Appendix B

Stream Classification & Valley Types

Stream Classification

Because of the great diversity of morphological features among rivers, a stream classification system was developed to stratify and describe various river types (Rosgen, 1994, 1996). The nature and range of the dependent form variables of river channels were delineated to help describe the variety of morphological stream types that do occur in nature. These types were not determined arbitrarily but rather were organized by measured data representing hundreds of rivers between 1969 and 1994 (Rosgen, 1994, 1996). Resultant stream types are a reflection of mutually adjusting variables that describe their unique sedimentological, hydraulic, morphological and biological characteristics.

Stream classification is based primarily on the measured bankfull stage morphology of the river because it is the bankfull stage that is responsible for shaping and maintaining the channel dimensions over time. However, rather than using the measured values of dimension, pattern and profile to define a stream type, the classification system is based on dimensionless morphological parameters required for scaling purposes.

Specific objectives of the stream classification system (Rosgen, 1994, 1996) are to: (1) predict a river's behavior from its morphological appearance based on documentation of similar response from similar types for imposed conditions; (2) stratify empirical hydraulic, sedimentological and biological relations by stream type by state (condition) to minimize variance; (3) provide a mechanism to extrapolate site-specific morphological data; (4) describe physical stream relations to complement biological and riparian ecosystem inventories and assist in establishing potential and departure states; and (5) provide a consistent, reproducible frame of reference for communicating stream morphology and condition among a variety of professional disciplines.

The stream classification system consists of a hierarchical assessment of channel morphology that includes four levels of assessment (Rosgen, 1994, 1996). The four levels provide the physical, hydrologic, sedimentological and geomorphic context for linking the driving forces and response variables at all scales of inquiry. The detail required at each level of assessment varies with the degree of resolution necessary to achieve the specific objectives previously stated.

Level I of the hierarchical assessment is the geomorphic characterization where streams are classified at a broad level on the basis of valley landforms and observable channel dimensions. Eight major morphological stream types can be identified (A, B, C, D, DA, E, F and G) using five initial definitive criteria: channel pattern (multiple-thread versus single-thread channels), entrenchment ratio, width/depth ratio, sinuosity and slope (**Figure B-1** and **Table B-1**, Rosgen, 1994, 1996). Entrenchment ratio is a measure of vertical containment described as the ratio of the flood-prone area width to bankfull width. The flood-prone area width is obtained at an elevation at two times the maximum bankfull depth. If the entrenchment ratio is less than 1.4 (± 0.2 to allow for the continuum of channel form), the stream is classified as entrenched or vertically contained (A, G, and F Stream Types) (**Table B-1**). If the entrenchment ratio is between 1.4 and 2.2, (+ or – 0.2), the stream is moderately entrenched (B Stream Types). If the ratio is greater than 2.2, the stream is not entrenched (C, E and DA Stream Types). Additionally, some stream types are associated with valley types that have well-developed floodplains (C, D, E and DA Stream Types), while other stream types are associated with valley types with no floodplains (A, B, certain D, G and F Stream Types). **Table B-1** describes the additional criteria (channel pattern, width/depth ratio, sinuosity and slope) for each major stream type.

Level II is the morphological description that classifies stream types within certain valley types using field measurements of the same criteria necessary for the broad-level classification from specific channel reaches and fluvial features (**Figure B-2**, Rosgen, 1994, 1996). In addition, the initial stream type is further subdivided by its dominant channel material size: bedrock (1), boulder (2), cobble (3), gravel (4), sand (5) and silt/clay (6). In total, 41 primary stream types exist. Subcategories of slope are also utilized along a slope continuum where the combined morphological variables are consistent for a stream type. However, for a particular stream reach that is steeper or flatter than the normal range of that type, a small letter sub-category is used to best reflect actual variables (Rosgen, 1994, p. 181): a+ (steeper than 0.10), a (0.04–0.10; slopes typical of A Stream Types), b (0.02–0.04; slopes typical of B Stream Types), c (0.001–0.02; slopes typical of C Stream Types), and c- (less than 0.001).

The various categories and threshold ranges were obtained from field data representing over 800 rivers using frequency distributions from each major stream type grouping to establish the interrelations of morphological data. The parameter ranges are described by the frequency distributions summarized in Rosgen (1996, Chapter 5). In addition, Rosgen also describes the process-integration and interrelated morphologic, hydraulic and sedimentological characteristics of each primary stream type. **Table B-2** lists management interpretations by Level II stream types.

Due to the continuum of channel form and shifts in stream types along river reaches, the definitive criteria values can depart from the typical ranges for a given stream type. These instances are indicative of (1) a transition between stream types and valley types that occurs when changing from an upstream reach into a downstream reach (spatial variability), (2) a shift in stability or condition influenced by variables described in *Level III* (temporal variability), and/or (3) an equilibrium threshold shift trending toward a new stream type (temporal and spatial variability). In these instances, the variables that best represent the dominant morphological type must be determined.

Level III assesses stream condition to predict river stability (e.g., aggradation, degradation, sediment supply, streambank erosion and channel enlargement). The stream classification system was developed with an understanding that a stability evaluation must be conducted at a higher degree of resolution (*Level III* assessment) than morphological groupings (*Level II*). Channel stability assessments, however, must be stratified by stream type and valley type for extrapolation purposes. Additional form variables are identified by stream type and their definitive criteria to determine a state or condition. Various processes and stream channel response to imposed changes in the controlling variables can then be inferred using time-trend aerial photo analysis and detailed field measurements (Rosgen, 1994, 1996, 2006). Variables assessed and introduced in this level include bank-height ratio (a measure of degree of channel incision determined as the lowest bank height divided by the bankfull maximum depth), meander width ratio (lateral containment or confinement measured by channel belt width divided by bankfull width), shear stress, shear velocity and total stream power. Prediction of streambank erosion (BANCS model; Rosgen, 1996, 2001, 2006), hydraulic analysis (Rosgen, 1996, 2006), sediment competence and transport capacity (Rosgen, 2006), and quantitative indices for river stability are also collected at this level (Rosgen, 1996, 2006).

Critical, but often difficult, in the stability assessments and interpretations is an understanding of what constitutes a natural process versus an acceleration of a natural process as streams can be stable, yet dynamic. It is essential to distinguish if the methods used in the river stability assessment predict the differences between natural, stable rates versus accelerated rates that may exceed a geomorphic threshold. The assessment requires a departure analysis of the existing condition reach from the reference reach condition to assist with these interpretations. Without such stability assessments for the reference and existing reaches, it is often difficult to understand the cause and consequence of change related to certain land uses that are the agents of disequilibrium.

Level IV is conducted to validate process-based assessments of stream condition, potential and stability as predicted from *Levels I–III*. Prediction of river system process is complex and uncertain; thus validation of the procedure is essential since restoration designs are based upon such predictions. Validation procedures include annual dimension, pattern, profile and material resurveys; annual streambank erosion studies; sediment competence validation; hydraulic relations using gauging stations or current meter measurements; and direct measurements of bedload and suspended sediment for the accurate estimate of sediment transport capacity. After reach conditions are verified, the validation data are used to establish empirical relationships for testing, validating and improving the prediction methods. In fact, the basic foundation of the stream classification system was developed from the author's *Level IV* field data collected over many years that were used to develop the prediction methodologies and for the interpretation and extrapolation of the basic relations. The field data involve sediment transport, streambank erosion rates, hydraulics and corresponding changes in the channel form variables, all of which are time-consuming and expensive to collect. It is necessary to validate the procedures for both the existing and reference reaches. In this manner, it is possible to measure natural streambank erosion rates and to obtain a wide range of natural variability of the dimensions, pattern and profile to determine acceptable rates and tolerances.

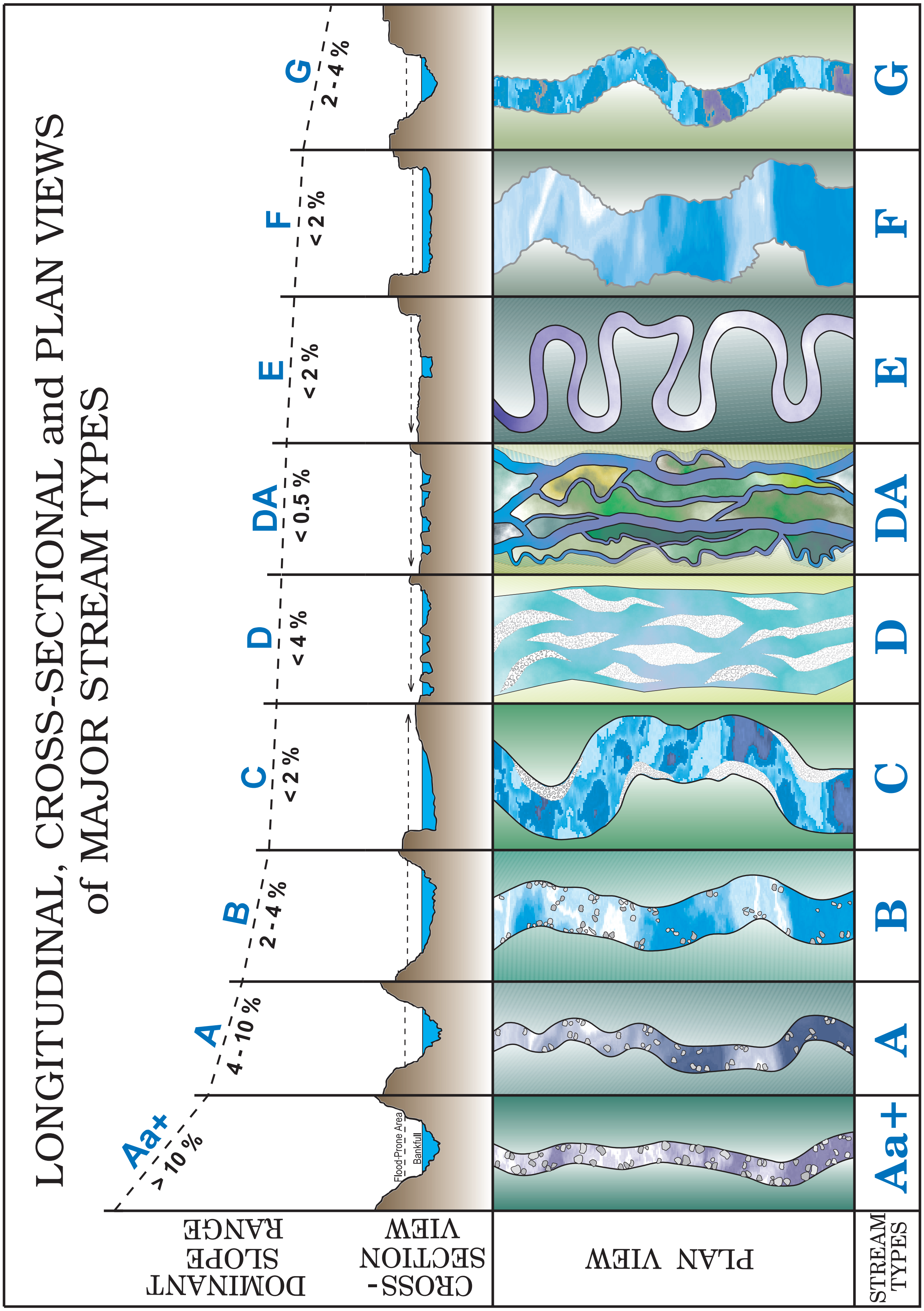


Figure B-1. Broad-level stream classification delineation showing longitudinal, cross-sectional and plan views of major stream types (Rosgen, 1994, 1996).

Table B-1. General stream type descriptions and delineative criteria for broad-level classification (Rosgen, 1994, 1996).

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform / Soils / Features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>0.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock- or boulder-dominated channel.	<1.4	<12	1.0 to 1.2	0.04 to 0.10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle-dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	0.02 to 0.039	Moderate relief, colluvial deposition and/or structural. Moderate entrenchment and width/depth ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools.
C	Low gradient, meandering, point bar, riffle/pool, alluvial channels with broad, well-defined floodplains.	>2.2	>12	>1.2	<0.02	Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<0.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment with abundance of sediment supply. Convergence. Divergence of bed features, aggradational processes, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.	>2.2	Highly Variable	Highly Variable	<0.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition with well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high washload sediment.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<0.02	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.2	<0.02	Entrenched in highly weathered material. Gentle gradients with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	<0.039	Gullies, step/pool morphology with moderate slopes and low width/depth ratio. Narrow valleys or deeply incised in alluvial or colluvial materials; i.e., fans or deltas. Unstable with grade control problems and high bank erosion rates.

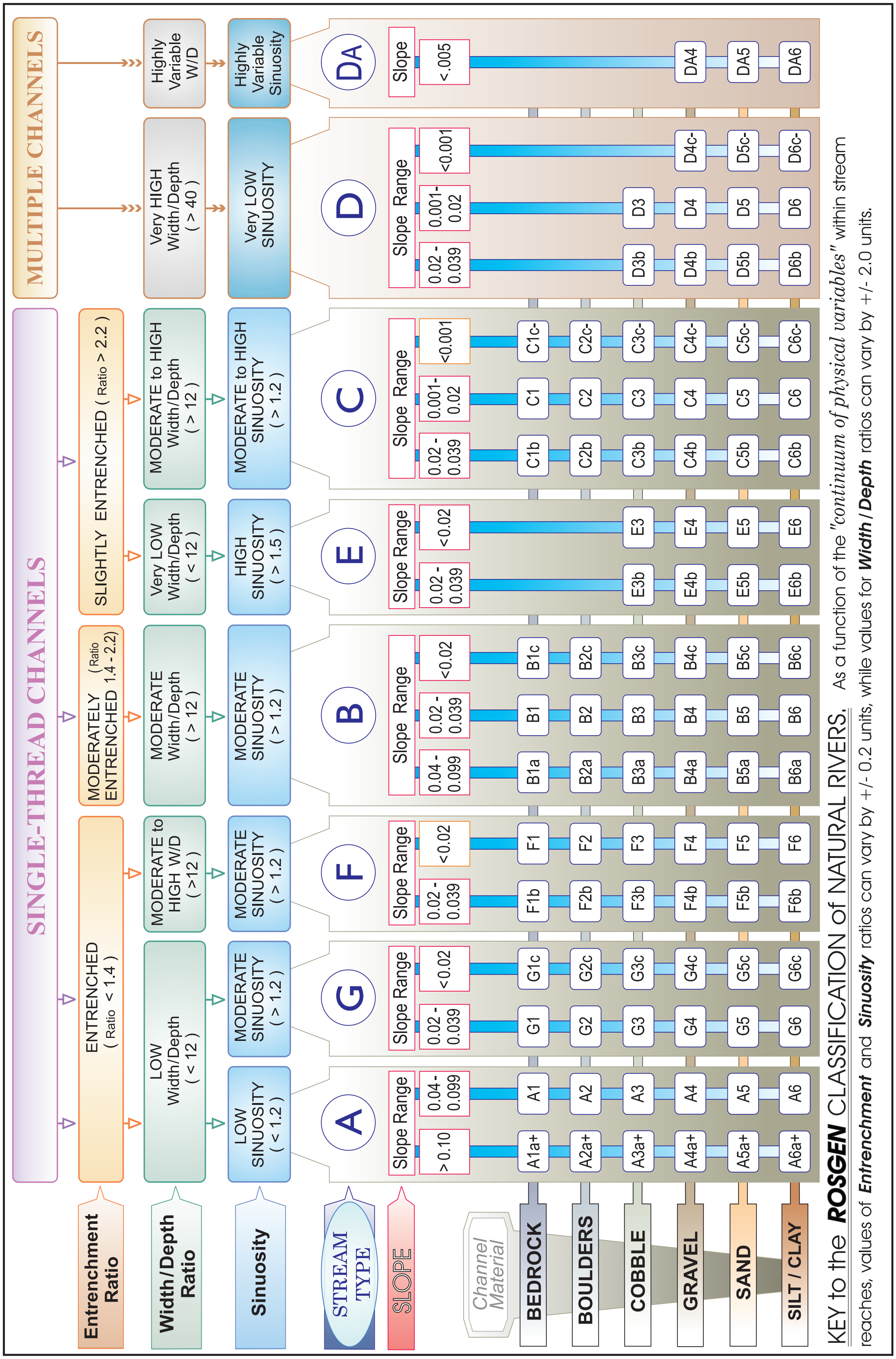


Figure B-2. Stream classification key for natural rivers (Rosgen, 1994, 1996).

Table B-2. Management interpretations of various stream types (Rosgen, 1994, 1996).

Stream Type	Sensitivity to Disturbance[a]	Recovery Potential[b]	Sediment Supply[c]	Streambank Erosion Potential	Vegetation Controlling Influence[d]
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	very high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate
D6	high	poor	high	high	moderate
DA4	moderate	good	very low	low	very high
DA5	moderate	good	low	low	very high
DA6	moderate	good	very low	very low	very high
E3	high	good	low	moderate	very high
E4	very high	good	moderate	high	very high
E5	very high	good	moderate	high	very high
E6	very high	good	low	moderate	very high
F1	low	fair	low	moderate	low
F2	low	fair	moderate	moderate	low
F3	moderate	poor	very high	very high	moderate
F4	extreme	poor	very high	very high	moderate
F5	very high	poor	very high	very high	moderate
F6	very high	fair	high	very high	moderate
G1	low	good	low	low	low
G2	moderate	fair	moderate	moderate	low
G3	very high	poor	very high	very high	high
G4	extreme	very poor	very high	very high	high
G5	extreme	very poor	very high	very high	high
G6	very high	poor	high	high	high

[a] Includes increases in streamflow magnitude and timing and/or sediment increases.
[b] Assumes natural recovery once cause of instabiilty is corrected.
[c] Includes supsended and bedload from channel derived sources and/or from stream adjacent slopes.
[d] Vegetation that influences width/depth ratio-stability.

Valley Types

Because stream morphology is invariably fixed to the landscape position, prior to the broad-level stream classification, valley types must be identified that integrate structural controls, fluvial process, depositional history, climate and broad life zones. Valley types are stratified into 12 broad geologic categories that reflect their origin and represent the boundary conditions that influence channel morphology (Rosgen 1994, 1996). **Table B-3** summarizes the valley types and their associated characteristics, separated by historic erosional or depositional processes and corresponding differences in valley slope, channel materials and width. Valley types and related landforms are the initial stratification of stream types (**Table B-3**). For example, highly dissected fluvial slopes (Valley Type VII) are indicative of steep, narrow, deeply incised, erosional A and G stream types. Narrow, low gradient streams in confined canyons and deep gorges (Valley Types IV) are characteristic of the entrenched F stream types. The 12 valley types are described in the following sections.

Table B-3. Valley types used in the geomorphic characterization (Rosgen, 1996, 2006).

Valley Types	Summary Description of Valley Types and Fluvial Landforms	Stream Types*, **
I	**Colluvial – Steep & V-Notched:** Steep, confined, V-notched valleys with rejuvenated side slopes often in colluvium and/or glacial deposition	**Aa+**, **A**
II	**Colluvial – Moderately Steep & Confined:** Moderately steep valley slopes with gentle to moderate side slopes associated with colluvial deposition and/or residual soils	**B**, [F], [G]
III	**Alluvial Fans:** Primarily depositional with characteristic alluvial fan landforms	
	(a) ***Active* alluvial fan:** Actively building fan surface with high sediment supply	**D**, [A], [F_b], [G]
	(b) ***Inactive* alluvial fan:** Non-building, stable fan with low sediment supply and generally well-established riparian vegetation	**B**, [F_b], [G]
IV	**Inner-Gorge:** Canyons, gorges, and confined alluvial valleys with gentle valley-floor slopes, steep valley walls, and meandering entrenched channels	**F**, **C**, B_c
V	**Glacial Trough:** Moderately steep, U-shaped glacial-trough valleys	**C**, **D**, B_c, [F], [G]
VI	**Bedrock:** Bedrock-controlled valleys with gentle to moderately steep valley slopes	**Aa+**, **A**, **B**, **C**, **F**, **G**
VII	**Fluvial-Dissected:** Steep, fluvial-dissected, high-drainage density, alluvial landforms	**Aa+**, **A**, **G**, B, F_b
VIII	**Alluvial:** Alluvial valley fills with well-developed floodplains	
	(a) Gulch Fill: Narrow and confined valleys with relatively steep valley side slopes and valley-floor slopes ranging from gentle to moderately steep	**B**, **$C_{(b)}$**, **E_b**, [A], [D], [F_b], [G]
	(b) Alluvial Fill: Moderately confined valleys with moderately steep side slopes and valley-floor slopes ranging from gentle to moderately steep	**B**, **$C_{(b)}$**, **$E_{(b)}$**, [A], [D], [$F_{(b)}$], [G]
	(c) Terraced Alluvial: Wide, unconfined valleys with gentle valley slopes bounded by river terraces, including Holocene or Pleistocene-age terraces	**C**, **E**, B_c, [A], [D], [F], [G_c]
IX	**Glacial Outwash:** Broad, gentle valley slopes associated with glacial outwash	**C**, **D**, B, [F], [G]
X	**Lacustrine:** Very broad and gentle valley slopes associated with glacio- and nonglacial-lacustrine deposits	**C**, **DA**, **E**, B_c, [F], [G_c]
XI	**Deltas:** Large river deltas and tidal flats constructed of fine alluvial materials from riverine and estuarine depositional processes; most often distributary channels, wave- or tide-dominated	**D**, **DA**, C, E
XII	**Eolian:** Broad, undulating valley terrain with gentle to steep valley slopes associated with materials deposited by wind and reworked by fluvial processes	
	(a) Eolian Sand:	
	1. Sand Dunes	**C**, **D**, [F], [G]
	2. Abandoned Beach Sand, Shoreline (Littoral) Drift, Foredunes, and Periglacial Sand Splays	**B**, [A], [F], [G]
	3. Sand Hills	**B**, A, [F], [G]
	(b) Eolian Loess: Associated with airborne silt-sized material from glacial and non-glacial processes, including ash deposits from volcanism	**B**, **C_b**, **E_b**, [A], [F_b], [G]

***Bolded stream types indicate the most prevalent stream type for that valley type**

****Bracketed stream types are most often observed under disequilibrium conditions**

Colluvial: Steep & V-Notched (Valley Type I)

This colluvial valley type is associated with steep, narrow, V-shaped drainageways with confined and entrenched (vertically contained) channels (**Figures B-4** and **B-5**). Some of the drainageways are influenced by deep-seated controls, such as faults, while others are cut through deep erosional and depositional debris. Elevational relief is high and valley-floor slopes are steep with steep valley walls. Valley materials vary from residual soils of sand and silt/clay to a mixture of unsorted depositional soils. Predominant materials are related to glacial deposition or a mixture of colluvium due to mass-wasting hillslope processes, including creep, slump-earthflow, debris flows, and debris avalanches. Some depositional soils are related to continental glaciation, such as from streams cut through indurated (compacted) glacial till. Most of the colluvial soils are primarily heterogeneous, unconsolidated, and noncohesive. Residual soils, such as sand and small gravel developed from grussic granite, can exist on extremely steep side slopes related to channels with bed slopes greater than 0.10 (A5a+ stream types) as observed in North-Central Idaho, Northwestern Montana, and the Southern Front Range of Colorado.

Based on the variety of materials associated with VT I, the streams are all high energy, but vary in sediment supply. Although many streams are first or second order (Horton, 1945; Strahler, 1957), their size or slope position does not determine whether the stream is supply-limited or not; rather, the supply is associated with the nature of the materials and the steep slope gradients (high stream power). The stream types dominated with deposits of flood debris or channel materials of silt/clay, sand, gravel, and cobble are associated with a high sediment supply (unlimited availability). Boulder- and bedrock-dominated channels are associated with low sediment supply (sediment-limited). The bedload in the sand, gravel, and cobble-dominated A stream types contribute to the very high sediment supply (Rosgen, 1996). Many of the cobble- and gravel-dominated stream types associated with the unlimited sediment supply are incised in landslide debris or glacial till. Steep arroyos in arid landscapes or with streams deeply incised through Pleistocene or Holocene terraces are also associated with this valley type.

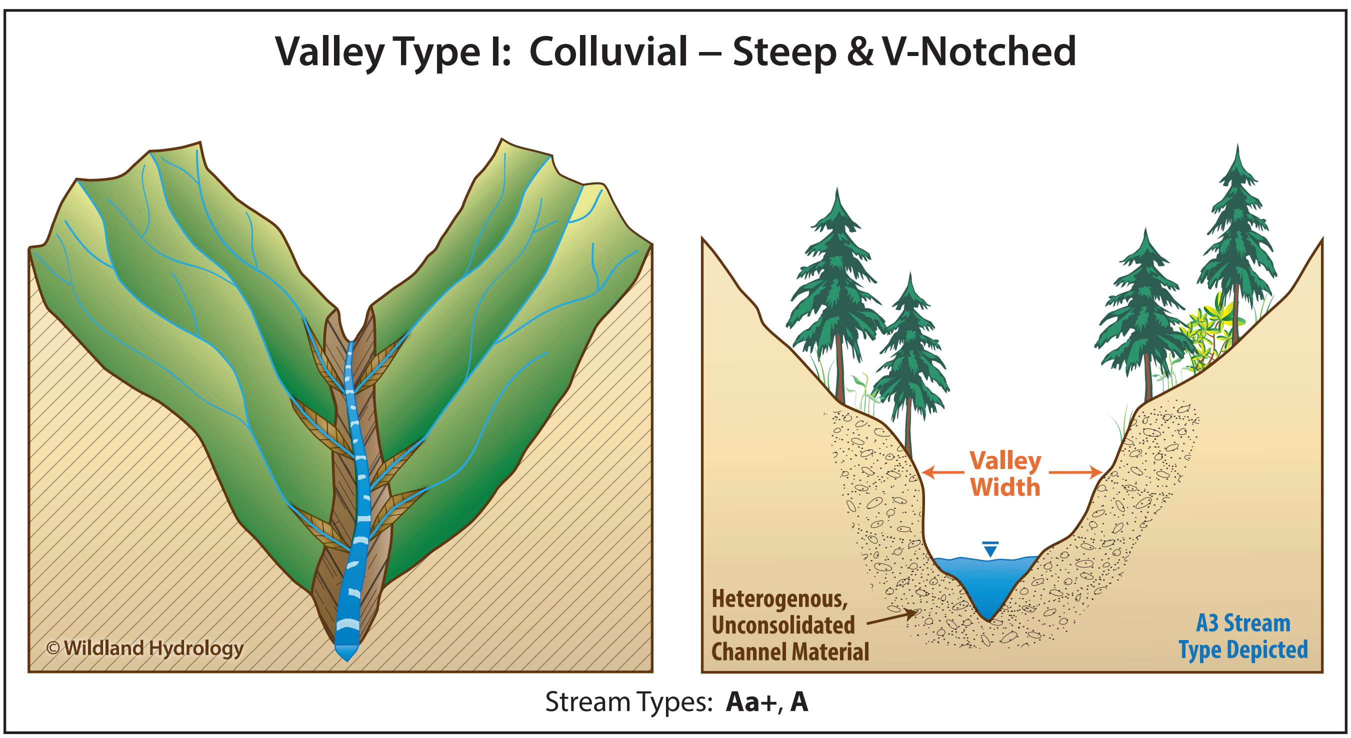


Figure B-4. Colluvial: Steep & V-notched canyons, Valley Type I.

Flow regimes are often dominated by snowmelt and/or stormflow runoff with some rain-on-snow systems; spring-fed systems are rare. Stream channels are predominantly ephemeral; however, perennial channels do occur. The vegetation types are generally coniferous, mixed hardwood to grassland communities. Riparian ecosystems are limited due to the low ground water tables and steep slopes. Wetland communities are rare. LWD is common in coniferous and mixed hardwood riparian ecosystems and often controls the bed stability by providing sufficient flow resistance and grade control.

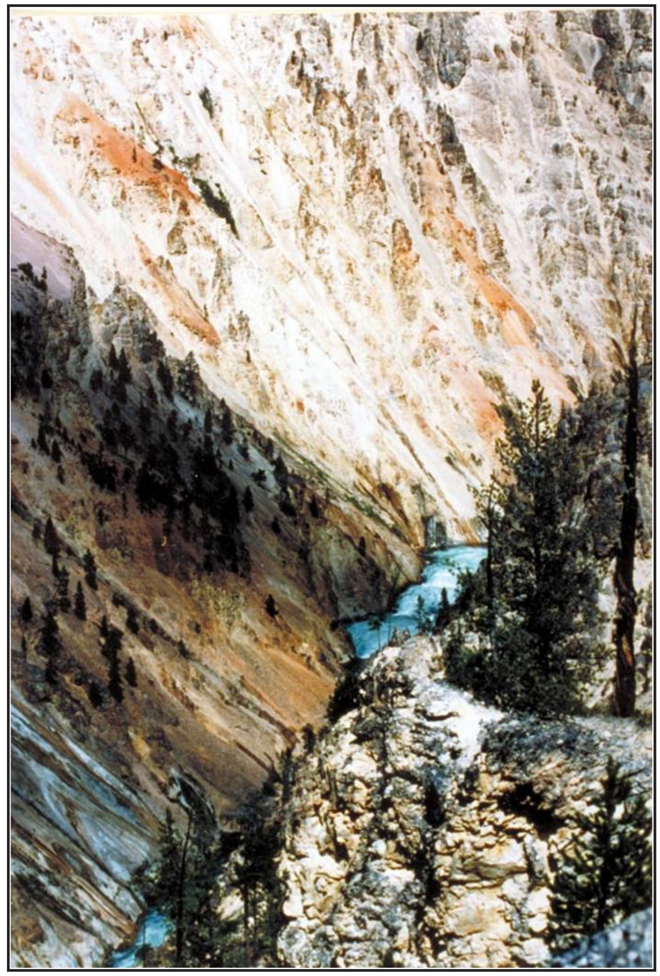


Figure B-5. Colluvial: Steep & V-notched canyons, Valley Type I (Rosgen, 1996).

Step–pool channels with steeper channel slopes exhibiting cascade bed features associated with Aa+ and A stream types are most commonly observed. Stream channel erosional processes vary depending on boundary materials and slope from very low and stable to highly erodible, producing debris torrents or debris avalanches. Often A stream types in certain hydro-physiographic provinces are the conveyance zones (track) for snow avalanches, which can scour side-slope vegetation from stream adjacent slopes. Characteristics of the associated A3(a+) to A5(a+) stream types include a very high sediment supply coupled with very high shear stress and unit stream power due to the low width-to-depth ratios, steep slopes, low sinuosity, and entrenched morphology; thus infrequent, high magnitude floods can have significant effects on channel processes, including sediment transport leading to debris flows and debris avalanches. Such infrequent, high magnitude flood events often enlarge these channel systems and deposit their erosional debris onto alluvial fans (VT III) immediately below these valley types.

Colluvial: Moderately Steep & Confined (Valley Type II)

This colluvial valley exhibits upland-dominated features with relatively stable, gentle- to moderate-sloping colluvial side slopes and moderately steep valley slopes less than 4.0% (**Figures B-6** and **B-7**). Depositional and residual soils are dominated by colluvial processes with isolated alluvial deposits. Soils are heterogeneous, unconsolidated, and noncohesive (except for silt/clay residual soils). The slopes are predominantly well-drained with little evidence of fluvial dissection. The dominant erosional hillslope processes are related to low rates of mass wasting, such as creep. Accelerated rates of surface erosion are rare, while the development of rills and gullies, slump-earthflow, debris flows, or debris avalanches are uncommon.

The sediment regime is associated with high energy and low sediment supply with sediment-limited conditions for the commonly occurring rapids and step–pool stream types. Observations by the author have shown that in-channel sediment storage, rates of streambank erosion, and flow-related sediment increases from adjacent hillslope processes are generally low. The streambed and streambank materials are often associated with coarse cobble and boulder lag deposits from previous floods. The streamflow is dominated by stormflow and snowmelt processes, although rain-on-snow can also occur. Streams can be ephemeral or perennial with the rare occurrence of spring-fed conditions.

Riparian vegetation communities associated with VT II are confined to a narrow corridor and can be comprised of mixed hardwoods and conifers, although grassland communities also occur. Understory in mixed hardwoods, and within some coniferous communities, is often associated with shade-tolerant woody plants, such as dogwood, rhododendron, viburnum, willow, and alder. Wetlands are rare due the well-drained slopes but can be found associated with sub-surface water concentrations at the toe of some slopes. LWD is common and compatible with the stability and function of the related stream types within this valley type. The LWD adds flow resistance, acts as grade control, and provides significant fish habitat. The LWD is mostly stable due to the low sediment supply and the moderate entrenchment, and helps redistribute and dissipate major flood-related high shear stress and stream power. The moderately steep side slopes and coniferous and/or deciduous overstory provide natural recruitment source of LWD to the stream channels.

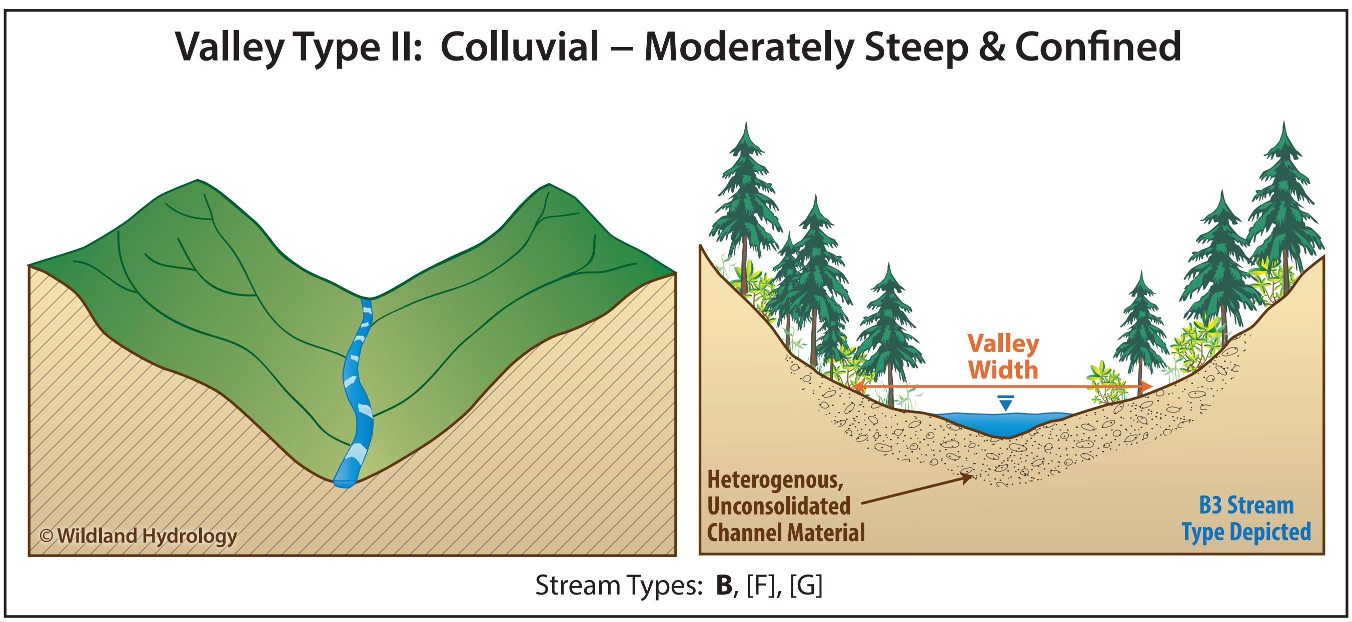


Figure B-6. Valley Type II, colluvial valleys with moderately steep valley-floor slopes and gentle to moderate side slopes.

This colluvial valley is generally associated with naturally confined and stable, low sediment supply, B stream types. The streams are normally rapids- or riffle-dominated with lower gradient, step–pool features associated with contraction and convergence scour pools due to the LWD influence. Less common are the high sediment supply F and G stream types that are observed generally under disequilibrium conditions, especially in urban corridors or highly-disturbed valleys.

Figure B-7. Valley Type II, colluvial valleys with moderately steep valley-floor slopes and gentle to moderate side slopes.

Alluvial Fans (Valley Type III)

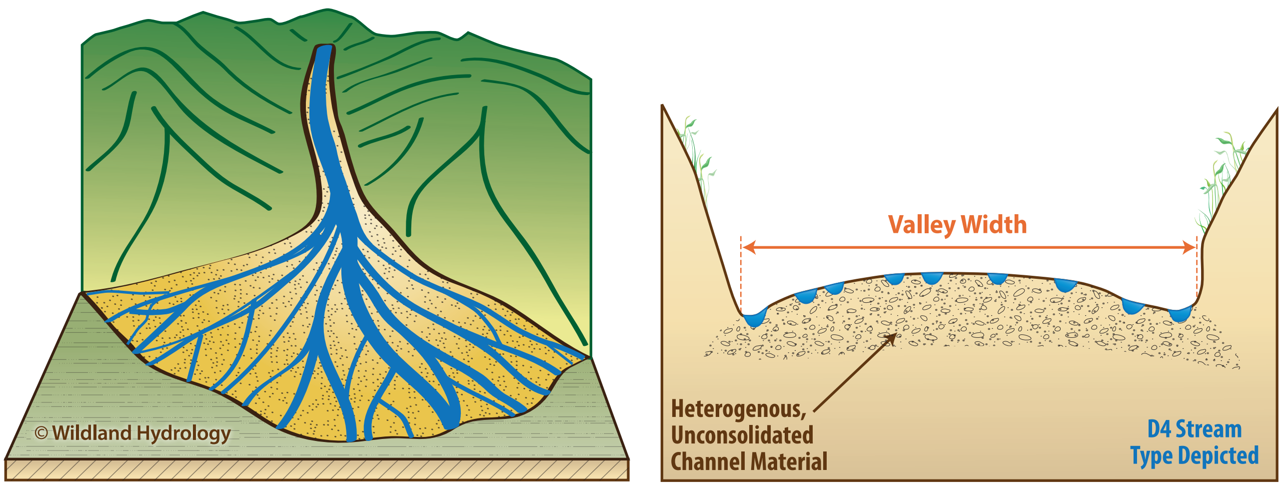
Alluvial fans are primarily depositional in nature with characteristic debris fan or alluvial fan landforms and moderately steep to steep valley slopes. Alluvial fans are formed over time by streams that deposit unconsolidated, heterogeneous, and noncohesive sediment as they transition from steeply-dissected terrain to flatter, down-valley terrain. This creates the fan-shaped deposit due to the decreased stream slope, shear stress, and stream power. The depositional alluvial fan surface is convex in cross-section view (National Research Council, 1996). The steeper slopes above the fan are generally associated with debris flows and debris avalanche, or high energy and high sediment supply systems typical of Aa+ and A stream types in VT I. Fans are often enlarged following flashy flows due to stormflow, rain-on-snow, and snowmelt flow regimes. Hurricanes in humid regions and debris flows in arid and semiarid landscapes often result in the active building of fans below erosive landscapes. Most streams that flow onto active alluvial fans are ephemeral, although larger systems in Alaska and Canada are perennial, and can be glacial fed. Rarely are spring-fed streams associated with active alluvial fans except at their toe. Wildfires are also common activators of alluvial fans (e.g., see Benda et al., 2003) due to increased magnitude and frequency of streamflow peaks, high upslope sediment supply, and corresponding debris flows. Similar to the work by Benda et al. (2003), alluvial fans are classified as (a) active, or (b) inactive.

Active alluvial fans, VT III(a), are associated with high bedload and sediment supply generated above the fan from erosive, steep channels and landscapes (**Figures B-8** and **B-9**). Little riparian vegetation establishes on active fans due to the frequent sediment deposition and well-drained, droughty surfaces. Flood debris and wildfires can add debris to this surface that can retard flood flows and induce localized sediment deposition (Benda et al., 2003). The unconfined, braided, distributary D stream types with flow convergence/divergence bed features are the most prevalent and natural form. Due to fan-head and through-fan trenching as well as basal scour and toe cutting that are associated with headcuts (Harvey, 2012), the confined and entrenched A, Fb, and G stream types also occur. In the presence of the entrenched stream types, the fan loses its capacity to store the excess sediment supply from upslope processes and routes the sediment to the trunk stream. Additional fans can also occur located at the outflow of the gullies that are cut through the fan surface.

Inactive alluvial fans, VT III(b), are no longer actively building or depositing sediment on the fan surface due to a low upstream sediment supply (**Figures B-8** and **B-10**). Riparian vegetation is generally well-established along a single-thread channel where the B stream type is common. The plant species are related to non-cohesive, well-drained, coarse-grained alluvium associated with cottonwood, conifers, and mixed hardwoods with a woody understory. In the arid west and southwest of the United States, fans are often associated with dry site woody species, such as sagebrush and rubber rabbit brush, with a grassed understory. Wetlands are rare and are generally not associated with alluvial fans due to the well-drained deposition. If a hardwood or conifer overstory establishes, then large wood can be recruited and be functional for river stability. As alluvial fans shift from being active to inactive, the stream types generally progress from a D to a G stream type, then to a B stream type as vegetation encroaches and the upstream sediment supply is greatly reduced. The largest of the B channels, if not derived from the fan-head trench with the lower local base level is often observed on the down-valley side of the trunk valley, where flows from the convex-shaped fan converge into the lower and deeper channel. The Fb and G stream types also occur less frequently and generally under disequilibrium conditions.

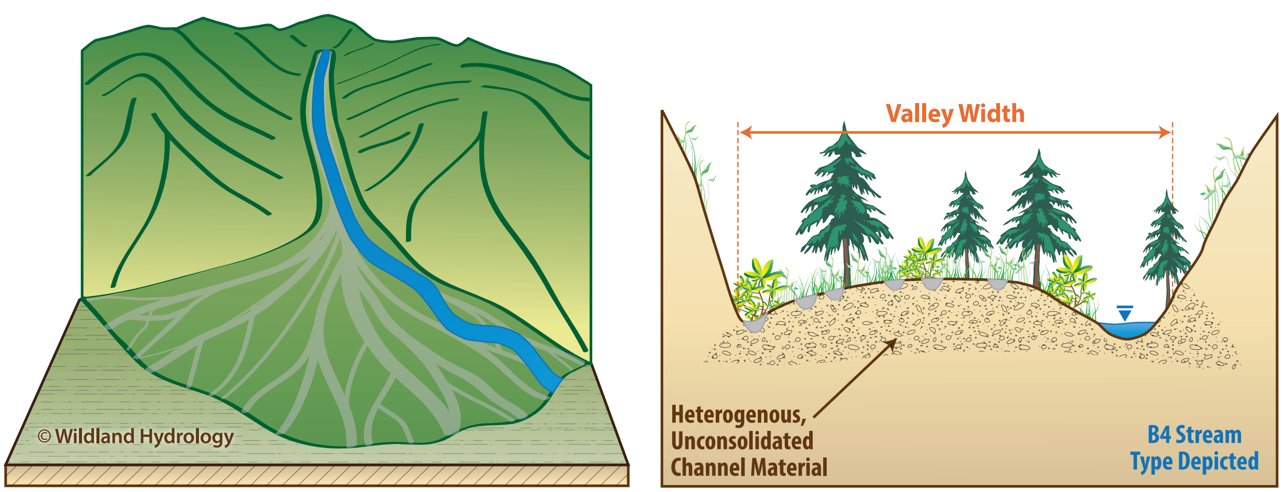
Colluvial fans also exist but are not characterized because they do not have evidence of fluvial erosion or deposition. The dominant deep subsurface water does not promote surface water concentrations or observable drainageways.

Valley Type III(a): Active Alluvial Fans



Stream Types: **D**, [A], [F_b], [G]

Valley Type III(b): Inactive Alluvial Fans



Stream Types: **B**, [F_b], [G]

Figure B-8. Valley Type III(a), *Active* alluvial fan, and Valley Type III(b), *inactive* alluvial fan

Figure B-9. Valley Type III(a), ***active*** alluvial fan, D stream type.

Figure B-10. Valley Type III(b), ***inactive*** alluvial fan, B stream types, Big Lost River Basin, Idaho.

Inner-Gorge (Valley Type IV)

The inner-gorge valley is related to canyons, deep gorges, and confined alluvial valleys characteristic of the classic meandering, entrenched, or deeply incised rivers. The channels are moderately confined between steep canyon walls; however, the valley-floor slopes have gentle elevational relief with slopes often less than 2.0% (**Figures B-11** and **B-12**). VT IV is often structurally-controlled, which limits lateral adjustment, but the streambeds are generally comprised of alluvium. The stream channels are generally deeply incised in highly weathered streambank materials due to thousands of years of combined downcutting and uplift of the land surface; thus many of the resultant stream types are often associated with tectonically uplifted valleys. Inner-gorge valleys are characteristic of the Colorado River in the Grand Canyon, the oxbows of the Lower San Juan River in Utah, the Lower Green River in Utah, the Rio Grande through Big Bend National Park in Texas, and the Shenandoah and Potomac Rivers near Harpers Ferry, West Virginia.

Depending on stream-side materials and tributaries, the suspended sediment supply is generally moderate to high during stormflow or snowmelt runoff. The majority of streams in this valley type are perennial as they represent larger stream orders and drainage basin size. The streams can be associated with stormflow and snowmelt runoff with some limestone regions (Karst geology) being spring-fed.

The riparian community is often limited due to the narrow bands of alluvium and is dominated by deciduous overstory, such as eastern hardwoods and cottonwood, with woody understory species, such as viburnum, dogwood, willow, and alder, and in more arid regions, the extensive invasion of salt cedar. Few wetlands exist in VT IV compared to other alluvial valley types due to the limited width of a floodplain or alluvial deposits. LWD is uncommon as the entrenched channel types result in high erosion and transport during flood events as flood waters are not dispersed onto large floodplains, and debris is not readily recruited from the limited stream-side riparian community. LWD does not play a significant role in channel roughness and habitat features of the stream types associated with VT IV.

The entrenched, high width-to-depth ratio F stream type with channel slopes less than 2.0% is most often found in VT IV; however, where the width of the valley floor accommodates both the channel and a floodplain, C stream types are often observed. Less common but observed on smaller inner-gorge valleys are the Bc stream types that are moderately entrenched.

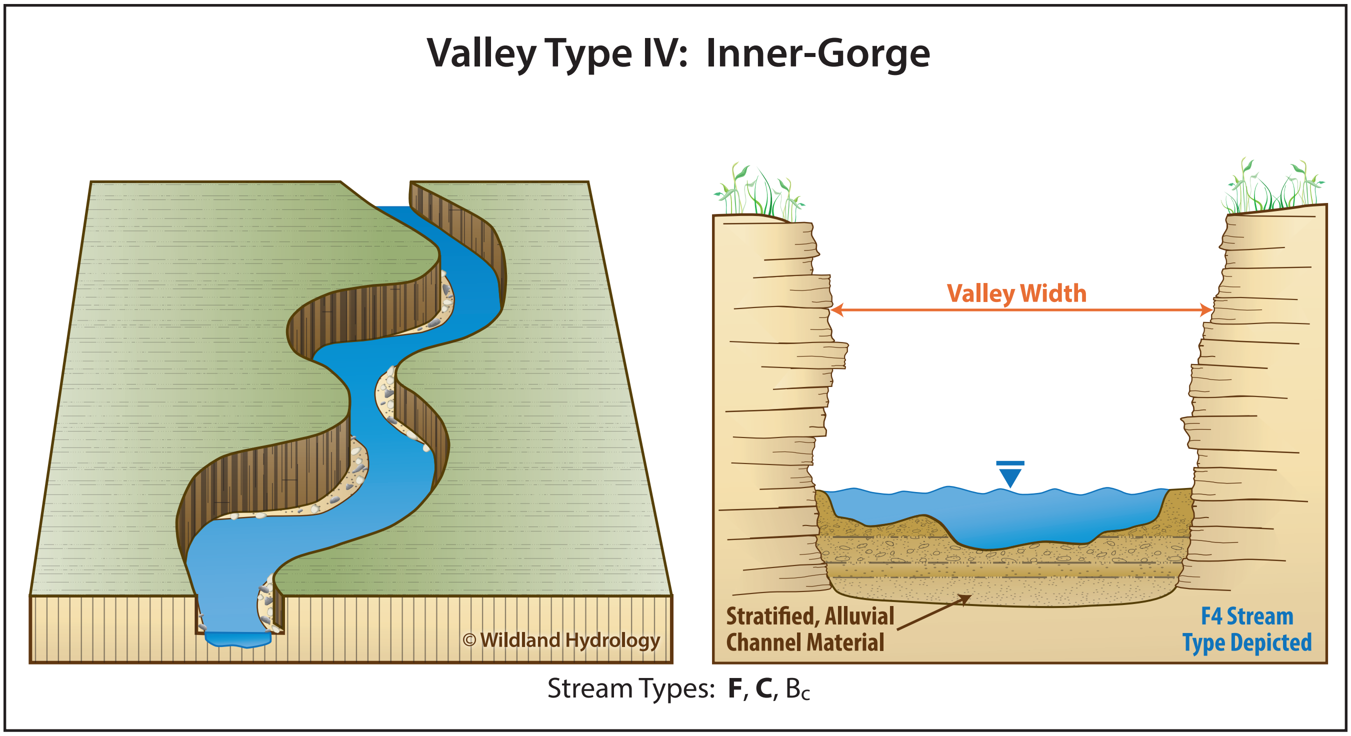


Figure B-11. Valley Type IV, inner-gorges with gentle valley-floor slopes and confined alluvial and bedrock-controlled valleys.

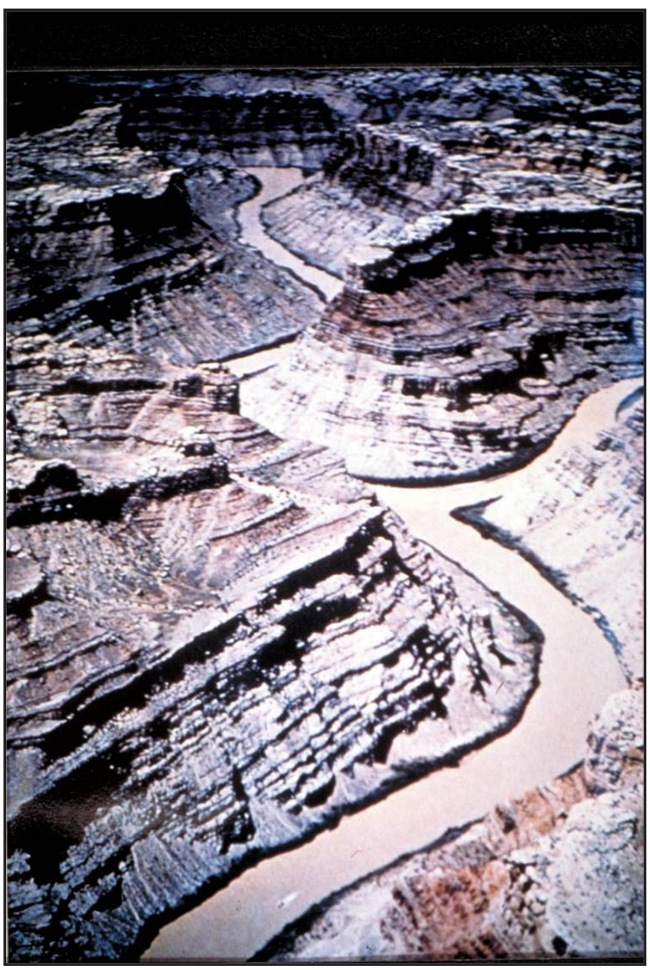


Figure B-12. Valley Type IV, inner-gorge valley.

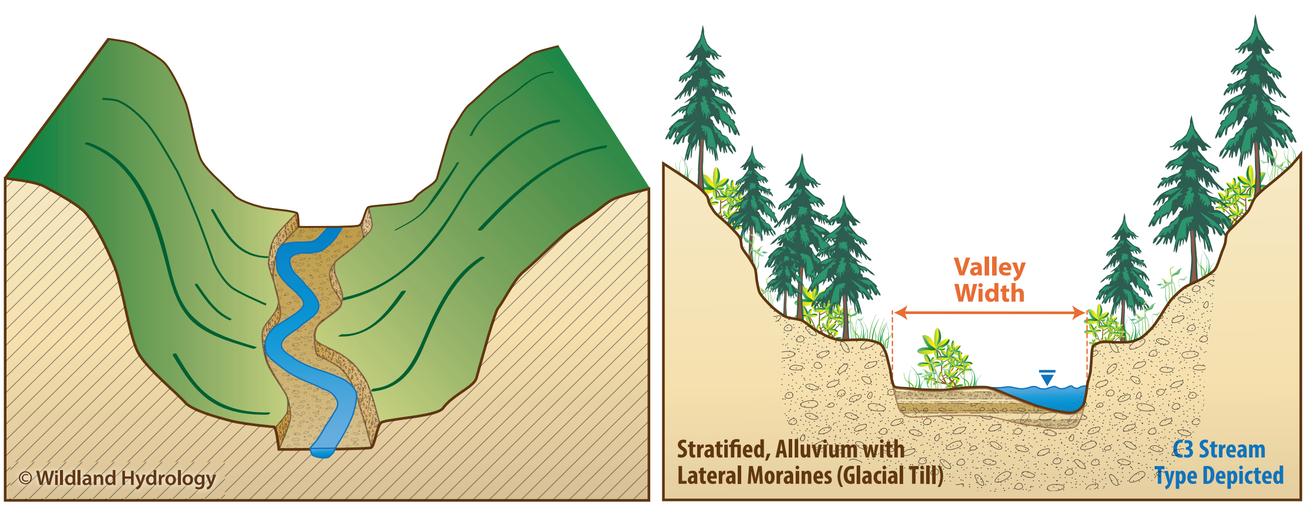
Glacial Trough (Valley Type V)

The glacial trough valley is characterized by a U-shaped valley being the product of glacial scouring and glacial debris deposition resulting in a moderately confined valley with moderate valley-floor slopes generally less than 4.0% (**Figures B-13**, **B-14** and **B-15**). Soils are derived from deposition of coarse glacial moraines or more recent alluvium from the Holocene period to the present. Local landforms include lateral and terminal glacial moraines, alluvial terraces, and floodplains. Deep, coarse deposition of glacial till is common in addition to glacio-fluvial deposits, with the finer mixture of glacio-lacustrine deposition above structurally-controlled reaches.

Many rivers in glacial trough valleys are high bedload systems due to the coarse sediment supply provided by lateral erosion against glacial terraces or moraines related to glacial till. The tills are associated with a heterogeneous, unconsolidated, unsorted, noncohesive mixture of boulders, cobbles, gravel, and sand, adding to the high bedload supply. In some instances, localized glacial lacustrine clays are exposed. Although the dominant deposition is from alpine or continental glaciation, the glacial tills are often reworked due to fluvial erosion. Streambank and bed erosion is often related to the presence of alluvium from floodplains and river terraces that contain a mixture of coarse to fine sediments. The coarse sediment supply from bed and streambank erosion within remnant glacial deposits on moderate stream gradients provides a high bedload sediment supply. Most of the flows in these valleys are associated with snowmelt-dominated and rain-on-snow hydrology; however, many have combined stormflow and snowmelt runoff sources. Spring-fed systems are rare.

Riparian vegetation is associated with relatively droughty, well-drained soils with conifer and deciduous overstory, such as cottonwood and sycamore, and a woody understory, such as alder and willow. Wetlands are uncommon within the riparian community due to the well-drained, coarse-textured alluvium. LWD is common from frequent recruitment due to rejuvenated (over-steepened) streambanks. The glacial trough valley is most commonly associated with the naturally occurring C and D stream types, while the presence of F and G stream types are generally related to disequilibrium conditions. The Bc stream type can also occur but is less frequently observed due to the presence of central, transverse, and side bars and active streambank erosion.

Valley Type V: Glacial Trough



Stream Types: **C**, **D**, B_c, [F], [G]

Figure B-13. Valley Type V, moderately steep valley slopes, U-shaped, glacial trough valleys.

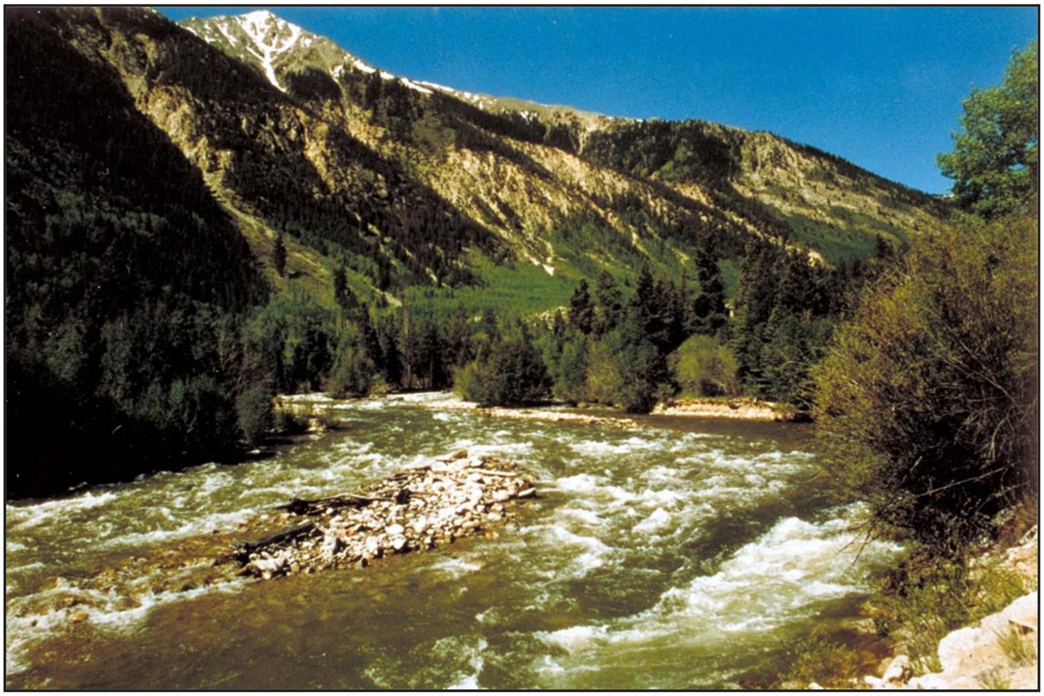


Figure B-14. Valley Type V, moderately steep valley slopes, "U" shaped glacial trough valleys (D and C stream types) (Rosgen, 1996).

Figure B-15. Valley Type V, moderately steep valley slopes, U-shaped glacial trough valleys.

Bedrock (Valley Type VI)

Bedrock valleys, often described as fault-line valleys, are structurally-controlled and dominated by bedrock outcrops and colluvial boulder slopes (**Figures B-16** and **B-17**). The valley-floor slopes vary from very steep (greater than 10.0%) in confined valleys to gentle (less than 2.0%) in unconfined valleys. Some alluvium occurs amidst the extensive colluvial deposits and bedrock outcrops, and stream patterns are controlled by the bedrock valley due to the nature of the bed and bank material and valley walls. The deeply entrenched, low gradient valleys that have bedrock-controlled streambeds and banks and appear as the previously described inner-gorge, VT IV, would correctly be typed as VT VI.

Sediment supply is very low with little sediment produced from the bed or streambanks and very low sediment storage resulting in sediment-limited systems. Streamflows are predominantly perennial and vary between stormflow- and snowmelt-dominated sources, although spring-fed systems can also be associated with bedrock outcrops.

Due to the bedrock, the riparian vegetation lies outside the bedrock fringe on stream-adjacent slopes, often comprised of conifers and mixed hardwoods with a limited woody understory. LWD is generally associated with the stream types in the steeper, confined valleys due to large debris jams that occur following major floods where the bedrock outcrops trap the large logs. The rock outcrops and large roughness elements of boulders, in addition to LWD when present, control the flow resistance.

The stream types and their associated dimension, pattern, and profile are dominated by the bedrock outcrops that influence both the streambanks and streambed. The Aa+, A, and B stream types predominantly occur within steep, confined valleys, whereas C, F, and G stream types occur in the wider and flatter bedrock-controlled valleys.

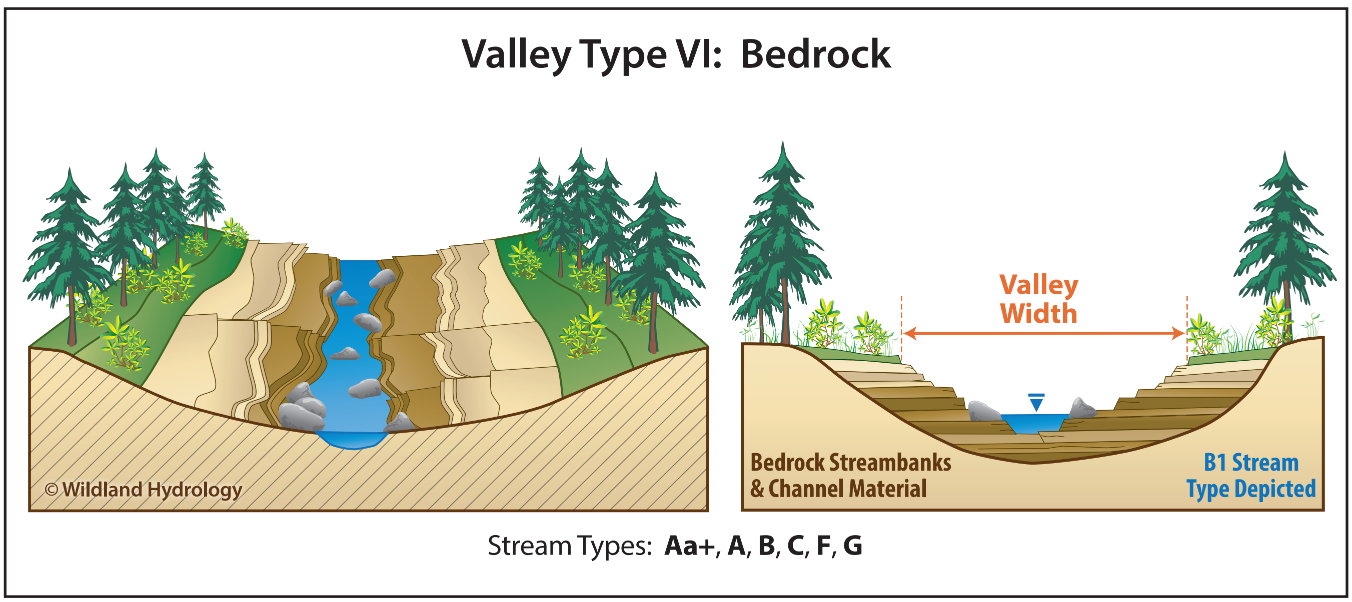


Figure B-16. Valley Type VI, bedrock-controlled valleys

Figure B-17. Bedrock-controlled Valley Type VI, F1 stream type, South Fork Rio Grande, CO.

Fluvial-Dissected (Valley Type VII)

The fluvial-dissected valley varies from moderately steep to steep, landforms with highly-dissected fluvial slopes, high drainage densities, and a very high sediment supply due to combined erosional processes from hillslope erosion and channel-source sediment (**Figures B-18** and **B-19**). Streams are characteristically confined and deeply incised in colluvium, alluvium, or residual soils. The highly erosive residual soils are often derived from sedimentary rock, such as marine shale or grussic granite. Lower slope positions of these fluvial-dissected landscapes contain alluvial deposits that can also be readily eroded due to the steep slopes and erodible soil types. These slopes are often associated with mass wasting processes (slump-earthflow and debris flows) and active surface erosion processes related to rills and gullies. The shale-derived soils are cohesive, contributing to high drainage density and mass wasting, while the noncohesive grussic granite is more dominated by surface erosion processes. This valley type can be observed over a variety of locations, including the provinces of the Palouse Prairie of Idaho, the river breaklands in Eastern Montana, the Great Basin or high deserts of Nevada and Wyoming, the Badlands of the Dakotas, and on fluvial landscapes dominated by Mancos Shale in Western and Southwestern Colorado.

The majority of these valleys are geologically active landscapes associated with a high to very high sediment supply and high energy stream systems. The flow regime is predominantly ephemeral and stormflow-dominated, although snowmelt also occurs in certain locales. The bedload transport can be very high in the sand and gravel A and G stream types due to the steep slopes, low width-to-depth ratios, and the confined and entrenched nature of the streams. Suspended sediment can also be very high due to the unlimited sediment supply related to channels deeply incised in the soils.

The riparian vegetation types are highly variable comprised primarily of perennial grasslands, annual grass-forb, pinion-juniper, dry site species conifers, mixed hardwoods, willows, alders, and other similar woody understory species. Typically, the plant and ground cover densities are low due to the erosive and droughty soils or heavy grazing pressure on the moderate to steep slopes. LWD influence is negligible and wetlands are rare to nonexistent.

Fluvial-dissected valleys are most commonly associated with Aa+, A, and G stream types ranging from cobble to silt/clay materials that have moderate to steep gradients, are entrenched or deeply incised, and confined and unstable due to the active lateral and vertical accretion processes; the B and Fb stream types also occur.

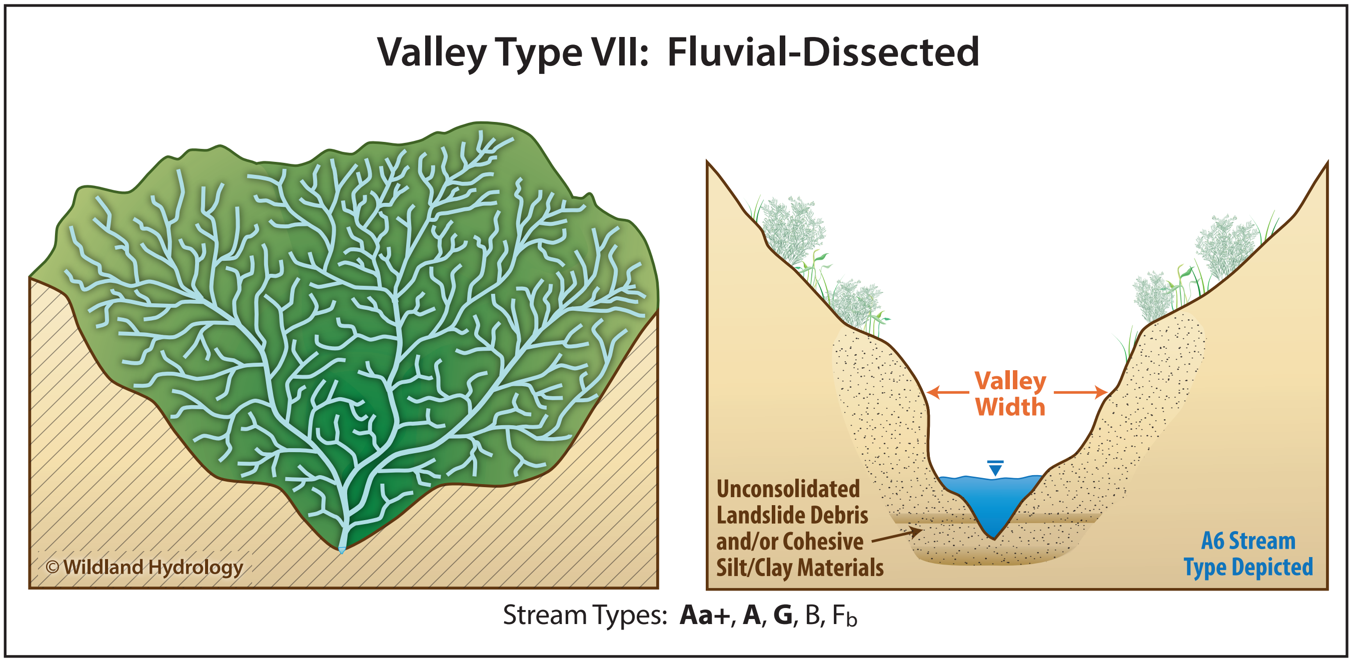


Figure B-18. Valley Type VII, steep, fluvial-dissected, high drainage density alluvial slopes.

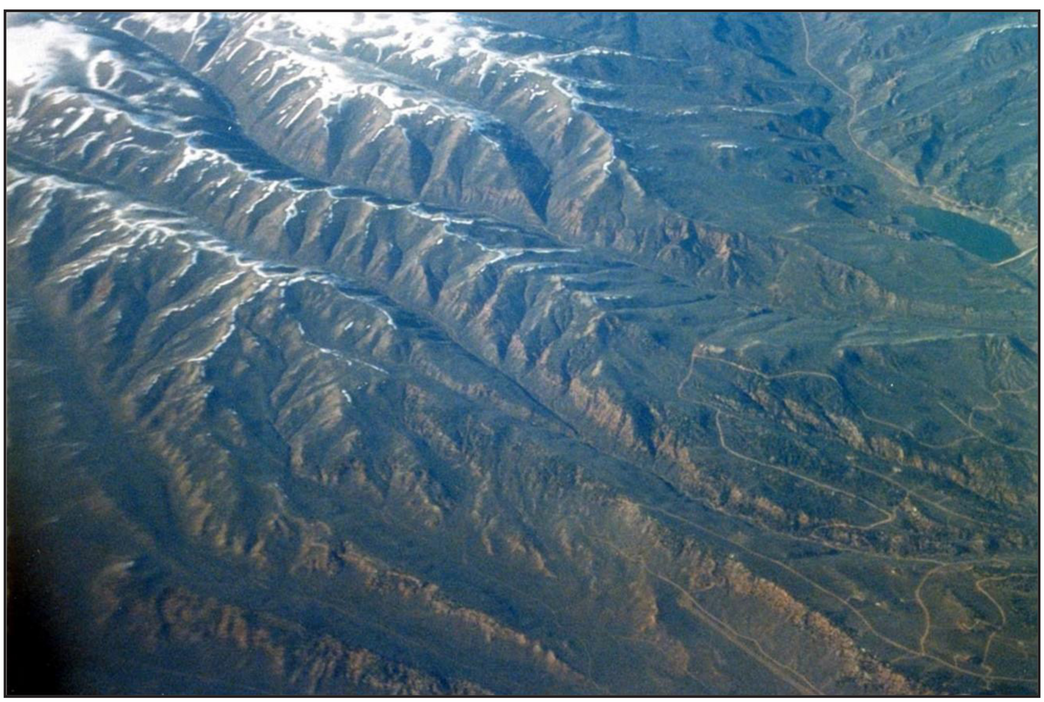


Figure B-19. Valley Type VII, steep, highly dissected fluvial slopes (A and G stream types).

Alluvial (Valley Type VIII)

The alluvial valley is associated with valley floors consisting of well-sorted and stratified alluvium originating from riverine and localized lacustrine depositional processes. Localized lacustrine deposits are often related to past and present beaver activity; heavy trapping and conversion of willow-dominated valleys to pastures created many incised channels in this alluvial valley (Wohl, 2000). Well-developed floodplains and Holocene terraces are common features along the riparian corridor. Riparian communities composed of wetlands and a variety of species are typical of this alluvial valley. The riparian community is critical for the stability and physical, biological, and chemical functions of the alluvial stream types associated with this valley type (Brooks and Brierley, 2002). Due to the presence of shallow water tables and the water holding capacity of alluvium, diverse, productive plant communities exist, including dense overstory, midstory, and understory stands. These communities range from selected conifers and deciduous trees that can withstand infrequent to frequent inundation on saturated soils, such as bald cypress and mixed hardwoods, to a variety of understory woody plants. LWD can be recruited from the floodplain and terraces; certain shallow-rooted riparian species are susceptible to streambank erosion and contribute to LWD in the channel.

VT VIII is mostly perennial with stormflow, rain-on-snow, glacial-fed, spring-fed, and snowmelt-dominated hydrographs. The dimension, pattern, and profile of the river channels are closely linked to the bankfull discharge. Channel adjustment is related to changes in the flow and sediment regimes as well as the riparian vegetation. The sediment regime is generally not supply-limited due to stored sediment and the streambank and streambed erosional processes. These alluvial valleys vary greatly in valley width and gradient and some are associated with depositional and erosional processes that are geomorphically unique from other alluvial valleys. Thus the alluvial valley type is divided into three subtypes: (a) *Gulch Fill Valley*, (b) *Alluvial Fill Valley*, and (c) *Terraced Alluvial Valley*.

Gulch Fill Valley, VT VIII(a), is most commonly associated with alluvial fill with narrow valley widths that confine the streams (**Figures B-20** and **B-21**). The valley has slopes that vary from gentle to moderately steep and contains narrow, but well-developed floodplains adjacent to relatively steep, colluvial side slopes. Stream orders generally range from 2–4, commensurate with the smaller streams associated with gulch fill valleys. Gulch fill valleys with gentle slopes generally contain confined C and E stream types, whereas the valleys with moderately steep slopes often contain B and steeper Cb and Eb stream types. The Fb and G stream types also occur, but often under disequilibrium conditions. Beaver dams commonly occur in this valley type.

Alluvial Fill Valley, VT VIII(b), is similar to the gulch fill valley but is wider and generally less steep with moderately confined stream channels (**Figures B-20** and **B-22**); stream orders also range from 2–4. The B and steeper C(b) and E(b) stream types commonly occur in VT VIII(b); however, A, D, F(b), and G stream types occur less frequently and generally under disequilibrium conditions. Beaver dams also frequently occur in this alluvial fill valley.

Terraced Alluvial Valley, VT VIII(c), is identified by the presence of multiple river terraces positioned parallel to the present river along broad, unconfined valleys with gentle valley slopes (**Figures B-20** and **B-23**). Alluvial terraces and floodplains are the predominant depositional landforms, which can produce a high sediment supply related to streambank erosional processes depending on the riparian vegetation. Pleistocene terraces can also occur in these valleys but their surfaces are much higher above the present river than the Holocene terraces. Terrace types can be distinguished to identify the sometimes complex geomorphic histories involving past erosional and depositional processes, such as fill terraces and cut terraces (Leopold et al., 1964). Stream orders are generally 4 or larger. VT VIII(c) is most commonly associated with C and E stream types that are slightly entrenched, meandering channels that develop riffle–pool bedforms; the Bc stream type also occurs. The A, D, F, and Gc are the unstable stream types in this valley type. The entrenched F and Gc stream types are often converted to Bc stream types if the channel is confined between terraces in the presence of riparian vegetation. Often, beaver can have sustainable populations and co-exist with stream channel function when their lodges are located in abandoned meander scrolls and oxbow lakes on the floodplains of larger rivers within this valley type.

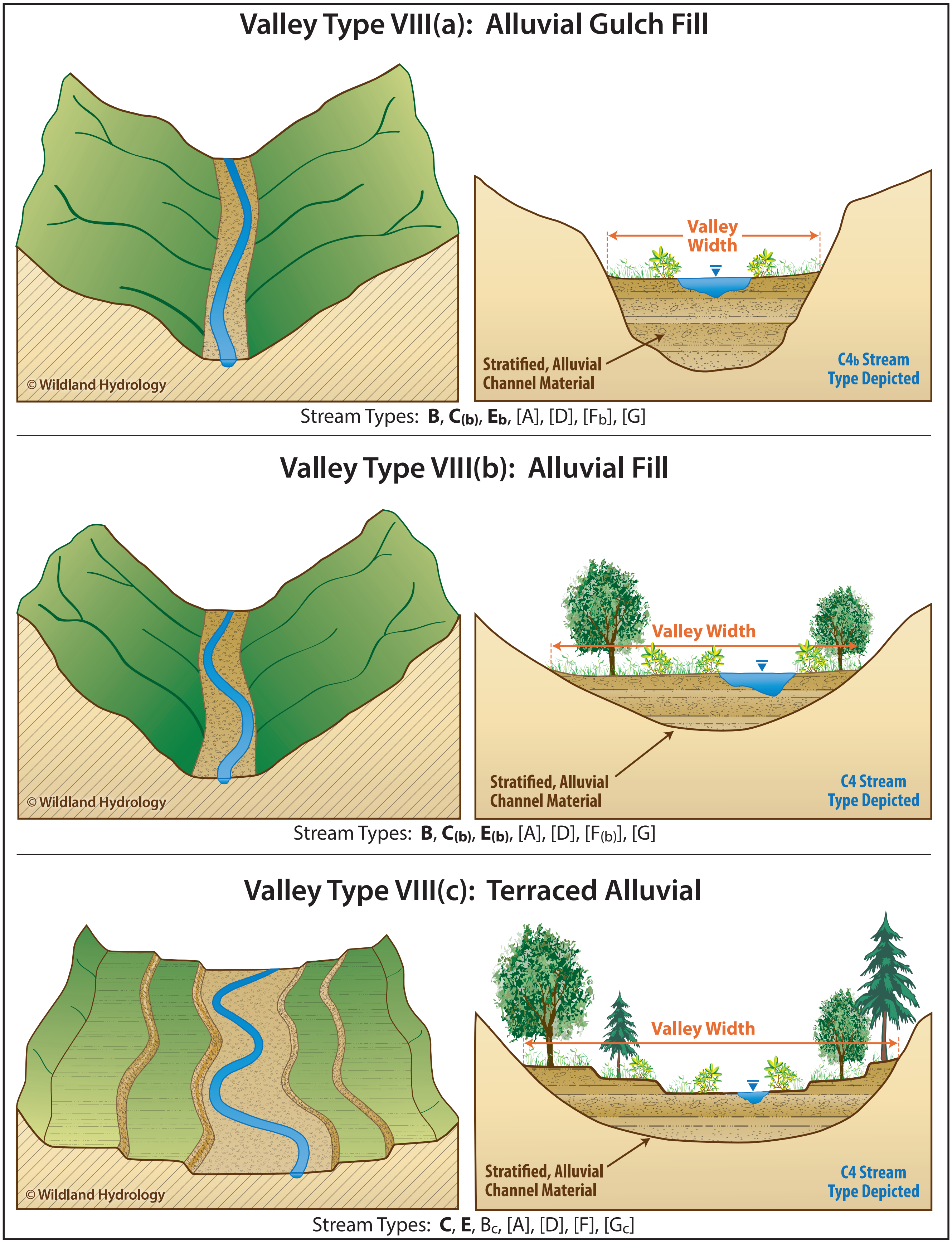


Figure B-20. Valley Type VIII(a) – Narrow alluvial gulch fill; Valley Type VIII(b) – Alluvial fill valley; and Valley Type VIII(c) – Terraced, alluvial valley

Figure B-21. Gulch fill Valley Type VIII(a), E4 stream type.

Figure B-22. Alluvial fill Valley Type VIII(b), C4 stream type.

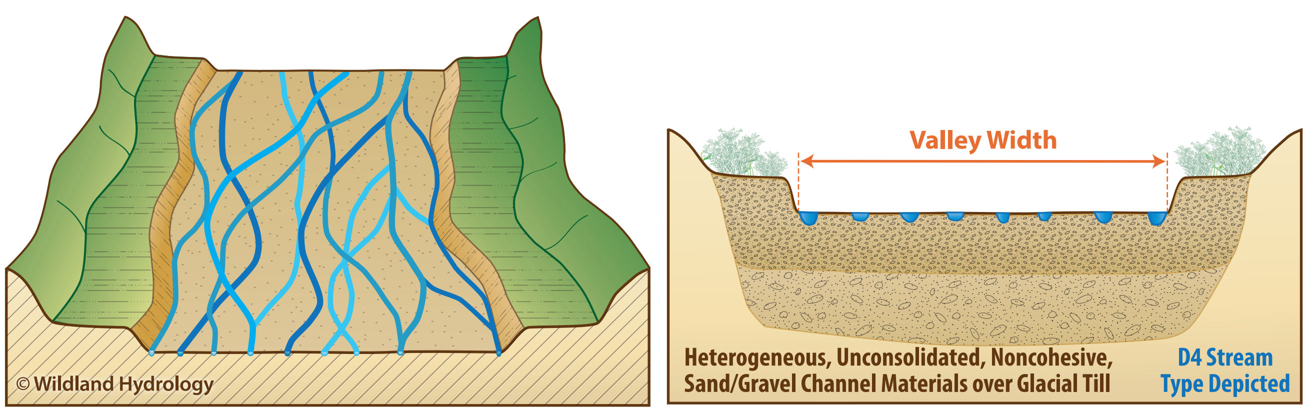
Figure B-23. Valley Type VIII(c), wide, gentle valley slope with a well-developed floodplain adjacent to river terraces.

Glacial Outwash (Valley Type IX)

The glacial outwash valley is observed as glacial outwash plains with gentle valley slopes associated with wide and expansive valley widths (**Figures B-24** and **B-25**). The valley floor is comprised of glacial, glacio-fluvial, and/or alluvial deposition related to glacial meltwater associated with gravel and sand-dominated materials in well-sorted, stratified layers; silt and clay can be present, but in lower percentages of the deposits. Streams can be laterally adjusting into glacial outwash terraces resulting in a very high sediment supply of coarse sand and gravel bedload. The flows are primarily glacial-fed, such as in Alaska and Canada, or snowmelt-dominated. Riparian vegetation is scarce in glacial-fed regions but not in snowmelt-dominated regions where mixed hardwoods (cottonwood) and conifers occur.

Braided, D stream types associated with convergence-divergence bedforms and the C stream type with numerous mid-channel bars predominate in the glacial outwash valley due to the high sediment supply and high rates of lateral migration. The streambanks are very erosive due to the high supplies of sand and gravel materials and lack of cohesive silts and clays. If sufficient riparian vegetation exists, the C stream type is the stable and common form. LWD does not play a significant role for influencing channel dimension, pattern, or profile in braided channels; however, LWD can be recruited from overstory species in meandering channels. Glacial outwash valleys are less frequently associated with the B stream type that is characteristic of a lower sediment supply. The F and G stream types are associated with disequilibrium conditions.

Valley Type IX: Glacial Outwash



Stream Types: **C**, **D**, B, [F], [G]

Figure B-24. Valley Type IX, broad, gentle valley slopes associated with glacial outwash.

Figure B-25. Valley Type IX, broad, gentle slopes, associated with glacial outwash (D stream type).

Lacustrine (Valley Type X)

The lacustrine valley is a former lake bottom that is very wide with gentle valley slopes and originates as either glacio-lacustrine or non-glacial (**Figures B-26** and **B-27**). Glacial lacustrine valleys are common along the northern one-third of the United States and many provinces in Canada where alpine and continental glaciation dominated the landscape. The Red River between Minnesota and North Dakota extending into Manitoba, Canada, is incised in a classic glacial lacustrine valley. Non-glacial lacustrine valleys are also common in non-glaciated regions of the United States and Canada. These broad lacustrine and riverine alluvial flats can exhibit peat bogs, expansive wetlands, oxbow lakes, and related fluvial features. Some soils are associated with compacted glacial deposits of clay underlying alluvial deposits. This valley type is typical of predominantly cohesive sediments of silt and clay, low bedload supply, and highly sinuous and low gradient channels. Bedload rates are minimal due to the low gradients and the nature of the smaller-sized alluvial materials. Most of the stream channels are associated with perennial flow dominated by snowmelt, stormflow, glacial-fed, or spring-fed hydrographs.

The high water table and well-developed floodplains result in a dense riparian community that helps maintain low rates of streambank erosion (Rosgen, 2001). The riparian community is often comprised of rhizomatous grass-like plants (Carex spp. and Juncus spp.), shrubby midstory plants of willow, and overstory hardwoods such as sycamore and cottonwood. Such species can withstand saturated soils and frequent inundation. Some riparian communities are predominantly grasses and grass-like plants due to anaerobic conditions in the soil that inhibit woody species colonization. The unconfined C, DA, and E stream types are most commonly observed; however, in many instances where streams have been impaired due to land uses such as poor grazing practices, or have been channelized causing lowering of the local base level, unstable F and Gc stream types are found. The Bc stream type also occurs less frequently. Beaver colonies can coexist in depressional areas in the wide floodplain and within the low sediment supply channels.

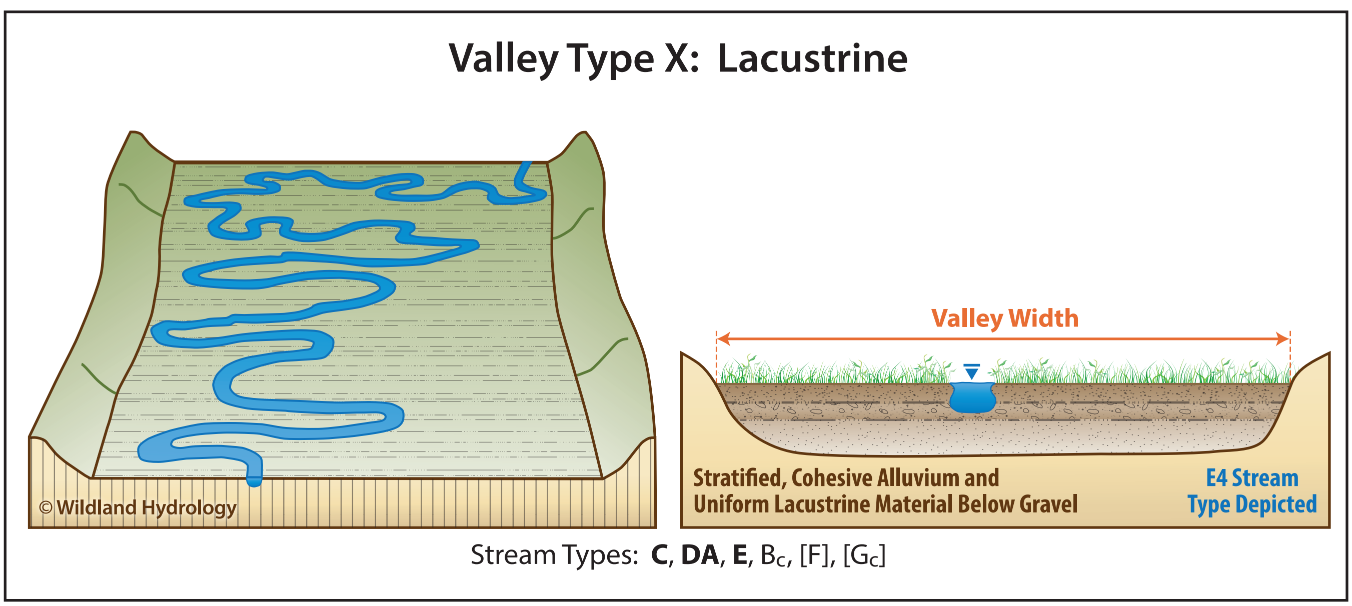


Figure B-26. Valley Type X, very broad and gentle valley slopes associated with glacio- and nonglacio-lacustrine deposits.

Figure B-27. Valley Type X, very broad and gentle valley slopes associated with glacio- and nonglacio-lacustrine deposits.

Deltas (Valley Type XI)

River deltas are a unique series of landforms consisting of river deltas and tidal flats constructed of fine alluvial materials originating from riverine and estuarine depositional processes (**Figures B-28** and **B-29**). Valley slopes are typically gentle and streams are unconfined. Deltas form by depositing alluvial sediment at the mouth of a river as it drains into base-level bodies of water such as lakes, fjords, or oceans due to a decrease in channel slope and energy to transport the sediment. Delta areas often include freshwater or saltwater marshes and crevasse splays.

Four morphologically distinct delta areas, initially described by Fisher et al. (1969), produce different stream types or patterns:

1) The high-constructive, elongated delta
2) The high constructive, lobate delta
3) The high-destructive, wave-dominated delta
4) The high-destructive, tide-dominated delta

Depositional processes dominate the high-constructive deltas, whereas the high-destructive deltas are dominated and shaped by the erosive processes of wave action or tidal currents. Elongated deltas are associated with mostly fine sediment, whereas the lobate delta often contains more coarse material. An additional delta landform is identified that represents extensive wetlands, peat, and cohesive sediments with multiple, stable channels typical of the low gradient anastomosed stream type.

The sediment supply is comprised primarily of suspended sediment with little to no coarse bedload. Some exceptions involve river deltas that deposit coarse sediment at the head (upstream end) of the delta. Streamflows are perennial involving tidal influence, stormflow, snowmelt, rain-on-snow, and glacial-fed hydrographs. Grasses and grass-like plants predominate with overstory species of bald cypress and other saturation-tolerant hardwoods. Little LWD exists due to the nature of the riparian ecosystem. Many deltas have been previously abandoned by the lowering of ocean levels (base level), tectonic action (base-level shifts), and reservoir stage lowering that has resulted in channel adjustments at their mouths. Due to the recent raising of ocean levels, deposition is extending headward creating flooding issues for urban development. Similar channel adjustments to local base-level changes can also occur due to lake fluctuations and changes in the operational hydrology of reservoirs.

The corresponding stream types found in delta areas are primarily the distributary channels of the DA stream type and the braided D stream type due to the active deposition of sediment that causes the splitting of flows in the main channel and delta front. The DA stream type is more common to the stable delta landforms that are tide-dominated with numerous wetland islands, and where the base level of the channel system is controlled by either lake or sea levels. Less commonly occurring are the single-thread C and E stream types, which are more likely found as transition stream types at the head of the delta valleys.

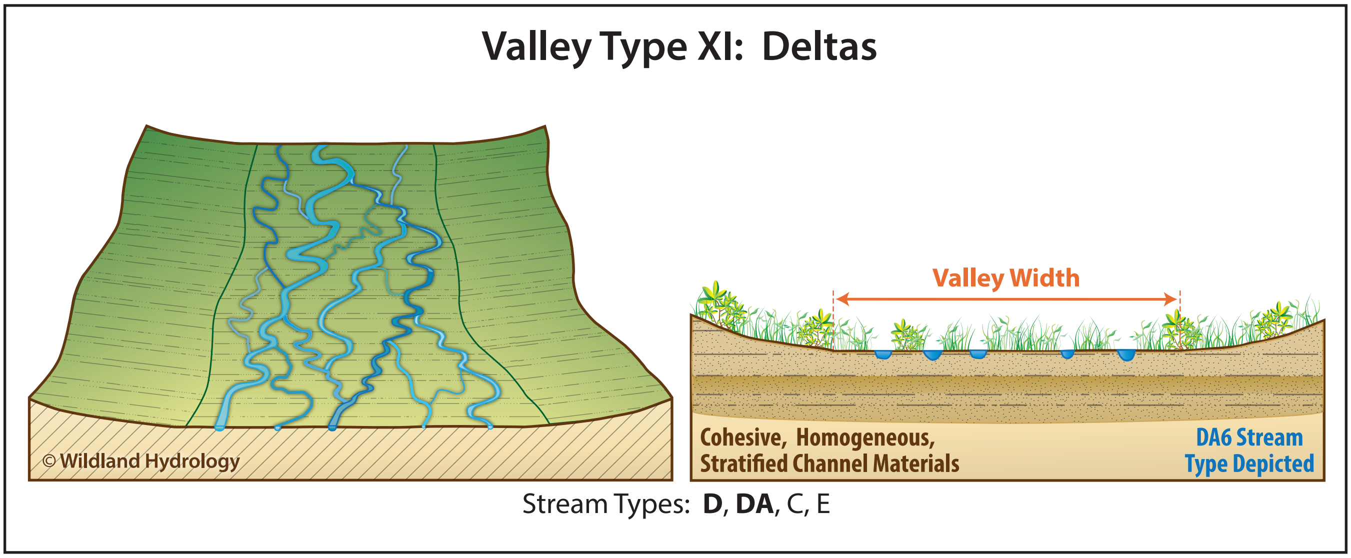


Figure B-28. Valley Type XI, Deltas.

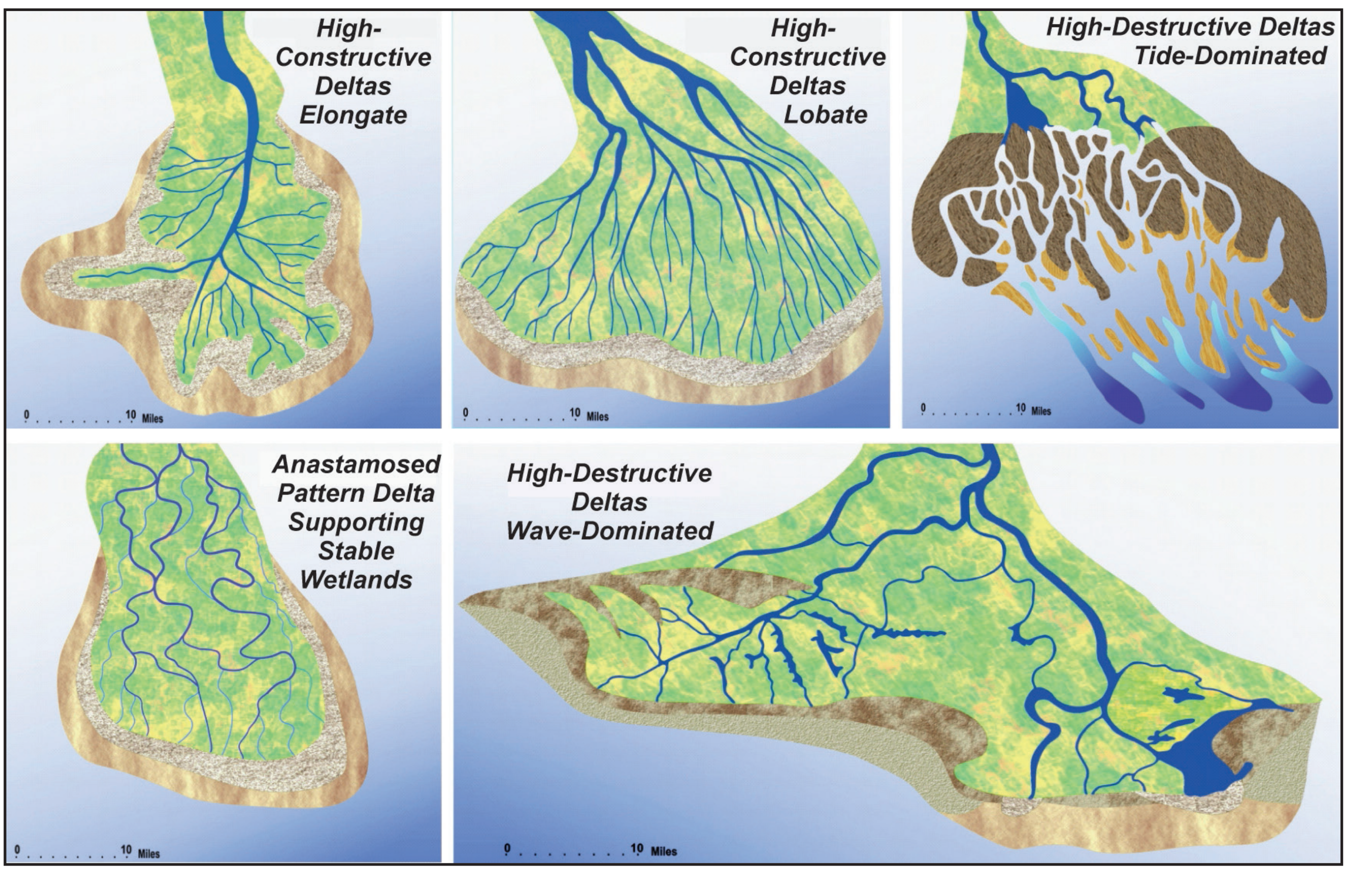


Figure B-29. Valley Type XI, Deltas.

Eolian (Valley Type XII)

Eolian landforms are wind-deposited soils reworked by running water and are subdivided into two major categories: a) *sand*, including sand dunes, abandoned beach sand, shoreline (littoral) drift, foredunes, periglacial sand splays, sand hills, and (b) *loess*, related to airborne deposits of silt. Loess deposits are extensive over portions of the Northwest, Midwest and Mid-Atlantic regions of the United States as well as throughout South America and Europe (Easterbrook, 1999; Bettis et al., 2003; Muhs and Bettis, 2003; Iriondo and Kröhling, 2007). The fine-textured sediment supply is generally high to very high due to the erosive nature of exposed soils. Flow regime variation is associated with perennial and ephemeral stormflow and snowmelt runoff, and is rarely related to a spring-fed regime. Upland vegetation predominates due to the droughty nature of the sites with some exceptions on lower gradient sand dune, braided channels and high precipitation regions. The low order streams of the sand hills and loess-dominated undulating terrain are often related to woody riparian species. LWD rarely plays a role in stream processes within the eolian landscape.

Eolian sand, VT XII(a), is associated with wind-deposited sand occurring in various landforms that are reworked by fluvial processes and typical of broad, undulating valley terrain (**Figure B-30**). VT XII(a) is further subdivided based on three predominant landforms and features: (1) *sand dunes*, (2) *abandoned beach sand, littoral drift, foredunes, and periglacial sand splays*, and (3) *sand hills*.

Sand dunes are comprised of eolian sand deposits as found in various geographical locations from deserts to high elevations as in the Sand Dunes National Monument near Alamosa, Colorado. Sand dunes generally have gentle to moderate valley-floor slopes and valley widths that promote unconfined and un-incised channels. The sand-dominated material is associated with high erosion rates and a very high sediment supply. The braided D stream type predominates in this valley type due to the high sediment supply and high rates of lateral migration. Bed features of the D stream type are associated with dunes and antidunes that provide flow resistance. The streambanks are highly erodible due to the sand materials and lack of cohesive silts and clays, and riparian vegetation rarely controls the channel morphology. If riparian vegetation is present in these well-drained, droughty sites, cottonwood, willow, and bunchgrasses can occur within the floodplains of C stream types; desert riparian community types will differ. The F and G stream types are uncommon and associated with disequilibrium conditions.

Abandoned beach sand, wind-related beach erosion and deposition adjacent to lakes and oceans, and periglacial sand splays are eolian sand landforms reworked by fluvial processes that vary from moderate to steep slopes based on the nature and location of the deposits. The narrow valley widths create predominantly confined to moderately confined channels. Many of these narrow valleys are associated with abandonment and over-steepening of beach sand (oceans or lakes) caused by base-level adjustments due to climate change or adjustment of base level due to tectonics. Typical landforms and features due to eolian processes in sand are shoreline dunes (foredunes), or littoral drift, and periglacial sand splays where onshore winds redistributed shoreline sands onto over-steepened terrain adjacent to oceans and large inland lakes. Due to the erosive nature of the soils and discontinuous moderate to steep slopes, the predominant, yet unstable stream types are the entrenched A, F, and G stream types. The stable form is the B stream type if sufficient riparian vegetation colonizes and helps to stabilize streambanks.

Sand hills are related to glacial and non-glacial eolian deposition. The valley morphology and stream types are similar to the previous eolian sand category (abandoned beach sand, etc.). The erosive nature of the soils and moderate to steep slopes require good vegetative cover to prevent erosion. Woody vegetation can occur in many of the drainageways.

Eolian loess, VT XII(b), is primarily an unconsolidated, silt-sized material deposited by wind (Ruhe, 1975). Loess landscapes generally have moderate to steep valley slopes with confined channels (**Figures B-30** and **B-31**). Loess commonly originates from periglacial processes, although non-glacial types of loess can occur, originating from volcanic ash, deserts, dune fields, and playa lakes (Iriondo and Kröhling, 2007). Periglacial loess is associated with braided D stream types and wind erosion from floodplains associated with glacial till and outwash plains (VT IX) that carried large amounts of glacial meltwater and sediments (Judson and Kauffman, 1990). During low flows, the floodplains were comprised of expansive amounts of silt/clay materials deposited from over-bank flows that were subsequently redistributed by wind.

Agricultural crops are the predominant vegetative cover (Getis et al., 2000); however, woody riparian vegetation occurs in many of the first and second order drainages. Removal of the woody riparian vegetation has led to rill and gully erosion in this highly erodible material, producing excess fine-grained channel source sediment. The B, Cb, and Eb stream types are the most prevalent stable form, while the A, Fb, and G stream types are observed most often under disequilibrium conditions. Delivered sediment from upslope, first and second order streams often results in alluvial deposition at the lower end of the valley, promoting a change in the valley and stream types to the alluvial VT VIII(a) and VT VIII(b) and the silt-dominated C(b) and E(b) stream types.

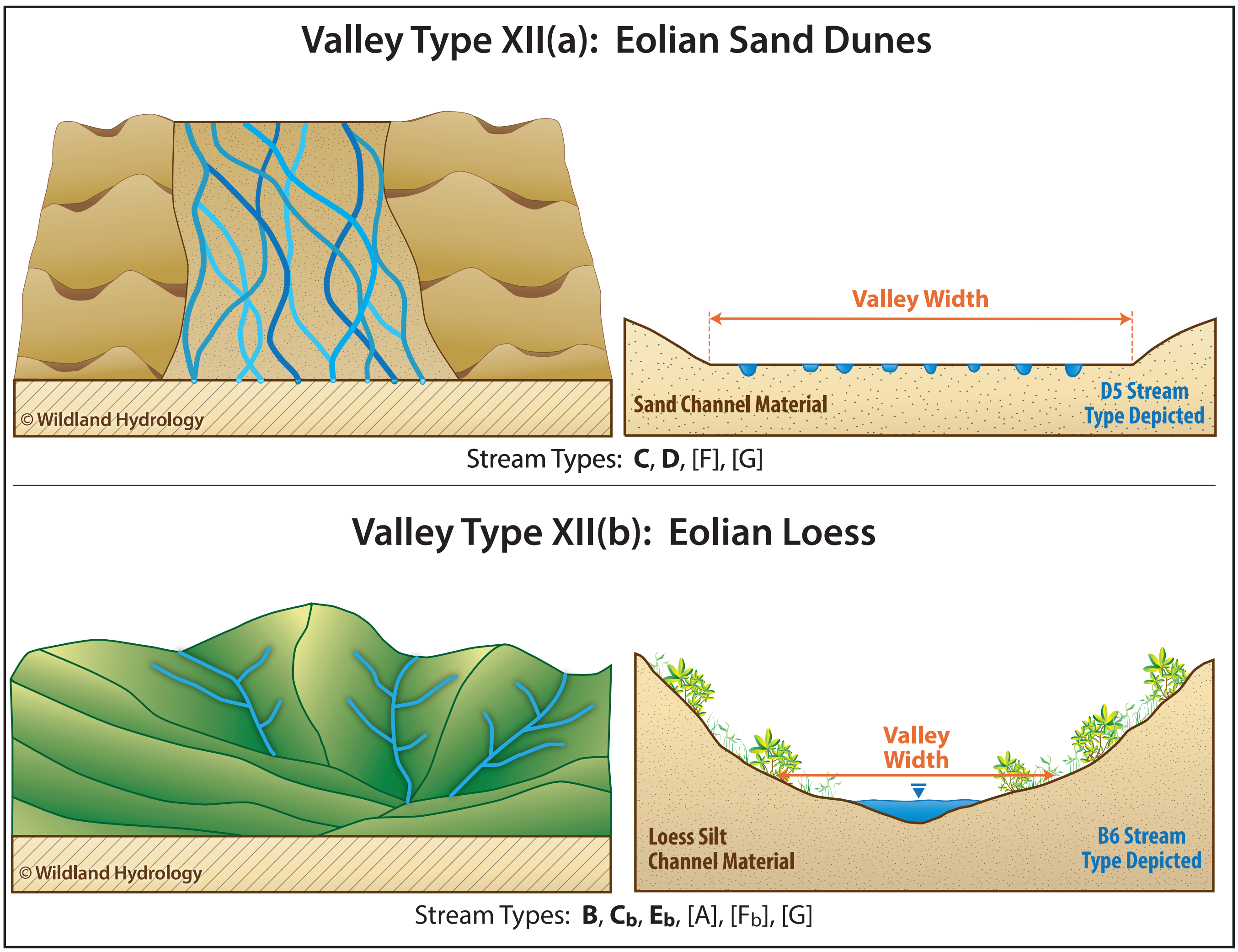


Figure B-30. Valley Type XII(a), eolian sand dunes, and Valley Type XII(b), eolian loess.

Figure B-31. Valley Type XII(a), Eolian Sand Dunes, Medano Creek, Great Sand Dunes National Park, CO.

Literature Cited

Benda, L., Miller, D., Bigelow, P., and Andras, K, 2003. Effects of Post-Wildfire Erosion on Channel Environments, Boise River, Idaho. Forest Ecology and Management, 178, 105–119.

Bettis, E.A., III, D.R. Muhs, H.M. Roberts and A.G. Wintle, 2003. Last Glacial Loess in the Conterminous U.S.A. Quaternary Science Reviews 22:1907–1946.

Brooks, A.P. and G.J. Brierley, 2002. Mediated Equilibrium: The Influence of Riparian Vegetation and Wood on the Long Term Evolution and Behaviour of a Near Pristine River. Earth Surface Processes and Landforms, 27:343–367.

Easterbrook, D.J., 1999. Surface Processes and Landforms, Second Edition. Prentice-Hall, New Jersey.

Fisher, W.L., L.F. Brown Jr., A.J. Scott and J.H. McGowen, 1969. Delta Systems in the Exploration for Oil and Gas: A Research Colloquium. University of Texas at Austin, Bureau of Economic Geology, Austin, Texas.

Getis, A., J. Getis and J.D. Fellmann, 2000. Introduction to Geography, Seventh Edition. McGraw Hill, New York, New York.

Harvey, A.M., 2012. The Coupling Status of Alluvial Fans and Debris Cones: A Review and Synthesis. Earth Surface Processes and Landforms, 37(1):64–76.

Horton, R.E. (1945). Erosional Developments of Streams and Their Drainage Basins: Hydrophysical Approach to Quantitative Morphology. Bulletin of the Geological Society of America, 56:275–370.

Iriondo, M.H. and D.M. Kröhling, 2007. Non-classical Types of Loess. Sedimentary Geology 202:352–368.

Judson, S. and M.E. Kauffman, 1990. Physical Geology (Eighth Edition). Prentice Hall, Englewood Cliffs, New Jersey.

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

Muhs, D.R. and E.A. Bettis, III, 2003. Quaternary Loess-Paleosol Sequences as Examples of Climate-Driven Sedimentary Extremes. Geological Society of America, special paper no. 370, pp. 53–74.

National Research Council, 1996. Alluvial Fan Flooding, 166 pp. National Academy Press, Washington D.C.

Rosgen, D.L., 1994. A Classification of Natural Rivers. Catena 22:169–199.

Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Rosgen, D.L., 2001. A Practical Method of Computing Streambank Erosion Rate. In Proceedings of the Seventh Federal Interagency Sedimentation Conference: Vol. 1, pp. II-9–II-15. Subcommittee on Sedimentation, Reno, Nevada.

Rosgen, D.L., 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology, Fort Collins, Colorado.

Strahler, A.N. (1957). Quantitative Analysis of Watershed Geomorphology. American Geophysical Union Transactions, 28:913–920.

Wohl, E., 2000. Mountain Rivers. Water Resources Monograph 14, American Geophysical Union, Washington, D.C..