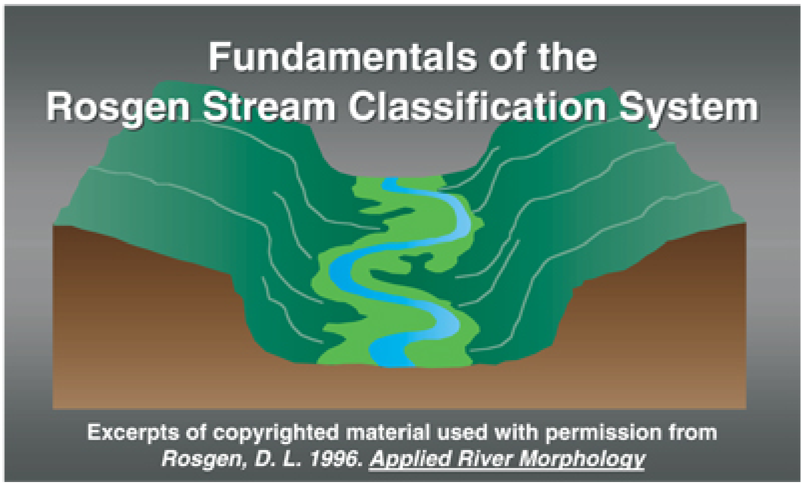


From: EPA Watershed Academy, http://www.epa.gov/watertrain/stream_class/index.htm, accessed 8/29/05

Introduction

This module introduces the basics of the Rosgen classification system, a widely-used method for classifying streams and rivers based on common patterns of channel morphology. The text and visuals presented here are copyrighted material reproduced by permission from the following source:

Rosgen, D.L. and H.L. Silvey. 1996. Applied River Morphology. Wildland Hydrology Books, Fort Collins, CO.

This module is a significantly abbreviated version of Chapters 4 and 5 from this publication, and includes only the basics of the Rosgen classification. Readers are referred to the original text for more detail. Additional information on stream stability can be found at the web-based assessment framework Watershed Assessment for River Stability and Sediment Supply (WARSSS), which uses this classification system. More information on stream structure is available at the Watershed Academy Web module Stream Corridor Structure.

Classification systems are used to organize entities into sets on the basis of their similarities or relationships. The main purpose of classifying is to minimize variation by recognizing definable groups with similarities, and increase one's knowledge about a member of such a group by observing the patterns characteristic of the group in general. Often, environmental classifications are based on measurable attributes of physical structure or pattern. Structure, in turn, is usually the result of physical processes and thus structurally-based classification categories are often related to natural processes or functions. Management decisions, as a rule, need to consider and be based on these natural processes or functions to be effective.

The reason for classifying streams on the basis of channel morphology, or form, is to aid the understanding of stream condition and potential behavior under the influence of different types of changes. Specific objectives of the Rosgen stream classification include:

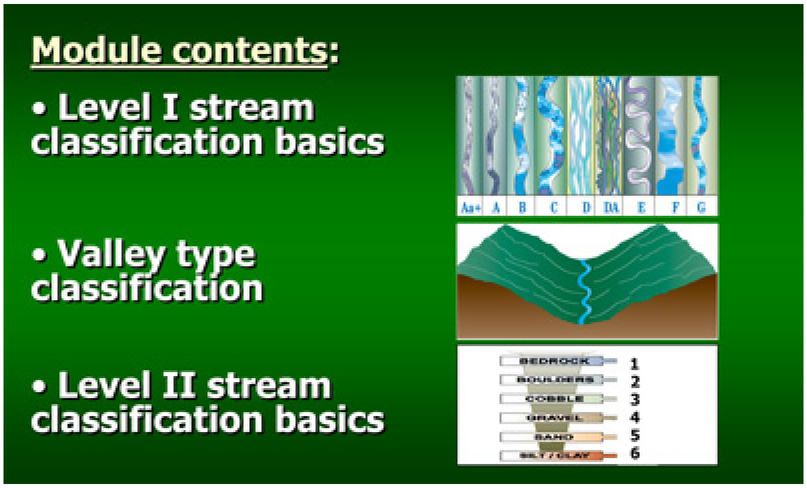
- Predict a river's behavior from its appearance;
- Develop specific hydraulic and sediment relationships for a given stream type and its state;

- Provide a mechanism to extrapolate site-specific data to stream reaches having similar characteristics; and

Provide a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines.

The three main sections of this module provide brief overviews of

- the Level I classification, which is based on the stream characteristics that result from relief, landform, and valley morphology;
- the Valley type, a primary determinant of stream form; and
- the Level II classification, which provides more detailed morphological description of stream type from field measurements of channel form and bed composition.

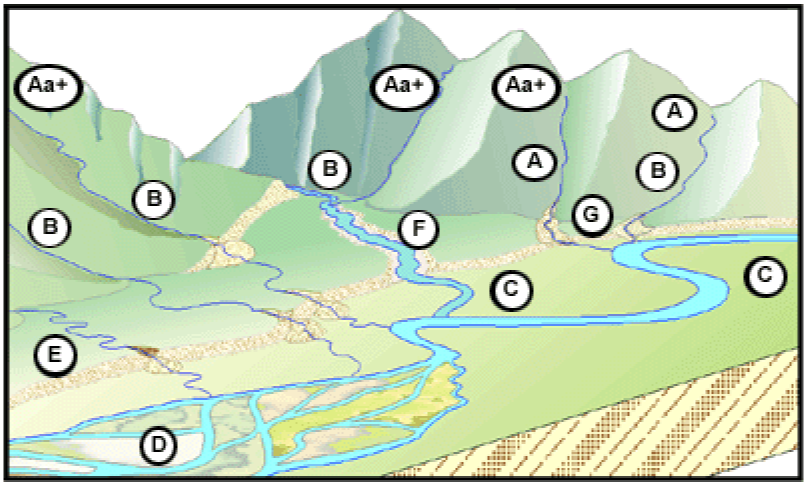


Part 1:
Level I Stream Classification

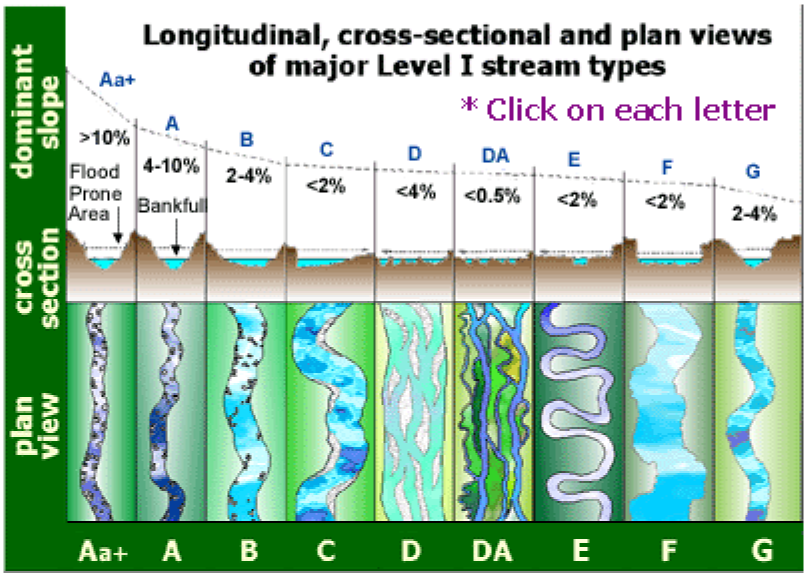
The Level I stream classification serves four primary functions:

1. provide for the initial integration of basin characteristics, valley types, and landforms with stream system morphology.
2. provide a consistent initial framework for organizing river information and communicating the aspects of river morphology. Mapping of physiographic attributes at Level I can quickly determine location and approximate percentage of river types within a watershed and/or valley type.
3. assist in the setting of priorities for conducting more detailed assessments and/or companion inventories.
4. correlate similar general level inventories such as fisheries habitat, river boating categories, and riparian habitat with companion river inventories.

The advantage of a broad, general classification is that it allows for a rapid initial delineation of stream types and illustrates the distribution of these types that would be encountered within a given study area. The Level I classification and delineation process provides a general characterization of valley types (addressed in the second part of this module), and identifies the corresponding major stream types, A through G, discussed here. Illustrations of the Level I stream types are shown in the accompanying figure; clicking on each stream type will also bring up a brief text description of that type in this text window.



The figure above shows how different Level I stream types tend to appear in different parts of the landscape. With proper training, Level I classification can be delineated on common information sources such as topographic maps and aerial photographs.



The “Aa+” Stream Type

Stream type “Aa+” is very steep (>10%), well entrenched, has a low width/depth ratio, and is totally confined (laterally contained). The bedforms are typically a step/pool morphology with chutes, debris flows, and waterfalls. The “Aa+” stream types often occur in debris avalanche terrain, zones of deep deposition such as glacial tills and outwash terraces, or landforms that are structurally controlled or influenced by faults, joints, or other structural contact zones. Streamflow at the bankfull stage in the "Aa+" stream type is generally observed as a torrent or waterfall. The "Aa+" stream types can be associated with bedrock, and zones of deep deposition and/or be deeply incised in residual soils. The "Aa+" can often be described as high energy/high sediment supply systems due to their inherently steep channel slopes and narrow/deep channel cross-sections. “Aa+” stream types may also be found in alluvial landforms, where a change in the base level of the mainstem channel initiates a headward expansion of the tributary network through a channel rejuvenation process. Examples of rejuvenation may be observed where lower-slope position streams are deeply incised in over-steepened adjacent side-wall slopes, or older holocene terrace features that have cut their way through to the elevation of the existing mainstem river. The “Aa+” stream types are often found in valley types I, III, and VII, discussed in the next part of this module.

The "A" Stream Type

Stream type "A" is similar to the described “Aa+”, in terms of associated landforms and channel characteristics. The exception being that channel slopes range from 4 to 10 percent, and streamflows at the bankfull stage are typically described as step/pools, with attendant plunge or scour pools. Normally, "A" stream types are found within valley types that due to their inherent channel steepness, exhibit a high sediment transport potential and a relatively low in-channel sediment storage capacity. Although a large number of "A" stream types occur as low-order streams, located at upper-slope positions, stream order for these stream types can range from 1st order up to 5th order or larger. Stream order referred to is that of Strahler, where the incipient crenulation of a drainage way on the landscape is order 1 and the confluence of the first two drainage ways become order 2 and so on. The influx of large organic debris can play a major role in determining the bedform and overall channel stability of "A" stream types. Landforms associated with deeply incised fanhead troughs are associated with both “Aa+” and "A" stream types. Valley types associated with the "A" stream types are I, III, and VII.

The "B" Stream Type

The "B" stream types exist primarily on moderately steep to gently sloped terrain, with the predominant landform seen as a narrow and moderately sloping basin. Many of the "B" stream types are the result of the integrated influence of structural contact zones, faults, joints, colluvial-alluvial deposits, and structurally controlled valley side-slopes which tend to result in narrow valleys that limit the development of a wide floodplain. "B" stream types are moderately entrenched, have a cross-section width/depth ratio (greater than 12), display a low channel sinuosity, and exhibit a "rapids" dominated bed morphology. Bedform morphology, which may be influenced by debris constrictions and local confinement, typically produces scour pools (pocket water) and characteristic "rapids." Streambank erosion rates are normally low as are the channel aggradation/degradation process rates. Pool-to-pool spacing is generally four to five bankfull widths, decreasing with an increase in slope gradient. Meander width ratios (belt width/bankfull width) are generally low which reflect the low rates of lateral extension. "B" stream types are usually found within valley types II, III, and VI.

The "C" Stream Type

The "C" stream types are located in narrow to wide valleys, constructed from alluvial deposition. The "C" type channels have a well developed floodplain (slightly entrenched), are relatively sinuous with a channel slope of 2% or less and a bedform morphology indicative of a riffle/pool configuration. The shape and form of the "C" stream types are indicated by cross-sectional width/depth ratios generally greater than 12, and sinuosities exceeding 1.2. The "C" stream type exhibits a sequencing of steeps (riffles) and flats (pools), that are linked to the meander geometry of the river where the riffle/pool sequence or spacing is on the average one-half a meander wavelength or approximately 5-7 bankfull channel widths. The primary morphological features of the "C" stream type are the sinuous, low relief channel, the well developed floodplains built by the river, and characteristic "point bars" within the active channel. The channel aggradation/degradation and lateral extension processes, notably active in "C" stream types, are inherently dependent on the natural stability of streambanks, the existing upstream watershed conditions and flow and sediment regime. Channels of the "C" stream type can be significantly altered and rapidly de-stabilized when the effects of imposed changes in bank stability, watershed condition, or flow regime are combined to cause an exceedance of a channel stability threshold. "C" stream types may be observed in valley types IV, V, VI, VIII, IX and X. They can also be found on the lower slope positions of the very low gradient valley type III.

The "D" Stream Type

The "D" stream type is uniquely configured as a multiple channel system exhibiting a braided, or bar-braided pattern with a very high channel width/depth ratio, and a channel slope generally the same as the attendant valley slope. "D" type stream channels are found in landforms and related valley types consisting of steep depositional fans, steep glacial trough valleys, glacial outwash valleys, broad alluvial mountain valleys, and deltas. While the very wide and shallow "D" stream types are not deeply incised, they can be laterally contained in narrower or confined valleys. Bank erosion rates are characteristically high and meander width ratios are very low. Sediment supply is generally unlimited and bed features are the result of a convergence/divergence process of local bed scour and sediment deposition. The multiple channel features are displayed as a series of various bar types and unvegetated islands that shift position frequently during runoff events. Adjustments in channel patterns can be initiated with either natural or imposed changes in the conditions of the encompassing landform, contributing watershed area, or the existing channel system. Aggradation and lateral extension are dominant channel adjustment processes occurring within a range of landscapes from desert to glacial outwash plains. Typically, the runoff regime is "flashy," especially in arid landscapes with highly variable extremes of stage occurring on an annual basis which generates a very high sediment supply. Braided channel patterns can be found developing in very coarse materials located in valleys with moderately steep slopes, to very wide, flat, low gradient valleys containing finer materials. The "D" stream type may develop within valley types III, V, VIII, IX, X, and XI.

The "DA" (Anastomosed) Stream Type

The "DA" or anastomosed stream type is a multiple-thread channel system with a very low stream gradient and the bankfull width of each individual channel noted as highly variable. Stream banks are often constructed with fine grained cohesive bank materials, supporting dense-rooted vegetation species, and are extremely stable. Channel slopes are very gentle, commonly found to be at or less than .0001. Lateral migration rates of the individual channels are very low except for infrequent avulsion. Relative to the "D" stream type, the "DA" stream type is considered as a stable system composed of multiple channels. Channel width/depth ratios and sinuosities may vary from very low to very high. The related valley morphology is seen as a series of broad, gently sloping wetland features developed on or within lacustrine deposits, river deltas or splays, and fine-grained alluvial deposits. The "DA" stream types make up a very small number of observed stream types, but are unique both in the process of their creation and maintenance. In certain locations operating at a "control" point within a valley, maintains the valley base level where a vertical balance exists between the rate of deposition and the rate of uplift. The geologic processes responsible for development of the anastomosed river include subsidence of sedimentary basins in tectonically active forelands, valley base level rise at the basin outlet, regional basin tilting derived from glacial-induced differential isostatic rebound, and the uplifting of sea or lake bed levels. The bedform features of the "DA" stream types are riffle/pool, similar to stream types "C" and "E." The streambanks and island surfaces between channels are well vegetated and constructed with either fine grained alluvium, or fine, cohesive depositional materials. The ratio of bedload to total sediment load is very low for these very stable stream types. The "DA" stream type normally occurs in valley types X and XI.

The "E" Stream Type

The "E" type stream channels are conceptually designated as evolutionary in terms of fluvial process and morphology. The "E" stream type represents the developmental "end-point" of channel stability and fluvial process efficiency for certain alluvial streams undergoing a natural dynamic sequence of system evolution. The "E" type system often develops inside of the wide, entrenched and meandering channels of the "F" stream types, following floodplain development on and vegetation recovery of the former "F" channel beds. The "E" stream types are slightly entrenched, exhibit very low channel width/depth ratios, and display very high channel sinuosities which result in the highest meander width ratio values of all the other stream types. The bedform features of the "E" stream type are predominantly a consistent series of riffle/pool reaches, generating the highest number of pools per unit distance of channel, when compared to other riffle/pool stream types (C, DA, and F). "E" type stream systems generally occur in alluvial valleys that exhibit low elevational relief characteristics and physiographically range from the high elevations of alpine meadows to the low elevations of coastal plains. While the "E" stream types are considered as highly stable systems, provided the floodplain and the low channel width/depth characteristics are maintained, they are very sensitive to disturbance and can be rapidly adjusted and converted to other stream types in relatively short time periods. The "E" stream type typically develops within valley types VIII, X, and XI.

The "F" Stream Type

The "F" stream types are the classic "entrench-ed, meandering" channels described by early day geomorphologists, and are often observed to be working towards re-establishment of a functional floodplain inside the confines of a channel that is consistently increasing its width within the valley. "F" stream types are deeply incised in valleys of relatively low elevational relief, containing highly weathered rock and/or erodible materials. The "F" stream systems are characterized by very high channel width/depth ratios at the bankfull stage, and bedform features occurring as a moderated riffle/pool sequence. "F" stream channels can develop very high bank erosion rates, lateral extension rates, significant bar deposition and accelerated channel aggradation and/or degradation while providing for very high sediment supply and storage capacities. The "F" stream types occur in low relief valley type III, and in valley types IV, V, VI, VIII, IX, and X

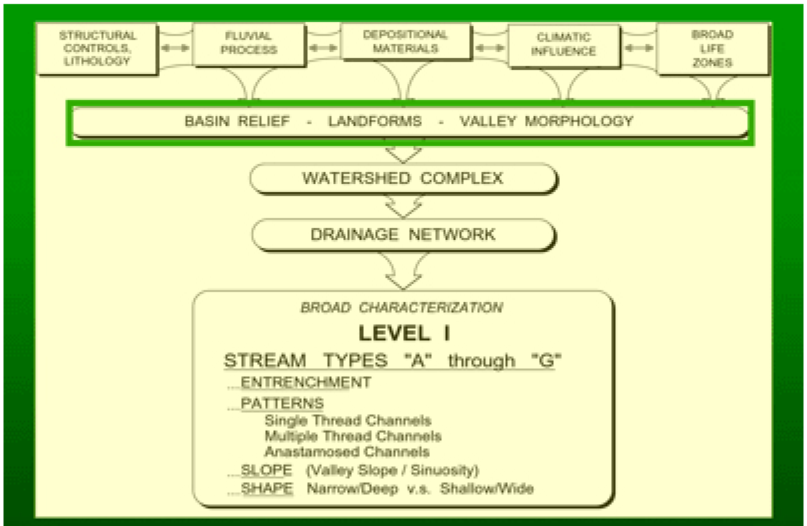
The "G" Stream Type

The "G" or "gully" stream type is an entrenched, narrow, and deep, step/pool channel with a low to moderate sinuosity. Channel slopes are generally steeper than .02, although "G" channels may be associated with gentler slopes where they occur as "down-cut" gullies in meadows. The "G" stream type channels are found in a variety of landtypes to include alluvial fans, debris cones, meadows, or channels within older relic channels. The "fanhead trench" which is a channel feature deeply incised in alluvial fans is typical of "G" type stream channels. With the exception of those channels containing bedrock and boulder materials, the "G" stream types have very high bank erosion rates and a high sediment supply. Exhibiting moderate to steep channel slopes, low channel width/depth ratios and high sediment supply, the "G" stream type generates high bedload and suspended sediment transport rates. Channel degradation and sideslope rejuvenation processes are typical. The valley types supporting the "G" stream types are I, III, V, VI, VII, VIII, and X. The "G" stream type can also be observed in valley types II, VI, VIII and X, under conditions of instability or disequilibrium that are often imposed by watershed changes and/or direct channel impacts.

Part 2:
Valley Morphology

Identification of valley types and related landforms can provide the basis for an initial indication of river morphology. For example, river breaklands and highly dissected fluvial slopes are indicative of steep, narrow, deeply incised, erosional A and G stream types. Narrow, confined canyons and deep gorges within landforms exhibiting low elevational relief characteristically contain "F" stream types. Broad alluvial valleys with well developed floodplains generally indicate the presence of "C" and "E" stream types. Cryoplanated uplands consisting of gentle terrain features, narrow valleys and colluvial slopes normally display relatively stable "B" stream types of both moderate width/depth ratio and entrenchment. Well vegetated, lacustrine meadows with a gentle gradient typically contain the sinuous "E" and "C" stream types, and glacial outwash valleys or plains often exhibit well developed, braided or "D" stream types.

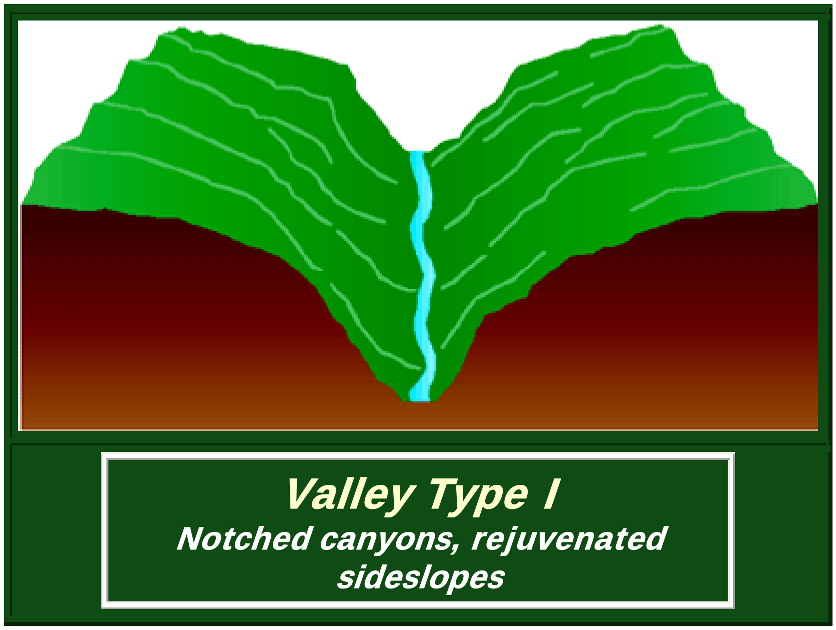
There are 11 valley types described in this section of the module. Click "next" at the top right side of your screen to begin viewing graphics and descriptions of each valley type.



Relationship of valley morphology to other factors involved in Level I stream type classification

Valley Type I
Notched canyons, rejuvenated sideslopes

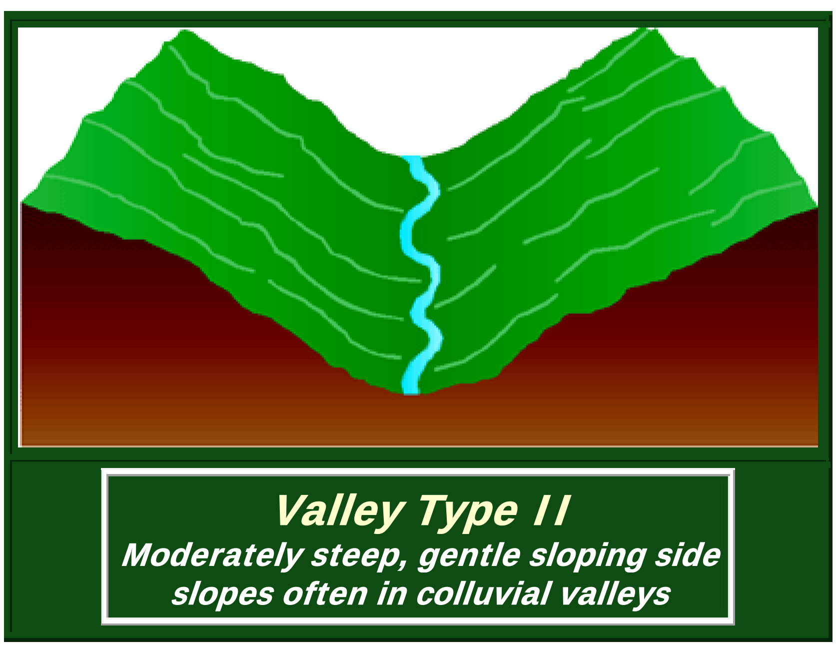
A Type I valley is V-shaped, confined, and is often structurally controlled and/or associated with faults. Elevational relief is high, valley floor slopes are greater than 2%, and landforms may be steep, glacial scoured lands, and/or highly dissected fluvial slopes. Valley materials vary from bedrock to residual soils occurring as colluvium, landslide debris, glacial tills, and other similar depositional materials. Stream types commonly observed in valley Type I include types "A" and "G" which are typically step/pool channels with steeper channel slopes exhibiting cascade bed features. Stream channel erosional processes vary from very low and stable to highly erodible, producing debris torrents or avalanches. Often the "A" stream types in certain hydro-physiographic provinces are the starting or conveyance zones for snow avalanches.



Valley Type II

Moderately steep, gentle sloping side slopes often in colluvial valleys

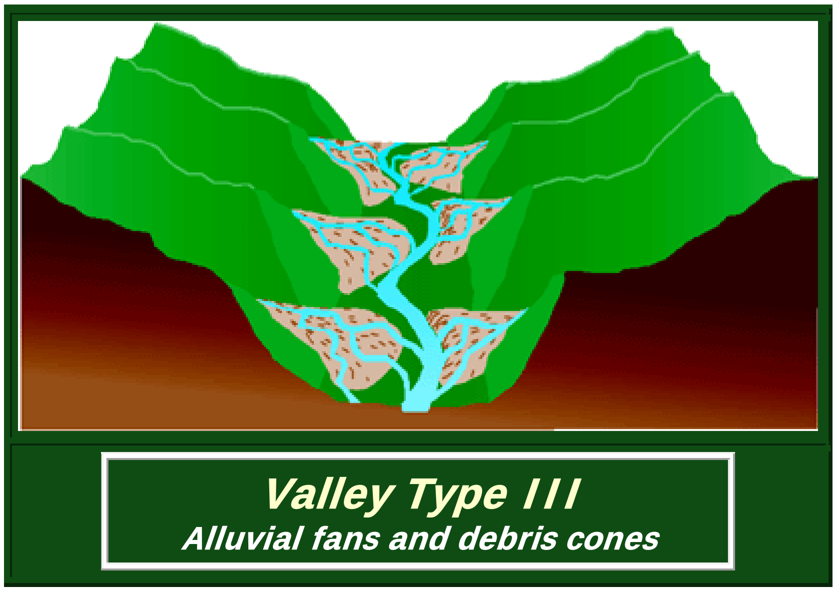
Valley Type II exhibits moderate relief, relatively stable, moderate side slope gradients, and valley floor slopes that are often less than 4% with soils developed from parent material (residual soils), alluvium, and colluvium. Cryoplanated uplands dominated by colluvial slopes are typical of the landtypes that generally comprise Valley Type II in the northern Rocky Mountains. The stream type most commonly found in Valley Type II are the "B" types which are generally stable stream types, with a low sediment supply and bed features normally described as "rapids." Less common are "G" stream types that are observed generally under disequilibrium conditions.



Valley Type III

Alluvial fans and debris cones

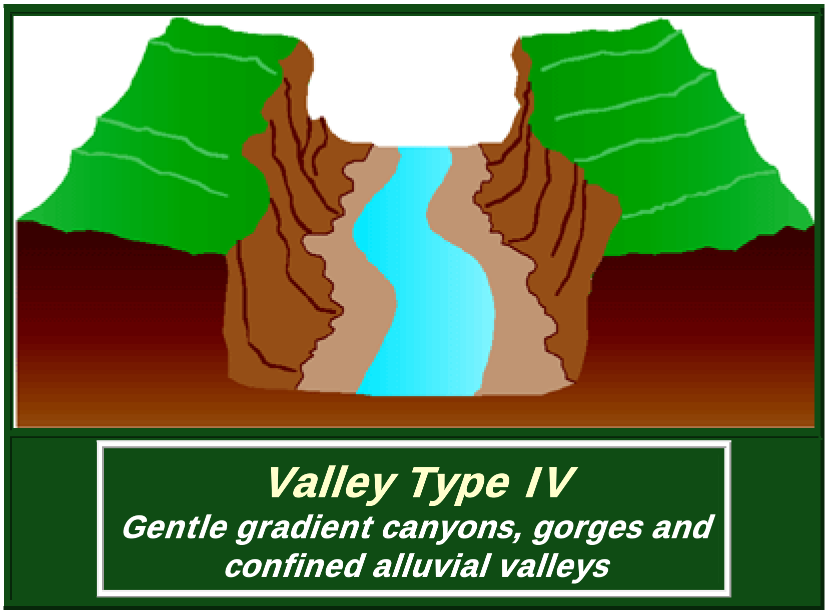
Valley Type III is primarily depositional in nature with characteristic debris-colluvial or alluvial fan landforms, and valley-floor slopes that are moderately steep or greater than 2%. Stream types normally occurring in Valley Type III are the "A," "B," "G," and "D" types. The "B" stream type which is less common on alluvial or colluvial fans occurs primarily on "non-building" stable fans and where riparian vegetation is well established along the drainage-way. The "G" stream type prevails where there is little established riparian vegetation in the presence of high bedload transport on actively "building" fans, similar to the multiple distributary channels of the "D" stream type.



Valley Type IV

Gentle gradient canyons, gorges and confined alluvial valleys

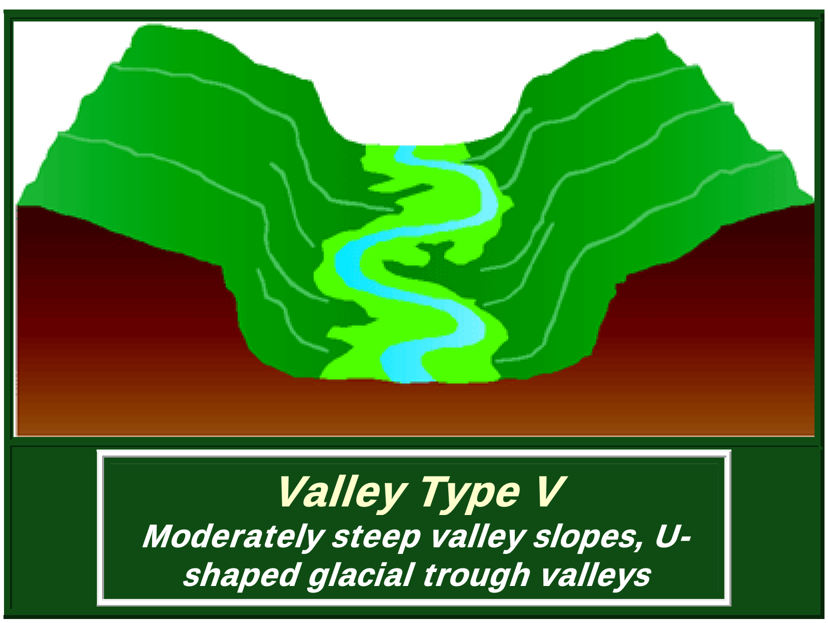
Valley Type IV consists of the classic meandering, entrenched or deeply incised, and confined landforms directly observed as canyons and gorges with gentle elevation relief and valley-floor gradients often less than 2%. Valley Type IV is generally structurally controlled and incised in highly weathered materials. These stream types are also often associated with tectonically "uplifted" valleys. The "F" stream type is most often found in Valley Type IV, however, where the width of the valley floor accommodates both the channel and a floodplain, C channels are often observed. Depending on streamside materials, the sediment supply is generally moderate to high.



Valley Type V

Moderately steep valley slopes, U-shaped glacial trough valleys

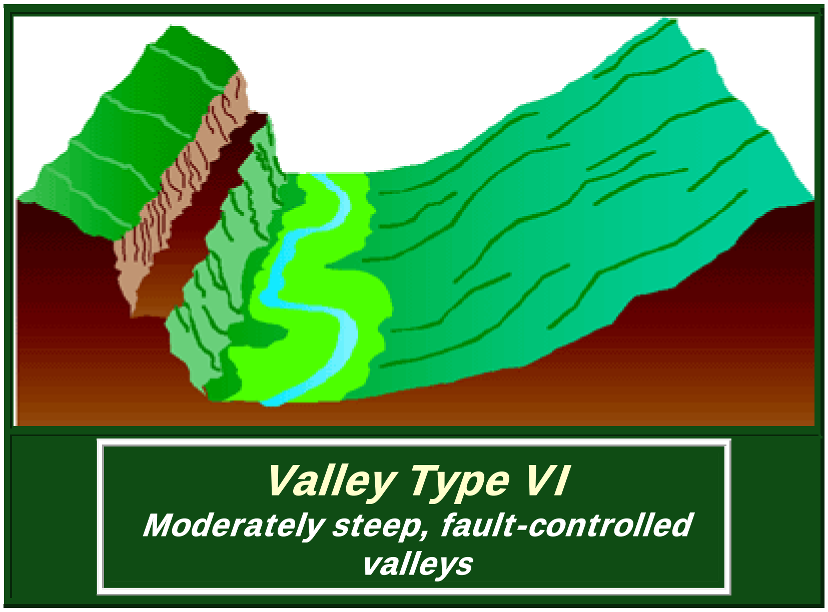
Valley Type V is the product of a glacial scouring process where the resultant trough is now a wide, "u"-shaped valley, with valley-floor slopes generally less than 4 percent. Soils are derived from materials deposited as moraines or more recent alluvium from the holocene period to the present. Landforms locally include lateral and terminal moraines, alluvial terraces, and floodplains. Deep, coarse deposition of glacial till is common, as are glacio-fluvial deposits, with the finer size mixture of glacio-lacustrine deposition above structurally controlled reaches. The stream types most often seen in Valley Type V are "C," "D," and "G."



Valley Type VI

Moderately steep, fault-controlled valleys

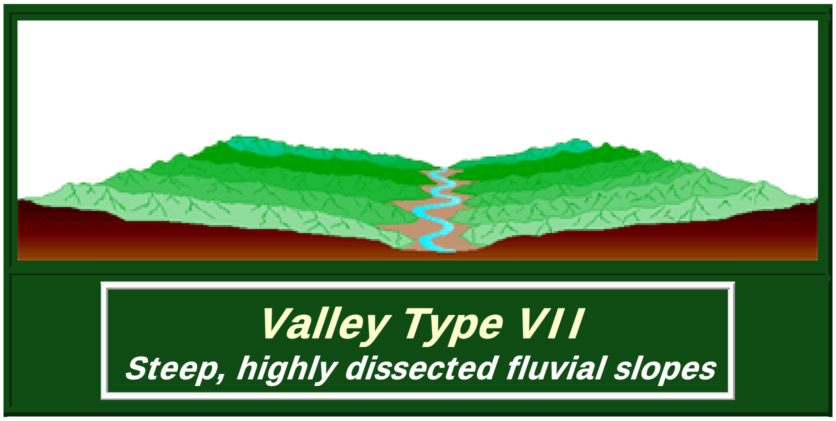
Valley Type VI, termed a fault-line valley, is structurally controlled and dominated by colluvial slope building processes. The valley-floor gradients are moderate, often less than 4 percent. Some alluvium occurs amidst the extensive colluvial deposits and stream patterns are controlled by the confined, laterally controlled valley. Sediment supply is low. Stream types are predominantly "B" types with fewer occasions of "C" and "F" types in the wider and flatter valley reaches. Under disequilibrium conditions, "G" stream types are observed.



Valley Type VII

Steep, highly dissected fluvial slopes

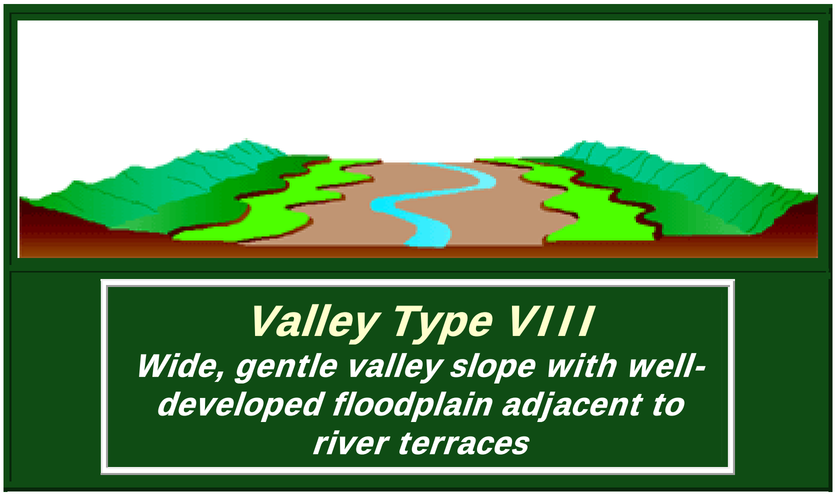
Valley Type VII consists of a steep to moderately steep landform, with highly dissected fluvial slopes, high drainage density, and a very high sediment supply. Streams are characteristically deeply incised in either colluvium and alluvium or in residual soils. The residual soils are often derived from sedimentary rocks such as marine shales. Depositional soils associated with these highly dissected slopes can often be eolian deposits of sand and/or marine sediments. This valley type can be observed over a variety of locations, from the provinces of the Palouse Prairie of Idaho, the Great Basin or high deserts of Nevada and Wyoming, the Sand Hills of Nebraska, to the Badlands of the Dakotas. The majority of stream types found in Valley Type VII are the "A" and "G" types which are channels that have moderate to steep gradients, are entrenched (deeply incised), confined, and unstable due to the active lateral and vertical accretion processes.



Valley Type VIII

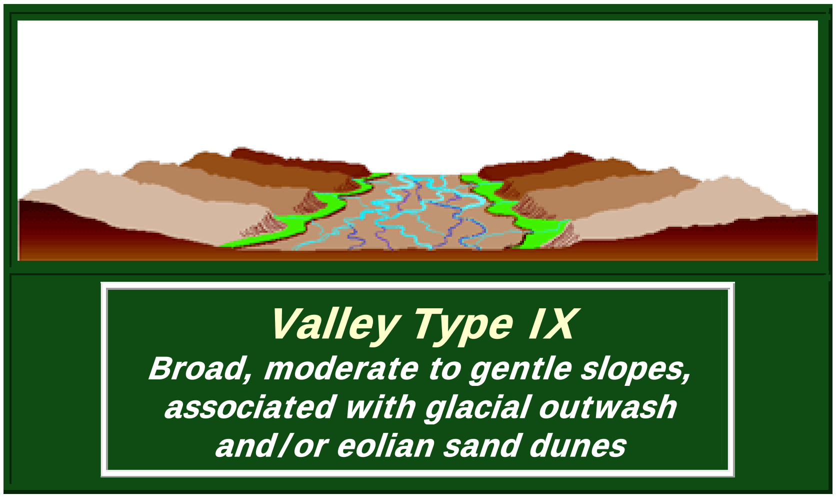
Wide, gentle valley slope with well-developed floodplain adjacent to river terraces

Valley Type VIII is most readily identified by the presence of multiple river terraces positioned laterally along broad valleys with gentle, down-valley elevation relief. Alluvial terraces and floodplains are the predominant depositional landforms which produce a high sediment supply. Glacial terraces can also occur in these valleys, but stand much higher above the present river than the alluvial (Holocene) terraces. Soils are developed predominantly over alluvium originating from combined riverine and lacustrine depositional processes. Stream types "C" or "E," which have slightly entrenched, meandering channels that develop a riffle/pool bed-form, are normally seen in the Type VIII valley. However, "D," "F," and "G" stream types can also be found, depending on local stream and riparian conditions.



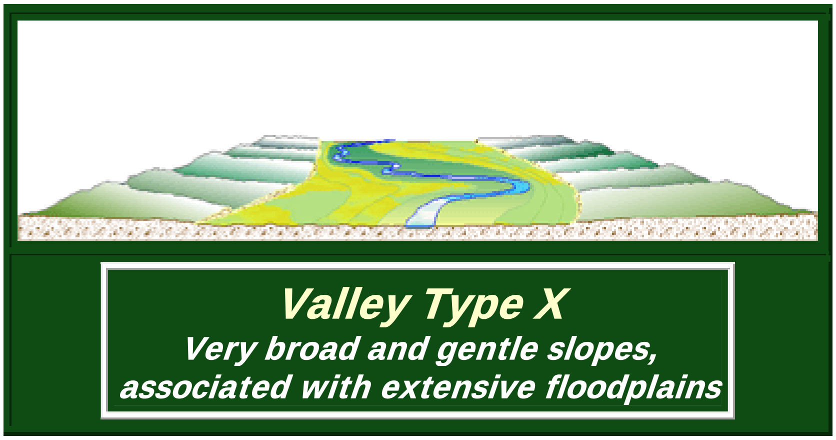
Valley Type IX
Broad, moderate to gentle slopes, associated with glacial outwash and/or eolian sand dunes

Valley Type IX is observed as glacial outwash plains and/or dunes, where soils are derived from glacial, alluvial, and/or eolian deposits. Due to the depositional nature of the developed landforms, sediment supply is high, and the commonly occurring "C" and "D" stream types are associated with high rates of lateral migration.



Valley Type X
Very broad and gentle slopes, associated with extensive floodplains

Valley Type X is very wide, with very gentle elevation relief and is mostly constructed with alluvial materials originating from both riverine and lacustrine deposition processes. Soils are primarily alluvium, and while less common, may also be derived from eolian deposition. Landforms commonly observed as Valley Type X are coastal plains, broad lacustrine and/or alluvial flats, which may exhibit peat bogs and expansive wetlands. Stream types "C," "E," and "DA" are the most commonly observed, although in many instances, where streams have been "channelized," or the local base level has been changed, "G" and "F" stream types are found.



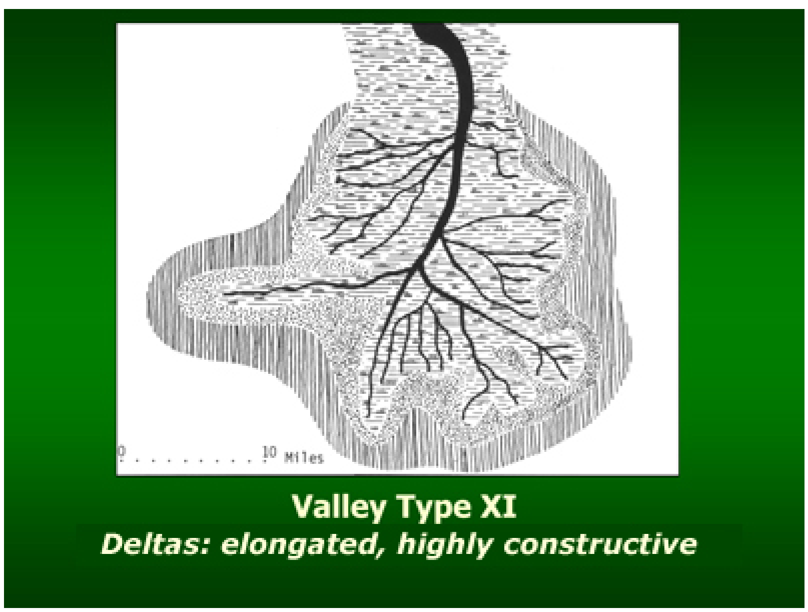
Valley Type XI
Deltas

Valley type XI is a unique series of landforms consisting of large river deltas and tidal flats constructed of fine alluvial materials originating from riverine and estuarine depositional processes. The Type XI valleys or delta areas are often seen as freshwater and saltwater marshes, natural levees, and crevasse splays. There are four morphologically distinct delta areas, which produce different stream types or patterns and include:

- the elongate, highly constructive delta (example shown here)
- the lobate, highly constructive delta
- the highly destructive, wave-dominated delta
- the highly destructive, tide-dominated delta

An additional delta landform is representative of extensive wetlands, peat, and cohesive sediments with multiple, stable channels typical of the "DA" (anastomosed) stream type.

The corresponding stream types found in delta areas are primarily the distributary channels of stream type "DA," or the multiple channel systems of the "D" stream type, along with occasional "C" and "E" stream types. The "DA" stream type is more common to the tide-dominated, stable deltas with numerous wetland islands, and the base level of the channel system controlled by either lake or sea levels.



Part 3:
Level II Stream Classification

Whereas Level I stream types are distinguished primarily on the basis of the valley landforms and channel dimensions observable on aerial photos and maps, Level II stream types are determined with field measurements from specific channel reaches and fluvial features within the river's valley. The Level II classification process employs more finely resolved criteria in order to address questions of sediment supply, stream sensitivity to disturbance, potential for natural recovery, channel response to changes in flow regime, and fish habitat potential.

Level II stream type delineation criteria are based on the following characteristics of channel cross-section, longitudinal profile, and planform features as measured and computed from collected field data. The flowchart shows how these selected criteria are used to conduct a Level II stream type classification.

Cross-sectional measurements

Entrenchment Ratio: A computed index value which is used to describe the degree of vertical containment of a river channel (width of the flood prone area at an elevation twice the maximum bankfull depth/bankfull width).

Width/depth Ratio: An index value which indicates the shape of the channel cross-section (ratio of bankfull width/mean bankfull depth).

Dominant Channel Materials: A selected particle size index value, the D50, representing the most prevalent of one of six channel material types or size categories, as determined from a channel material size distribution analysis.

Longitudinal Profile measurements

Slope: Slope of the water surface averaged for 20-30 channel widths.

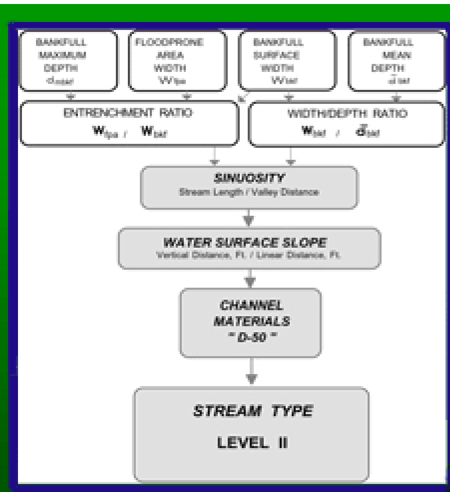
Bed Features: Secondary delineative criteria describing channel configuration in terms of riffle/pools, rapids, step/pools, cascades and convergence/divergence features which are inferred from channel plan form and gradient.

Plan-form (pattern) measurements

Sinuosity: Defined as stream length/valley length or valley slope/channel slope).

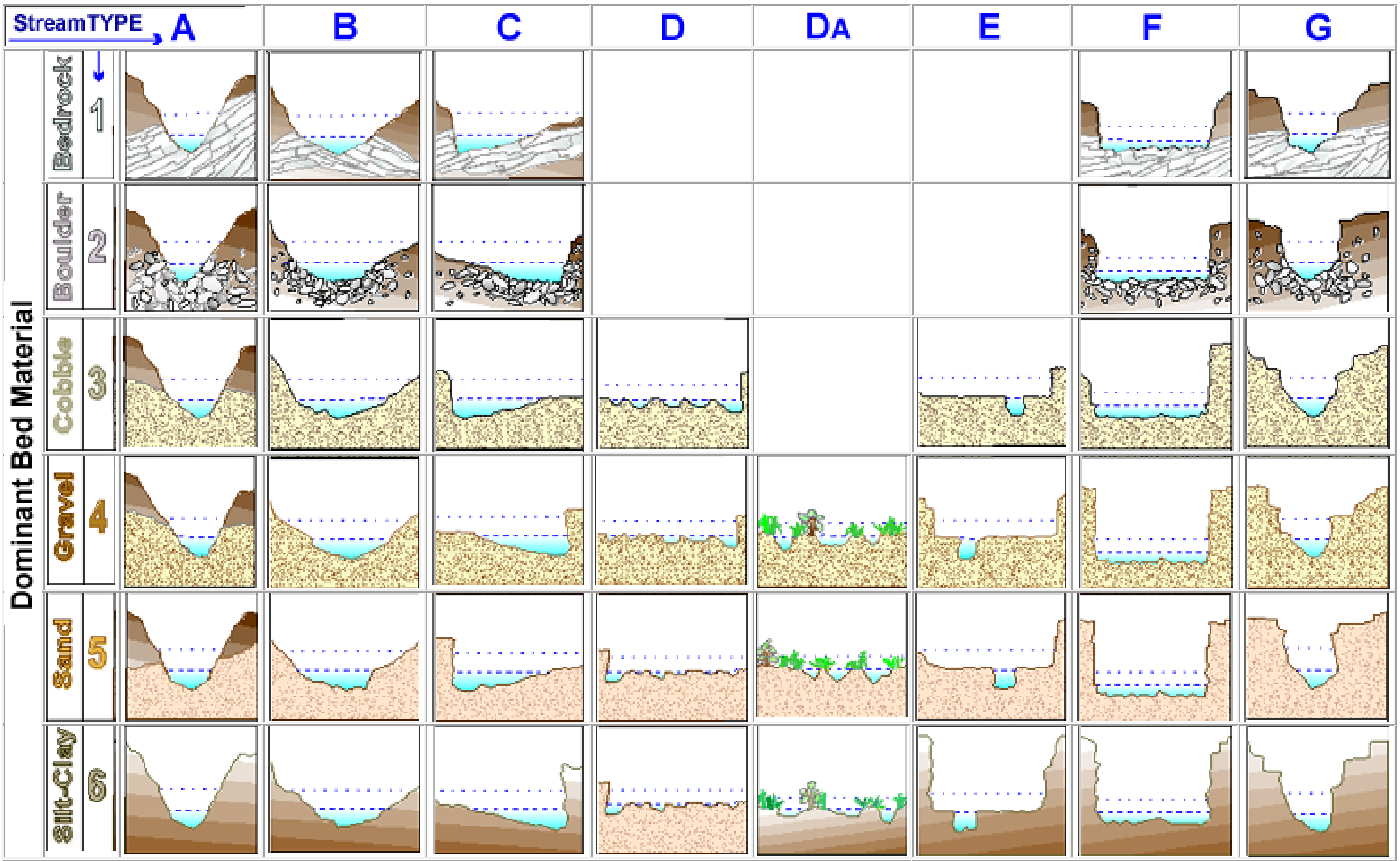
Meander Width Ratio: A secondary delineative criteria defined as meander belt width/bankfull width that describes the degree of lateral channel containment, and is primarily used in assisting aerial photo delineation of stream types.

This figure illustrates the representative channel cross-section configurations, dominant particle size class of the stream bed materials, and channel form measurements for the full set of 41 Level II stream types. The nine Level I, or major stream types are refined by the addition of six categories of channel materials (bedrock through silt and clay); and by field measurement of entrenchment, sinuosity, width/depth ratio, and water surface slope. The naming of Level II stream types combines the Level I letter (A through G) with the number representing the dominant bed material (1 through 6), resulting in type names such as B3, C4, A2, and so on. Note that the blank areas in this chart are due to the fact that certain (usually large particle) bed material sizes are not naturally found in combination with certain (usually low-gradient) channel types.



Identifying Level II stream types builds on Level I by adding field measurements of channel form and bed materials. Click on image for large view (PDF, 19kb).

Summary of the Level II Types and Delineative Criteria



Entrnch-ment.	<1.4	1.4 - 2.2	<2.2	n/a	<4.0	<2.2	>1.4	>1.4
W / D Ratio	<12	>12	>12	>40	<40	<12	>12	<12
Sinuos -ity	1-1.2	>1.2	>1.2	n/a	variable	>1.5	>1.2	>1.2
$H_2$0 Slope	.04-.099	.02-.039	<.02	<.04	<.005	<.02	<.02	.02-.039

Gathering Field Data for Level II

The Reference Reach

The morphological variables used to define stream types at Level II can and do change within short distances along a river channel, due to changes in geology and tributary influence. A Level II classification may apply to a reach that is only a few tens of meters in length, or to a reach distance of several kilometers. It is important to note that data from individual channel reaches are not averaged over entire basins. Extrapolations necessary to describe the variety of stream types that may exist within a broad area are instead based upon Level II field measurements taken from selected "reference" reaches. Interpretations developed on the basis of data and analysis related to the reference reach can then be extrapolated to other similar reaches, where such detailed data is not readily available.

The use of a reference reach concept enables Level II stream type classifications to be completed for other similar areas without requiring extensive on-site data collection. It is essential, however, to

1. calibrate the bankfull channel dimensions at gaging stations for representative stream types within the particular hydro-physiographic regime;
2. use aerial photography and topographic maps for preliminary identification of stream types; and
3. measure and analyze representative or reference reaches to verify the initial interpretive classifications.

Bankfull discharge

The stage or elevation of bankfull discharge is the single most important parameter used in Level II classifications. The stage of bankfull discharge is related to channel dimensions such as width, and channel patterns such as meander length, radius of curvature, belt width, meander width ratio and amplitude. Moreover, the bankfull channel width is required to estimate two of the five primary Level II criteria (i.e., entrenchment ratio and width/depth ratio).

Field Determination of Bankfull Stage. The most consistent bankfull stage determination is obtained from identification of the top of the floodplain. This elevation is where incipient flooding begins for those flows that extend above the bankfull stage. Many floodplains are constructed as the river moves laterally, away from established point bars. The elevation of the top of point bars and the bankfull stage thus share a common elevation that is directly related to the development of floodplains within the valley, given the current climate regime. It is important for the field observer to recognize the physical and morphological difference between a low terrace and floodplain, since alluvial channels with well developed floodplains can often have low elevation river terraces (abandoned former floodplains) adjacent to the channel. For those stream types that exhibit a well-developed floodplain, - such as the "C," "D," "DA," and "E" types - the bankfull stage is easily and reliably identified as the elevation of the floodplain.

Where floodplains are not well developed, the identification of bankfull stage must be determined by field stage indicators that may be combined as corroborating evidence for an indication of a consistent and common elevation. The appropriate use of any or all of the bankfull stage indicators requires adherence to four basic principles:

1. Seek indicators in the locations appropriate for specific stream types.
2. Know the recent flood and/or drought history of the area to avoid being mislead by spurious indicators (e.g., colonization of riparian species within the bankfull channel during drought, or flood debris accumulations caught in willows that have rebounded after flood flows have receded).

3. Use multiple-indicators wherever possible for reinforcement of a common stage or elevation.
4. Where possible, calibrate field determined bankfull stage elevations and corresponding bankfull channel dimensions to known recurrence interval discharges at gaged stations. This procedure can verify the difference between the floodplain of the river and a low terrace.

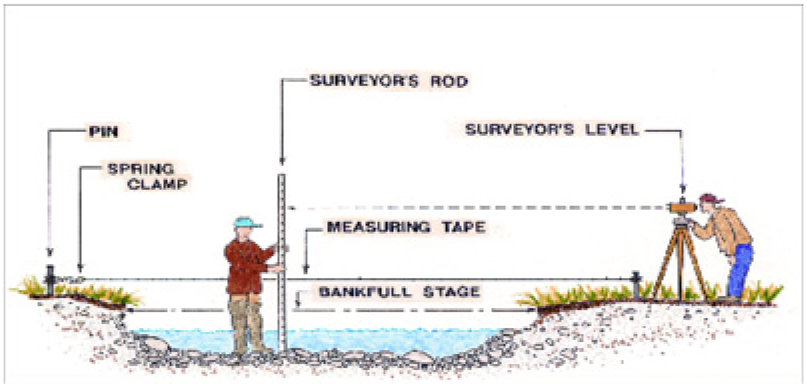
There are several visual or physical indicators of the bankfull stage that enable field determination of this important parameter for areas where streamflow records are not available. The bankfull stage indicators vary in their importance and discriminating power for different stream types. A partial listing of these indicators follows:

a. The presence of a floodplain at the elevation of incipient flooding.
b. The elevation associated with the top of the highest depositional features (e.g., point bars, central bars within the active channel). These depositional features are especially good stage indicators for channels in the presence of terraces or adjacent colluvial slopes.
c. A break in slope of the banks and/or a change in the particle size distribution, (since finer material is associated with deposition by overflow, rather than deposition of coarser material within the active channel).
d. Evidence of an inundation feature such as small benches.
e. Staining of rocks.
f. Exposed root hairs below an intact soil layer indicating exposure to erosive flow.
g. Lichens and - for some stream types and locales - certain riparian vegetation species

Calibrating Bankfull Stage to Known Streamflows. A common error in the Level II classification process is the failure of field observers to calibrate the elevations of appropriate field indicators of bankfull stage to known streamflows. Such calibration is essential until one gains sufficient field experience in a given locale to be sure of the proper interpretation of those indicator features representing the stage or elevation of the bankfull discharge. The recommended procedure for calibrating field identified bankfull stage with known streamflows and return period is as follows:

1. Locate all current and discontinued stream gaging stations within the study basin and/or in nearby similar basins.
2. Make a field visit to each station to collect supplemental data which will be needed to interpret existing hydrologic records at each station. Note that these field visits are not an unnecessary extravagance, nor are they likely to be a major time encumbrance. Investigators will be fortunate if they can find a half-dozen gaging stations within a selected study area, and often it may be necessary to travel outside the area of interest to obtain representative data for extrapolation.
3. The use of information in Table 5-1 will serve as a check list for procedures to be performed at the gaged site. A portion of the data to be collected is not entirely necessary for stream classification, but is necessary to perform the sediment and hydraulic analyses described in Chapter 7.
4. Table 5-2 provides a form for recording gaged and field data. The primary uses of these data involve the calibration of field-estimated bankfull stage to a corresponding measured record). To this available published data, one must add their own collected field-data, describing the reference reach slope, particle size distribution, bankfull stage and channel characteristics, hydraulic geometry, and, of course, stream type.

A field guide for bankfull stage determination and conducting a stream channel survey was recently published by the USDA Forest Service, (Harrelson et al, 1994). This guide is very helpful in describing stream survey methods, bankfull stage surveys, pebble counts, and other channel inventory methods. A video produced by the USFS (1994) is also very helpful in selecting bankfull stage.



Measuring a stream channel cross section. Determination of bankfull stage and related measurements in the field are especially important for correct Level II classification.

Entrenchment

The term "entrenchment ratio," which is the vertical containment of the river, has been quantitatively defined (Rosgen 1994) to provide a consistent method for field determination. The entrenchment ratio is the ratio of the width of the flood-prone area to the surface width of the bankfull channel. The flood-prone area width is measured at the elevation that corresponds to twice the maximum depth of the bankfull channel as taken from the established bankfull stage.

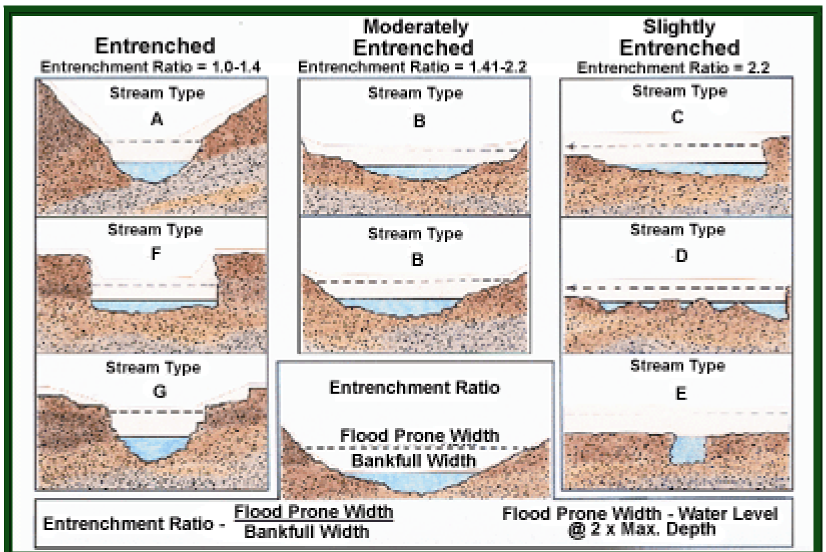
The accompanying figure shows representative entrenchment ratios from cross-sections of various stream types. The degree of entrenchment described by these ratios is based on empirically derived relationships between flood-prone areas and bankfull channel cross-sections, developed from hundreds of stream channel measurements representing a majority of the described stream types. Ratios of 1-1.4 represent entrenched streams; 1.41-2.2 represent moderately entrenched streams; and ratios greater than 2.2 indicate rivers only slightly entrenched in a well-developed floodplain.

Several steps are needed to determine entrenchment. To measure the width of the flood prone area, select the elevation that corresponds to twice the maximum bankfull channel depth as determined by the vertical distance between bankfull stage and the thalweg of a riffle. Field observations show that for most stream types, this elevation is associated with a < 50 year return period flood, rather than with a very rare flood. The entrenchment ratio is based in part on dimensionless rating curves that plot mean depth to bankfull depth (d/dbkf) against the corresponding discharge ratios (Q/Qbkf) (Dunne and Leopold 1978).

The 50-year recurrence interval flood discharge yields a dfpa/dbkf ratio of between 1.3 to 2.7 across all stream types, with an average ratio value of 2.0. Obviously, this value is also a function of the total width of the flood prone area available to the river. Field verification of hundreds of cross-sections, is the basis for using the value of 2 times the maximum depth at the bankfull stage to estimate the elevation and extent flood-prone area in the field. The average ratio value selected is 2.0 rather than the stratified Level II ratios of 1.3 to 2.7. When mean values were used rather than maximum values, the low terrace elevations in the C stream types would not have been included in the flood-prone area, contrary indicators from the gage data/flood stage data.

Based on these observations, twice maximum bankfull depth was selected as an index, to represent an estimate of the representative flood prone area elevations.

For stream types that are only slightly entrenched (e.g., stream types "C," "D," "DA," and "E"), flows greater than the bankfull stage overtop their streambanks and extend onto their floodplain. This natural phenomena does not hold true for deeply entrenched channels (e.g., stream types "A," "F," and "G") where the actual top-of-bank elevations are much higher than the bankfull stage. For entrenched channels, streamflows greater than bankfull increase in depth much faster than in width, as discharge increases. In entrenched channels, the "flood-prone" area increases only marginally in width with an increasing flow-stage above bankfull elevations. The distribution of shear stress (a product of the specific weight of water, hydraulic mean depth and channel slope) and of very high velocity gradients (high boundary stress) on both high banks of an entrenched channel during floods is partly responsible for the associated high bank erosion rates observed in the "A," "F," and "G" stream types.



Entrenchment ratios for some Level I stream types.

Width/Depth Ratio

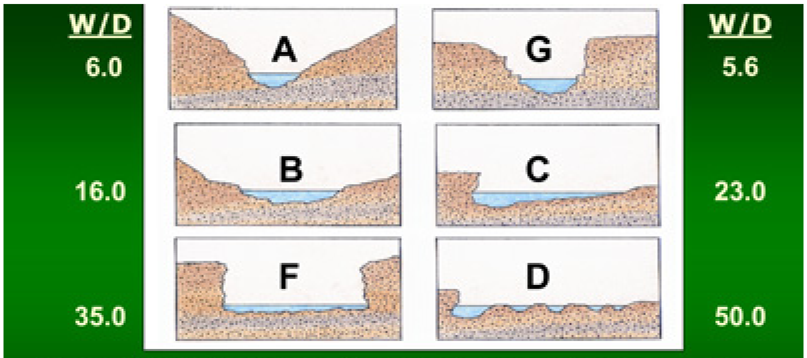
The width/depth (W/D) ratio is defined as the ratio of the bankfull surface width to the mean depth of the bankfull channel. The width/depth ratio is key to understanding the distribution of available energy within a channel, and the ability of various discharges occurring within the channel to move sediment. Of the Level II criteria, the W/D ratio is the most sensitive and positive indicator of trends in channel instability. Determination of the width/depth ratio provides a rapid, visual assessment of channel stability.

Measurement of the width/depth ratio is also valuable for describing channel cross-section shape and comparison of ratio values can be used to interpret shifts in channel stability following disturbances to channels or watersheds. Osterkamp et al. (1983) derived power functions used to predict streamflow using W/D ratios as a surrogate for channel sediment characteristics and the distribution of shear stress. Osborn and Stypula (1987) used W/D ratios to characterize channel hydraulics by describing channel boundary shear as a function of channel shape.

The distribution of energy within channels having high W/D ratios (i.e., shallow and wide channels) is such that stress is placed within the near bank region. As the W/D ratio value increases (i.e, the channel grows wider and more shallow), the hydraulic stress against the banks also increases and bank erosion is accelerated. The accelerated erosion process is generally the result of high velocity gradients and high boundary stress, as mean velocity, stream power, and shear stress decrease in the presence of an increase in width/depth ratio values. Increases in the sediment supply to the channel develop from bank erosion, which - by virtue of becoming an over widened channel - gradually loses its capability to transport sediment. Deposition occurs, further accelerating bank erosion, and the cycle continues.

For all stream types except multiple thread channel, a W/D ratio of 12 is the high end value for "A," "G," and "E" stream types and the low end value for "B," "C," and "F" stream types. Analyses of field data showed a width/depth ratio continuum value of 10, but a ratio value of 12 was selected as the most frequently observed value. The W/D ratio value of 12 is empirically derived, but is related to physical processes governing the distribution of energy and resultant sediment transport. Channel dimension, pattern, profile, and corresponding stream types change when the width/depth ratio is significantly altered.

Width/depth ratios should be determined on selected reference reaches using the same criteria for determining bankfull stage indicators and bankfull channel measurements. That is, the selected reach should be free to adjust its boundaries in response to frequent flows and should not have excessive deposition, nor constrictions. Wherever possible, at least one or more permanent cross-section should be established to permit resurveying so that changes in state or stability of a stream may be effectively determined. Permanent benchmarks for use as reference elevations can be installed using either cemented or driven metal rods. Width/depth ratios are determined from measured channel cross-sections.

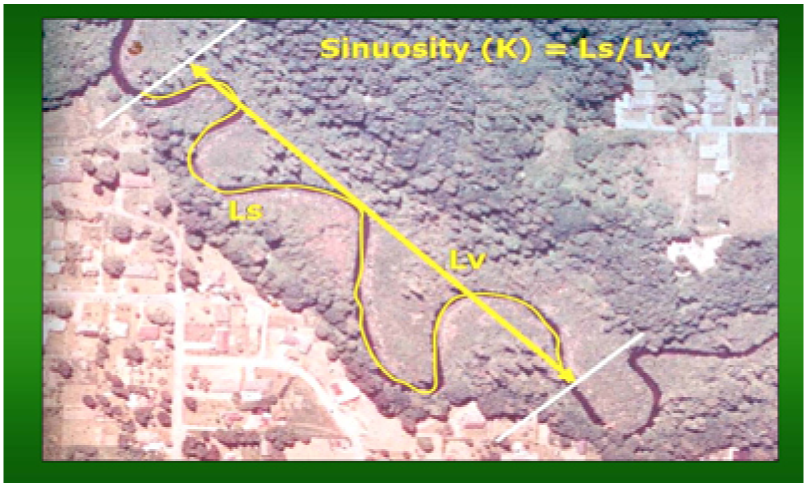


Example Width/Depth ratios for cross-sections of various Level I stream types
W/D = Bankfull surface width/Mean bankfull depth

Sinuosity

Sinuosity is the ratio of stream length to valley length. It can also be described as the ratio of valley slope to channel slope. Meander geometry characteristics are directly related to sinuosity, consistent with the principle of minimum expenditure of energy. Langbein and Leopold (1966) suggested that a sine generated curve describes symmetrical meander paths, permitting the estimation of a radius of curvature for meander bends, as developed from data analyses related to meander wavelength and channel sinuosity. Applying the same analyses techniques to an expanded data set, Williams (1986) found highly significant relations between predicted vs. observed values for radius of curvature and channel sinuosity for 79 streams.

Sinuosity, however, carries the least weight of all the criteria used to delineate Level II morphologies. It is used primarily as a channel plan-form and mapping indicator for Level I classification, since it is based on easily observable and interpreted patterns. Sinuosity can be modified by bedrock control, roads, channel confinement (lateral containment), and vegetation. As channel gradient and dominant particle size decreases, there is generally a corresponding increase in sinuosity. Sinuosity can best be measured using aerial photography as previously described in Level I classification.



Slope

The slope of the water surface is a major determinant of river channel morphology, and of the related sediment, hydraulic, and biological functions. A longitudinal profile surveyed along a selected channel reach is recommended to be established for slope determinations. When integrated with previous stream classification data, the longitudinal profile survey can also provide slope facet information that can be related to depth and particle sizes for specific bed features. Sediment transport as well as designs for river restoration or fish habitat structures often require such in-dividual slope facet data. With a sufficient array of longitudinal profile data, specific characteristics of riffles, runs, glides, and pools can be compared between each feature and between features of other stream types. It is desirable to describe riffles or pool dimensions in terms of ratios of average slope, depth, and particle size. The existing quality of the surveyed bed features can be related to their response potential by reference reach comparisons.

Water surface slope is determined along the longitudinal profile of the channel by measuring the difference in water surface elevation per unit stream length. Slope measurements should be taken through a channel reach that is a minimum of 20 channel widths in length or for a distance equal to two meander wavelengths. The water surface slope should be measured by taking the difference in elevation from the one bed feature to the same bed feature either upstream or downstream. For riffle/pool channels, it is generally best to measure from the top of one riffle to the top of another. It is important to measure the actual stream length rather than estimating the length or running a tape that does not follow the actual channel alignment to avoid overestimating slope. Instruments should be used for elevation change which are appropriate to accurately measure 0.1 feet change in 100 feet distance. The use of clinometers should be discouraged for measuring stream slope, except for very steep streams over 10 percent. On lower gradient reaches, clinometers tend to consistently over-estimate water surface slope. Laser levels are often preferred, as one person can accurately obtain all of the survey data needed for a stream reach inventory. Hand levels with zoom scopes, properly used in conjunction with survey rods, have given sufficiently accurate slope readings.

Channel Materials

When inventories of channel materials are obtained, there is often some confusion as to what and how to sample. For stream channel classification purposes, channel material refers primarily to the surface particles that make up both the bed and banks within the bankfull channel.

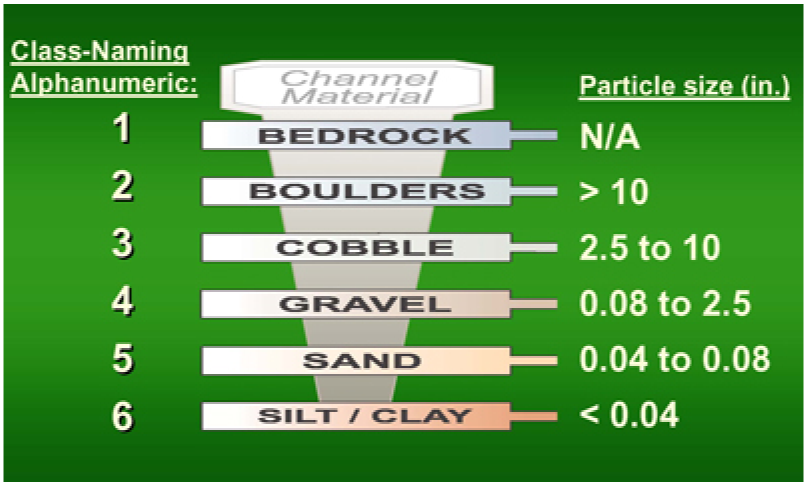
Wolman (1954) first developed the "pebble-count" method for field determination of the particle size distribution of channel materials. Wolman's method, since modified to account for both bank and in-channel material, for sands and smaller particle sizes, and for bedrock is used for Level II stream classification. The modified Wolman method (Rosgen 1993a) uses a stratified, systematic sampling method based on the frequency of riffle/pools and step/pools occurring within a channel reach that is approximately 20-30 bankfull channel widths in length (or two meander wavelengths). The modified method adjusts the material sampling locations so that various bed features are sampled on a proportional basis along a given stream reach.

For example, assume that across two meander wavelengths, 70% of the channel reach length is composed of riffles and 30% is composed of pools. A minimum of 70 observations should be taken within riffle areas and 30 observations should then be taken within pool areas, such that the minimum sample size totals 100. In addition, the particles should be sampled at systematic intervals along a given transect or sample route. To avoid potential bias, the actual particle picked up for measurement must be selected on the "first blind touch," rather than seen and then selectively picked up.

This procedure ensures that a representative pebble count may be obtained through proportional sampling of riffles, steps, and pools. Representative sampling is essential, since the generally flatter, deeper pools contain finer sized materials relative to the coarser materials found in steeper, shallower riffles and steps. The designed proportional procedure is necessary to counter the observer's natural tendency to sample only the shallow areas that promotes easy wading and to selectively sample the more obvious, larger particles.

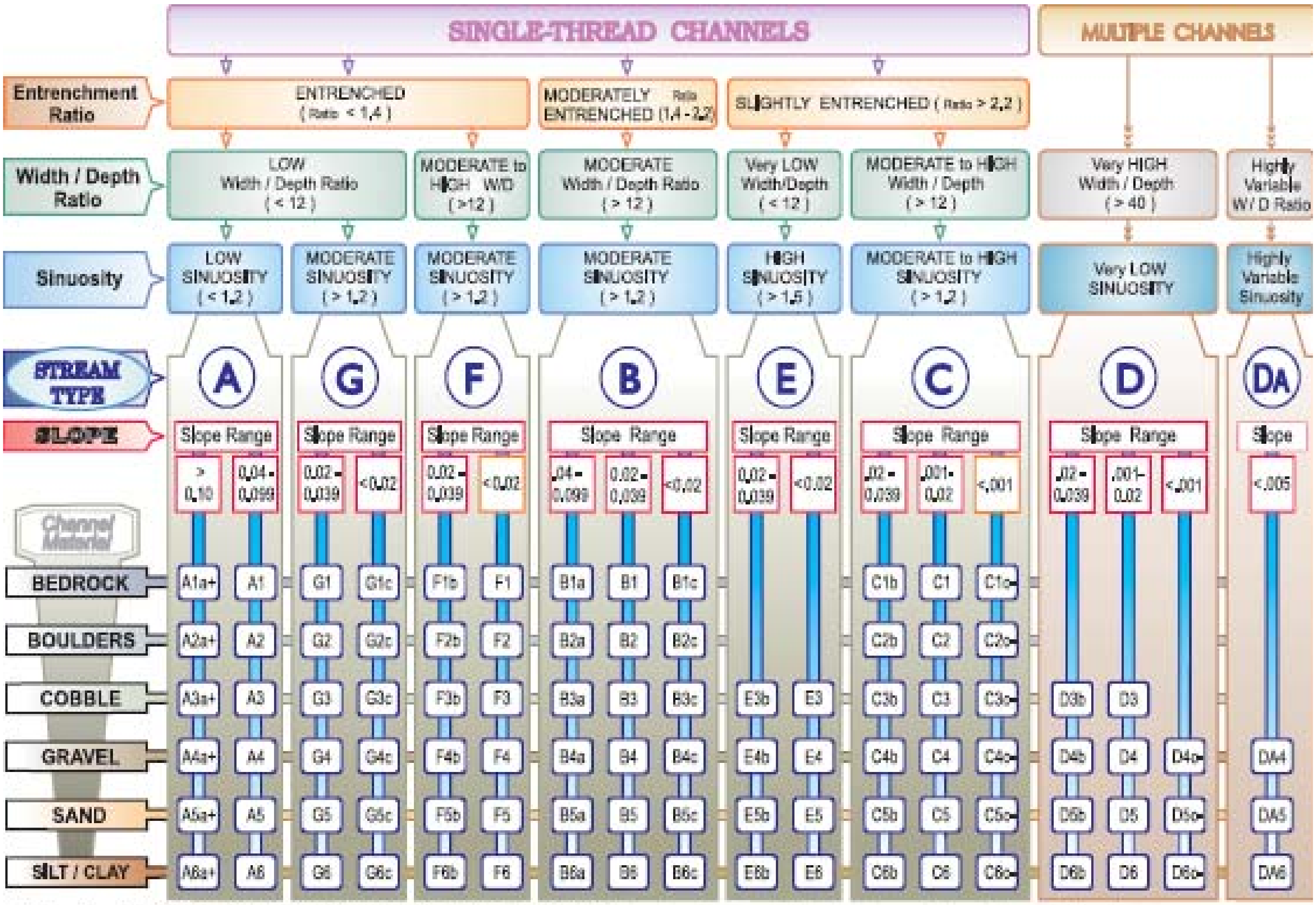
The intermediate axis of the particle is measured such that the particle size selected would be retained or pass a standard materials sieve of fixed opening. Particles sampled along transects in the pools are tallied separately from those sampled in the riffles on the pebble count field data form (PDF, 195 kb). The segmented particle size data is then added together for a composite total for stream classification purposes. However, the separate data sets are used to provide additional data for biological and sediment source/transport evaluations. The data for the riffles, pools, and composite totals can be effectively plotted for individual interpretations on log-normal graph paper. In some bi-modal particle distributions the indexed D-50 particle (50 per cent of the sampled population is equal to or finer than the representative particle diameter) may not even be present. In this case, the dominant particle size should be determined as that particle size which has provided the largest number of observations. The Y axis to the right of the log-normal graph is used to plot the number of particles rather than percent. These data related to individual particles will also provide additional biological and sediment source/yield interpretations for individual bed features or reach sediment characteristics. To obtain the representative median particle diameter or the D-50 index diameters, the pebble count data is then plotted on a log-normal graph as a cumulative percent.

Pebble count sampling accuracy can be further improved by using a tape line with equally spaced intervals to assist in determining an appropriate location for selecting in-channel particles for measurement. Pebble count data can be tallied separately for riffles, runs, glides, and pools, and then be summed to obtain a distribution of the total number of particles sampled.



Summary

This training module contains a small portion of the descriptive information, graphics and field techniques used to classify stream types at Rosgen Level I and Level II. For more in-depth information, readers are referred to the original source document. The figure below is a quick-reference key to all the Level II stream types and the ranges of values typical of their delineative criteria.



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.