# An Overview of Factors Affecting River Stability

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ABSTRACT

Anticipating the potential for and recognizing the existence of channel instabilities is a critical aspect of locating and designing highways in river environments. Channel instabilities include oscillations in channel-bed elevation, variations in river orientation and location, and major river migrations or meanders. Factors affecting river stability have been classified as natural or accelerated. Natural instabilities result from changes in hydrometeorology whereas accelerated erosion is usually a result of man's activities within the watershed. Identifying channel instabilities requires an understanding of the geomorphic processes occurring within the watershed in question and an awareness of all activities that affect it. A thorough analysis of the stability of the river system should include consideration of past changes in the system and changes in progress, as well as a geomorphic analysis to predict future changes.

Rivers are dynamic, open systems--dynamic because they are constantly changing and open because they can be significantly influenced or changed by a variety of external forces and factors. They are a complex combination of physical parts working together to form a whole. The dynamic nature of rivers and factors influencing their geometric stability are discussed in this paper.

The amount of water flowing in a river at an instant is variable. Some rivers carry no flow during dry times, but virtually all rivers experience episodes of flooding. The amount of material or sediment transported also fluctuates constantly. Although these changes are usually understood and anticipated in designs, other changes are not. These other changes include oscillations in channel-bed elevation, variations in river orientation and location, and major river migrations or meanders within the valley. Figure 1 illustrates dramatically the changes in channel geometry that can take place. These changes in channel geometry, location, and planform should be of primary interest to the highway engineer designing in river environments.

It is important that engineers designing in river environments recognize and anticipate channel instabilities. A background and approach for recognizing river instabilities are provided in this paper. It starts by discussing geomorphic erosion processes to provide a knowledge of the physical processes involved and to allow for a proper interpretation of channel instabilities. This is followed by discussions of natural and man-induced causes of channel instabilities. Finally methods for identifying channel instabilities are covered. Each of these items is discussed in more detail by Brown (1).

## GEOMORPHIC EROSION PROCESSES

The hydraulic geometry of a river system (i.e., its width, depth, and planview form) is a function of the external constraints applied to the particular system. These external constraints include water discharge, sediment discharge, valley slope, and those constraints imposed by the region. During the design life of a typical engineering project, the valley slope and geologic constraints can be assumed to be constant; however, the water discharge and the sediment discharge cannot, because water and sediment discharges will vary with every flow event. Because the hydraulic geometry of a channel is a function of these dynamic elements, a river system will attempt to adjust its geometry in response to these changing conditions to maintain or create a condition of dynamic equilibrium with respect to its own water and sediment load and channel makeup. The geomorphic approach then, looks at channel bank erosion as a natural mechanism of the system to maintain its own equilibrium. The following sections will consider how the flow of water and sediments in alluvial channels affect channel width, depth, and sinuosity.

### Functional Relationships

Geomorphic proportionalities that describe functional relationships between the water and sediment load of a channel and the resulting channel size, shape, and sinuosity have been examined by numerous authors. Notable among these are Leopold et al. (2), Lane (3), Schumm (4), and Simons and Senturk (5). More recently a review of these relationships was presented by DeCoursey (6). To demonstrate the effect of changes in flow and sediment load on channel morphology, the geomorphic relationships can be summarized by Equations 1-5.

$$W \sim Q, Q_s \tag{1}$$

$$w/d \sim Q_s \tag{2}$$

$$d \sim Q \tag{3}$$

$$S_c/D_{50} \sim Q_s/Q \tag{4}$$

$$P \sim S_v/Q_s \tag{5}$$

where

- $W$ = stream width,
- $Q$ = water discharge,
- $Q_s$ = sediment discharge,
- $d$ = stream depth,
- $S_c$ = channel slope,
- $D_{50}$ = mean sediment size,
- $P$ = sinuosity, and
- $S_v$ = valley slope.

These equations are simplified approximations of complete power relationships. In their simplified form, however, they can be used to look qualitatively at changes that can be expected to develop in response to fluctuations in water and sediment load.

Water and sediment discharges are rarely constant, and Equations 1-5 indicate that channels are constantly trying to adjust their width, depth, and planview form. This is true from a morphologic point of view. From a practical engineering standpoint, however, a quasi-equilibrium channel geometry can be defined based on dominant sediment and water discharge conditions. The dominant channel form is that

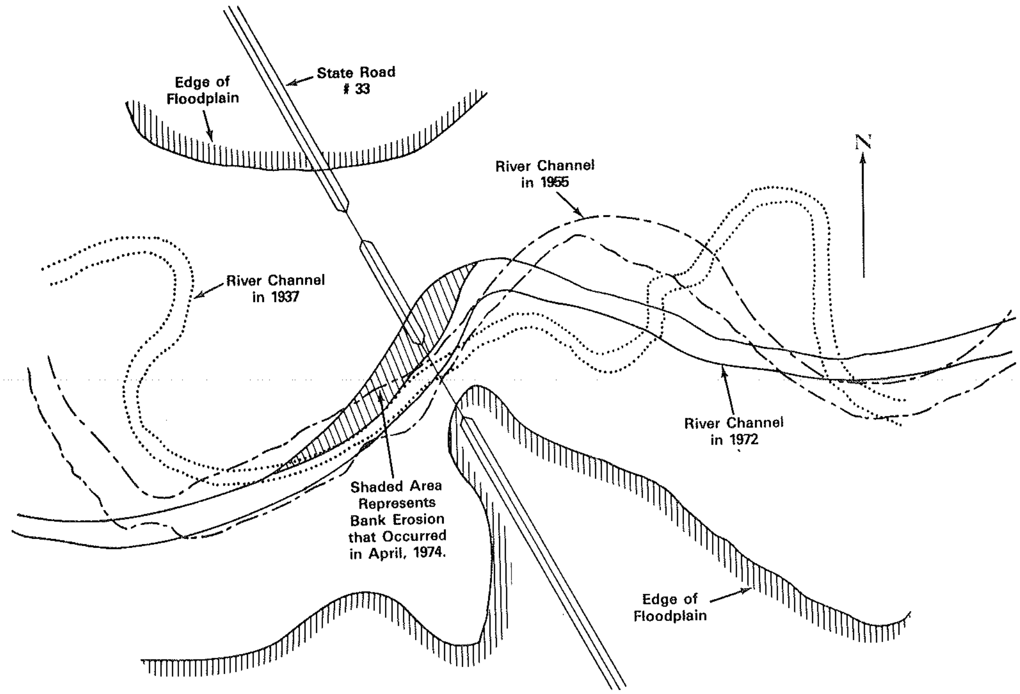


FIGURE 1 Shifts in channel pattern of the Homochitto River at Rosetta, Miss.

which is evident from aerial photography and maps. The stability of this quasi-equilibrium channel form is of primary concern to the engineer designing structures in the vicinity of a river channel.

As mentioned previously, the quasi-equilibrium channel form (that is, its width, depth, and plan view geometry) is a function of dominant sediment and water discharge conditions. The notation of flow frequency plays an important role in defining these dominant conditions. It has been suggested that these dominant conditions be defined as the discharge conditions equaled or exceeded on 0.6 percent of the days of record (or 1 day out of 170 days) (7).

Thus shifts in these dominant conditions (i.e., changes in the frequency distributions) will threaten the stability of a given channel reach in accordance with Equations 1-5 (using dominant values of $Q$ and $Q_s$ as the variable). Equations 1-5 can be used to signal changes in the plan view form or geometry of a channel based on short- or long-term changes in dominant values of $Q$ and $Q_s$.

To provide a better understanding of the geomorphic proportionalities presented in Equations 1-5, the following section will look at the geomorphic processes described in the equations, consider some of the more common causes of morphologic imbalance, and explain typical system responses to these events.

## Geomorphic Response

Three geomorphic responses or processes can result from changes in dominant channel flow and sediment conditions. These are channel widening, channel deepening, and changing plan view form (a change in sinuosity or meander pattern). All of these responses will cause some level of streambank erosion.

Channel widening is evidenced through an increase in channel width, with or without an increase in channel depth. Consideration of Equation 1 indicates that an increase in flow or sediment discharge results in a tendency toward channel widening. When both sediment discharge and flow increase, however, the channel section can be expected to increase its depth as well as its width (see Equations 2 and 3). When only sediment load increases, width increases but the depth may decrease. In this case the channel is said to be aggrading, implying that the channel has filled in because of an excess of sediments.

Channel deepening is a process of channel degradation that increases the depth of the channel. Channel degradation can cause bank instability by producing a steeper bank angle. Whether or not instability actually occurs is a function of the properties of the bank materials and the original bank geometry. Channel deepening results from increased flow without an appreciable increase in sediment discharge (Equation 3). Increased flow rates can result from an overall increase in the volume of water moving through the channel or an increase in channel slope.

Changing plan view form includes changes in channel shape and position as viewed from above. Changes in plan view form are most often exhibited through the downstream migration of meandering bends and changes in the sinuosity of meander bends. Other examples include the shifting of channels and the cutting off of meander bends. Generally these changes are manifested by an adjustment of channel slope to conform with changes in flow or sediment discharge. These changes can be illustrated through an evaluation of Equations 4 and 5.

Equation 4 indicates that either a reduction in sediment discharge or an increase in water discharge will result in a reduction of the channel slope. These slope reductions result in increased channel sinuosity and/or channel-bed degradation; both of which lead to a tendency toward increased bank erosion. Also, Equation 5 indicates that a reduction in sediment discharge will result in an increase in channel sinousity, again, leading to increased bank erosion.

It is important to recognize that the three geomorphic processes just discussed (channel widening, channel deepening, and changing plan view form) are often interrelated and can occur simultaneously or in sequence. For example, adjustments in channel slope through degradation often are accompanied by increases in channel sinuosity and bank caving or channel widening. Also, the initiation of a given process at a particular site may initiate another process either upstream or downstream. For example, an aggrading channel reach can cause an increase in sinuosity in a downstream reach.

As indicated, shifts in dominant flow conditions cause the geomorphic responses discussed. Shifts in dominant flow conditions can result from either natural or man-induced causes. Recognizing the occurrences that can trigger channel instabilities is a first step in dealing with the problem of channel instability. The more common causes of natural and man-induced or accelerated erosion are discussed in the following sections.

NATURAL EROSION

Natural erosion results from natural occurrences such as normal fluctuations in hydrologic conditions, extended drought or rainy periods, as well as single, extreme storm events. All of these events can cause short-term shifts in the magnitude of the dominant flow conditions, resulting in the adjustments in channel form previously described. For example, extended periods of high flow will cause a temporary shift in dominant discharge levels and possibly a corresponding upward shift in dominant sediment load conditions as well. Previous discussions indicated that these changes result in tendencies toward increased channel widths and depths, as well as a reduction in channel sinuosity. The reduced sinuosity results in a trend to shift meander bends downstream. Each of these responses will increase tendencies toward bank erosion. Similar responses are characteristic of single-flow events as well.

Conversely, consider extended drought periods and the corresponding reductions in flow and sediment transport rates. Equations 1-5 indicate that under these conditions, reductions in channel width and depth and an increase in sinuosity could be expected. Because of the reduced flow conditions, these responses occur within the confines of the dominant channel banks and thus do not pose any significant erosion hazards.

Channel modifications resulting from natural erosion processes include the gradual downstream migration of channel bends and channel avulsions, such as the development of meander cutoffs. When meander cutoffs occur, they can result in extensive reshaping of upstream channel networks. The sudden increase in channel slope that results when a cutoff occurs will result in upstream channel degradation and a tendency toward increased meander activity, both of which will affect channel bank stability.

The extent and rate of change due to the occurrence of a channel cutoff will be relative to the amount of increase in slope produced. If the stream has a relatively flat slope the cutoff would produce a very small increase in stream slope and, therefore, the impact would be lessened. Any changes in response to the new impact(s) would be correspondingly less severe and would occur over longer periods of time.

Natural erosion processes often are difficult to anticipate because they are so dependent on hydrologic events. A seemingly stable river system could suddenly become unstable as a result of a prolonged period of high flow or a single excessive storm event. The uncertain nature of hydrologic events makes it difficult to anticpate such occurrences.

ACCELERATED EROSION

Accelerated erosion can result from some human activity within the watershed that influences flow and sediment transport rates and, thus, morphologic erosion processes. Human activities that influence morphologic erosion processes include agricultural activities, urbanization, construction activities, streambed sand and gravel mining, interbasin water transfers, and reservoir development and operation. Human activities are the most common causes of channel instabilities and, in general, are more widespread and of greater magnitude than natural erosion. Because accelerated erosion is associated with human activities, it often is possible to anticipate any impact on bank stability and provide adequate bank protection in advance. The following discussions will examine the ways that each of the activities mentioned previously affects channel morphology.

Agriculture-related activities include cultivating and harvesting crops, and grazing cattle and other animals. Deforestation and related activities also are included as agricultural activities. The general result of agricultural activity is toward increased peak flows and increased sediment yield. The result will be toward an increase in channel width and a reduction in overall channel sinuosity. Additionally, the grazing of animals along streambanks reduces the vegetative cover, and the continual movement of animals up and down the streambanks can have a significant effect on bank stability.

Stream-channel straightening is another activity that has been associated with agricultural activity in the past. In the early 1900s channel straightening was a common practice in the central and southern agricultural states to make available additional farmlands along the meandering channels of the region. These activities greatly increased the channel slopes of the modified channels. Currently the geomorphic response in these regions is extensive channel-bed degradation and accelerated meander activities. Both of these responses are a result of attempts by the channel to readjust to its previous slopes.

Urbanization normally causes significant increases in the magnitude of runoff events while reducing their duration. Fully developed urban areas are also low sediment producers because of the large percentage of land covered by impervious surfaces. As a result, urbanization reduces the sediment inflow to a river. The combination of the increased peak runoff rates and the reduced sediment loads will result in channel degradation, channel widening, and a reduction in channel sinuosity. Each of these activities will contribute to increased meander activity.

Construction activities are known to increase discharge and sediment loads. The increased discharge (or runoff) results from clearing and grubbing activities that strip away the vegetative cover, which normally acts as a flow retardant. Removal of the vegetative cover (as well as grading and other construction activities) bares and disturbs the soil, accelerating the erosion process and increasing sediment yields to tributary streams. The response of the system to the increased discharge is to increase its width and reduce its meander radius. The response to the increased sediment load is a building up of the channel base level, which when combined with the increased discharge level, will result in accelerating the tendency for channel banks to erode. However, because construction activities usually are temporary, these system responses will be short lived.

Streambed mining is another activity that upsets the natural balance in a river environment. Sand and gravel mining activities affect the sediment movement and supply in a channel system. Excess mining produces both a steeper energy slope in the vicinity of the operation and a reduction in sediment load downstream from the operation. Both of these activities increase the energy available in the water discharge downstream from the mining operation, which increases the potential for bank erosion.

Interbasin transfers of flow are becoming more and more common as the demands on water resources increase. Diverting flow from one basin to another will increase both the magnitude and duration of flows in the receiving channel. Here again, the channel will respond by attempting to increase its dominant width and depth and reducing its sinuosity. These responses will result in a period of channel instability and bank erosion until the new channel regime is established.

Reservoir development and operation for storage and flood control also has an impact on downstream bank stability. Reservoirs trap the incoming sediment load and release clear-water discharges. The clear water released has a higher energy level, because it is not carrying sediment. In an attempt to reduce the energy level, the flow stream will attack the channel bed and banks, producing both degradation and lateral instability. Besides trapping the sediment load, regulating the reservoir also changes the downstream flow characteristics. To satisfy requirements for generating power as well as for irrigation and navigation, reservoir regulation policies encourage higher sustained downstream discharges than was characteristic before regulation. The increased duration of these higher discharges will produce tendencies toward bank erosion. Reservoir operations, particularly for generating hydropower, produce sudden stage fluctuations, which result in saturation and draining cycles on downstream channel banks.

## IDENTIFYING CHANNEL INSTABILITY

The goal of any evaluation of stream stability is to detect change and interpret the associated threat to the highway stream crossing or the highway encroachment on the floodplain. The previous discussions indicated some of the more common causes of channel instability. An awareness of the factors that can cause instability is important in identifying channel instabilities. An approach for recognizing river system stability problems includes regional awareness, awareness of natural processes and activities that affect stability, and data collection and analysis procedures. These three topics indicate that the evaluation processes for detecting change have become more sophisticated. Changes that herald instability include long-term and persistent changes in energy gradient, streambed elevation, stream sinuosity, streambed form and material size, stage versus discharge relationships, sediment transport, and similar physical indicators of a variable and troublesome river.

### Regional Awareness

Awareness of the region indicates a knowledge of the stability of river systems within the same geomorphic region. It is probably a more useful tool for new highway stream crossings where there is a need to anticipate and recognize the potential for future problems. Problems at an existing structure scheduled for reconstruction or repair are more apparent and will usually be accompanied by a problem history.

Many regions in the United States are prone to gradation problems that, with few exceptions, are caused by streams that flow through valleys or regions composed of fine alluvial material. Most bridge crossings near the lower Mississippi River suffer from some type of gradation problem, and this is also true for western Tennessee and the Missouri River and its tributaries.

A review of local experiences and problems with existing structures and stream crossings can reveal whether a river or the region is prone to channel instabilities. An absence of problems in the past would suggest that none are likely in the future, provided similar design standards are followed. However, the bridge or hydraulic engineer faced with repeated or prolonged lateral and bank erosion, local or general scour, problems with debris, fill, and gradation, must carry the evaluation process further.

### Awareness of Activities and Geologic Processes that Affect Stability

As discussed earlier in this paper, there are many activities and geologic processes that affect channel stability. As indicated, human activities within a watershed play a major role, and quite often are the culprit, in cases of channel instability. The importance of these activities on the character, stability, and hydraulic hazards occurring in streams dictates that an attempt be made to identify and consider them during analysis.

Two types of activities affect channel stability: direct instream and watershed characteristics. It is commonly accepted that instream activities have profound effects on stream stability. The principal causes for instability are streambed mining, major channel realignments, and dams. The 110 case histories of problems with stream stability that were analyzed by Keefer et al. (8) illustrate the overriding influence of man's activities. With only two exceptions, the problems presented in the case histories were caused or heavily influenced by attempts to change some aspect of a river's natural morphology.

In addition to examining ongoing processes, it is desirable to communicate with organizations likely to create problems. Government agencies such as the U.S. Army Corps of Engineers plan projects well in advance. Impacts of their activities can be anticipated and accounted for with proper planning. Impacts from the private sector such as gravel mining or changes in land use may be harder to anticipate.

Although instream activities are easier to identify, watershed characteristics can also have immediate and far-reaching effects, and they account for many of the drastic changes that have occurred in streams. Watershed characteristics that affect channel stability include changes in hydrometeorologic conditions and land use. Changes in land use are the most common, and can be related to agriculture or to urbanization and construction activities. Because changes in watershed characteristics usually take more time to develop than instream activities, the subsequent hydraulic hazards develop more gradually. Instability resulting from watershed changes, however, is often more pervasive and more difficult to protect against than instream hazards.

The ever present condition of natural geologic and geomorphic processes must accompany the awareness of problems resulting from human activities. Brice and Blodgett (9) developed a detailed classification scheme oriented primarily toward lateral stability of rivers as summarized in Figure 2, which provides an excellent quick-reference guide to the types of alluvial channels. The indication of stability for each of the various types of streams (e.g., meandering, braided, incised) shown in the figure are discussed at length in that report and by Brown, McQuivey, and Keefer (10).

Analysis of river system stability must include an examination of the river both at the crossing site and upstream and downstream to determine what processes, conditions, and impacts are likely to cause adverse consequences. Comparing these with recognized problem-producing thresholds and damaging responses of the river system can provide insights into whether problems related to stream stability are present at the site.

## Data Collection and Analysis Methods

An awareness of the activities that affect stream stability will provide valuable clues for detecting the presence of stability problems as described previously. Not all engineers, however, will be comfortable with these techniques. In any case, a direct verification of unstable conditions is necessary, and several ways to identify gradation problems and erosion processes are available.

Verification of an unstable river condition is difficult from two standpoints. First, the time span is usually long. Perception of change in riverine conditions is limited by the quality of records or knowledge of prior conditions. The progression of changes to date is the primary indicator of what the future holds. Second, the changes occur in the channel bottom, at remote locations, and often are not persistent. Perennial streams cover the channel bottom and little notice is taken of gradation processes. Natural flow variations and flow regulation vary the depth frequently and only systematic records averaged over long periods will draw attention to the problem. Local scour and contraction scour problems can be obscured by aggradation as the flood flow recedes. Point bars and other fluvial indicators of stability problems may relocate with even minor flows and disarm the uninitiated observer.

Casual observation is not an adequate way to detect problems. Trouble is often not evident until piling supports erode out of the channel bed. Even then the problem may not be detected if the bridge is visited only at high flows or subsurface inspections are not made. Inspection procedures seldom include space or even a checklist for hydraulic and erosion problems, and trouble is often not reported until irreversible damage is sustained.

The data collection and analysis methods used for a particular site will vary with the required level of effort. The level of analysis chosen for a job will be a function of several considerations including instability indicated by awareness, size and character of the river system, cost of the project, availability of requisite data, expertise of persons conducting the analysis, and potential economic and social consequences of damage. An effort to attain balance must guide the level of analysis.

Detection of stability problems requires analysis of either newly compiled or existing data and evidence obtained over periods of several years. It is necessary to determine by some means the change in streambed form, meander patterns, elevation of the channel bottom and/or water surface elevation for a given discharge as a function of time. In some instances knowledge of sediment load or streambed material size may be desirable. A history of each site should be created and evaluated. Techniques for collecting and evaluating data may vary depending on whether interest is in new design or remedial measures. The following is a summary of several analysis techniques that can be used.

### Long-Term Observations of Streambed Elevations

Long-term streambed elevation data is extremely valuable for channel stability analysis. Unfortunately streambed elevation data are often scarce or unavailable. Sources of streambed elevation data include

- Data from railroad, pipeline, or old highway bridge surveys;
- Streambed elevation data reported at some gauging stations (these data are updated periodically);
- Historic surveyed channel profiles; and
- Navigation studies.

Another possible source of future streambed elevation data is from periodic bridge inspection reports, many of which are available for the past 30 years. It is highly recommended that measurements be made from bridge decks to streambed as a part of bridge inspections, particularly for streams in regions prone to gradation problems.

### Observations of Changes in Stage Versus Discharge Relationships

In many instances, data on the changing bed level may not be available. In these instances analysis of the variation in stage versus discharge relationships at gauging stations is valuable. Long-term data for streamflow are available for many streams of a reasonable size at the gauging stations of the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers. Shifts in the rating curves that relate river stage to discharge are often good clues to gradation changes. Changes in the rating curves at gauging stations along the Missouri River as documented by Sayre and Kennedy (11) illustrate the rather dramatic changes that have taken place as a channel degrades. The degradation is primarily due to completion of large reservoirs on the river and efforts to maintain a navigation channel.

Analysis of gauging station stage trends is, again, easily done and yields useful information on long-term trends. On many occasions the USGS and Corps of Engineers have already performed the analysis. Gauging station records are excellent because many cover periods of 30 years or longer.

### Observation of Changes in Sediment Load

Another type of useful information available from gauging stations is sediment load. Although only a few stations have continuous sediment data, when available they can provide clues to the presence of gradation problems. By definition, aggradation takes place when sediment inflow to a river exceeds sediment outflow. Degradation occurs when outflow exceeds inflow. Any change in the long-term sediment load signals an imbalance in the stream system. Such imbalances lead to lateral movement, bank sloughing, and gradation problems.

The Missouri River has a number of long-term sediment measuring stations. Data from Sayre and Kennedy (11) illustrate the changes that take place in sediment load when gradation problems occur. A 100-fold change in sediment load (sand, silt, and clay) took place in the early 1950s when the dams above Omaha were closed. This time period coincides with the beginning of major gradation changes along the river.

### Streambed Profile Analysis

Another method for verifying the presence of grada-

TABLE 1 Interpretation of Observed Data

| OBSERVED CONDITION | CHANNEL RESPONSE STABLE | UNSTABLE | DEGRADING | AGGRADING |
|---|---|---|---|---|
| Alluvial Fan | | | | |
| Upstream | | √ | | √ |
| Downstream | | √ | √ | |
| Dam and Reservoir | | | | |
| Upstream | | √ | | √ |
| Downstream | | √ | √ | |
| River Form | | | | |
| Meandering | √ | √ | Unknown | Unknown |
| Straight | | √ | Unknown | Unknown |
| Braided | | √ | Unknown | Unknown |
| Bank Erosion | | √ | Unknown | Unknown |
| Vegetated Banks | √ | | Unknown | Unknown |
| Head Cuts | | √ | √ | |
| Diversion | | | | |
| Clear water diversion | | √ | | √ |
| Overloaded with Sediment | | √ | √ | |
| Channel Straightened | | √ | √ | |
| Deforest Watershed | | √ | | √ |
| Drought Period | √ | | | √ |
| Wet Period | | √ | √ | |
| Bed Material Size | | | | |
| Increase | | √ | | √ |
| Decrease | | √ | Unknown | √ |

tion changes is stream profile evaluation. The idea is similar to measuring the change in bed elevation from the bridge deck. Instead, a longitudinal profile of the thalweg is surveyed and compared to a historic profile.

Profile analysis requires considerable effort if it is necessary to perform the actual survey. A rough profile analysis can occasionally be performed by plotting as a function of time the elevations of cross sections at pipeline crossings and railroad bridges and obtaining other similar data. This may be required when gauging station records or other more readily available data are lacking. The U.S. Army Corps of Engineers conducts potamology surveys and maintains sediment ranges on many major streams. Data from these sources may be useful in determining bed level changes with time.

Observations of Changes in Stream Classification

River and watershed classification provides insight into typical watershed behavior and response. It also provides information on impacting activities within the watershed. Channel stability can be interpreted from classifications and from field visits. A summary of interpretations taken from Keefer et al. (8) is given in Table 1.

Observations from Maps and Aerial Photographs

A comparison of changes in the channel system with time can be made by using time sequential maps and aerial photographs. This method shows extreme changes in channel alignment and flow habit with time as depicted in Figure 1. These comparisons can signal changes in vertical instability as well as lateral instability because all modes of instability often occur simultaneously. Also, aerial photographs often provide evidence of bank slumping which is indicative of bank undermining caused by streambed degradation. Plotting overlays of meanders and channel movement as a function of time often reveals alarming instabilities. Figure 2 shows an example of the utility of aerial photographs for charting and interpreting channel changes.

Data Sources

Government agencies such as the U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Soil Conservation Service, and U.S. Forest Service, local river basin commissions, and local watershed districts are valuable sources of data pertinent to analysis of stream stability. Information that these agencies can provide includes historic stream-

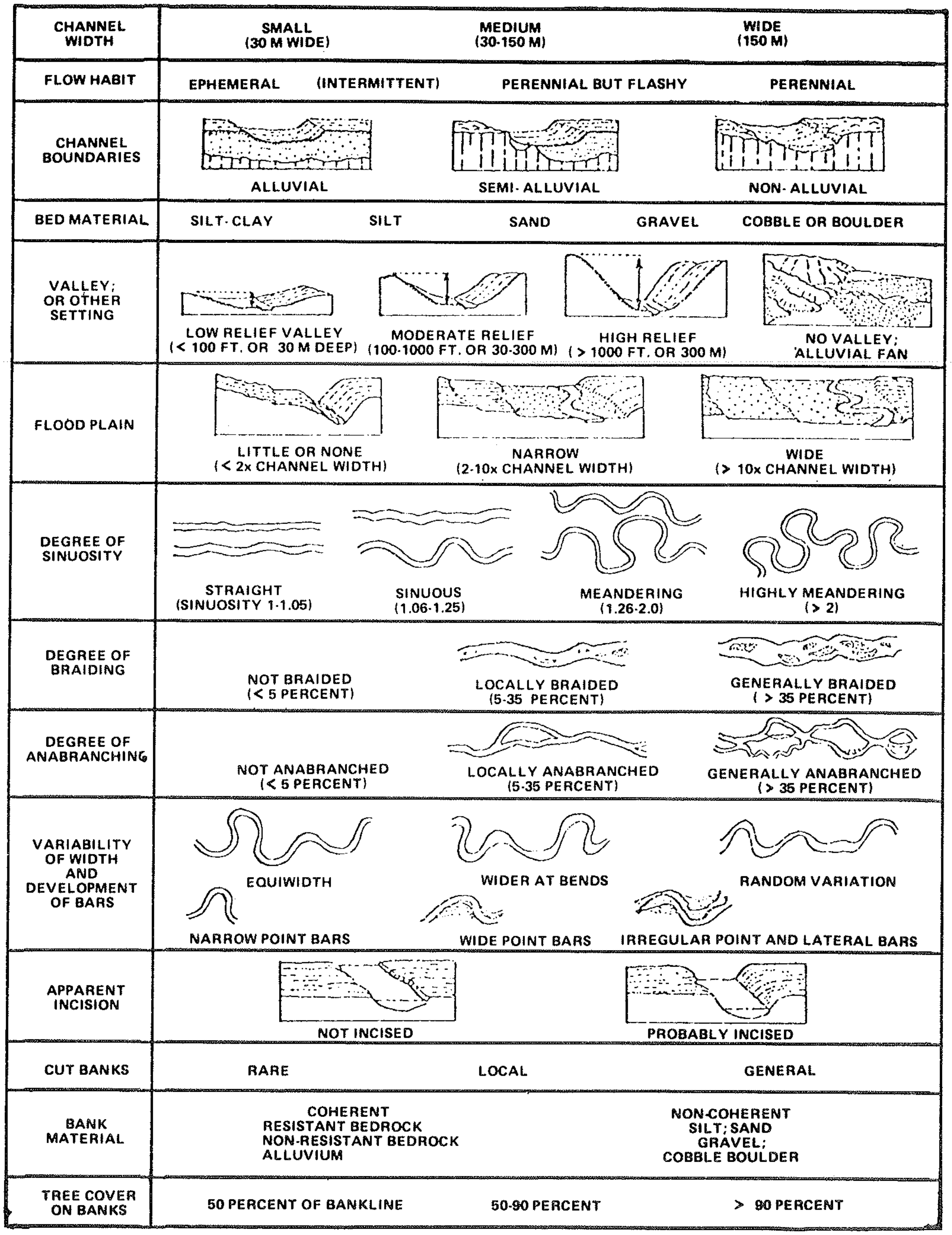


FIGURE 2 Stream properties for classification stability analysis.

bed profiles, stage versus discharge relationships, sediment load characteristics, and very importantly, aerial photographs. These agencies also often have records of past system activities that might have affected stability and might give an indication of future instability characteristics. A checklist of pertinent and peripheral data is so extensive that careful paring of options is essential. The goal of this analysis is to detect and quantify change--the indicator of instability. The engineer should strive to inspect the minimal data set that will result in a conclusion. The checklist of data sources given below demonstrates the possibilities.

- Topographic maps
- Planimetric maps
- Aerial photographs
- Transportation maps
- Triangulation and benchmarks
- Geologic maps
- Soil data
- Climatological data
- Stream flow data
- Sedimentation data
- Quality of water data
- Irrigation and drainage data
- Flood control data
- Hydro-power data
- Basin and project reports
- Environmental reports and data
- Personal interviews
- Paleohydrologic evidence
- Diaries and personal records
- Field trip and inspection reports

SUMMARY

Recognizing and anticipating channel instabilities is an important part of locating and designing highways in river environments. Channel instabilities include oscillations in channel bed elevation, variations in river orientation and location, and major river migrations or meanders. Factors affecting river stability have been classified as natural or accelerated. Natural instabilities result from changes in hydrometeorology whereas accelerated erosion is usually a result of man's activities within the watershed.

Identifying channel instabilities requires an understanding of the geomorphic processes occurring within the watershed in question and an awareness of all activities that affect stability. A thorough analysis of system stability should include consideration of past system changes and changes in progress, as well as a geomorphic analysis to predict future changes.

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# Assessment of Channel Stability at Bridge Sites

**JAMES C. BRICE**

ABSTRACT

Assessment of channel stability from field study and the comparison of time-sequential aerial photographs provides information that is needed in site selection, bridge design, and countermeasure placement. Channel instability is indicated by bank erosion, progressive degradation (or aggradation) of the streambed, or natural scour and fill of the streambed. Bank erosion rates are related to stream type and are proportional to stream size. Predictions of future rates are based on past rates, as measured on time-sequential photographs or maps, and on the typical behavior of meander loops. Significant degradation of the streambed can usually be detected from indirect field evidence. The sites of greatest potential scour along a channel can be identified from channel configuration. Shift of the thalweg, which is a factor in the alignment of piers, is related to stream type and can be assessed from aerial photographs.

Hydraulic problems at bridges, although less prevalent than structural problems, are nevertheless significant. In the United States the annual damage to bridges and highways from floods has been estimated at $100 million during years of extreme floods (1). Stream-related damage and maintenance problems also occur when there are no floods, but the expense of such damage and problems is difficult to estimate. A study of hydraulic problems at bridges (2) has indicated that damage by streams can be reduced by considering channel stability in site selection, bridge design, and countermeasure placement.

The objective of this paper is to give a brief summary of geomorphic methods used to assess stream channel stability. These methods are presented in greater detail in a research report published by the Federal Highway Administration (3), and a checklist