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National Engineering Handbook**

Chapter 7 Basic Principles of Channel Design

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Cover photo: Where modification of the stream or channel is needed to achieve restoration goals and objectives, alteration of dimensions, pattern, and profile may be needed, resulting in designs ranging from minimal changes to large-scale rehabilitations.

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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654.0700 Purpose

Channel design may involve the stabilization or realignment of an existing stream, or it may involve the creation of an entirely new channel. There are a wide variety of sources and techniques for designing stable channels that are available to the designer. These techniques may focus on a variety of open channel design work ranging from natural stream restoration to a strictly structural project. However, these techniques need to be applied to the appropriate conditions and stream types. The purpose of this chapter is to provide a framework for the designer to assess the use and application of several of the analysis and design techniques presented in subsequent chapters. This chapter provides some background which should be useful in the evaluation of these techniques to address specific goals, constraints and conditions. To provide a context for the different design techniques, a clear description of threshold and alluvial channels is presented in this chapter. In addition, a general description of channel design variables and approaches is presented. These broad, and occasionally overlapping, categories of stream types and design approaches can be used to evaluate the appropriateness of the design techniques for a specific objective and site.

654.0701 Overview of channel design

A stable channel is often defined as a channel where the planform, cross section, and longitudinal profile are sustainable over time. While channel migration may not always be acceptable due to project or site constraints, it is important to note that a natural channel can migrate and still be considered stable, in that its overall shape and cross-sectional area do not change appreciably. Design methodologies and approaches may be used to estimate the conditions that may result in such movements. Design features are also often employed to reduce the frequency and magnitude of these changes.

Another common goal for a channel restoration design is that long-term aggradation and/or degradation should be small enough to allow for economical channel maintenance. Ideally, a channel should be self-sustaining and not require any maintenance. Many design methodologies can be used to design a channel which is in balance with the incoming sediment load. However, it is also important for the designer to recognize that manmade, as well as natural channels may aggrade or degrade over time or in response to specific storm events. Sediment impact assessments can be used to quantify what storm events may result in a sediment disequilibrium and to quantify the expected aggradation, so that appropriate maintenance can be budgeted. Design features can also be employed to counteract a tendency for bed degradation.

A variety of applicable open channel analysis and design techniques are available to the designer. The approaches used in open channel design range from those that apply to a natural stream restoration, to those that are more applicable to a strictly structural project. The specifics and details regarding the use and application of several analysis and design techniques are presented in subsequent chapters. This chapter provides a framework in which to evaluate these techniques. While techniques may have the same general objective, the specifics of their applicability should be understood before one approach is chosen over another. Where there is uncertainty regarding the appropriate technique to use, it is recommended that the designer consider several applicable techniques and look for agreement on critical design elements.

Each technique presented and described in this handbook has advantages and disadvantages. One approach may require more certainty in specific background information than another. In other situations, one approach may result in a type of channel which may not satisfy a given ecological goal, while another may result in a more expensive, but potentially more ecologically beneficial project. In addition, different analysis and design techniques are more appropriate for use on specific stream types and systems than on others. For example, some of the techniques are appropriate only for fixed-bed systems, while others are appropriate for mobile-bed systems. While all of the presented techniques have been successfully used, there are many examples where they have been misapplied and have resulted in projects which performed less than ideally.

Many papers and descriptions compare and contrast the different design methods and approaches that are presented in this chapter. The purpose of this document is not to evaluate each of the techniques as being more suitable than others, but to present the user with sufficient information to understand the application of the individual techniques. It is left to the user to review and assess the applicability of each of the techniques to the project site.

654.0702 Channel types

The nature of the interaction of the flows and sediments with the channel boundary should be used in the selection of the appropriate design approach. Channels can be divided into two general categories based on the sediment load and the stability of the channel boundary during normal flow. These two categories are threshold and alluvial channels. The general design approaches for each are defined and contrasted in this chapter. In subsequent chapters, specific design techniques are presented and described. Since there is not always a sharp demarcation between these two very broad categories, transition channels are also described.

(a) Threshold channels

A threshold channel is defined as a channel in which channel boundary material has no significant movement during the design flow. The term threshold is used because the channel geometry is designed such that applied forces from the flow are below the threshold for movement of the boundary material.

A threshold type of channel or stream includes cases where the bed is composed of very coarse material or erosion resistant bedrock. Streams where the boundary materials are remnants of processes no longer active in the stream system may be threshold streams. Examples are streambeds formed by high runoff during the recession of glaciers or dam breaks and streams armored due to reduction in the upstream sediment supply and degradation. Photographs of examples of threshold channels are provided in figures 7–1 through 7–3.

Fine sediment may pass through threshold streams as throughput or wash load. Generally, wash load should not be considered part of the bed-material or sediment load for stability design purposes even if there are temporary deposits on the streambed at low flow. However, throughput or wash load may be an environmental issue.

Threshold channels do not have the ability to quickly adjust their geometry, as do alluvial channels, because the material forming the channel boundary is not erodible within the normal range of flows, and there is no significant exchange between the sediment in transport and the bed. At flows larger than the design flow or

Figure 7–1 Gabion-armored threshold channel

Figure 7–2 Grass-lined threshold channel

Figure 7–3 Bedrock threshold channel

during extreme events, threshold channels may become destabilized for short periods, with harmful morphological impacts. Since threshold channels do not adjust their dimensions to the natural runoff hydrograph, the concept of channel-forming discharge is generally not applicable.

The design goal of a threshold channel design technique is to produce a channel that has positional or engineering stability. As long as the flows in the channel are below the design discharge, the particles that make up the channel boundary are stable, and the section, plan, and profile of the channel should be essentially static over time. The use of threshold design does not necessarily imply the absence of sediment movement, but rather that the transport capacity is sufficiently large to carry the sediment load through the system without meaningful deposition at boundary stresses less than those required to erode (mobilize) the boundary. For this reason, threshold channels are often designed near the erosion threshold of the boundary during design flows to prevent deposition that would change channel characteristics.

The reader should note that in some literature, the term threshold channel refers to a channel that is at the threshold of movement. In this case, these channels are also referred to as incipient motion channels. This defines a situation where the particles in the channel boundary are at the initiation of motion, not some point below movement. However, as defined in this handbook, the boundary of a threshold channel is below this point for flows up to the design discharge, not directly at the threshold of motion.

(b) Alluvial channels

Alluvial streams and channels have bed and banks formed of material transported by the stream under present flow conditions. There is an exchange of material between the inflowing sediment load and the bed and banks of the stream. The sediment transported in an alluvial channel tends to be coarser and of a larger amount than that transported in a threshold channel. Examples of alluvial channels are shown in figures 7–4 through 7–6. Since natural alluvial channels adjust their width, depth, slope, and planform in response to changes in water or sediment discharge, an alluvial channel will not be as static as a threshold channel.

Figure 7–4 Sand-bed alluvial channel

Figure 7–5 Sand and gravel-bed alluvial channel

Figure 7–6 Gravel-bed alluvial channel

Alluvial channel designs require an analysis of channel stability. An alluvial stream is defined as stable when it has the ability to pass the incoming sediment load without significant degradation or aggradation, and when its width, depth, and slope are fairly consistent over time. The design goal of an alluvial channel design technique is often to produce a channel that has dynamic equilibrium or geomorphic stability. Bank erosion and bankline migration are natural processes and may continue in a stable channel. When bankline migration is deemed unacceptable, then engineering solutions must be employed to prevent bank erosion. Bank protection technology is not addressed in this chapter, but a review of issues and design considerations are in NEH654.14.

(c) Transition channels

A clear distinction between threshold and alluvial channels may not always be apparent. One reach of the stream may be alluvial, while another has the characteristics of a threshold channel. A threshold reach can be changed to an alluvial reach by flattening the slope. A stream may be alluvial at low discharges when there is an adequate sediment supply, and then act like a threshold channel at high discharges. Conversely, a channel may function as a threshold stream at low flows, but during very high discharge become mobile. An example is shown in figure 7–7. In these situations, it is often appropriate to apply both threshold and alluvial channel design techniques.

If an armor layer is present, a stream may be a threshold channel at low flows and on the rising limb of a flood hydrograph, but behave as an alluvial channel at high flows when the armor layer is mobilized, and on the falling limb of the flood hydrograph, when sediment is being deposited. Therefore, it is important to evaluate channels through their entire flow range to determine how they will react to natural inflow conditions and how their stability status may change as a function of discharge.

The armor layer of a gravel bed stream is shown in figure 7–8. Note the much finer subsurface bed material exposed when a few cobbles were removed from the armor layer. Armor layer thickness is typically equal to the D_{90} particle size of the subsurface material. Figure 7–9 shows an armor layer that had formed on the delta of a reservoir and then was destroyed when the water level was lowered.

Figure 7–7 Boulder-bed channel that could be a threshold channel or an alluvial channel, depending on the design discharge

Figure 7–8 Subsurface layer exposed after removal of three cobbles from the armour layer

Figure 7–9 Degradation through armor layer

654.0703 Perennial, intermittent, and ephemeral streams

The flow conditions that a channel may experience through the year may also have an influence on the choice of the appropriate channel design technique. Both threshold and alluvial streams may be classified as perennial, intermittent, or ephemeral, depending on the duration of flow over the course of the year. Definitions of these terms are not precise. Following are stream definitions that have been used by the U.S. Geological Survey (USGS) since the early 1920s (Meinzer 1923):

Perennial—A stream that flows continuously. Perennial streams are generally associated with a water table in the localities through which they flow.

Intermittent or seasonal—A stream that flows only at certain times of the year when it receives water from springs or from some surface source such as melting snow in mountainous areas.

Ephemeral—A stream that flows only in direct response to precipitation, and whose channel is above the water table at all times.

A perennial stream is one that almost always has some flow. Osterkamp and Hedman (1982) provide a more definitive definition.

> *A perennial stream is a stream that exhibits a measurable surface discharge more than 80 percent of the time.*

Intermittent streams may be differentiated from ephemeral streams in that intermittent streams flow continuously for periods of at least 30 days. An intermittent stream flows only seasonally or sporadically. At times, the flow may infiltrate into the pores of the bed and flow only as ground water. An ephemeral stream generally flows only after a significant rainfall event. Channel processes and morphology are significantly affected by the fact that the discharge is intermittent.

The concept of channel-forming discharge is most applicable to perennial streams. Channel geometry in alluvial intermittent and ephemeral streams is typically a remnant of the last major flow event, rather than a theoretical channel-forming discharge (fig. 7–10). In addition, in ephemeral streams, sediment transport most often occurs as a response to infrequent and flashy hydrologic events. These events cause temporal and spatial episodes of aggradation and degradation and a significantly variable sediment yield. Channel reaches under such flow conditions can be out of phase, and this episodic behavior suggests that ephemeral stream channels may be inherently unstable. Thus, the channel-forming discharge concept may not be applicable.

Figure 7–10 Remnant terraces in an ephemeral stream from previous high-flow events

654.0704 Channel design variables

Traditional channel design methods for fixed-boundary or threshold channels focus on efficient flow conveyance where water surface elevation and velocity are of primary importance. The independent hydraulic design variables are the design discharge and channel roughness. The dependent hydraulic design variables are width, depth, and slope. Channel roughness is a dependent variable if there is a choice of boundary materials. In channel design, these dependent variables are adjusted to achieve the desired hydraulic conditions. Attention is given to the hydraulic losses due to changes in the channel configuration and obstructions such as bridge piers and culverts. Hydraulic design can be accomplished using the energy or momentum equations, in conjunction with a resistance equation such as Manning's equation. The channel boundary is assumed to be immobile at the design discharge, and bed-material sediment inflow is negligible. Traditional methods are applicable for the design of flood control, drainage or irrigation channels lined with a nonerodible material, such as concrete or grass, and for earth channels and ditches with bank protection and little or no sediment inflow. Traditional methods can also be used for design and analysis of natural streams, where the stream boundary is immobile.

Channel design becomes more complicated in alluvial channels, where the bed is mobile and where bed-material sediment inflow is significant. In addition to water surface elevation, efficient transport of sediment becomes a focus in the hydraulic design of alluvial channels. Alluvial streams have the capability to adjust their channel geometry to efficiently transport sediment. The design process seeks to achieve a state of dynamic equilibrium by computing and selecting appropriate values for channel geometry. In some cases, site or project constraints make the ideal channel geometry infeasible. In such cases, erosion control features may be designed or sediment removal maintenance plans implemented.

The independent hydraulic design variables for an alluvial stream include the inflowing discharge hydrograph, bed-material gradation, streambank characteristics, and sediment inflow. The dependent hydraulic design variables for an alluvial stream are width, depth, slope and planform. Hydraulic roughness is generally a function of the bed material, but bank roughness may be considered a dependent variable in some cases. These dependent variables must be selected so that the channel will pass the incoming sediment load without significant degradation or aggradation.

In addition to the energy or momentum equations and a hydraulic resistance equation, a sediment transport equation is needed to calculate appropriate hydraulic geometries. A geomorphic relationship from a reference reach or a selected hydraulic geometry relationship is also required. In some cases, where the existing channel is stable and watershed characteristics are not changing, channel dimensions can be based on a preexisting condition. The design is more challenging when the project reach is unstable due to straightening, channelization, or changing hydrologic or sediment inflow conditions, as is the case in most land use conversion areas. The characteristics of threshold and alluvial channels are summarized in table 7–1.

Table 7–1 Characteristics of threshold and alluvial channels

	Threshold channel	**Alluvial channel**
Channel boundary	Immobile at design discharge	Mobile
Bed-material sediment inflow	Usually small or negligible	Significant
Dependent variables	Width Depth Slope Roughness, if there is a choice of boundary materials	Width Depth Slope Planform Bank roughness Roughness due to obstructions or structures
Independent variables	Design discharge Channel roughness	Design hydrograph Channel-forming discharge Bed-material sediment inflow Bed material Streambank characteristics
Design equations	Energy Momentum Resistance	Energy Momentum Resistance Sediment transport Geomorphic relationship
Design goal with respect to channel stability	Pass the design discharge below the top of bank without mobilizing the boundary	Pass the incoming sediment load without significant aggradation or degradation or planform change

654.0705 Channel design methods and approaches

Channel design approaches can be broadly categorized by their applicability to threshold or alluvial channels. For threshold channels, the recommended design method will provide a stable channel boundary that will not unravel. This is accomplished for a design discharge and a specified channel boundary material. Channel cross-sectional dimensions and channel slope are selected, and velocities and/or shear stresses are calculated iteratively, using the energy or momentum equations and a hydraulic resistance equation, so that calculated values do not exceed acceptable critical values. Hydraulic design methods for threshold channels are well established and available from several sources. The most significant methods are reviewed in NEH654.08. Two methods are recommended for the hydraulic design of threshold channels: the allowable velocity method and the allowable shear stress method. In general, the allowable velocity method is most applicable when the channel will be lined with a variety of different materials, while the allowable shear stress method is often applied in the design of gravel-bed channels. Neither of these methods provides unique solutions for channel dimensions of width, depth, and slope. However, this limitation is not critical to the hydraulic design in terms of stability because the boundary is immobile.

For alluvial channels, hydraulic design methods require sediment transport analysis to ensure sediment continuity through the project reach. The recommended design methodology suggests analytical solutions of resistance and sediment transport equations, in combination with application of fluvial geomorphic principles. When possible, alluvial channels are sized for the channel-forming discharge.

The recommended design method generates a preliminary channel geometry that can transport the incoming water and sediment load for the selected channel-design discharge. Development of this preliminary or initial design geometry is based on a single discharge, the channel-forming discharge. The design philosophy for alluvial channels is to use appropriate fluvial geomorphic principles combined with analytical equations for flow resistance and sediment transport to solve for the dependent design variables of width, depth, slope, and planform. Geomorphic principles that can be used with the analytical equations include analogy methods, hydraulic geometry, and the extremal hypothesis. Project constraints often narrow the range of feasible solutions. Alluvial channel design techniques are addressed in more detail in NEH654.09.

The long-term stability of the preliminary channel design is evaluated using a flow-duration curve or a long-term hydrograph that includes the full range of discharges. Sediment impact analysis is described in NEH654.13. Design adjustments may then be made to the channel design based on issues related to stability, flood effects, and sedimentation. Characteristics of the hydraulic design philosophies for threshold and alluvial channels are shown in table 7–2.

Table 7–2 Hydraulic design philosophies

	Threshold channels	Alluvial channels
Design discharges	Maximum design discharge	Channel-forming discharge Flow-duration curve and/or long-term hydrograph
Design criteria	Critical velocity/shear stress	Continuity of sediment
Dependent variables	Width, depth, and slope (roughness if there is a choice of boundary material)	Width, depth, slope, planform, bank roughness, and roughness due to obstructions or structures
Design equations	Energy, momentum, and hydraulic resistance	Energy, momentum, hydraulic resistance, sediment transport, and geomorphic relationship

Some of the analysis, which is based on a threshold assumption, is also used in the design alluvial channel. Some of the degrees of movement that an alluvial channel may undergo may not be permissible. Hard or threshold design techniques may be used to restrict stream movement towards a road or a building, for example. Threshold methods are also used to design stream features such as toe protection, riffles, spurs, barbs, vanes, and deflector dikes. The use and design of these features are described in NEH654.14.

Threshold channels are designed so that the streambed is immobile for the full range of natural discharges, as long as these discharges are below the design flow. In alluvial channels, it is important to determine the discharge at which the streambed begins to move. This can be accomplished using the threshold criteria described in NEH654.08 and is especially important in a channel with an armor layer. Sediment transport capacity dramatically increases when the armor layer is disrupted or destroyed, and the coarse material becomes thoroughly mixed with the substrate material. Stability of vegetated or gravel banks can be determined using allowable velocity methods or shear stress methods. A mobile streambed is not necessarily unstable, but mobile beds require a higher level of analysis to determine stability, within the context of the limitations or requirements of the design.

(a) Analogy method

The analogy method is used to select channel dimensions and is based on the premise that conditions in a reference reach with similar characteristics and watershed conditions can be copied to the project reach. The method can be used for both threshold and alluvial channels, but if used for threshold channel design, bed stability in the project channel should be checked using threshold methods. For alluvial channels, the analogy method is used to select one of the primary dependent design variables of width, depth, or slope (preferably width). The design width is adapted from a selected reference reach, and the remaining two variables are calculated, using hydraulic resistance and sediment transport equations.

Planform can also be determined using the analogy method. The reference reach must be stable and alluvial and have the same channel-forming discharge as the project reach. A stable channel is one in which the stream's planform, cross section, and longitudinal profile are sustainable. Channel features may migrate laterally and longitudinally. The reference reach may be upstream or downstream from the project reach, or in a physiographically similar watershed. The bed and banks in the project and reference reaches must be composed of similar material, and there should be no significant hydrologic, hydraulic, or sediment differences in the reaches.

If a stable predisturbance width and planform can be identified, then the preexisting channel dimensions can be used with the analogy approach. This is feasible if historical width and planform can be determined from mapping, aerial photos, and/or soil borings. This technique is generally not applicable if the watershed water and sediment runoff characteristics or the base level have changed over time.

(b) Hydraulic geometry method

A suitable hydraulic geometry relationship can be used to select a value for one of the dependent variables for the channel-forming discharge. The hydraulic geometry method is similar to the analogy method, but it is more useful because a range of discharges is used. Hydraulic geometry theory is based on the concept that a river system tends to develop in a predictable way, producing an approximate equilibrium between the channel and the inflowing water and sediment (Leopold and Maddock 1953). The theory typically relates a dependent variable, such as width or slope, to an independent or driving variable such as channel-forming discharge or drainage area.

Hydraulic geometry relations are sometimes stratified according to bed-material size, bank vegetation, or bank material type. Rosgen (1998) suggests the use of stream classification as an appropriate tool for differentiating hydraulic geometry relations. Hydraulic geometry relationships are developed from field observations at stable and alluvial cross sections. These relationships were originally used as descriptors of geomorphic trends. Data scatter is expected about the developed curve, even in the same river reach (as described and shown in NEH654.0905. It is important to recognize that this scatter represents a valid range of stable channel configurations due to variables such as geology, vegetation, land use, sediment load and gradation, and runoff characteristics. The transfer of hydraulic geometry relationships developed for one watershed to another watershed should be performed with extreme care. The two watersheds should be similar in historical land use, physiography, geology, hydrologic regime, precipitation, and vegetation.

Both the hydraulic geometry method and the analogy method depend on comparison to channels that are fully adjusted. Specifically, the reference reach, or a channel whose dimensions are used in a hydraulic geometry plot, are not evolving to a different form. If the watershed in which the channel to be designed is likely to change due to changes in water and sediment supply, this assumption can be problematic.

(c) Analytical method

Once one of the dependent design variables (preferably width) is determined using analogy or hydraulic geometry methods, the other two dependent design variables (depth and slope) should be calculated using an analytical, or computational, method. This is accomplished using one of several resistance and sediment transport equations available in the literature. If the resistance and sediment transport equations are solved simultaneously for a specified channel-forming discharge, a family of solutions can be calculated.

The analytical solution for depth and slope that matches the analogy or hydraulic geometry solution for width provides the three dependent design variables. The analytical family of solutions can also be used without the analogy or hydraulic geometry methods to determine the third dependent design variable. The wide range of possible solutions from the analytical calculations can be narrowed by the assigned project constraints. For example, a maximum width constraint might be imposed by right-of-way limits, and a maximum depth constraint might be imposed by flood control considerations. The valley slope would impose a maximum slope constraint. Another approach is to assume that the channel will form its geometry such that the minimum amount of energy is expended. This assumption will provide a unique solution at the minimum slope on the family of solutions.

Characteristics of the analogy, hydraulic geometry, and analytical design methods are summarized in table 7–3.

Table 7–3 Characteristics of analogy, geometry, and analytical hydraulic design methods

	Basis	**Requirements**	**Recommended for determination of**
Analogy	Channel dimensions from a reference reach can be transferred to another location	Reference reach must be stable and alluvial Reference reach must have same channel-forming discharge, valley slope, and similar bed and bank characteristics	Top width of channel-forming discharge channel and planform
Hydraulic geometry	Channel dimensions can be determined from regression relationships with independent variables	Regression curves must be developed from stable and alluvial reaches and from physiographically similar watersheds	Top width of channel-forming discharge channel and planform
Analytical	Depth and sediment transport can be calculated from physically based equations	Estimates of bed-material gradation and resistance coefficients must be obtained	Depth and slope

(d) Hybrid design techniques

Several techniques are available that include a combination of analytical, as well as analogy and hydraulic geometry design methods. Two of these techniques are presented in this handbook.

NEH654.10 presents a two-stage channel design approach for drainage ditches. This is a modification of many of the commonly used threshold design techniques to provide a floodway bench. The intent of this technique is to better mimic alluvial processes by providing a flood plain within the ditch.

NEH654.11 outlines a channel design technique based on the morphological and morphometric qualities of the Rosgen classification system. This approach is often referred to as the Rosgen design approach. The essence for this design approach is based upon measured morphological relations associated with bankfull flow, geomorphic valley type, and geomorphic stream type.

654.0706 Sediment impact assessment

The energy of flowing water constantly reconfigures the physical form of flood plain and stream habitats, primarily through modification of alluvial topography by fluvial action. However, to maintain an equilibrium of channel structure and function, especially in the context of riverine fisheries habitat, natural mechanisms that supply, transport, and deposit watershed materials must remain operative along the river continuum, from the basin to the reach-level scale. Alluvial and threshold channels maintain channel geometries that reflect the quantity of water and the size and characteristics of sediment delivered to them from their drainage basins. Maintenance of channel form and function requires that all of the mass and sizes of sediment supplied to the channel be transported in equilibrium, so that over the long term, the channel neither aggrades nor degrades.

A sediment impact assessment should be conducted for all projects involving changes to the existing channel or the creation of a new channel. This can be accomplished using visual or qualitative assessments for relatively simple projects or by using a numerical model that incorporates solution of the sediment continuity equation for more complex projects. The choice of the appropriate technique to assess the sediment impact of a proposed project includes an assessment of not only the project goals, type of channel, and watershed condition but also an assessment of the impact of project failure. Sediment impact assessments are described in more detail in NEH654.13.

654.0707 Conclusion

The following channel design chapters of this handbook present and describe several systematic hydraulic design methodologies and design techniques. The objective of each of these methodologies is to fit the channel design into the natural system within the physical constraints imposed by other project objectives and constraints. Some techniques are more appropriate for conditions where the design channel boundary is expected to be immobile at design flows, while others are more applicable to conditions where the design channel is expected to be in dynamic equilibrium with its sediment load.

Where appropriately applied, each of the presented design methodologies should be systematic; that is, when used by different engineers with the same project objectives, design results should be similar. However, since each technique is based on different assumptions and is applicable to different conditions, it should not be expected that all of the techniques will result in exactly the same design. The technique or approach that is selected should be appropriate not only for the project goals but also the nature of the sediment-flow exchange with the channel boundary. The physical principles upon which these approaches are based are outlined in the following chapters. The user should evaluate these to determine the applicability to the project specific site. Where there is uncertainty in the nature of the channel and the appropriateness of the design technique, many designers use several techniques and look for agreement on critical design elements.