Step 4. Land Cover and Reach Hydrology

Overview

Background:
Step 4 evaluates how watershed land use, riparian vegetative cover, and other hydrologic features influence the quantity and rate of water and sediment run-off that may occur in a reach after storm events. Changes in runoff characteristics may explain observed changes in channel size and shape, why the channel is adjusting, or why the channel may be sensitive to further modifications. For instance, two watersheds with similar valley shapes, geology, and soils, may have very different sized streams due to markedly different amounts of vegetative cover next to their channels or within their watersheds. A relatively narrow, deep, riffle-pool stream may become very wide and aggraded (filled in with sediment) if the riparian vegetation is removed.

Evaluation:
You will interpret changes in run-off characteristics in the steps using the data sources listed below. You may also have first-hand knowledge of land cover/land use changes that you want to consider when interpreting map and orthophoto information.

Land cover/land use (LcLu) analysis will be conducted using SGAT, which automates delineation of the river corridor and the summation of LcLu types within the river corridor and watershed for each reach (see below).

Data sources:

- GIS coverages - A statewide land cover / land use GIS coverage is available from the Vermont Center for Geographic Information (VCGI). Please contact the River Management Section to obtain the LcLu statewide land use data. The data from which it was created was produced in 2002, possibly making the data obsolete for areas that have developed recently. It is important that you field verify LcLu data, particularly within the river corridor. Many regional planning commissions and towns also have GIS coverages available and can provide printed maps for a fee upon request. When using a GIS coverage be sure to note when the data was created. In some areas even data collected 10 years ago may be obsolete for determining current land cover.
- Aerial photos and orthophotos - Photographs are available at most NRCS offices, the Department of Environmental Conservation Water Quality Division, and some regional planning commissions. Your town office may also have aerial and orthophotos available. Orthophotos are available for purchase from the VT Tax Department Mapping Program. Note that the Vermont Mapping Program provides every town with a set of orthophotos for the town's geographic area, and that these photos are usually available for use at town offices.
- Local knowledge - If you suspect rapid land use changes in your watershed, consult land managers, town officials, and citizens who can inform you of recent land use changes. Town tax maps can assist in tracking changes in residential and commercial development.

Evaluation with SGAT:
SGAT generates total surface area for each land cover/land use (LcLu) type within each reach's watershed (Step 4.1) and river corridor (Step 4.2).

Data Sheet 4. Land Cover-Reach Hydrology

4.1 WATERSHED LAND COVER / LAND USE (SGAT)

Meta Data:

- Land use – land cover (2002 statewide)
- Land use - land cover (1990s statewide)

Background:
Lakes, wetlands, and perennial vegetation play an important role in a watershed by storing water and trapping sediment, which helps to reduce flood peaks and maintain summer base flows in rivers and streams. Urban development and cropland typically increase the peak and change the duration of storm-water and sediment runoff events.

Evaluation:
SGAT clips the current LcLu layer to the reach sub-watersheds and generates a table named "**S14LW13**" that sums the percent area of each LcLu type in the reach watershed. This is done in Step 13 of SGAT. This table can be imported into the DMS where the dominant and sub-dominant LcLu types and percent composition for each reach's watershed are automatically calculated and stored.

For **historic** LcLu consult the 1970's series orthophotos. Older aerial photos, town tax maps, and local knowledge may also indicate or confirm land cover changes.

In consideration of the time commitment necessary to conduct an accurate assessment of LcLu from historic orthophotos that have not been digitized, you may decide to focus only on those sub-watersheds where visually significant changes have occurred (i.e., noticeable increases or decreases in urban or crop land). Since you will be looking at the 1970s orthophotos later in Step 6.4 to assess meander migration, this may be the most efficient time to red flag those sub-watersheds that merit an assessment of historic land cover/land use. Visually estimate dominant historic LcLu from maps, aerial photos, and orthophotos, or find the resources and/or assistance to have the historic orthophotos for sub-watersheds of interest digitized to complete the same GIS-based analysis that can be done with digital layers for current LcLu.

Menu

Wetlands	Open water (lakes, ponds, reservoirs, streams) and wetlands.
Forest	Coniferous and/or deciduous forest – rural **low** density development.
Shrub	Small trees, shrubs, and unmanaged grasses.
Field	Agriculture – pasture or hayfield / orchard.
Crop	Agriculture – land tilled to grow crops.
Urban	Moderate to high density residential, commercial, industrial, roads.

Impact Rating for Watershed Land Cover/Land Use

H	High - 10% or more of the reach watershed is crop and/or urban
L	Low - Between 2 and 10% of reach watershed is crop and/or urban
NS	Not Significant - Less than 2 % of reach watershed is crop and/or urban

Data Entry:
When the SGAT data is uploaded to the DMS the percentage of each land use in the watershed will automatically be determined for each reach. The historical land use in the watershed must be manually entered into the DMS.

4.2 CORRIDOR LAND COVER / LAND USE (SGAT)

Meta Data:

- Land use – land cover (2002 statewide)
- Land use - land cover (1990s statewide)
- Digital corridor land use - land cover

Background:

Land use/land cover within the stream corridor is particularly important with respect to sediment deposition and erosion during annual flood events. Wetlands, ponds, and perennial vegetation moderate storm water and sediment runoff, while the impervious surfaces within urban areas and the exposed soils found in cropland have the potential to increase watershed inputs.

Evaluation with SGAT:

SGAT will clip the current digital LcLu layer to the reach corridor and generate tables that can be automatically uploaded into the DMS where the dominant and sub-dominant LcLu types and their percent coverages within each reach's river corridor will be calculated and stored. Be sure **not** to sum the data for the entire corridor area upstream of the reach break; skip SGAT Step 13 for this parameter. This parameter is only for the corridor of the reach. The SGAT table needed for this step is **S14LC12**.

Menu

Wetland	Open Water (lakes, ponds, reservoirs, streams) and wetlands.
Forest	Coniferous and/or deciduous forest.
Shrub	Small trees, shrubs, and unmanaged grasses.
Field	Agriculture - pasture or hayfield / orchards, groves, nurseries.
Crop	Agriculture - land tilled to grow crops.
Residential	Developed land with rural roads and houses and land that is managed as lawn.
Commercial	Developed land with retail businesses and larger state roads and Interstate highways.
Industrial	Developed land with industry.

Impact Rating for Corridor Land Cover/Land Use

H	High - 10% or more of reach corridor is crop **and/or** developed
L	Low - Between 2 and 10% of reach corridor is crop and/or developed
NS	Not Significant - Less than 2 % of reach corridor is crop and/or developed

Data Entry:

When the SGAT data is uploaded to the DMS the percentage of each land use in the corridor will automatically be determined for each reach. The historical land use in the corridor must be manually entered into the DMS.

4.3 RIPARIAN BUFFER WIDTH (FIT)

Meta Data:

- 1:5K orthos
- Digital corridor land use - land cover
- 1:5K orthos, recent coverages & photos, field observation

Background:
The riparian buffer is the area of land directly adjacent to the channel along the channel's banks and floodplain which is covered with native woody vegetation and largely unmanaged (i.e. allowed to grow naturally with no cutting or cultivation). Riparian buffers protect and enhance water quality, fish and wildlife habitats, aesthetics, and recreational values associated with streams and rivers. The roots of grasses, shrubs, and trees are critical to the ability of stream bank soils to withstand the erosive power generated during high water events. Streams without riparian vegetation often experience high rates of lateral erosion and may see such large increases in sediment that they undergo major adjustment of channel dimension, pattern, and profile. Riparian vegetation plays an important role in aquatic ecosystems by providing food and cover for stream-dwelling organisms as well as habitat and travel and dispersal corridors for terrestrial wildlife.

Evaluation:
Using orthophotos, estimate the dominant and sub-dominant buffer width category along the right and left banks (determined facing downstream) of the reach. It is likely that the reach you are evaluating has varying buffer widths along its length. *The dominant width is not the average width* but rather the width category (from the menu) that occurs most often throughout the reach (see example in Figure 4.1). If you are using GIS software you can overlay the VHD stream layer on the orthophotos and use the software's buffering tool to delineate the buffer width categories in order to help visualize the buffer condition.

Menu

5 to 25 feet
26 to 50 feet
51 to 100 feet
> 100 feet

Fallow land, historically cleared and/or cultivated and now reverting back to woody vegetation, may be difficult to interpret using orthophotos. If during windshield surveys or Phase 2 assessments you encounter fallow fields reverting to woody vegetation along a stream reach (but assessed here as having no buffer), you should revise the Phase 1 data. Agricultural and lawn or other highly managed household vegetation is not considered part of the riparian buffer.

Using the FIT in SGAT index the sections of the stream that have a buffer width less than 25 feet in width. This will help in the identification of potential buffer enhancement projects.

Impact Rating for Riparian Buffer Width (Automated by the DMS)

H	High – Greater than 20% of the right and/or left bank has a buffer <25 feet.
L	Low – Between 5-20% of the right and/or left bank has a buffer <25 feet
NS	Not Significant – Less than 5% of the right and/or left bank has an inadequate buffer.
No Data	No data sources are available to determine the width of the riparian buffer.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Enter the dominant and sub-dominant buffer width into the DMS. Use the FIT to index areas of stream with less than 25 feet of buffer.

4.4 GROUNDWATER & SMALL TRIBUTARY INPUTS

Meta Data:
- 1:24K topos, 1:5K NHD
- 1:24K topos, 1:5K NHD, NWI maps
- 1:5K NHD, NWI maps, field observation

Data Sources:
- USGS 1:24,000 topographic maps (hard copy, or digital)
- Vermont Hydrography Data Set (VHD) 1:5,000 stream coverage (if you don't have access to this coverage use surface waters on USGS 1:24,000 topographic maps)
- National Wetlands Inventory (NWI) maps
- The NWI maps for Vermont are produced by the U.S. Fish and Wildlife Service and are developed from aerial photo interpretation and limited field checking. The Vermont maps are mostly based on 1:80,000 scale color infrared aerial photos taken in 1978. These maps show the general locations of wetlands, ponds, lakes, and streams and are available in digital format from the U.S. Fish and Wildlife Service National Wetlands Inventory at http://www.nwi.fws.gov/. Paper copies of the maps can be obtained from the DEC Water Quality Division.
- Vermont Significant Wetland Inventory (VSWI) maps
- The VSWI maps are regulatory wetland maps produced from the NWI maps by the Vermont Agency of Natural Resources. A GIS data layer has been produced from these maps and is available from VCGI. Note that the regulatory wetlands shown on the VSWI maps are a subset of all of the various wetland and deepwater habitats shown on the NWI maps. For more information, contact the Vermont Wetlands Office at 802-241-3770.
- Local Knowledge

Background:
Groundwater plays an important role in maintaining healthy aquatic ecosystems. When Vermont's streams and rivers are experiencing temperature extremes (during both winter and late summer), groundwater inputs are essential in moderating water temperatures such that streams remain habitable and productive for aquatic organisms. Fish adapted to cold water habitats, such as Brook Trout (*Salvelinus fontinalis*), are particularly sensitive to water temperature, and will often move to areas of a stream that are fed by groundwater upwellings, springs, or seeps to overwinter or seek refuge during the hot summer months. In addition to moderating water temperatures, ground water is essential in maintaining stream flows, and thus available habitat, during late summer and during drought years when most of the base flow in streams is provided by groundwater.

Evaluation:
Using the VHD 1:5000 stream coverage, wetland maps (see below), and local knowledge, estimate the abundance of groundwater inputs that flow directly to the channel from adjacent wetlands, small tributaries, springs and seeps. If you do not have access to a 1:5,000 stream coverage, use the 1:24,000 USGS topographic maps. Although small tributaries may not be shown as blue lines on topographic maps, they are usually present in areas where contour lines form tight upside-down V's (see Appendix D about reading topographic maps).

Menu

Abundant	Frequent wetlands, seeps, springs, or small tributaries adjacent to channel.
Minimal	Occasional wetlands, seeps, springs, or small tributaries adjacent to channel.
None	No wetlands, seeps, springs, or small tributaries adjacent to channel.
No Data	No data sources are available to determine if the impact exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Manually enter the data for groundwater and tributary influence into the DMS for each reach.

Step 5. Instream Channel Modifications

Overview

Background:
Most of the information you have collected so far, with the exception of riparian corridor and watershed land use, has defined the natural fluvial geomorphic setting of the stream reaches within your watershed. Before assessing the impacts associated with instream channel modifications, it is important to remember these assumptions made for conducting these stream geomorphic assessments:

- Although rivers are dynamic, changing their channel form (or geometry) continually through erosion and depositional processes, they have a central tendency of form and process that has a predictable relationship with surrounding watershed land forms and which may undergo significant change naturally with climate changes over time; and
- Human-related physical change to river channels, floodplains, and watersheds often mimic and/or change the rate of natural physical processes in the watershed.

Because human-related changes often produce predictable channel responses, we can establish reference, or "equilibrium," conditions for different stream types and then analyze how different modifications to a channel cause a channel response, adjustment, or departure from the reference condition of the stream.

In Step 5, you will look at the instream channel modifications that have occurred over time. These parameters will be useful in predicting the condition, current adjustment process, and sensitivity of the stream reaches in your watershed.

Data Sheet 5. Instream Channel Modifications

5.1 FLOW REGULATION AND WATER WITHDRAWALS (FIT)

Meta Data:
- 1:24K topos, 1:5K NHD & orthos
- 1:24K topos, 1:5K NHD & orthos, files
- 1:24K topos, 1:5K NHD & orthos, files, field obs.

The following DEC Programs maintain information about flow regulations:
- Water Supply Division – 241-3400 (public water supply withdrawals)
- Facilities Engineering, Dam Safety Section – 241-3454

Background:
Structures that completely span a channel, such as dams, can significantly alter the quantity and duration of water and sediment runoff and may cause a stream to undergo both vertical and lateral channel adjustment processes. Depending on the timing and magnitude of flow regulation and the stream types and conditions above and below the facility, these adjustment processes may occur annually or they may occur quickly when the flow alteration first occurs and then slow as the stream adjusts to new flow and sediment regimes.

Impoundments and water withdrawals can impact instream habitat and biota, especially during naturally low flow periods that typically occur in Vermont in August, September, and February. In addition to channel adjustments that may affect the structure of instream habitat, additional withdrawal of water can

expose streambed substrates, effectively reducing the amount of habitat area available for aquatic organisms. 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 and lowers the water away from near-bank cover, thereby reducing available habitat. Impoundment of stream flow can also warm waters substantially due to longer periods of and greater surface area of solar exposure, making streams less habitable for many aquatic organisms, especially for cold-water fish species such as Brook Trout (*Salvelinus fontinalis*).

Evaluation:
Most large dams are shown on the USGS topographic maps as a short black line crossing the stream blue line. Another source of data is the ArcView dam shapefile from VCGI named "Emergencyother_Dams". This can help you locate these large dams, but you will still need to contact other sources to find out how they are operated. Consult with DEC Facilities Engineering, Dam Safety Section and Water Supply programs, town records, utilities, landowners, and businesses that may be able to provide information on projects and facilities that regulate the flow or withdraw water from the stream reach. Choose from the menu list to describe the type of withdrawal or flow regulations present in the reach.

Menu

Type

Withdrawal	A withdrawal of water from the stream
Bypass	The water is diverted away from the channel and re-enters down stream.
Run of River	Upstream or in reach flows are impounded. Flow quantity spilling or released below the dam is the same as flow quantity entering the impoundment at all times.
Store and Release	Water is impounded and stored and released only during certain times.
None	No known flow regulation or water withdrawals. Select "none" if you have completed the appropriate research and have found no evidence of flow regulations.
No Data	No data sources are available to determine if a flow regulation or water withdrawal exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Size

Small	Impoundments not much wider than river itself or withdrawals not affecting the channel forming flow.
Large	Impoundments much wider than river itself (creating a reservoir) or withdrawals significantly affecting the channel forming flow.

Use

Drinking
Irrigation
Flood Control
Hydro-electric
Recreation
Other

Impact Rating for flow regulation and withdrawals

H	High - stream flows and channel geometry are affected by a cross-channel weir or dam with a water intake structure and /or a visible instream impoundment that has affected sediment depositional patterns or a withdrawal large enough to alter the channel forming flow.
L	Low – cross-channel weir and intake structures present but there is no apparent change in channel geometry and depositional patterns or change in sediment deposition due to water withdrawals.
NS	Not Significant – either no flow regulation OR small water intake structure with no cross-channel weir.
No Data	Unknown if there are flow regulations
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Use the Feature Indexing Tool (FIT) in SGAT to note the locations of flow regulations and water withdrawals within the reach. When the FIT data is uploaded into the DMS the data will be automatically populated for each reaches where a flow regulation or withdrawal is indicated. For reaches with "none", "no data" or "not evaluated" the data field must be manually entered into the DMS.

5.2 BRIDGES & CULVERTS (FIT)

Meta Data:
- 1;24K topos, 1:5K NHD & orthos
- 1;24K topos, 1:5K NHD & orthos, files
- 1;24K topos, 1:5K NHD & orthos, files, field obs.

Background:
Stream crossing structures are often undersized to handle the stream's annual high flow events and present serious impediments to less frequent flood flows. Undersized bridges and culverts essentially act as dams during high water and may cause vertical and lateral stream adjustments similar to those caused by dams. Undersized structures may also be inadequate to move sediment, which may collect upstream in the middle of the channel causing the stream to split, or bifurcate. Eventually, these mid-channel bars push the flow to the right or left of the bridge resulting in the often sharp "S" bend in the channel observed on the orthophoto. This process can result in a hazardous situation if the stream outflanks the bridge or culvert during a flood and also may lead to major channel adjustments. Supplemental bridge and culvert assessment protocols are included in the Stream Geomorphic Assessment program (see Appendix G). These protocols, the ANR Bridge and Culvert Assessment, are not required during a Phase 1 assessment but they will help in identifying structures that are potentially impacting the geomorphic condition of stream reaches.

Figure 5.1 Perched culverts often restrict the movement and migration of fish and other stream dwelling organisms.

The ANR Bridge and Culvert Assessment protocols can also help you identify those structures that are impediments to fish and wildlife movement and migration. Stream crossing structures can act as migration barriers to fish and wildlife that move through the stream channel or along the adjacent riparian areas. Culverts, in particular, present migration barriers to many fish species, when constructed too steep or too long, such that flow velocities in the culvert may be too great for fish to swim through. Undersized culverts also become barriers when the outlet becomes perched above the channel bed due to the lack of sediment movement through the structure and the resulting channel bed degradation that occurs downstream (Figure 5.1). In general, bridges usually are less likely than culverts to impede fish and wildlife movements. Culverts installed large enough and at-grade with the channel bed, such that natural stream bottom conditions are maintained within the culvert, are less likely to become migration barriers to aquatic species movement.

Evaluation:
Record the number of bridges or instream culverts within the reach by counting the number of times the reach is crossed by roads and driveways as shown on topographic maps and/or orthophotos. Identify other bridges and culverts, especially those on driveways or recently constructed roads that do not appear on the maps and orthophotos, during your windshield survey. Bridges and culverts are likely to be located near reach breaks, as reach breaks often coincide with bedrock outcrops or a narrowing of the valley, which are also good locations for building stream crossing structures. Make sure not to double-count bridges and culverts from one reach to the next. Calculate and record the length of the reach that is impacted by stream crossing structures, as described in the menu below.

Impact Rating for bridges and culverts

H	High - ≥ 20 % of reach length is channelized, has split flow, or makes a sharp "S" bend upstream or downstream of bridges or culverts
L	Low – 5 to 20 % of reach length is affected by bridges or culverts (as described in menu above)
NS	Not Significant – < 5 % of the reach is impacted by bridges or culverts
No Data	No data sources are available to determine if the impact exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Use the FIT in SGAT to locate the stream crossings. If you know whether it is a bridge or culvert enter than into the FIT, otherwise enter Unknown in the DMS. You will enter the crossings as a point file and manually enter length of reach affected by the crossing in the "length field" in the FIT within the SGAT extension. Once uploaded the DMS will automatically populate the DMS and determine the length of impact from bridges and culverts for each reach.

5.3 BANK ARMORING or REVETMENTS (FIT)

Meta Data:
- 1:24K topos & orthos
- 1:24K topos, orthos, files
- 1:24K topos, orthos, files, field obs.

Background:
Bank revetments intended to "fix" stream channels in place often contribute to channel movement and adjustment. This is because revetments are typically applied to the symptom of bank erosion while the underlying channel adjustment processes that are causing the bank erosion are overlooked. Attempts to

lock in the vertical and lateral position of a channel while it is under adjustment may set back the channel adjustment process, prolonging or preventing recovery of the stream channel back into a state of equilibrium or imposing a new state of equilibrium dependent upon the stream type and the maintenance of the armored condition. Furthermore, many revetments typically fail and/or cause further channel adjustments to propagate upstream or downstream. This is especially true where a stream has vertically incised (or cut down into its stream bed), losing access to its floodplain. Where this channel adjustment process is occurring, rock rip-rap frequently becomes undermined, fails, and then contributes to aggradation and widening of the channel.

Bank armoring (also called revetments) can be made from natural material such as whole trees or stumps, or wooden cribs filled with stone and willow shoots. Typically in Vermont, bank revetments have been made of rock rip-rap to protect the bank from scour and undercutting, particularly along the outside bends of channels where the current is the strongest (Figure 5.2).

Figure 5.2 Examples of Vermont stream banks hard armored with rock rip-rap. Note the continued erosion and bank failure upstream of the rip-rap sections.

Evaluation:
Use the orthophotos, information from the NRCS and DEC Stream Alteration Engineers, and windshield surveys to document the location and length of the stream channel (in feet) that is armored, either on the **right bank** and/or the **left bank**. Record the type of bank armoring present using the menu choices. Use the ArcView extension, Feature Indexing Tool (FIT), to document the locations and lengths of bank armoring and revetments. Follow the directions in Appendix P for using the FIT.

Streambank condition surveys have been a popular water resource assessment activity for decades. Check with NRCS and the Regional Planning Commission in your area to see if streambank surveys which include erosion and bank revetment mapping have been completed. This information may be useful here. You may even consider having a couple summer interns complete a streambank survey.

Menu

Rip-rap	Rock or stone rip-rap
Hard bank	Concrete or other hard bank treatments
Multiple	Multiple bank revetments
Other	Other bank stabilization, including tree revetments and log cribbing
None	No bank armoring in the reach. Only select this option if you have seen the entire reach.
No Data	No data sources are available to determine if bank armoring exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Impact Rating for human-placed bank armoring

H	High – ≥ 20 % of the right and/or left bank
L	Low – 5 to 20 % of the right and/or left bank
NS	Not Significant – < 5 % of the right and/or left bank
No Data	No data sources are available to determine if bank armoring exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Use the Feature Indexing Tool (FIT) in SGAT to note the locations of bank armoring and revetments. When the FIT data is uploaded into the DMS the data will be automatically populated for each reaches where a bank armoring or revetments are indicated. For reaches with "none", "no data" or "not evaluated" the data field must be manually entered into the DMS.

5.4 CHANNEL STRAIGHTENING (FIT)

Meta Data:
- 1:24K topos, 1:5K NHD & orthos
- 1:24K topos, 1:5K NHD & orthos, files
- 1:24K topos, 1:5K NHD & orthos, files, field obs.

Background:
Channel straightening is the process of changing the natural path of a river through activities such as windrowing and straightening.

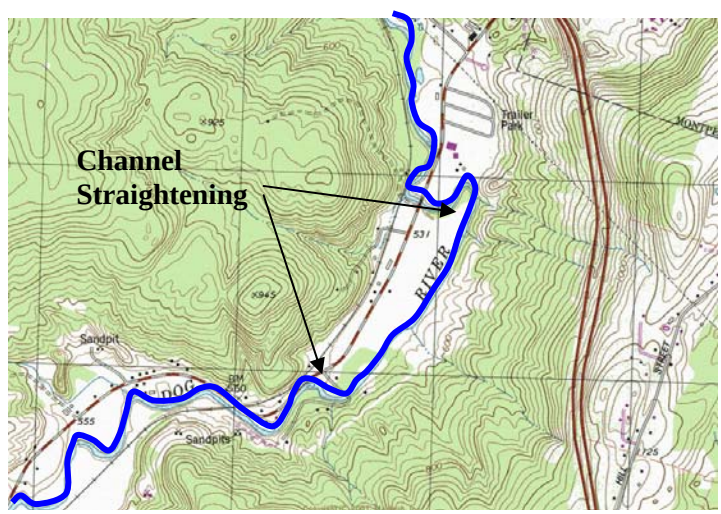


Figure 5.3 Channel modifications identified on a topographic map.

Channel straightening may increase the downstream hazard potential due to an increase in water velocity and power from the increased channel slope, loss of access to the floodplain, and disturbance of the channel bed armor (larger substrates that typically cover the upper layer of the channel bed). When the channel slope is increased, the velocity increases. This extra force may cause the river to degrade, or cut down vertically into its bed. Often the sediment that used to be in the bottom of the river of the now straightened area is re-deposited downstream of the straightened area. This results in aggradation, or building up, of the channel bed in this downstream area. Aggradation, in turn, can result in channel widening, bank instability, and other channel responses, most of which are detrimental to both riverside land and aquatic habitat (MacBroom, 1998).

Pushing gravel to the stream margins without physically removing it from the stream is called windrowing, which may impact the morphology of the river. For example, many reaches of the White River and its tributaries in central Vermont were windrowed following the floods of the 1970's. Gravel was bermed up, and gravel bars were removed from the river to "improve" the channel's capacity to move flood waters. During the following decades some reaches experienced major damage caused by the changed morphology of the river. Damages included widening and bank erosion, downcutting, and significant

changes in the cross-sectional geometry of the river. These reaches remain sensitive to change and adjustment due to these instream modifications, especially during flood events (NRCS 2001).

Evaluation:
Check with the DEC stream alteration engineers, NRCS staff, and town road commissioners for documentation of historic channel straightening projects. Some straightened reaches are easy to read off of topographic maps or orthophotos (Figure 5.2). Use the FIT to measure and document the total reach length (in feet) of reach length that has been straightened. Record the type of channel straightening along the reach, using the menu choices below. Follow the directions in Appendix P for downloading and using the RIT.

Menu

Straightening	Manual straightening of a channel without windrowing
With Windrowing	Pushing gravel up from the stream bed onto the top of either bank as a part of the straightening of the river.
None	No known channel straightening. If you have completed the appropriate research and have found no evidence of channel straightening, select "none".
No Data	No data sources are available to determine if the channel has been straightened.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Impact Rating for channel modification

H	High – ≥ 20% or reach has been channelized
L	Low – 5 to 20 % channelized
NS	Not Significant – < 5% of the reach affected by channel modifications
No Data	No data sources are available to determine if the channel has been straightened.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Use the Feature Indexing Tool (FIT) in SGAT to note the locations of channel straightening. When the FIT data is uploaded into the DMS the data will be automatically populated for each reaches where a channel straightening is indicated. For reaches with "none", "no data" or "not evaluated" the data field must be manually entered into the DMS.

5.5 DREDGING AND GRAVEL MINING HISTORY (FIT)

Meta Data:

- Interviews - DEC, NRCS
- Interviews - DEC, NRCS, Towns, others

Background:
Dredging and mining gravel bars from a channel may initiate a channel evolution process (see Appendix C). Such activities straighten and steepen the channel and cause the river to cut down and erode its bed. The stream channel eventually aggrades with sediments supplied from upstream reaches as headcuts in the streambed move up-valley (Kondolf, 2001).

Evaluation:
Using information and records from the DEC Stream Alteration Engineers and NRCS field office staff , determine if dredging or gravel mining has occurred in the reach, and if so, determine the relative fre-

quency and volume of gravel extraction. Some of this information may also be available from local excavators and road commissioners. Record the dominant type of gravel removal which occurred in the reach using the menu below. For instance, if landowner gravel mining is occurring today where the reach was historically used for commercial mining, you would choose commercial mining as the dominant type, because of the relatively high frequency and volume of gravel removal. Dredging for flood conveyance may be intermediary between landowner gravel removal and commercial mining with respect to frequency and volume.

Menu

Gravel Mining	Recent or historic landowner removal of gravel from channel for personal use.
Dredging	Recent or historic removal of bed materials to increase channel cross-section for flood conveyance or navigation purposes.
Commercial Mining	Historic (pre-1988) large-scale commercial extraction of gravel from channel.
None	No known dredging or gravel mining. If you have completed the appropriate research and have found no evidence of channel modification select "none".
No Data	No data sources are available to determine if dredging or gravel mining occurred.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Impact Rating for dredging and gravel mining

H	High - Used historically for commercial gravel mining, dredged for flood remediation
L	Low – Used occasionally for annual 50 cubic yards of gravel extraction by landowner
NS	Not Significant - No gravel mining or post-flood dredging operations
No Data	No data sources are available to determine if dredging or gravel mining occurred.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Data Entry:
Use the Feature Indexing Tool (FIT) in SGAT to note the locations of dredging and gravel mining. When the FIT data is uploaded into the DMS the data will be automatically populated for each reaches where a dredging or gravel mining is indicated. For reaches with "none", "no data" or "not evaluated" the data field must be manually entered into the DMS.

Step 6. Floodplain Modifications and Planform Changes

Overview

Background:
These protocols examine changes to lands adjacent to rivers and streams that may affect the vertical and lateral containment of flood flows. River corridors, first delineated in Step 3, are used to examine those lands that may be important primarily to the lateral (or horizontal) movement of flows. Infrastructure and other developments that restrict the lateral movement of flood flows, however, also directly or indirectly (through channel adjustment) restrict the vertical access of a channel to its floodplain.

Though we often associate floodplains with large rivers, over time, even streams in semi-confined valleys will have created a certain amount of floodplain. In addition to providing floodwater storage and attenuation, a floodplain is often the space (or river corridor) through which stream channels meander over time, undergoing planform adjustment and thereby slope adjustment. The availability of space for slope adjustment is critical to the stream in reaching equilibrium with the size and quantity of sediment produced in the watershed. A stream cut off from its floodplain may have less room to meander and be forced into a higher gradient form. If this higher gradient translates into stream power that can move even larger particles in the stream bed, the channel may begin to degrade (or incise), cutting down into its streambed and initiating the channel evolution process (see Appendix C).

Evaluation:
Similar to the evaluation of channel modifications in Step 5, in this step you will evaluate floodplain modifications and planform changes that have occurred over time in order to help predict whether reaches are in adjustment. The floodplain modification and planform change parameters examined in Step 6 will be very useful in predicting the condition, current adjustment process and sensitivity of the stream reaches in the watershed.

Data Sheet 6. Floodplain Modifications And Planform Changes

6.1 BERMS, ROADS, IMPROVED PATHS, RAILROADS (FIT)

Meta Data:
- 1:24K topos, 1:5K orthos
- 1:24K topos, 1:5K orthos, files
- 1:24K topos, 1:5K orthos, files, field obs

Data Sources:
- USGS 1:24,000 topographic maps (digital or hard copy)
- 1990 series 1:5000 Orthophotos (digital or hard copy)
- Berms—NRCS Flood Damage Remediation (Emergency Watershed Protection, EWP) Reports
- Berms—DEC Stream Alteration Engineers

Background:
Berms, roads, railroads and improved paths and the hardened embankments often used to protect them, limit the lateral adjustments of the stream within the corridor and may contribute to onset of vertical adjustments within the channel (Figure 6.1). Developed land, including highways, roads, and railroads, in close proximity to the stream may be a clue that the stream bank has been bermed to protect the infrastructure and investments. For instance, after the 1973 flood many berms, or levees, intended to elevate

the stream embankment to prevent flooding of adjacent lands, were built. In some places, trees have grown on these berms, and are young forests (about 25 years old).

Evaluation:
Determine the location of the river corridor length along which berms, roads, railroads, or improved paths run *parallel* to the stream on either bank (see Appendix E for river corridor delineation). Use the Feature Indexing Tool (FIT) in SGAT to document the locations of berms, roads, railroads and improved paths. Indicate whether these floodplain encroachments occur on one bank at a time or both banks at the same time (Figure 6.2. Berms are difficult to identify on orthophotos and are best identified as part of the Step 7 windshield survey or through other data sources such as flood damage remediation reports. Write *None* if you know there are no berms, roads, railroads, or improved paths (as defined in Glossary, Appendix Q) in the river corridor. Also write *None* if there are no roads or railroads and you have no information about berms or improved paths. If, during windshield surveys or Phase 2 assessments, you find berms, new roads, or improved paths, the Phase 1 evaluation of this parameter should be modified. Follow the directions in Appendix P for using the FIT.

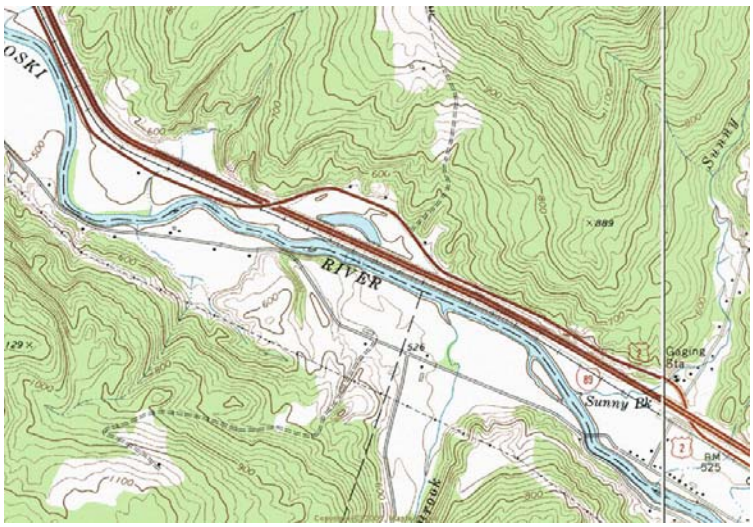


Figure 6.1 Route 2, Interstate 89 and the railroad are all located within the corridor of the Winooski River. The meander bends were likely cut off when the railroad was built.

Stream crossings, where the road, berm, railroad or improved paths runs perpendicular to the stream, are considered under Step 6.2 and are not a part of this parameter. These structures are not necessarily a problem with respect to floodplain function unless berms and fill were used to elevate the road, bridge or culvert. Note berms on the watershed map with a "B." Retain a paper map or digital GIS shape file of berm and road encroachments for later use in quality assurance documentation, field verification and for display purposes.

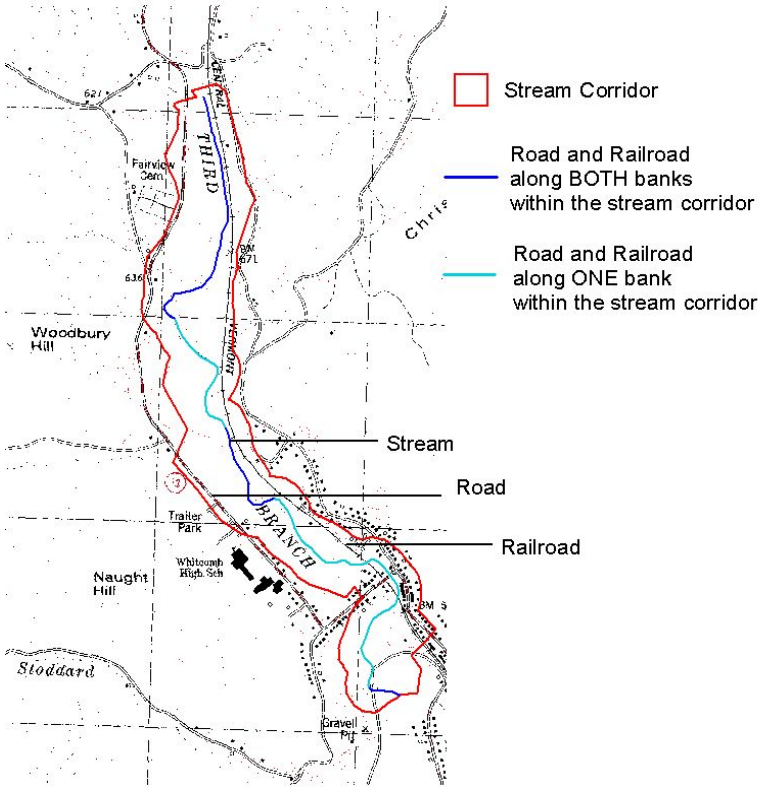


Figure 6.2 Note the difference between a berm or road along one bank versus both banks at the same time.

Menu

One Side	berms, roads, railroads, or improved paths located within river corridor on one side of the stream at a time
Both Sides	berms, roads, railroads, or improved paths located on both sides of the stream
None	No evidence of berms, roads, railroads, or improved paths in river corridor
No Data	No data sources are available to determine if an impact from berms, roads or improved paths exists in the river corridor.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated. Further work should be completed.

Impact Rating for berms, roads, railroads, and improved paths

H	High – berms, roads, railroads or improved paths are within river corridor along ≥ 20 % of the right and/or left bank
L	Low - berms, roads, railroads or improved paths are within river corridor along between 5% to 20% of the right and/or left bank
NS	Not Significant - berms, roads, railroads or improved paths are within river corridor along < 5% of the right and/or left bank
No Data	No data sources are available to determine if an impact from berms, roads or improved paths exists in the river corridor.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated. Further work should be completed.

Data Entry:
Index the berms, roads, railrods and improved paths under "encroachments" in the FIT in SGAT. For the berms, roads, railroads and improved paths, if used properly, the Feature Indexing Tool (FIT) in SGAT will create a dbf table that can be automatically uploaded into the DMS. Once the FIT data is uploaded into the DMS, the impact rating will be attributed based on the percent of the reach length that has been encroached upon for each separate impact of berms, roads, improved paths and railroads. Use the meta data in the DMS to indicate whether the percent of reach paralleled by berms, roads, railroads or improved paths for the reach have been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

6.2 RIVER CORRIDOR DEVELOPMENT (FIT)

Meta Data:
- 1:24K topos, 1:5K orthos
- 1:24K topos, 1:5K orthos, files
- 1:24K topos, 1:5K orthos, files, field obs

Data Sources:
- USGS 1:24,000 topographic maps (digital or hard copy)
- 1990 series 1:5000 orthophotos (digital or hard copy)
- Emergency 911 GIS coverage (available from VCGI website at http://www.vcgi.org.)

Background:
Development encroaching on the floodplain and river corridor may result in a confinement of flood flows, as described above in section 6.1, and may also effectively decrease the lateral extent to which the outside meanders of a stream can migrate away from one another (Figure 6.3). The extent to which a channel migrates laterally, as measured by the distance between the outer limits of its meander bends on opposite banks, is called the "meander belt width" and is described further in section 6.5. Decreasing the meander

belt width of a channel may limit the ability of the channel to adjust to changes in channel slope, thereby leading to an increase in channel slope, which in turn can lead to bed degradation as stream power increases, potentially triggering a channel evolution process (Appendix C).

Houses and other structures that encroach into the river corridor and floodplain may represent a flood hazard and may, in addition, pose threats to infrastructure, investments, and habitat downstream due to the increased flood velocities and stream power if the encroachments result in a confined and steeper stream.

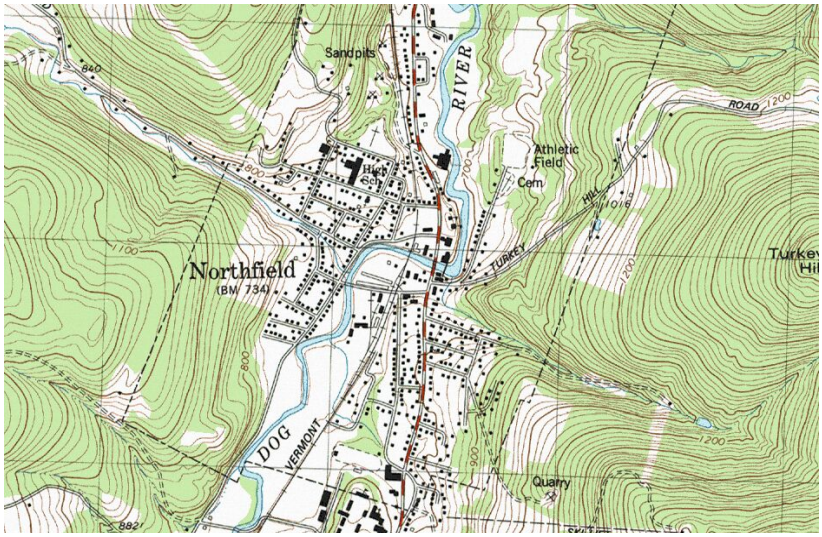


Figure 6.3 Development within the river corridor and floodplain.

Evaluation:
Use the FIT in SGAT to indicate the location of development on either the one bank or both banks at the same time. Index the locations of houses, fill (including bridge and culvert fills), parking lots or other development within the river corridor on either bank (see Appendix E for river corridor delineation). Indicate whether the development occurs on **one bank at a time or both banks at the same time**. Write *None* if you know there are no developments within the river corridor along the reach. Do not include roads, railroads, berms or improved paths parallel to the stream and within the stream corridor. These roads should be included in Step 6.1 Berms and Roads.

Menu

One Bank	Development located within the corridor on one bank only
Both Banks	Development located within the corridor on both banks in the same location
None	No known development within the river corridor
No Data	No data sources are available to determine if river corridor development exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated. Further work should be completed.

Impact Rating for river corridor development (DMS)

H	High – developments are within river corridor along ≥ 20% of the right and/or left bank
L	Low – developments are within river corridor along between 5% to 20% of the right and/or left bank
NS	Not Significant – developments are within river corridor along < 5% of the right and/or left bank
No Data	No data sources are available to determine if river corridor development exists.
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated. Further work should be completed.

Data Entry:
Use the FIT in SGAT to index the location of river corridor development on one bank or both banks at the same time. Once the FIT file is uploaded, the DMS will automatically determine the impact rating based on the percent of the reach impacted. Use the meta data in the DMS to indicate whether the impact from river corridor development has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

6.3 DEPOSITIONAL FEATURES

Meta Data:

- 1:5K orthos
- 1:5K orthos, other aerial photos
- 1:5K orthos, field obs.

Background:

Bars are deposits of sediment located within the channel margins that have a height in excess of the mean water level. A point bar is adjacent to the bank and located on the inside bank of a bend in the channel (i.e., a meander bend), whereas a mid-channel bar is not attached to the banks, has stream flow to either side of it, and is generally found in straight reaches.

An unvegetated bar is a sign that the bar has recently been formed and is growing. Mid-channel bars, large unvegetated point bars, and delta bars may indicate an increased sediment load (from upstream) and the high likelihood that the streambed is actively aggrading and/or undergoing rapid lateral movement. The sediment source for these bars may be from bank failures or the degradation of the channel bed upstream. It may also be from upland sources such as construction sites, road washouts, or valley side slope failures. (Note that in some situations equal-sized, alternating unvegetated point bars in a naturally high sediment yielding watershed may be a part of the reference, or "equilibrium," channel condition.)

Evaluation:

For large and medium sized rivers and streams, large unvegetated bars are often visible on orthophotos. If you are examining the orthophoto on the computer, zoom in on the channel to observe gravel bars. Note the presence of unvegetated mid-channel, point, or delta bars and record the appropriate menu item on the data sheet. These bars can also be noted in the field during the windshield survey. Small streams, particularly those in forested areas will be difficult to impossible to evaluate using orthophotos. These streams will need to be assessed during the Step 7 windshield survey and Phase 2 or 3 assessments.

When evaluating bars in the Phase 1 assessment you will only note those bars that are largely unvegetated, either devoid of vegetation or have only sparse pioneer vegetation occupying less than 25 percent of the surface area of the bar. In the field, during Phase 2 and Phase 3 Assessments, you may observe bars that are well vegetated.

Menu

Mid-channel	Flows evident on either side of mid-channel sediment deposit
Point	Large unvegetated sediment deposits located at the inside of meander bends—choose this menu item only if bars are greater in width than the observed wetted channel
Delta	Sediment deposits where tributary enters mainstream channel
Multiple	Multiple types of sediment deposition features in reach—use only where none of the above deposit types are dominant
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
Islands	Well-vegetated mid-channel deposits of sediment
None	No evidence of mid-channel, point, or delta bars
No Data	Unknown if there are depositional features—unable to see the stream on orthophoto due to forest cover and/or inability to access entire reach during windshield survey
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Impact Rating for depositional features

H	High – Numerous, large unvegetated mid-channel, point and/or delta bars present (channel may appear braided)
L	Low – Some mid-channel bars and intermittent large point bars
NS	Not Significant – Typical point bars, no mid-channel bars present
No Data	Unknown if there are unvegetated depositional features—due to forest cover and/or inability to access entire reach during windshield survey
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

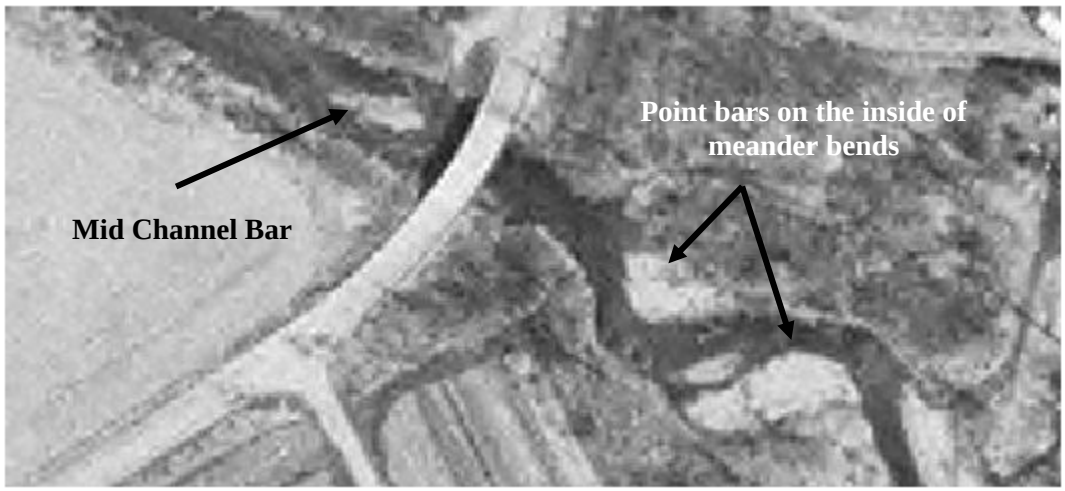


Figure 6.4 Mid channel and point bars as viewed on a digital orthophoto viewed in GIS software..

Data Entry:
Manually enter the data and associated impact from depositional features into the DMS for each reach. Use the meta data in the DMS to indicate whether the impact from depositional features has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

6.4 MEANDER MIGRATION / CHANNEL AVULSIONS (FIT)

Meta Data:
- 2003 NAIP color photos
- 1:5K orthos (1990s & 1970s)
- 1:5K orthos (1990s & 1970s), other aerial photos
- 1:5K orthos (1990s & 1970s), field obs.

Background:
A migrating channel moves by eroding the outer banks of its meander bends such that the channel's bends move sideways and downstream over time. Some amount of lateral migration is natural in most alluvial streams systems, but the rate of migration may be increased in streams that are out of balance with their watershed inputs. A bifurcated, or braided, channel is one that has split into two or more active channels. An avulsed channel is one that has suddenly changed location and cut a new section of channel within its valley, abandoning the old section of channel, which may appear as a dry river or long, narrow wetland on the valley bottom.

Channels change course for various reasons. Streams often undergo dramatic migrations and avulsions due to changes in the sediment supply and/or sediment transport capacity of the channel. Sediment building up on the channel bed can force flows laterally to the outside of a channel bend, eroding even the most stable stream banks (migration), or can divert flow to the inside of a channel bend, cutting off entire meander bends (avulsion). Streams can change course as the result of catastrophic channel avulsions due to floods, debris jams, undersized road crossings structures, or because of past channelization practices. Often the loss of woody riparian vegetation causes or exacerbates channel migration and increases avulsion occurrences on certain sensitive, depositional stream types.

Orthophotos can be used to look for areas where the river has migrated, bifurcated, or avulsed. By comparing orthophotos from different time periods, reaches that have migrated, bifurcated, or avulsed extensively can be distinguished from reaches that have stayed in the same location over the same period of time (Figures 6.4A and 6.4B). Substantial changes in channel location usually occur in the lower, depositional zone of the watershed. On large streams, migration, bifurcation, and avulsions can be easily seen on the orthophotos (Figure 6.4A), but channel avulsions on small streams in the upper watershed cannot easily be determined from orthophotos, even though they may occur in that area. The presence of channel avulsions on small streams can only be confirmed through a field visit.

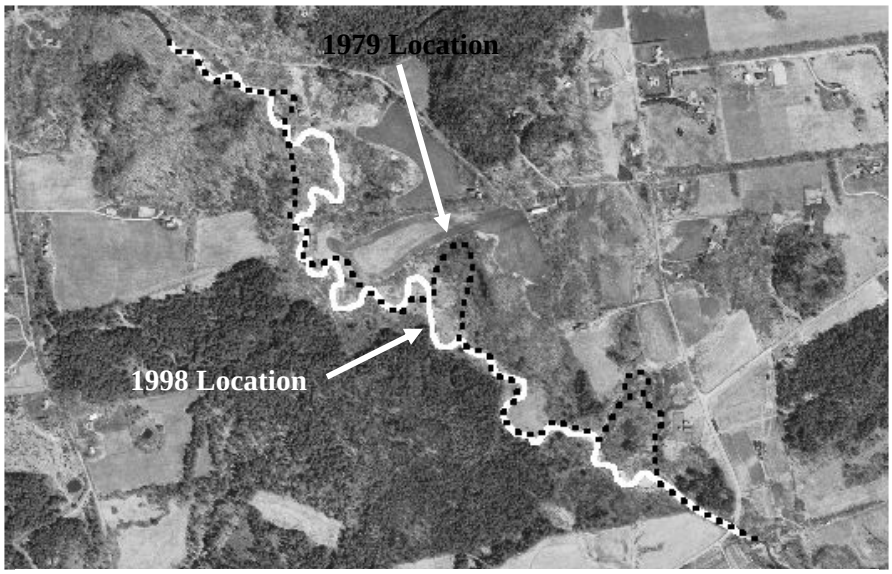


Figure 6.5A Meander Migration and Avulsion: High Impact

Evaluation:
To identify channel migration, bifurcation, and/or avulsions on large and medium sized rivers and streams, compare the path of the channel from similarly scaled orthophotos of different years. You should use the most recent orthophotos series that span a period of approximately 20 years. For instance the orthophotos produced in the late 1970's should be compared with the series produced in the 1990's. Digitize on the computer or manually trace on mylar or paper overlays the historic and current channel locations. Look for places where the two channel lines diverge to identify channel migration and/or avulsions that have occurred during the time period covered by the photos. See detailed instructions below.

Overlay method for evaluating channel migration: Place the tracing paper or mylar on top of a historic orthophoto (i.e. the 1970s orthophotos). Mark a north arrow on the tracing paper, write the name and date of the underlying orthophoto on the tracing paper. Using a colored pencil, mark reference points (a silo, a cross-roads, a V-shaped intersection, etc.) that also appear on the recent series of photos that you are using. Using this same color pencil, trace the course of the river. Mark the active channel and all abandoned channels.

Next overlay the tracing paper or mylar on the recent orthophoto (i.e. the 1990's orthophotos) for the same location. If necessary, adjust the scale of the recent orthophoto to match that of the historic photo with the aid of the computer or copy machine. Line up the reference points on the tracing paper that you marked from the historic photo with the same landmarks on the recent photo (silo, cross-roads, V-shaped intersection). Using a *different* colored pencil, trace the course of the river and all abandoned channels onto the tracing paper.

Compare the recent and historic channel locations to identify areas of extensive channel migration and channel avulsions. Since the late 1930's at least eight complete statewide sets of aerial photos have been taken over Vermont. Since the late 1970's these photos have been orthogonally corrected (see list in Appendix D). Photos earlier than the 1970's series can be used to further examine channel movement and meander migration.

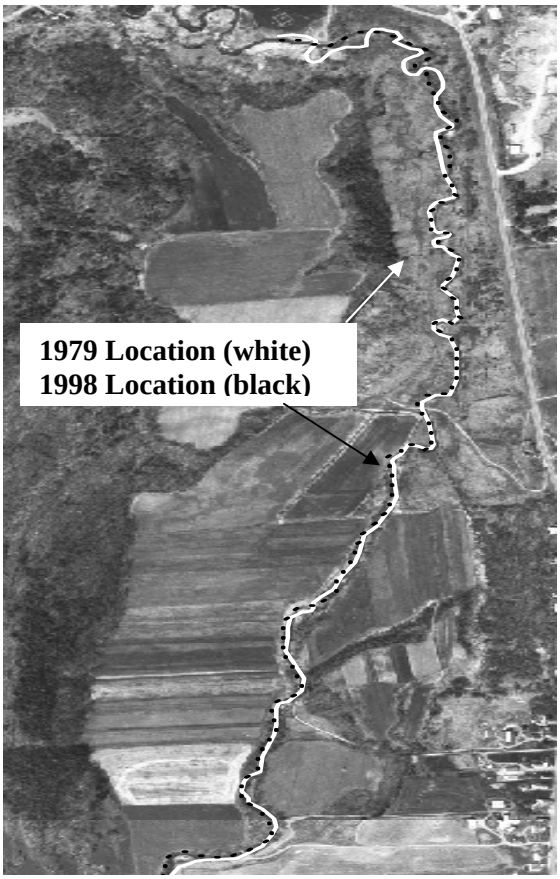


Figure 6.5B Meander Migration: Low Impact

Menu

Migration	Channel has migrated by eroding its outer banks on meander bends
Flood Chute	During high flow the channel accesses an area outside the channel, normally on the inside of a meander bend.
Bifurcation /Braiding	Stream flow has split into two or more active channels
Avulsion	Channel planform has changed due to meander cut-offs
Neck Cut-off	A neck cutoff forms as two meanders migrate towards one-another and the neck of land between them is *about* to be cut off
None	None of the above
No Data	Unknown if there are channel migrations or avulsions— unable to see the stream on orthophoto due to forest cover and/or inability to access entire reach during windshield survey
Not Evaluated	All data sources (as described by the meta data) HAVE NOT been evaluated.

Impact Rating for meander migration

H	High - Frequent occurrences of channel migration, flood chutes, bifurcation and braiding, channel avulsions an/or neck cut-offs along reach evident in historic orthophoto comparison
L	Low - Few occurrences of channel migration, flood chutes, bifurcation and braiding, channel avulsions an/or neck cut-offs evident in historic orthophoto comparison
NS	Not Significant - No channel migration, flood chutes, bifurcation and braiding, channel avulsions an/or neck cut-offs evident
No Data	Unknown if there are channel migrations, bifurcations, or avulsions—due to forest cover and/or inability to access entire reach during windshield survey

Data Entry:
Manually enter the data and associated impact for meander migration into the DMS for each reach. Use the meta data in the DMS to indicate whether the impact from meander migration has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

6.5 MEANDER WIDTH RATIO

Meta Data:
- 1:5K NHM, 1:5K orthos
- Field - survey

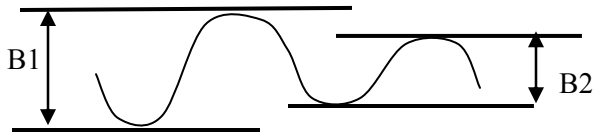
Background:
The meander belt width is the horizontal distance between the opposite outside banks of fully developed meanders determined by extending 2 lines (one on each side of the channel) parallel to the valley (and parallel to each other) from the lateral outside extent of each meander bend along both sides of the channel (Figure 6.5).

The meander belt width can change radically within a reach due to channel constrictions from floodplain encroachment, surficial and bedrock geology, small changes in valley slope, and other factors. Unconfined, gravel-based streams in shallow-sloped valleys that are in regime have belt widths generally in the range of 5 to 8 times the width of the channel (Leopold 1994 and Williams 1986). Lower values may indicate that the stream has become straighter and steeper, possibly degrading its bed and losing access to its floodplain. Higher values may indicate that the stream, possibly due to an increase in fine sediment, has started to aggrade and become more sinuous, decreasing its channel slope as it migrates laterally.

Evaluation:
This parameter is only evaluated for those reaches you typed in Step 2.10 as C or E riffle-pool or ripple-dune reference stream types in narrow (NW) and unconfined (BD and VB) valleys. For these reaches calculate the meander width ratio (MWR) by dividing the belt width (B) by the bankfull channel width (W_{bkf}), determined in Step 2.8. For reaches that have been straightened for more than half (50%) of the reach length, do not measure belt width, but rather enter the channel width under the belt width column on the data sheet. This will result in a meander width ratio value of one ("1") for the reach, which is rated as "high" impact. For naturally confined and braided stream types, do not enter a value for belt width. Instead, select the Not Evaluated check box in the DMS.

Determining Belt Width: Use orthophotos in conjunction with topographic maps to determine the reach's average belt width. Topographic maps help you discern the valley direction, and recent orthophotos offer the most accurate location of channel meanders. Two rules to remember when drawing the meander belt width are: 1) do not cross the toe of either valley wall (generally); and 2) follow the direction of the valley (i.e., draw the parallel lines that represent the belt width roughly parallel to the valley walls).

After establishing the two parallel lines containing the belt width, measure and record the average (to the nearest foot) of at least three belt widths in the reach. Divide the average belt width (B) by the channel width (Wbkf) to calculate meander width ratio (MWR) (Figure 6.5). Retain a paper map or digital GIS shape file of locations used for belt width measurements for later use in quality assurance documentation, field verification and for displaying the data.



MWR = B / W_{bkf}

Figure 6.6 Example of measuring average belt width in a broad unconfined valley. In this example the belt width is the average of B1 and B2 values.

Appendix H provides more background information on meander width ratios and several examples of belt width measurements using Vermont orthophotos.

Impact Rating for meander width ratio

H	High - calculated MWR is < 3 **or** > 10
L	Low - calculated MWR is ≥3 and <5 **or** >8 and ≤ 10
NS	Not Significant - calculated MWR is ≥5 and ≤ 8
N/A	Not applicable for certain stream types (where MWR entered as "0")

Data Entry:
Manually enter the value for belt width into the DMS for each reach. The DMS will use the belt width to automatically calculate the meander width ratio and attribute an associated impact rating. Use the meta data in the DMS to indicate whether the impact from meander width ratio has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

6.6 WAVELENGTH RATIO

Meta Data:
- 1:5K NHM, 1:5K orthos
- Field - survey

Background:
Like the meander width ratio, the wavelength ratio can also change radically within a reach due to channel constriction from floodplain encroachment, surficial and bedrock geology, small changes in valley slope, and other factors (see Figure 6.7). Unconfined, gravel-based streams in shallow-sloped valleys have wavelengths generally in the range of 10 to 12 times the width of the channel (Leopold 1994 and Williams 1986). Higher values may indicate that the stream has become straighter and steeper, possibly degrading its bed and losing access to its floodplain. Lower values may indicate that the stream, possibly due to an increase in fine sediment, has started to ag-

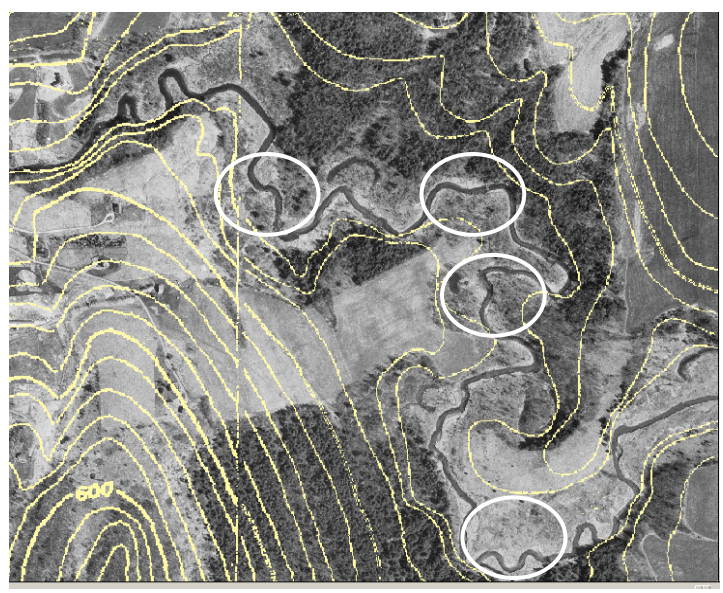


Figure 6.7 Example of a reach with both regular and irregular meanders. Representative wavelengths measured to generate wavelength ratios are circled.

grade and become more sinuous, decreasing its channel slope as it migrates laterally.

Evaluation:
This parameter is only evaluated for those reaches you typed in Step 2.10 as C or E riffle-pool or ripple-dune reference stream types in narrow (NW) and unconfined (BD and VB) valleys. For these reaches calculate the wavelength ratio (WLR) by dividing the wavelength (L_m) by the bankfull channel width (W_{bkf}), determined in step 2.8. For reaches that have been straightened for more than half of the reach length, do not measure the wavelength, but rather enter the channel width in the wavelength column on the data sheet. This will result in a wavelength ratio value of one ("1") for the reach, which is rated as "high" impact. For naturally confined and braided stream types, do not enter a value for belt width. Instead, select the Not Evaluated check box in the DMS.

Determining Wavelength: Meander wavelength is measured as the distance in feet between two lines drawn perpendicular with the fall line of the valley, one drawn at the beginning and one at the end of the meander wavelength (Figure 6.6). The beginning and end points of the meander wavelength are located at thalweg inflection points, or cross-over points. Alternatively, the beginning and end points may be set at the apex of bendway curves. A meander wavelength consists of two bendways. Use orthophotos in conjunction with topographic maps to determine the reach's average meander wavelength. Topographic maps help you discern the valley direction, and recent orthophotos offer the most accurate location of channel meanders and thalweg inflection points. Measure at least three wavelengths in the reach to determine the average wavelength for the reach. Remember that this is not the same parameter as sinuosity. Calculate wavelength ratio (WLR) by dividing the average wavelength (L_m) by bankfull channel width (W_{bkf}).

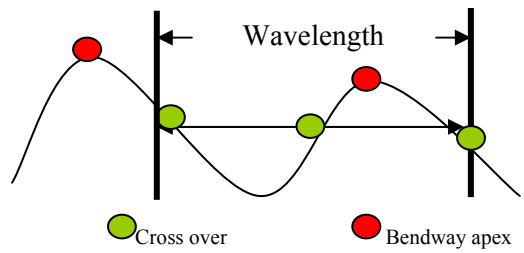


Figure 6.8 Meander wavelength measured from cross-over to cross-over

$$\mathbf{WLR = L_m / W_{bkf}}$$

Retain a paper map or digital GIS shape file of locations used for wavelength measurements for later use in quality assurance documentation, field verification and for displaying the data. Appendix H provides more background information on wavelength ratios and several examples of wavelength measurements using Vermont orthophotos.

Impact Rating for wavelength ratio

H	High – calculated WLR is < 6 **or** > 16
L	Low - calculated WLR is ≥6 and <8 **or** >14 and ≤16
NS	Not Significant - calculated WR is ≥8 and ≤14
N/A	Not applicable for certain stream types

Data Entry:
Manually enter the value for wavelength into the DMS for each reach. The DMS will use the wavelength to automatically calculate the wavelength ratio and attribute an associated impact rating. Use the meta data in the DMS to indicate whether the impact from wavelength ratio has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

Step 7. Bed and Bank Windshield Survey

Overview

Background:
The Bed and Bank Windshield Survey is an essential component of the watershed assessment. In this step you have the opportunity to field verify the reaches you have described using maps and other remote sensing techniques. Even though you will not be able to see all reaches from the roads, you may be able to see enough to assess certain parameters and pick out obvious problems and/or verifications of Phase 1 data. You may also choose to float larger, low gradient rivers and streams by canoe to complete the windshield survey, as this is an efficient way to see a lot of the stream system in a short period of time.

Evaluation:
The main focus of the Windshield Survey is to field check Phase 1 data collected so far, as well as note the condition of and materials that make up the stream bed and banks. Based on the amount of time you have, and figuring on an average of 30 minutes per stop (including drive time), plan your driving route and stops to ensure that you survey a good representation of the different stream types in the watershed.

Be aware that the bed and bank conditions at or near the road crossing may not represent the conditions of the reach as a whole. As discussed in Step 5.2, bridges and culverts may have profound impacts on the fluvial processes and geomorphic conditions of the stream reaches. To further evaluate the potential impacts of road crossing structures on geomorphic and habitat conditions and connectivity of the watershed use the ANR Bridge and Culvert Assessment protocol and field forms (Appendix G).

Before you begin your windshield survey, print out the Phase 1 Reach Summary Report from the Phase 1 database (see Appendix B) and review the Phase 1 data for each reach. Note any data you feel is questionable and verify this data during the windshield survey. Take the reach summary reports and topographic maps for each reach and the watershed with you to make notations or corrections to the data. Table 7.1 lists the parameters which particularly benefit from field verification. Standard map codes and symbols for field maps are included in Appendix A.

In addition to filling out Data Sheet 7 (described below), take photographs of notable features and typical reach conditions. Keep a photo log so you can label your photos by reach number. A standard photo log form is provided in Appendix A.

Table 7.1 Phase 1 parameters which particularly benefit from field verification

Step No.	Parameter	Notes
2.11	Reference Stream Type	Verify the stream type, bed form, bed material and sub-class slope
2.10	Valley Type and Confinement	Verify reach breaks as defined by valley form
3.2	Grade Controls	Verify locations of known grade controls, record on map the types and locations of any additional grade controls observed
4.3	Riparian Buffer	Verify dominant riparian buffer width category for the reach
4.4	Groundwater Inputs	Record locations of any observed small tributaries and groundwater inputs (wetlands, seeps, springs) not already noted
5.1	Flow Regulation / Water Withdrawal	Verify locations of known flow regulation and water withdrawal structures, record any additional structures observed
5.3 and 5.4	Channel and Bank Modifications	Verify types, locations, and extent of channel modifications and bank armoring
6.1 and 6.2	Corridor Encroachments – Berms, Roads, and Development	Verify locations and extent of berms, roads and development in reach river corridor
6.3	Sediment Storage	Verify type and relative size of sediment deposits, record any additional sediment deposit features observed

Data Sheet 7: Bed And Bank Windshield Survey

7.1 BANK EROSION - RELATIVE MAGNITUDE (FIT)

Background:
All stream banks erode to some degree. Bank erosion is a natural ongoing process, and it is unrealistic to think that bank erosion can be or should be totally eliminated. While bank erosion is occurring naturally over time, it is a process that may be accelerated or decelerated by human activities. The concern is not that erosion occurs, but rather the location and rate at which it occurs.

Henderson and Shields (1984) define natural erosion as the processes that occur without significant human activities in the drainage basin or catastrophic natural events such as volcanic eruptions or forest fires. They define accelerated erosion as erosion that is atypically high in magnitude and is different in nature than the erosion experienced at the site or reach in question in the recent past. Both natural events (e.g., high flows) and human activities (e.g., changes in land use) can cause accelerated erosion (Johnson and Stypula 1993).

Accelerated bank erosion is both a symptom and cause of channel adjustment processes. High, vertical banks with low root density and a high percentage of non-cohesive, fine-grained sediments (i.e., sand and gravel) have the highest potential to erode. Eroding banks may not only change the cross-section of the channel where they occur, but they can contribute to aggradation and other channel adjustments downstream, adding tons of sediment to stream reaches that are depositional and sensitive to an imbalance in the sediment load.

Bank erosion can be an important source of sediment to a stream system over time; however, rapid and extensive bank erosion can result in large quantities of sediment entering a stream system, potentially threatening aquatic habitats and biota. Fine sediments can embed gravel and cobble stream bottoms, reducing available habitat for aquatic insects, fish and other biota and potentially even smothering fish and salamander eggs and young.

Evaluation:
Bank erosion is evident by the presence of bare soil extending up the bank, fallen vegetation or slumped soil at the base of the bank, or undercut fractured banks that look like they are going to fall off into the river. Mark the presence of bank erosion on the map with the letters “BF,” and record whether it occurs on the right or left bank.

Retain a paper map or digital GIS shape file of bank erosion locations for later use in quality assurance documentation, field verification and for displaying the data.

Use the Feature Indexing Tool (FIT) in SGAT to document the location of erosion within the reach on both the **right bank and left bank**.

Menu

Bank Erosion	Description
High	Bank erosion observed along $\geq$ 20% of the right and/or left bank
Low	Bank erosion observed along between 5 and 20% of the right and/or left bank
None	Bank erosion observed along < 5% of the right and/or left bank
Not Evaluated	The reach was not accessed during the windshield survey.

Data Entry:
Use the FIT in SGAT to identify the locations of erosion on both the right and left bank. When the FIT

data is imported the lengths of erosion for each reach will be automatically calculated and the impact will be assigned. Use the meta data in the DMS to indicate whether the bank height or erosion has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

7.2 DEBRIS / ICE JAM POTENTIAL

Background:
Debris jams are important to channel stability and aquatic habitat. In general, woody debris promotes stream equilibrium and high quality instream habitat. On the other hand, hazards from debris jams associated with lateral erosion or channel avulsion may endanger infrastructure, such as bridges that are too narrow, as well as land uses or development occurring close to the channel. Debris jams are a common cause of channel avulsions, especially on alluvial fans.

Understanding where ice jams may occur is important for several reasons. Flooding associated with ice jams may be significantly higher than the for the same discharge in open channel conditions. Flooding from an ice jam occurs very quickly. Ice jams can cause damage to stream crossings, when the jam form against them. Ice jams may also cause damage to buildings, roadways and utilities as the ice blocks begin moving when the jam is released.

Figure 7.1 Ice jam formation at a dam on the Winooski River

Evaluation:
Look for places where an unconfined channel suddenly becomes constricted or where a relatively straight reach takes a dog-leg or tight radius turn. One example of a place with a high potential for debris or ice jamming would be where a river has to make a tight turn under a bridge that is too narrow. Over-widened, shallow streams with mid-channel bars associated with channel slope transitions or changes in channel confinement are also places with high potential for debris or ice jamming. A large, channel-spanning, dead-fall tree, if suspended above the bed but firmly lodged against channel banks or valley side slopes, may also catch debris during high flow events. Mark your map with the location of known debris or ice jams with the letters “DJ”.

DEC River Management Engineers, road and highway foreman, river resource professionals, town officials, and local residents may all be sources of information on where ice and debris jams have occurred historically.

Menu

Bend	Sharp angle (>90 degree) turn in channel planform
Bridge	Narrow or low clearance bridge and/or multiple bridge piers
Culvert	Small diameter compared to stream width and/or multiple culvert openings
Shallow	Wide-shallow channel with mid-channel bars
Debris	Observed jams of woody debris
Multiple	More than one type of potential cause for debris jam
None	No potential debris or ice jam
Not Evaluated	The reach was not accessed during the windshield survey.

Impact Rating for debris/ice jam potential

H	High - Existing jams causing erosion and stream migration near infrastructure, or recorded history of jams and flooding impacts
L	Low - Channel dimension, pattern, and profile suggest jams are possible but there is not a recorded history of flooding and erosion impacts
NS	Not Significant – No noticeable sharp bends, narrow stream crossings, or wide, shallow channel areas that may lead to ice and debris jamming, no recorded history of jamming
Not Evaluated	The reach was not accessed during the windshield survey.

Data Entry:
Enter the potential debris jam type and associated impact rating into the Phase 1 DMS under Step 7. Use the meta data in the DMS to indicate whether the debris jam potential has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

Step 8. Stream and Watershed Impact Ratings

Overview

Background:
Since the Phase 1 Watershed Assessment is largely dependent on remote sensing data, it is assumed that the channel and floodplain modifications identified elicit predictable responses by the various stream types due to assumed changes in channel slope and watershed inputs of sediment and water caused by these modifications.

An example would be the well-documented response that certain riffle-pool streams undergo following channelization and floodplain development. The increased channel slope and stormwater runoff initiate major adjustment processes. Such streams exhibit a high degree of vertical and lateral adjustment and at times may become high erosion hazard areas, threatening channel equilibrium in both upstream and downstream reaches, and possibly containing little or no habitat value.

The Step 8 Impact Rating and Priority Ranking process involves adding up the impact scores for the various Phase 1 parameters, and using this total impact rating as a "red-flagging" tool top identify reaches that may be in adjustment and outside the range of natural variability.

Data Sheet 8: Stream And Watershed Impact Rating

8.1 TOTAL IMPACT SCORE

Evaluation:
Once each parameter in Steps 4, 5, 6, and 7 have been assigned an impact rating of High, Low, or Not Significant, these ratings are translated into a total impact score. To do this the impact ratings are assigned numeric values of 2, 1, and 0 for High, Low, and Not Significant, respectively. To calculate the impact rating for each reach, the DMS automatically assigns the appropriate values to the impact ratings from Data Sheets 4 through 7. For those parameters where you did not have adequate information to rate impacts, and you selected the "No Data" or "Not Evaluated" choice on the impact rating menu, the DMS will use a "0" impact rating value when determining the total impact for the reach.

Next the DMS sums all the impact rating values to determine a total impact scores for each reach. Although this could be completed manually if you choose, this step is done automatically for you in the DMS . The DMS report titled "Stream and Watershed Impact Ratings" summarizes the range of impact scores for all the reaches you evaluated in the watershed. A DMS report named "Summary of Categorical Impacts" also provides categorical impact scores, which are sub-total scores for each of the following categories: Land Cover and Reach Hydrology (Step 4); Channel Modifications (Step 5); Floodplain Modifications and Planform Changes (Step 6); and Bed and Bank Condition (Step 7).

Reaches which scored low impact ratings because you were unable to collect information for one or more parameters should be tracked using the Step 8 DMS report. As complete information is gathered for a given parameter, enter this data into the Phase 1 DMS and it will re-calculate the impact ratings for that parameter and recalculate the total impact rating for the reach. Remember to update Phase 1 data, impact ratings and meta data with field verified information collected during windshield surveys and Phase 2 and Phase 3 assessments.

Menu

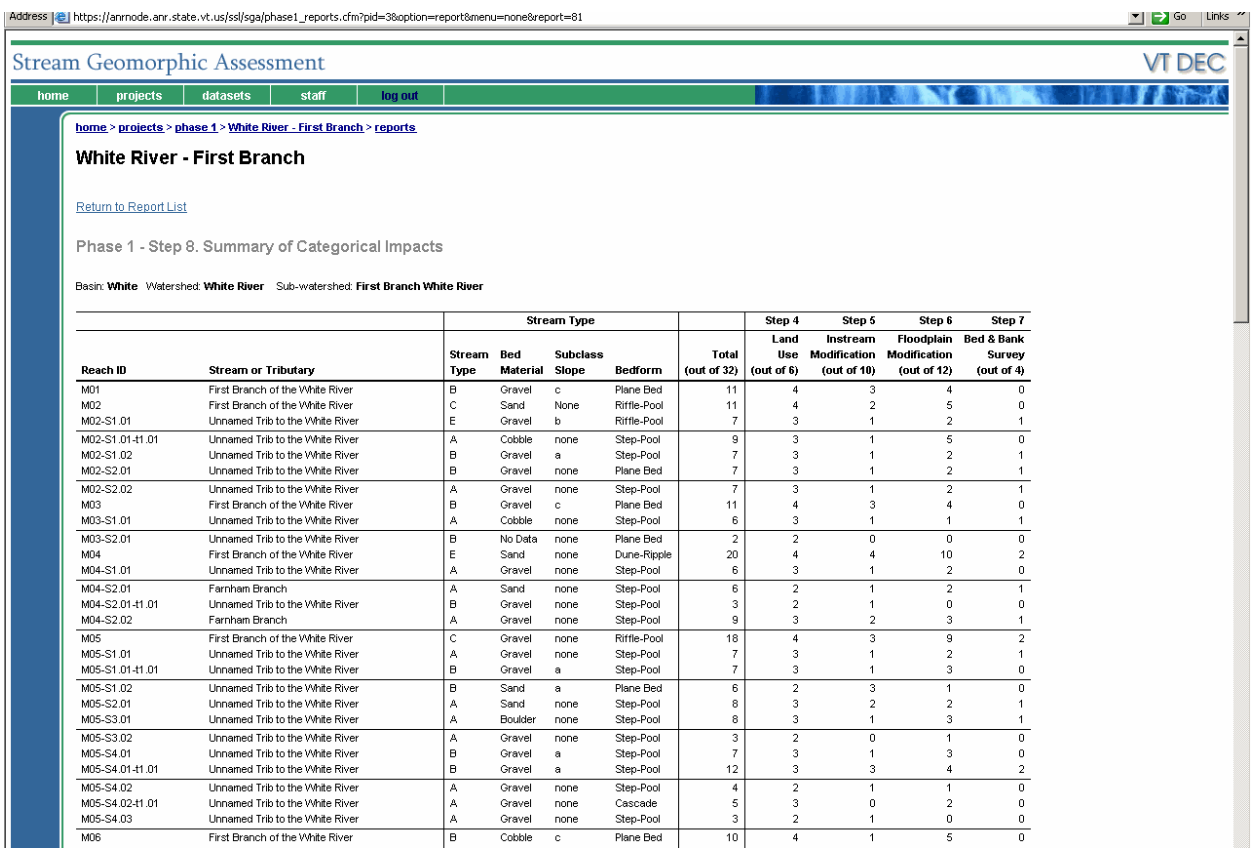
2	High (H)	Strongly Evident – Highly Significant
1	Low (L)	Evident – May Be Significant
0	Not Significant (NS)	Not Evident – Insignificant
0	No Data or Not Evaluated	Unknown – No data collected

8.2 PRIORITY RANKING

Evaluation:
The DMS report "Summary of Categorical Impacts" provides total and categorical impact scores. You can use this report to rank reaches for different stream management priorities. For instance, reference reaches (indicated by low impact ratings) may be identified to aid in the evaluation of impacted reaches having similar stream and valley settings.

When establishing the priority ranking of the reaches within a watershed, be sure to track those reaches that received low total impact ratings due to one or more parameters being rated as "No Data" or "Not Evaluated". For instance, there may be reaches for which no information was initially available to complete an impact rating for bank erosion, flow modification, bank armoring, and dredging history. If further assessment revealed that each of these parameters would be rated as a "high" impact, the total impact would be significantly higher and potentially result in a much higher priority ranking for the reach.

There are many different ways to prioritize your reaches, based on your goals and objectives for the watershed. There is a place on the data sheet for you to make notes on what criteria you used to prioritize your reaches for further assessment. The priority ranking is not entered into the database because the ranking may change from season to season or as your assessment goals and objectives.



		Stream Type					Step 4	Step 5	Step 6	Step 7
Reach ID	Stream or Tributary	Stream Type	Bed Material	Subclass Slope	Bedform	Total (out of 32)	Land Use (out of 6)	Instream Modification (out of 10)	Floodplain Modification (out of 12)	Bed & Bank Survey (out of 4)
M01	First Branch of the White River	B	Gravel	c	Plane Bed	11	4	3	4	0
M02	First Branch of the White River	C	Sand	None	Riffle-Pool	11	4	2	5	0
M02-S1.01	Unnamed Trib to the White River	E	Gravel	b	Riffle-Pool	7	3	1	2	1
M02-S1.01-t1.01	Unnamed Trib to the White River	A	Cobble	none	Step-Pool	9	3	1	5	0
M02-S1.02	Unnamed Trib to the White River	B	Gravel	a	Step-Pool	7	3	1	2	1
M02-S2.01	Unnamed Trib to the White River	B	Gravel	none	Plane Bed	7	3	1	2	1
M02-S2.02	Unnamed Trib to the White River	A	Gravel	none	Step-Pool	7	3	1	2	1
M03	First Branch of the White River	B	Gravel	c	Plane Bed	11	4	3	4	0
M03-S1.01	Unnamed Trib to the White River	A	Cobble	none	Step-Pool	6	3	1	1	1
M03-S2.01	Unnamed Trib to the White River	B	No Data	none	Plane Bed	2	2	0	0	0
M04	First Branch of the White River	E	Sand	none	Dune-Ripple	20	4	4	10	2
M04-S1.01	Unnamed Trib to the White River	A	Gravel	none	Step-Pool	6	3	1	2	0
M04-S2.01	Farnham Branch	A	Sand	none	Step-Pool	6	2	1	2	1
M04-S2.01-t1.01	Unnamed Trib to the White River	B	Gravel	none	Step-Pool	3	2	1	0	0
M04-S2.02	Farnham Branch	A	Gravel	none	Step-Pool	9	3	2	3	1
M05	First Branch of the White River	C	Gravel	none	Riffle-Pool	18	4	3	9	2
M05-S1.01	Unnamed Trib to the White River	A	Gravel	none	Step-Pool	7	3	1	2	1
M05-S1.01-t1.01	Unnamed Trib to the White River	B	Gravel	a	Step-Pool	7	3	1	3	0
M05-S1.02	Unnamed Trib to the White River	B	Sand	a	Plane Bed	6	2	3	1	0
M05-S2.01	Unnamed Trib to the White River	A	Sand	none	Step-Pool	8	3	2	2	1
M05-S3.01	Unnamed Trib to the White River	A	Boulder	none	Step-Pool	8	3	1	3	1
M05-S3.02	Unnamed Trib to the White River	A	Gravel	none	Step-Pool	3	2	0	1	0
M05-S4.01	Unnamed Trib to the White River	B	Gravel	a	Step-Pool	7	3	1	3	0
M05-S4.01-t1.01	Unnamed Trib to the White River	B	Gravel	a	Step-Pool	12	3	3	4	2
M05-S4.02	Unnamed Trib to the White River	A	Gravel	none	Step-Pool	4	2	1	1	0
M05-S4.02-t1.01	Unnamed Trib to the White River	A	Gravel	none	Cascade	5	3	0	2	0
M05-S4.03	Unnamed Trib to the White River	A	Gravel	none	Step-Pool	3	2	1	0	0
M06	First Branch of the White River	B	Cobble	c	Plane Bed	10	4	1	5	0

Figure 8.1: Example of DMS report summarizing impacts by category

The DMS report titled “Downstream and Upstream Impact Graph” can be used to graph the total impact scores for each reach along the longitudinal profile of the mainstem or tributaries. This graphical organization of the data shows the upstream/ downstream position and proximity of reaches with different impact levels, which can inform management decisions. For instance, if a highly impacted reach, which may potentially be in-adjustment, is located just upstream of a reach that has received a very low impact rating; you may be concerned about adopting a strategy to protect the low impact reach.

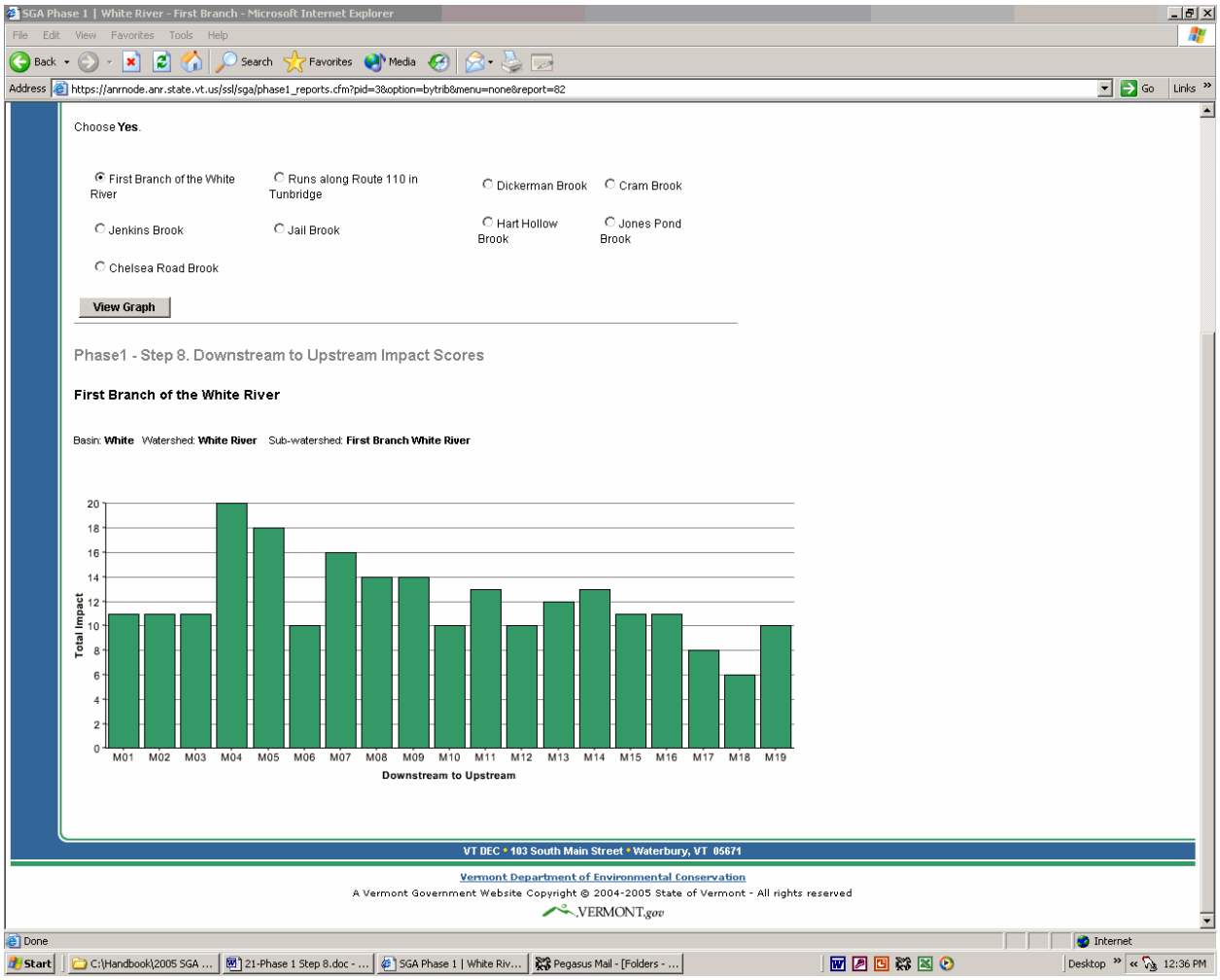


Figure 8.2 - Example of downstream to upstream locations of impacted reaches.

Steps 9. Provisional Geomorphic Condition Evaluation

Overview

Background:
The Provisional Geomorphic Condition Evaluation is comprised of three separate, yet interrelated, evaluations of the reaches in your watershed, which are: adjustment process, reach condition, and reach sensitivity. These evaluations will prove to be valuable information at the watershed level. Once the Phase I data is entered, the DMS will automatically generate a report listing the ratings for the reach adjustment process, condition and sensitivity.

The DMS tools described below help determine the geomorphic condition of reaches by examining the impact ratings and characterizations that were made for sixteen of the Phase 1 parameters. The value in completing this process, however, is that Phase 1 evaluates the parameters that may **cause** channel adjustment (i.e., floodplain modifications or land use/land cover), while Phase 2 and Phase 3 assessments evaluate **effects** of those modifications by measuring direct signs of impacts and channel adjustment within the channel and riparian area. Together the cause and effect factors provide a more complete picture of potential adjustment processes occurring in a reach and within your watershed.

As with any Phase 1 parameter, observations and measurements made in the field for the **same** parameter should supercede remote sensing and computer generated data. Values entered into the Phase 1 DMS should be changed if a field exercise shows they are wrong or that they mischaracterize the reach. *Remember to indicate where you supplant Phase 1 data with data generated from Phase 2 or 3 assessments by changing the meta data in the DMS.* As the ANR statewide DMS becomes populated with data generated in the field for different stream types and watersheds from around Vermont, the Phase 1 impact ratings and reach condition evaluations will increasingly provide a more complete picture of how to assess reach conditions watershed-wide and offer more powerful guidance in setting field assessment priorities.

Step 9 does not require any data entry into the DMS. The DMS generates a report named "Adjustment Process and Reach Condition" that lists a Phase I score for the four adjustment processes as well as the provisional condition and sensitivity.

Data Sheet 9: Geomorphic Condition

9.1 CHANNEL ADJUSTMENT PROCESS

Notes on Channel Evolution, Exceptions, and Outliers: The Phase 1 Step 9 DMS Report attempts to factor in the sequence of adjustments that occur in one of the more common channel evolution process seen in Vermont. It is important, however, to remember the sequential and temporal aspects of the channel evolution process (Appendix C). For instance, channel degradation may be followed by channel widening, which is often followed by channel aggradation and plan form adjustment. If your provisional Phase 1 assessment shows channel degradation as the current process, it may be reasonable to find (in the field) an incised, widened channel that is currently aggrading. In this example, the Phase 1 may have correctly picked up on **causal** factors that should indicate channel degradation, but perhaps due to interceding flood events, the channel evolution process continued to the adjustment processes that often follow degradation. Such discrepancies do not necessarily represent assessment error. They are important to explore because they provide important insights into the situations where cause and effect did not play out as expected; or where the evolution process has continued and your reach is experiencing a different adjustment process beyond what the causal factors indicate. Finding out why a reach did not respond or adjust to certain stressors as predicted, or has moved to a different stage of channel evolution and /or adjustment process, is important to developing a management plan for the reach.

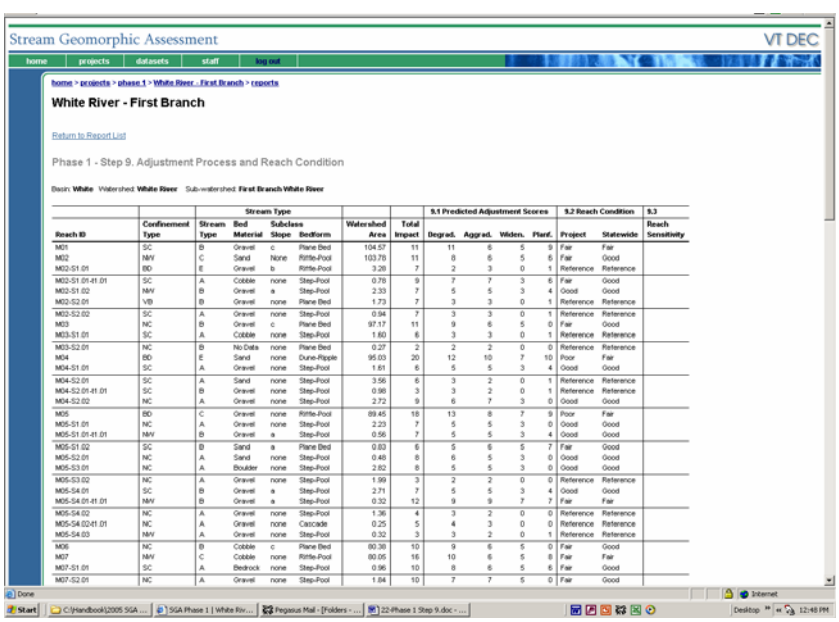
Background: Detailed descriptions of channel evolution and channel adjustment processes are provided in Appendix C and Step 6 of the Phase 3 Handbook. Phase 1 data can be used to set a hypothesis and provisionally assign adjustment processes that may be occurring in the reaches in your watershed based on modifications of their channels, floodplains, and/or watershed and riparian vegetation.

Evaluation:
Vermont ANR has developed a DMS Report named "Adjustment Process and Reach Condition" that adds together impact scores (2, 1, or 0) for specific Phase 1 parameters that have been shown to initiate or influence different channel adjustment processes (see DMS query flow chart in Appendix B). The query provides a score for each of the four adjustment processes in the Phase 1 DMS and displays the values in the report mentioned above. This report provides total impact ratings and provisional adjustment process (Table 9.1) scores for each reach (Figure 9.1).

Initially the highest scoring adjustment process may be considered the current adjustment process occurring in the reach. Many reaches may have a high score for two or more adjustment processes. Usually if a stream is undergoing one type of adjustment (especially degradation or aggradation) then it will be undergoing other forms of adjustment as well. You may consider the second highest score the "concurrent adjustments". Since channel adjustment processes are typically the result of the cumulative effect of different stressors, a minimum cut-off value of 4 has been established to recognize that, while all reaches will likely have some impacts, they may not necessarily be in adjustment. There may be multiple adjustment processes with the same or nearly the same score, greater or equal to 4, which may indicate multiple adjustments under way in the reach. If none of the adjustment processes have a score greater than or equal to the cut-off value, it may indicate that the reach is in equilibrium (not in adjustment).

Table 9.1 Phase 1 adjustment process options

Degrading	Downward erosion of stream bed via a head-cutting process
Aggrading	Excessive sediment build up on streambed and bars
Widening	Erosion of both banks leading to an over-widened streambed
Planform	Rapid and/or irregular meander movement and pattern
None	No significant adjustment process indicated
Multiple	Multiple adjustments indicated



		Stream Type						9.1 Predicted Adjustment Scores				9.2 Reach Condition		9.3
Reach ID	Confinement Type	Stream Type	Bed Material	Subclass Slope	Bedform	Watershed Area	Total Impact	Degrad.	Aggrad.	Widen.	Planf.	Project	Statewide	Reach Sensitivity
M01	SC	B	Gravel	c	Plane Bed	104.57	11	11	6	5	9	Fair	Fair	
M02	MV	C	Sand	None	Riffle-Pool	103.78	11	8	6	5	6	Fair	Good	
M02-S1.01	BD	E	Gravel	b	Riffle-Pool	3.26	7	2	3	0	1	Reference	Reference	
M02-S1.01-41.01	SC	A	Cobble	none	Step-Pool	0.78	9	7	7	3	6	Fair	Good	
M02-S1.02	MV	B	Gravel	a	Step-Pool	2.33	7	5	5	3	4	Good	Good	
M02-S2.01	VB	B	Gravel	none	Plane Bed	1.73	7	3	3	0	1	Reference	Reference	
M02-S2.02	SC	A	Gravel	none	Step-Pool	0.94	7	3	3	0	1	Reference	Reference	
M03	NC	B	Gravel	c	Plane Bed	97.17	11	9	6	5	0	Fair	Good	
M03-S1.01	SC	A	Cobble	none	Step-Pool	1.60	6	3	3	0	1	Reference	Reference	
M03-S2.01	NC	B	No Data	none	Plane Bed	0.27	2	2	2	0	0	Reference	Reference	
M04	BD	E	Sand	none	Dune-Ripple	95.03	20	12	10	7	10	Poor	Fair	
M04-S1.01	SC	A	Gravel	none	Step-Pool	1.61	6	5	5	3	4	Good	Good	
M04-S2.01	SC	A	Sand	none	Step-Pool	3.56	6	3	2	0	1	Reference	Reference	
M04-S2.01-41.01	SC	B	Gravel	none	Step-Pool	0.98	3	3	2	0	1	Reference	Reference	
M04-S2.02	NC	A	Gravel	none	Step-Pool	2.72	9	6	7	3	0	Good	Good	
M05	BD	C	Gravel	none	Riffle-Pool	89.45	18	13	8	7	9	Poor	Fair	
M05-S1.01	NC	A	Gravel	none	Step-Pool	2.23	7	5	5	3	0	Good	Good	
M05-S1.01-41.01	MV	B	Gravel	a	Step-Pool	0.56	7	5	5	3	4	Good	Good	
M05-S1.02	SC	B	Sand	a	Plane Bed	0.83	6	5	6	5	7	Fair	Good	
M05-S2.01	NC	A	Sand	none	Step-Pool	0.48	8	6	5	3	0	Good	Good	
M05-S3.01	NC	A	Boulder	none	Step-Pool	2.82	8	5	5	3	0	Good	Good	
M05-S3.02	NC	A	Gravel	none	Step-Pool	1.99	3	2	2	0	0	Reference	Reference	
M05-S4.01	SC	B	Gravel	a	Step-Pool	2.71	7	5	5	3	4	Good	Good	
M05-S4.01-41.01	MV	B	Gravel	a	Step-Pool	0.32	12	9	9	7	7	Fair	Fair	
M05-S4.02	NC	A	Gravel	none	Step-Pool	1.36	4	3	2	0	0	Reference	Reference	
M05-S4.02-41.01	NC	A	Gravel	none	Cascade	0.25	5	4	3	0	0	Reference	Reference	
M05-S4.03	MV	A	Gravel	none	Step-Pool	0.32	3	3	2	0	1	Reference	Reference	
M06	NC	B	Cobble	c	Plane Bed	80.36	10	9	6	5	0	Fair	Good	
M07	MV	C	Cobble	none	Riffle-Pool	80.05	16	10	6	5	8	Fair	Fair	
M07-S1.01	SC	A	Bedrock	none	Step-Pool	0.96	10	8	6	5	6	Fair	Good	
M07-S2.01	NC	A	Gravel	none	Step-Pool	1.84	10	7	7	5	0	Fair	Good	

Figure 9.1 Example of a DMS query output of provisional adjustment process scores.

See Appendix B to learn how the query generates Phase 1 Provisional Adjustment Scores.

9.2 REACH CONDITION

Background:
A Provisional Geomorphic Condition Evaluation process has been established in the Phase 1 protocols to use the provisional adjustment process ratings to derive a condition rating for each reach. To support the prioritization of reaches in Step 10, derivation of geomorphic conditions are made relative to the most impacted reaches ***within*** your watershed, as well as those in relation to other highly impacted streams throughout Vermont. Reach conditions are defined using the following four categories:

Reference: A reach with no significant channel or floodplain modifications and an adjacent forested riparian buffer should score as a **reference reach** in a near-natural condition. Other reaches that have been modified or lack a buffer are evaluated on the extent to which their condition has departed from the reference condition of the same stream type.

Good: Most streams in Vermont have experienced some degree of human-induced change to their watershed, floodplain, and/or channel. Where a stream is undergoing only minor adjustments or has substantially adjusted to previous modifications and is returning to a dimension, pattern, and profile in regime with watershed inputs, it should be evaluated as a reach in **good condition**. For instance, streams that have undergone planform adjustments in response to watershed clear-cutting or road building decades ago may be near a reference condition today (e.g. entering Stage V of the channel evolution process, Appendix C). A stream in good condition differs from a reference condition stream in that it is still undergoing adjustments due to current or historic modifications, land cover changes, or riparian buffer re-establishment. Streams in good condition may still be adjusting their belt width or building a floodplain but compared to the stream in fair condition they are within the range of natural variability expected for the reference condition of the stream.

Fair: Streams in **fair condition** are fully in adjustment, possibly already experiencing or heading toward major and rapid changes due to recent floodplain and channel modifications, land cover changes, and/or loss of riparian buffer. Channels undergoing incision (i.e. head-cutting), widening, or rapid lateral movement (i.e. planform adjustment) should score in fair condition.

Poor: An entrenched reach, for instance in a narrow or unconfined valley (Stage II of channel evolution – Appendix C), or one that is severely over-widened and out of regime with respect to sediment transport (i.e., aggrading) should be evaluated as a reach in **poor condition**. Unless the stream has started to braid, with large mid-channel bars that can be seen on the orthophotos, it may be difficult to know whether the stream is in fair or poor condition without further field assessments.

The DMS generates a "within watershed" reach condition score from the provisional adjustment process scores using the following formula:

Condition Score:

$$\frac{(HS - deg) + (HS - aggr) + (HS - wid) + (HS - plan)}{(4 \times HS)}$$

Where:

HS = Highest adjustment process score (for any reach in your watershed)
deg = reach degradation score
aggr = reach aggradation score
wid = reach widening score
plan = reach planform score

In the example shown in Figure 9.1, a value of 10 was the highest adjustment process score (reach T4.1/S1 for planform adjustment) in the set of reaches. The database query would assign 10 as the HS value and calculate condition scores. For example, reach M19 in Figure 9.1 would have a condition score of [(10-6) + (10-9) + (10-7) + (10-8) / (4 x 10) = 0.25 = Poor

Evaluation:
The DMS report generated for Step 9.1, "Adjustment Process and Reach Condition," calculates condition scores **based** on the formula in the box above and provides provisional stream conditions for each reach based on the scores in menu above (Figure 9.1).

It is important to note that the DMS is using the highest score within your project area to calculate the "project" reach condition rating. These results are calibrated to fall within the possible range of scores assessed

within **your** watershed. This has the advantage of helping you target the reaches within your watershed that have the highest impacts.

A between watershed or "statewide" reach condition is also generated in this report. The Vermont River Management Program uses Phase 1 assessments completed in Vermont and uses a statewide high adjustment score value to generate a statewide reach condition using the computation process described above. This value will allow you to compare the condition ratings of your reaches to each other as well as with those from assessed reaches around Vermont.

Menu

0.85 – 1.0	**Reference**	In Equilibrium – no apparent or significant channel, floodplain, or land cover modifications; channel geometry is likely to be in balance with the flow and sediment produced in its watershed
0.65 – 0.84	**Good**	In Equilibrium but may be in transition into or out of the range of natural variability – minor erosion or lateral adjustment but adequate floodplain function; any adjustment from historic modifications nearly complete
0.35 – 0.64	**Fair**	In Adjustment – moderate loss of floodplain function; or moderate to major planform adjustments that could lead to channel avulsions
0.00 – 0.34	**Poor**	In Adjustment and Stream Type Departure - may have changed to a new stream type or central tendency of fluvial processes – significant channel and floodplain modifications may have altered the channel geometry such that the stream is not in balance with the flow and sediment produced in its watershed

9.3 REACH SENSITIVITY

Background:
Step 7 of the Phase 2 Handbook and Step 6 of the Phase 3 Handbook have more detailed discussion and guides on the factors affecting stream reach sensitivity and may be useful reading prior to reviewing the stream sensitivity.

Evaluation:
The DMS automatically assigns a sensitivity rating to the reaches in your watershed based on the reference stream type. This sensitivity rating represents the inherent characteristics of the stream "in regime" and does not take into consideration any adjustments. Table 9.2 outlines the sensitivity ratings that will be assigned to each of the reference stream types. The sensitivity rating can be viewed for each reach in the DMS report named "Adjustment Process and Reach Condition".

Table 9.2 Phase 1 reach sensitivity assigned based on reference stream type

Reference Stream Type	Reference Stream Sensitivity
A1, A2, B1, B2, C1, C2	Very low
G1, G2, F1, F2	Low
B3, B4, B5, C3, E3	Moderate
C4, C5, E4, E5, A3, A4, A5, G3, F3	High
G4, G5, F4, F5	Very High
D3, D4, D5	Extreme

Step 10. Like Reach Evaluation

Background

The purpose of a "Like Reach Evaluation" is to group reaches in the watershed by similar stream types (product of Step 2) and similar geomorphic condition assessments (product of Step 9).

Grouping streams by like reaches is useful in selecting a manageable number of reaches for which to conduct the more detailed Phase 2 and Phase 3 assessments. By collecting detailed information on a few reaches that represent all the stream types in your watershed you are better able to characterize the entire watershed without conducting extensive and time-consuming field surveys on the entire watershed.

Evaluation

The DMS report titled "Like Reach Evaluation" assists with the evaluation of like reaches by creating the following table. The user must supply the sorting criteria (See Figure 10.1).

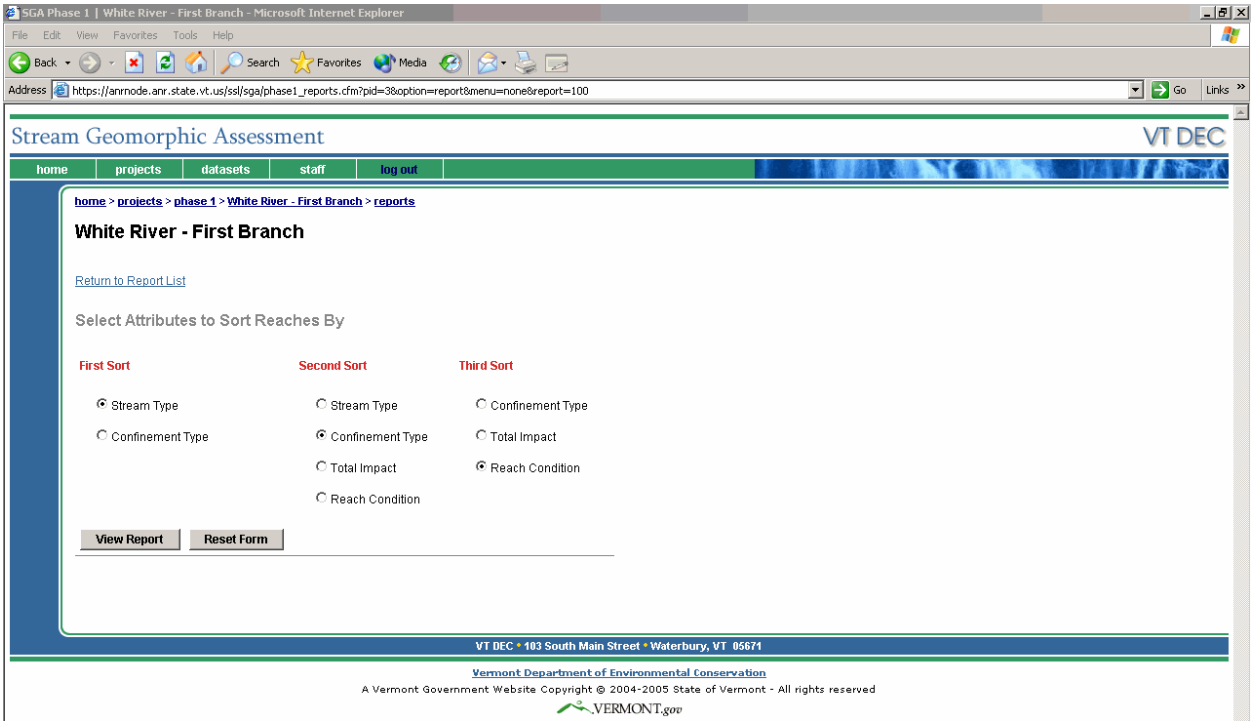


Figure 10.1. The user must supply the sorting criteria for the Like Reach Evaluation report. The DMS allows for a first, second and third sort.

Once the user has specified the sorting criteria the DMS will generate a report (See Figure 10.1). The user can update the sorting criteria and re-run the report to generate different like reach groupings.

Phase 1 Quality Assurance Protocol

Background:
Completing the Quality Assurance Protocol is critically important to the data documentation process, which will allow your assessment team and local, regional, state, and federal partners to ascertain the accuracy and completeness of your geomorphic assessment work.

High quality data, which is complete and accurate, may form the basis of meaningful natural resource and river management projects, and is therefore one of the primary goal of any assessment program. Often, both time and budgetary constraints do not support the collection of high quality data throughout a watershed. Documentation of any assessment deficiencies should not necessarily be viewed as failure, but rather as the first step in identifying future assessment needs.

Evaluation:
After completing all or parts of Steps 1 through 10 of the Phase 1 Stream Geomorphic Assessment Handbook, you should complete the Quality Assurance Sheet in Appendix A and enter the information in the Phase 1 QA DMS. Use the following protocols in completing the QA sheet.

QUALITY ASSURANCE WORKSHEET

QA Team Leader: The name of the local quality assurance team leader.

ANR Team Leader: The ANR staff member serving on the quality assurance team who will conduct the State QA review.

Training: Indicate the types of ANR sponsored training received by one or more members of your assessment team:

Phase 1: Training on the completion of a watershed orientation and Steps 1 – 10.
SGAT: Training on the use of the Stream Geomorphic Assessment Tool, including the GIS extension and the SGAT handbook.
Quality Assurance (QA): Specialized training to complete quality assurance reviews.

Watershed Orientation Completed: Indicate whether or not a watershed orientation was completed.

Reach Break Review: Indicate whether a trained member of the assessment team reviewed the reach breaks that were made in Step 1 and verified in Steps 2 and 3. This review is conducted to ensure reach break consistency, and is ideally done by the local or State QA team leader.

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

Tools Used to Collect Data: Transcribe the information about the tools and materials used to complete a protocol step, as was recorded at the bottom of the Step 1 through 7 data sheets.

Confidence Level: Using the following definitions, circle the level that best describes the confidence that you and your assessment team have in the Phase 1 data collected for each step in the protocols:

Low to Moderate – Unsure of protocols and/or used minimal historic data sources; 1:5000 stream coverages were not available; little to no field verification.

Moderate – Understood and followed Phase 1 Protocols; used at least one historic data resource for parameters where appropriate; little of no field verification; suspect some watershed, channel, or floodplain modification activities not known.

Moderate to High – Understood and followed Phase 1 Protocols; used many historic data resources for parameters where appropriate; some field verification; suspect some watershed, channel, or floodplain modification activities not known.

High – Used many data resources; historical activities in area well-documented; field verified all questionable assessments; suspect few modification activities not known.

***Data Completed*:** Date the protocol step was initially completed.

Data Updated: Date the Phase 1 data for a protocol step was revised based on new or additional data sources or field assessments, including windshield surveys.

Date of Local QA Team Review: Date a quality assurance review of the Phase 1 data for a protocol step was completed by the local QA team leader.

Date of State QA Team Review: Date a quality assurance review of the Phase 1 data for a protocol step was completed by the State QA team member.

Comments: Any comments relaying details about the tools and materials that were used or why a confidence level was selected. Document any issues, things missing and why, questions, problems you may have had along the way.

Basic QA checks to be completed before sending data to the River Management Program

The following list a QA checks has been developed to help you improve your QA documentation and find some of the more common errors that have been encountered during the Phase 1 quality assurance process. In some cases, DMS QA reports have been developed to assist with these checks. Completing these checks before requesting the final QA review by the DEC River Management Program will ensure a more timely State QA check.

1) Print out the DMS report tables 1- 8. Using a map of the watershed, review the data to see if it makes sense.

- Check to see that the slopes and stream types seem true to what you see on the map. Some maps in VT are in meters, and it is easy to take the elevations in meters, while the lengths are collected in feet. If you see what appears to be a steep narrow valley and the slopes in steps 2.3 and 2.5 are shallow; indicating a "C" stream type, be sure that the data was collected in the same units. (Stream types may have to be adjusted accordingly if there are changes made to slope values.)
- Review the confinement types. Where there is a steep narrow looking valley, "V" shaped, on the map check to see what confinement type chosen was. Where an attempt was made to measure the valley width in these steeper valleys a large confinement ratio may be derived, giving a "broad" or "very broad" confinement type. If "broad" or "very broad" was chosen, does it seem reasonable. Guidance in the handbook suggest choosing a "narrow to confined valley type for these "V" shaped valleys; pending field verification.

- In Step 3 you can check for alluvial fan and valley side slopes to see that the chosen characteristic seems reasonable. Remember that the alluvial fan is only counted on the reach itself, not on tributaries entering the reach.

2) Document information for the reach itself:
   - If there are parameters where information was evaluated, but a "No Data" was chosen as the impact score, make a note in the comments field as to why; for example: "bank erosion seen at bridge crossing, but total amount not determined so no impact chosen."
   - Use the meta data where data is supplemented by windshield survey, Phase 2, or Phase 3 data. It is important to keep track of where data has been confirmed or collected in the field, by using the check boxes.

3) Comparing channel straightening impacts (Step 5.4) with belt width and meander ratios (Steps 6.5, and 6.6) for consistency. For Step 5.4; if you chose a high impact for channel modification, that is 30% of reach was modified, then the impact score for steps 6.5 and 6.6 should also be high (these measurements are only done for C / E streams). For step 6.5 and 6.6, no measurement is taken if more than 50% of the reach is straightened, the channel width will be entered for the values in step 6.5 and 6.6, this will make the impact high. If there are discrepancies, note if there was a meander that may have been measured in Step 6.5 / 6.6. In some cases, the assessor measured a single "nice" looking meander in an otherwise straightened reach. For an accurate impact score, assess the average condition for the reach, and pass over measuring the outlier, albeit regime-looking meander.

These basic checks will help the data collector and RMP understand the limitations, concerns, and potential needs of the data which has been collected to date. Please contact the RMP with any questions or comments as you go through your review.

State QA reviews are greatly enhanced by providing the State QA leader with a CD containing the following data and information at the completion of the assessment:

- All assessment data recorded on the ANR Stream Geomorphic Assessment Phase 1 Data Sheets and entered into the current version of the ANR Phase 1 DMS.

- The entire SGAT project burned onto a CD.

- The FIT theme documenting the locations of:
  - Alluvial Fans
  - Bank Armoring or Revetments
  - Bridges and Culverts
  - Buffers Less Than 25' wide
  - Development
  - Dredging
  - Encroachments
  - Erosion
  - In stream Flow Regulations
  - Grade Controls
  - Migration
  - Straightening
  - Any additional spatial data for any of the Phase I parameters.

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