7.3) were made. Check boxes have <u>not</u> been provided in the lower left hand corner of the over-widening section to indicate the stream type departure. Over-widening is not evaluated as the cause of a stream type departure as are the vertical adjustments of degradation and aggradation.

7.4 CHANGES IN PLANFORM

The planform is the channel shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other adjustment processes such as aggradation and widening. When a river changes planform (Figure 7.5) and cuts a new channel, a change in channel slope usually results, sometimes initiating another channel evolution process. This evolution process will start with degradation if the channel slope is increased, or with aggradation if the slope is decreased. Indicators of planform change (noted in the left hand column on the RGA Form) are:

- Flood chutes, which are longitudinal depressions where the stream has straightened and cut a more direct route usually across the inside of a meander bend;
- Channel avulsions, where the stream has suddenly abandoned a previous channel alignment;
- Change or loss in bed form structure, sometimes resulting in a mix of plane bed and pool-riffle forms;
- Island formation and/or multiple thread channels;
- Additional large deposition and scour features in the channel length typically occupied by a single riffle-pool sequence (may result from the lateral extension of meander bends).
- Thalweg not lined up with planform. In meandering streams the thalweg typically travels from the outside of a meander bend to the outside of the next meander bend. Pools are located on the downstream third of the bends. Riffles are at the cross-over points between two pools on successive bends. During planform adjustments, the thalweg may not line up with this pattern.

This parameter assesses not only the presence of flood chutes and channel avulsions, but also the likelihood that they will occur. Channels sometimes change course as the result of catastrophic channel avulsions due to a debris jam, a road crossing, or loss of riparian buffer and bank instability, or they may change course due to human interference through channel straightening (Figure 7.5).

Refer to your Field Notes for the following signs or conditions that may be evidence of channel planform adjustments:

1.3 = floodplain encroachments present
3.1 = significant bank present
2.9 = sinuosity changes within the segment or reach
2.10 = runs only or riffles that are partial or transverse
2.11 = riffle spacing off (< 5 or > 7 channel widths for C and E stream types)
3.1 = excessive bank erosion on outside bends
4.8-4.9 = flood prone constrictions present
5.1 = mid, side, delta, or islands present
5.2 = flood chute, neck cutoffs or channel avulsions
5.5 = straightening present

Figure 7.5 Planform Change: In this example, the thalweg was previously on the right bank under both low flow and bankfull flow conditions. Now the thalweg has shifted to the left bank as seen under low flow conditions.

Major Planform Adjustment: In the upper right hand corner of the planform section of the RGA form, evaluations concerning the extensive lateral erosion of outside bends and evidence of channel avulsions and mid-channel bars are set apart with a darker border lines. If both of these parameters are assessed in the poor condition category, then rate the segment (or reach) as "poor" in the planform adjustment process regardless of how the other two or three evaluations (within Step 7.4) were made. Check boxes have not been provided in the lower left hand corner of the planform section to indicate the stream type departure. Planform adjustment is not evaluated as the cause of a stream type departure as are the vertical adjustments of degradation and aggradation.

7.5 CHANNEL ADJUSTMENT PROCESS

In this step, the adjustment process scores are reviewed. You will decide which processes are active and ongoing, which occurred historically, and then which stage of channel evolution the segment is in. The scores given to each of the four adjustment processes are transferred to the RGA Form (Table 7.5) and sub-totaled under each of the four condition categories. Calculate the condition rating by dividing the total score by 80 (which is the total possible score for the RGA).

Indicate those adjustments that occurred historically and where adjustments have led to stream type departures (STD) by checking the appropriate boxes in Table 7.5 on the RGA field form (transfer the checks from steps 7.1 - 7.4). Then assess what stage of channel evolution best describes the condition of the segment (or reach) based on the types of adjustments, when they occurred in time, and the models provided in Appendix C. Also indicate which channel evolution model you used (F and D-stage models explained in Appendix C). See the example of a completed Adjustment Scores Table in Figure 7.6.

On the "channel adjustment processes" line below Table 7.5 on the RGA field form, list the active adjustment processes that received scores in the fair to poor range in steps 7.1 through 7.4. In some instances there may be more than one process occurring. List any concurrent processes that received a score of 10 or less.

7.5 Channel Adjustment Scores – Stream Condition – Channel Evolution Stage

Condition Departure	Reference N/S	Good Minor	Fair Major	Poor Extreme	STD*	Historic	Condition Rating: (Total Score / 80)	Channel Evolution Stage:
Degradation				4	√	√	0.4	III (F-stage)
Aggradation		14						
Widening			6				7.6 Stream Condition: Poor	
Planform			8					
Sub-totals:		14	14	4	Total Score: 32			

Channel Adjustment Processes: __Widening and Planform after historic Degradation__

Figure 7.6 Example of Channel Adjustment Scores filled in from Steps 7.1 to 7.4 to determine Channel Evolution Stage and Stream Condition.

7.6 STREAM CONDITION

Table 7.1: RGA Score Ranges

0.85 – 1.0	Reference Condition
0.65 – 0.84	Good Condition
0.35 – 0.64	Fair Condition
0.00 – 0.34	Poor Condition

Use the table to the right to assign a stream geomorphic condition for the stream segment (or reach). This step requires some discretion, as you may encounter any number of reasons why the condition as scored does not fit with what your seeing in the field. If you record a condition descriptor that is different from that suggested by the rating table (above) be sure to record your rationale on both the RGA field form and in the Phase 2 database. This method of assessing the stream condition is preferred over going back to the adjustment process assessments and changing scores so that the desired ratio can be achieved. For example, for the stream assessed above (Figure 7.6), the condition rating came out as "0.4", which puts it in the "fair" range shown in the table, but the stream condition was described as "poor." The rationale was the Stream Type Departure from a "C" to an "F" stream type. It is appropriate to rate a stream in poor condition when it is experiencing extreme adjustment outside the expected range of natural variability for the reference or modified stream type. A stream type departure is an indication that channel and/or floodplain geometry may have changed to such a degree that the fluvial processes involving the transport of water, sediment and debris have changed in response to a set of natural and/or human stressors. These changes often lead to further change, either back to the reference condition or to a new equilibrium condition.

Either way, the on-going adjustments may cause erosion-related conflicts and/or aquatic ecosystem impacts.

7.7 STREAM SENSITIVITY

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor. With the help of Table 7.1, use the existing stream type and the stream condition to evaluate the sensitivity of your segment or reach. Remember to use the existing stream type determined in Step 2.14, not the reference stream type assigned at the top of the RGA form. If the existing stream type represents a departure from a reference or modified reference stream type then you will use the far right-hand column of Table 7.1.

Table 7.2 Phase 2 Stream Sensitivity Ratings based on existing stream type, condition and departure.

Stream Type Group	Existing Geomorphic Stream Type[1]	Sensitivity		
		Reference or Good Condition	Fair-Poor Condition in Major Adjustment	Poor Condition, Represents a Stream Type Departure
1	A1, A2, B1, B2	Very Low	Very Low	Low
2	C1, C2	Very Low	Low	Moderate
3	G1, G2	Low	Moderate	High
4	F1, F2	Low	Moderate	High
5	B3, B4, B5	Moderate	High	High
6	B3c, C3, E3	Moderate	High	High
7	C4, C5, B4c, B5c	High	Very High	Very High
8	A3, A4, A5, G3, F3	High	Very High	Extreme
9	G4, G5, F4, F5	Very High	Very High	Extreme
10	D3, D4, D5	Extreme	Extreme	Extreme
11	C6, E4, E5, E6	High	Extreme	Extreme

Assigning a sensitivity rating to a stream is done with the assumption 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 those undergoing degradation or aggradation, may become acutely sensitive. Step 6.2 of the Phase 3 Handbook provides a more detailed description of the factors involved in assessing stream sensitivity.

VT River Management Program
Phase II QA Protocol

Introduction & Purpose:

The Vermont River Management Program (RMP) has developed this Quality Assurance (QA) protocol to ensure the integrity of its Rapid Geomorphic Assessment (RGA) data. High quality data, which is complete and accurate, will form the basis of meaningful natural resources and river management projects, and is therefore one of the primary goals of any assessment project. Documentation of any assessment deficiencies should not necessarily be viewed as a failure, but rather as the first step in identifying future assessment needs.

1 Geomorphic stream types from the Rosgen (1994) Classification System.

Step 1: Automated QA and Assessor Documentation

After all data collected during the Phase 2 RGA has been entered into the DMS, the first step of the QA process is to run through the automated "QA Check." This step follows data entry Step 7 in the DMS and is meant to increase the efficiency of the QA effort by quickly identifying suspect or inconsistent data.

During this process, the DMS will scan through the data set in an attempt to identify fields that may have been left blank, data entry errors, and other possible discrepancies within the data set. A reach or segment will register as "Provisional" as long as "issues" remain unaddressed. For each potential issue that the DMS finds during this process, you are given two options. Either 1.) make an appropriate adjustment to the relevant data, or 2.) provide a comment explaining why the data is correct as it is entered. This process is meant as a way to highlight potential errors, but also as a way for you to provide further documentation on the characteristics of each segment.

This automated QA process is broken down into five sub-steps. They are as follows:

X.1 Conflicting Phase 2 blank fields – This step searches for those fields that are only partially filled out (i.e. you noted a beaver dam but did not indicate the length of reach affected).

X.2 General Phase 2 Blank Fields – This step searches for those fields that should never be left blank (assuming the reach was assessed).

X.3 Fix Conflicting data – This step searches for potential conflicts within the Phase 2 data set

X.4 Reconcile Phase 1 data and Phase 2 data – This step searches for potential conflicts between Phases 1 and 2.

X.5 Check RGA Data (Step 7) – This step compares Phase 1 and 2 data to how you scored the Rapid Geomorphic Assessment to highlight areas that may be scored differently.

Once all issues have been adjusted or commented on, a reach will register as "Complete", and once all relevant reaches register as complete, the project registers as Complete and you have finished the automated QA process. NOTE: Changes made to a project after it has been registered as Complete may cause the project to fail one or more QA Checks. **Make sure that any changes to the data do not cause a project to revert back to Provisional status**.

The comments you provide during this QA step can be found in the QC Comment Report on the Phase 2 reports page in the DMS. This report will be utilized by the RMP staff when conducting a more detailed QA assessment of the data set.

Step 2: Manual Review of Data

In this step of the QA assessment you will manually review the accuracy of the data. Print out both the Phase 1 and Phase 2 Reach Summary Reports for all relevant reaches and segments. Compare the data between Phases 1 and 2 to confirm that all fields that can be in agreement, are in agreement, as well as to confirm that conclusions made about stream processes and channel evolution have taken the Phase 1 data into consideration. It is important that you utilize maps and orthos to confirm that the data collected seems appropriate.

Please utilize the QA Worksheet (Appendix A) to ensure a complete review of the data set.

Step 3: File Upload

Confirm that all cross-section data has been entered and uploaded to DMS and that all required Phase 2 shape files – including FIT themes and Segmentation Points – have been zipped together and uploaded to the DMS.

Step 4: Address Additional QA Concerns and Provide QA Documentation

After fully reviewing your data and uploading all associated files to the DMS you will need to contact your regional River Scientist to make them aware of the project's status. Someone from RMP will then conduct an additional QA assessment and document any potential discrepancies they find, as well as provide comments on where the data might be improved or clarified. You will then be sent a copy of this QA document and will be required to provide your own documentation that explains how these discrepancies or comments were addressed (i.e. how data was corrected or further clarification was given). These comments can be inserted directly into the QA document provided by RMP staff.

A copy of this QA document containing both RMP comments and how they were addressed should then be provided to your Regional Scientist for final review along with copies of all relevant field forms, worksheets, maps, digital copies of photos and an associated photo log. If RMP Staff deems everything is satisfactory you will insert the final copy of the QA document into your final project report and will have at that time completed all necessary QA steps. This QA document will also become part of any River Corridor Plan that is developed using your data set (please refer to Step 4.2 in the River Corridor Planning Guide for further directions).

QA Protocol Worksheet

Step 1: Automated QA and Assessor Documentation

All five steps of the on-line QA Check have registered as “Complete”?

- □ X.1 Conflicting Phase 2 blank fields
- □ X.2 General Phase 2 Blank Fields
- □ X.3 Fix Conflicting data
- □ X.4 Reconcile Phase 1 data and Phase 2 data
- □ X.5 Check RGA Data (Step 7)

Step 2: Manual Review of Data

Print out both the Phase 1 and Phase 2 Reach Summary Reports for all relevant reaches and segments. It is important that you utilize maps and orthos to confirm that the data collected seems appropriate.

Please utilize the check list below to ensure a complete review of the data set. If any of the below questions cannot be simply answered “yes” or “no,” then it might suggest a comment would be useful.

Field Notes & Phase 1 Update – Comprehensive Review:

- □ Are their fields not captured during the Phase 1 assessment that can be updated with relevant information captured during Phase 2? Potential updates include:
    - □ Valley Width – Can the (estimated) Phase 1 width be updated with a more accurate (measured) Phase 2 width? Only update the valley width if the Phase 2 values represent the reference valley width. If the Phase 2 valley width has been narrowed by a road or berm do not update the Phase 1. In this situation be sure to check the “human caused change in valley width”.
    - □ Stream Type, Bed Material and Bed Form – Where Phase 2 is in reference condition the Phase 1 should be updated.
    - □ Ground Water – Though the two phases differ in their specificity, Phase 2 data for springs/seeps/tribs and wetlands should generally agree with the abundance of ground water noted in Phase 1.
    - □ Channel Bars, Meander Migration and Ice/Debris Jams – Phase 1 should be updated to whatever degree possible.

□ If there are significant corridor encroachments, is there a human caused change in valley type? Where there is a change in valley confinement from unconfined to confined is there also a stream type departure?

□ Does the stream type selected match the channel dimensions (cross-section data)? If not explain why.

□ If the stream is in reference or good condition, does the measured channel width make sense compared to the Phase 1 channel width calculated in SGAT (remember, A and E stream types might be over-estimated in Phase 1)?

Where the reach has been segmented:

□ Did you enter a reason for segmentation?

□ Where the stream type of any segment is not the same as the Phase 1 stream type, is it identified as either a sub-reach or stream type departure?

RGA

□ Was the appropriate form used? Field form should be chosen based on Phase 1 reference confinement type, unless plane bed by reference.

□ Do the adjustment processes reflect field data? If the data is not immediately reflected in the adjustment process scores, are there sufficient comments that support the process chosen? **Use Table 1-1 below** to help evaluate this question.

□ Was there a stream type departure? If so, is this adequately represented in the related adjustment process?

□ Is the Channel Evolution Stage strongly supported by the relative adjustment process scores, data and comments?

RHA – Not Yet Written
Cross-sections:

□ Where multiple cross-sections have been done, does the one entered into the spreadsheet for the segment or reach best represent the adjustment process? Is there a note to indicate which cross-section was used as representative?

□ Do all cross-sections suggest the same stream type? Where they do not, were the reaches segmented? If not, has an explanation been provided?

□ **Do cross-sections extend beyond bank full, from valley wall to valley wall**? The important thing is that the cross-section generally captures the channel within its valley setting (i.e. the relative slopes and heights of banks and terraces, flood prone area, etc.).

□ **Do cross-sections identify all important features**, specifically the bankful, thalwag, recently abandoned floodplain and other terrace features?

File Uploads

□ All cross-section data entered and uploaded to DMS?

All required Phase 2 shapefiles – including FIT themes and Segmentation Points – have been uploaded to the DMS?

Degradation	**Present ?**	**Widening**	**Present?**
Entrenchment Ratio < 2.0	☐	Low Degradation Score (< 11)	☐
Incision Ratio > 1.4	☐	W/D Ratio > 30	☐
Degraded Plane Bed (result of degradation)	☐	Incision > 1.4	☐
HCC in Confinement (from unconfined to confined)	☐	Entrenchment Ratio < 2.0	☐
"F" or "G" Stream Type Departure (or "B" in unconfined Valleys	☐	Significant Bank Armoring	☐
Significant Berms/ Roads/ Rail/ Imp. Path / Development within corridor	☐	Bed Sediment Storage (mid/side/diagonal bars)	☐
Upstream Flow Reg (greater flow or decreased sediment supply)	☐	Stormwater Inputs	☐
Avulsions (resulting in channel straightening) or neck cut-offs	☐	Current Channel Width (Ph2) > Reference Width (Ph1)	☐
Head Cuts, Nick Points Or Tributary Rejuvenation	☐	Steep Riffles	☐
Dredging or Straightening	☐	Flood Chutes, Neck Cut-offs, Channel Avulsions or Braiding	☐
Stormwater Inputs	☐	Flow Regulation (greater flows or greter sediment supply)	☐
No Grade Controls	☐	"D" Stream Type Departure	☐
Eroded Riffle Type	☐	"A" or "B" to "F" Stream Type Departure	☐
Aggradation	**Present?**	**Planform**	**Present?**
W?D Ratio > 30	☐	Changing Sinuosity Within Reach	☐
Flood Chutes, Avulsions (resulting in abandoned channel), Braiding	☐	Significant Berms/ Roads/ Rail/ Imp. Path / Development within corridor	☐
Aggraded Plane Bed (result of aggradation)	☐	Bank Erosion > 20%	☐
Homogeneous Substrate	☐	Bed Sediment Storage (mid or side bars)	☐
Impoundment (resulting in decreased flows or increased sediment supply)	☐	Meander Migration	☐
Constriction causing aggradation above or below	☐	Runs Only/ Partial Riffles/ Diagonal Bars	☐
Bed Sediment Storage (mid/side/diagonal bars)	☐	5 > Riffle/ Step Spacing > 7 Channel Widths (for C or E Streams)	☐
Embedded Substrate	☐	Constrictions Smaller Than Floodprone Width	☐
Dredging or Straightening	☐	Flood Chutes/ Neck Cuts/ Avulsions/ Braiding	☐
Downstream Flow Reg (decreased flows or greater sediment supply)	☐	Dredging or Straightening	☐
Steep Riffles	☐	Eroded or Sedimented Riffles	☐
Sedimented Riffles (mostly runs)	☐		

Table 1-1: In this table, each adjustment process is accompanied by those data features indicative of that process. Check off which features were present in this reach. If more than 50% of the features for any adjustment are present, it suggests that process is active, and should likely score Fair or Poor in Step 7 of the Phase 2 assessment.

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