Chapter 6
Practical Aspects of Stability Design

6-1. General

This chapter provides guidance and examples for various practical aspects of design for stability. The main causes of the type of instability to be controlled are reviewed briefly in each case. General principles of channel equilibrium and response are reviewed in Chapter 2. Stability problems with flood control channels are discussed in detail in Chapter 3.

6-2. Ranking of Flood Control Methods

From the viewpoint of minimizing channel stability problems, methods of flood control can be generally ranked in the following order of acceptability:

a. Nonstructural flood control measures such as floodproofing, evacuation, and flood warning systems.

b. Levees set back clear of the meander belt.

c. Levees within the meander belt.

d. Off-channel detention basins.

e. Upstream flood retention or detention structures.

f. Flood bypass channel.

g. Clearing and snagging (reduced roughness).

h. Enlarged compound cross section with existing low-flow channel left intact. (The low-flow channel carries average dry-season flow.)

i. Channel widening with or without levees.

j. Channel deepening with or without levees.

From a safety viewpoint, on the other hand, channelization measures like *h* and *i* above tend to be more defensible than structural measures such as *b*, *c*, and *e*. Potential conflicts between stability and safety requirements should be discussed with local interests and considered together with economic, social, and environmental factors. Table 6-1 shows the potential for several flood protection measures to cause instabilities in various types of river channels.

6-3. Alignment and Planform

Earlier flood control projects often involved extensive realignment of pre-existing streams and channels. Sinuous or meandering channels were straightened to improve hydraulic conveyance or to eliminate eroding bends, often without sufficient consideration of potential effects on long-term stability. Severe instability in profile and cross section often occurred in and beyond the project length, and the treated length of channel often reverted eventually to a meandering state unless expensive remedial measures were undertaken (Figure 3-6).

6-4. Single-Channel Streams

a. Most existing channels are sinuous to some degree. Current practice is generally to retain existing alignments where practicable. Even where an entirely new channel is to be constructed, arguments can be made for a sinuous rather than a straight alignment. Keller and Brookes (1984) state “Consideration of meandering in channelization projects should be encouraged wherever feasible because meandering channels often have a more consistent pattern of sediment routing, are morphologically more stable, have more hydrological and biological diversity, and aesthetically are more pleasing.” Similar comments are made by Nunnally and Shields (1985). Flood control channels stabilized on meandering alignments are shown in Figures 6-1 and 6-2. Points that can be made in support of sinuous alignments include the following:

(1) Retention of a sinuous alignment avoids problems of excessive slope associated with straightening.

(2) Straight channels transporting bed material tend to form alternating side bars that induce submeandering in the low-flow channel (see Figure 3-2). This may eventually lead to resumption of full-scale meandering.

(3) Sinuous channels have greater local variability of depth, velocity, and cross-sectional shape, which is attractive for fish habitat.

b. Where a sinuous alignment is retained, however, it may be appropriate to eliminate or improve severe bends that are subject to rapid bank erosion and flow disturbances (Figure 6-3). Where the channel is widened by side cuts on alternating sides, the sinuosity can thereby be reduced to some degree (see Figure 3-3).

Table 6-1
Rating of Flood Control Measures for Channel Stability

Flood Protection Measures	Channel Types[*]									
1. Non-structural: floodproofing, flood warning, evacuation.	0	0	0	0	0	0	0	0	0	0
2. Levees: set beyond stream meander belt.	1	2	2	1	1	1	1	2	1	1
3. Levees: set within stream meander belt or along bankline.	2	5	5	4	3	3	2	4	2	2
4. Off-channel flood detention basin.	2	3	3	3	2	2	2	2	1	1
5. Within-channel flood detention basin.	4	5	5	5	4	4	3	4	2	2
6. Major flood storage reservoirs.	3	4	4	4	3	3	2	3	1	1
7. Floodway, diversion, or bypass channel.	4	5	5	5	4	4	4	5	3	3
8. Compound channel - low-flow pilot plus flooding berms.	5	8	8	7	7	6	6	7	4	4
9. Significant channel widening.	6	9	9	8	8	6	7	7	5	5
10. Significant channel widening and deepening.	7	9	9	9	9	8	8	8	6	7
11. Significant channel widening, deepening, and straightening.	8	10	10	10	10	8	9	9	7	8

No Stability Impacts   0 2 4 6 8 10   Major Impacts On Stability
|..|..|..|..|..|..|..|..|..|..|

------------ Channel Stability Rating Scale ---------------

[*]Note: See paragraph 2-2 for a complete description of the channel types.

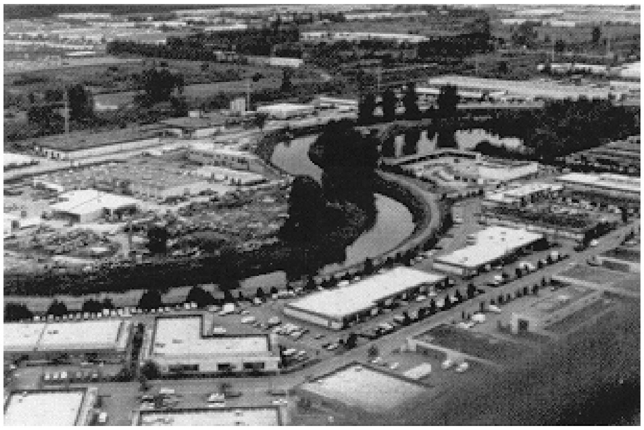


Figure 6-1. Regulated river with levees on meandering alignment

c. Generally accepted standards for the layout of new sinuous channels are not available. A general principle that can be followed is to match the wavelength to that of a corresponding natural meandering channel, that is, a stream in similar soils with similar channel-forming discharges. Relationships between meander wavelength and channel width are discussed in paragraph 5-9. A suggested relationship between meander wavelength and bank-full (channel-forming) discharge is shown in Figure 5-17.

d. In the absence of generally accepted guidelines for radius of curvature and deflection angle, it is suggested that where possible, radius of curvature should be at least five times the channel width, and that the deflection angle of a single bend should not exceed 90 degrees. Natural streams often have tighter meander curvature (paragraph 5-9).

6-5. Multichannel Streams

a. Some streams consist of two or more subchannels over substantial parts of their length. Examples include the Snake River near Jackson Hole, Wyoming, as described in paragraph 3-12 and the Tanana River at Fairbanks, Alaska, as described in paragraph 3-17. Braided rivers (Figure 2-5) constitute a limiting case.

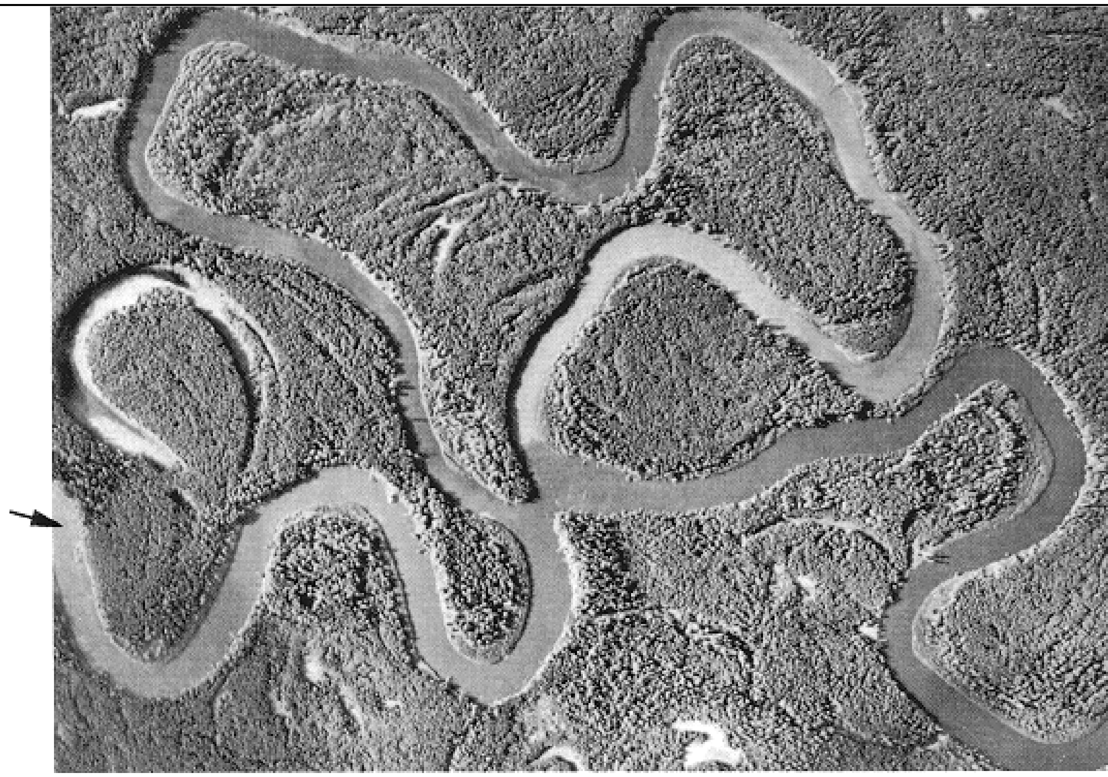
b. In modifying a multichannel stream to increase its flood conveyance, various alternatives might be considered, as illustrated in Figure 6-4. Alternative A (Figure 6-4a), involving levees set well back from the active channel shift zone, is usually the most economical and least troublesome to maintain. Alternative B (Figure 6-4b) is likely to be the most expensive because deep scour may have to be provided for at any point along the levees. Alternative C (Figure 6-4c), although it may appear desirable because it reclaims more land from the river, is liable to raise flood stages and to meet with environmental objections. However, each case should be examined on its merits. Detailed study of historical maps and aerial photographs may reveal that the shift pattern is more predictable than it first appeared to be.

6-6. Alluvial Fans

a. The general characteristics of alluvial fans are described in paragraph 2-2. A typical residential development on an alluvial fan in California is illustrated in Figure 2-4. In considering the location and alignment of flood control channels, it is important to determine whether the fan is actively aggrading or whether it is in a stable or degrading state geomorphologically. If the fan surface is generally unvegetated and the principal channel spills easily and is "perched" in relation to ground at equal distances from the apex (Figure 6-5), the fan is likely to be actively aggrading. On the other hand, if the surface is generally well vegetated between channels and the main channel is well incised, the fan may be stable or even degrading.

b. On aggrading fans, developments requiring flood protection should often be discouraged because expensive flood control structures and ever-increasing maintenance may be required to keep the flow in the existing main channel or channels as their bed levels build up with deposited bed material. If the existing main channel is perched, it may be preferable to select a lower initial route or fall line for the flood control channel. It should be recognized that selected routes may not be maintainable indefinitely because of constraints on maintenance, especially during flood events, and because on some fans, the risk of catastrophic flood-debris events can be much more severe than previously observed floods. If development proceeds with recognition of risks, consideration may be given to sediment control features including debris basins and concrete linings, as discussed in paragraph 6-7*c* below. On an alluvial fan, a debris basin would normally be located at the head of the fan, unless the main sediment supply is located farther downstream (Figure 6-6).

c. On stable or degrading fans, problems of alignment and planform are essentially those of multichannel streams. In some cases it may be desirable to construct levees along the route of the main channel, closing off



a. Before project: natural meanders

b. After project (diversion structure and channel): controlled meanders

Figure 6-2. Construction of a meandering alignment

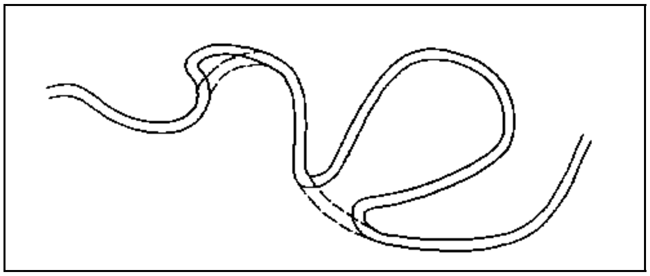


Figure 6-3. Alignment modifications to eroding bends

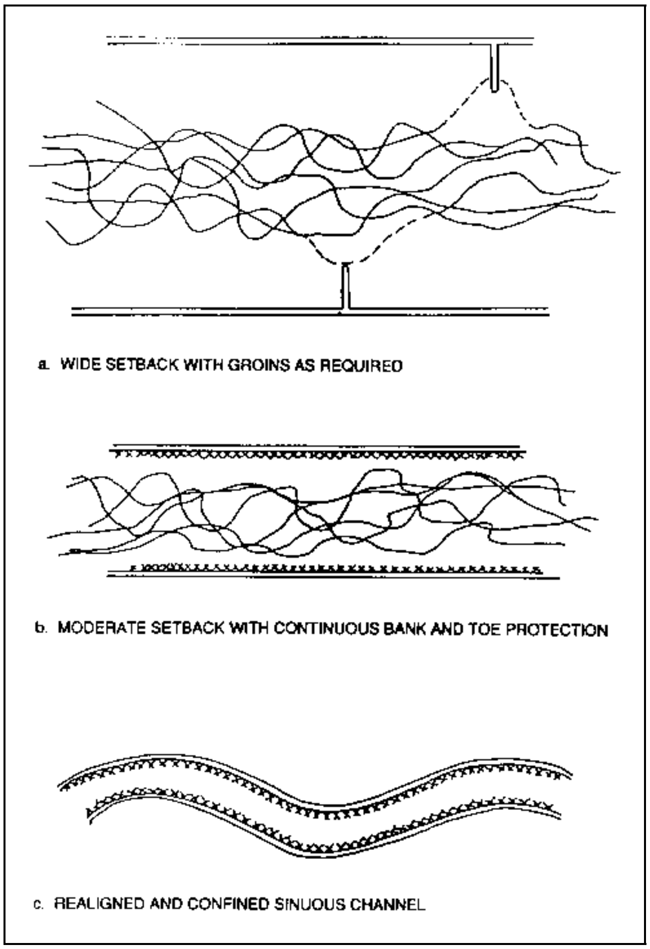


Figure 6-4. Alternative levee locations along braided channel

secondary channels or retaining them as escape routes for spills at designed low points in the levee system.

d. In some places where development has occurred on closely adjacent alluvial fans (piedmonts or bajadas) all issuing from the same mountain range, cross-slope interceptor channels have been used to pick up flows from

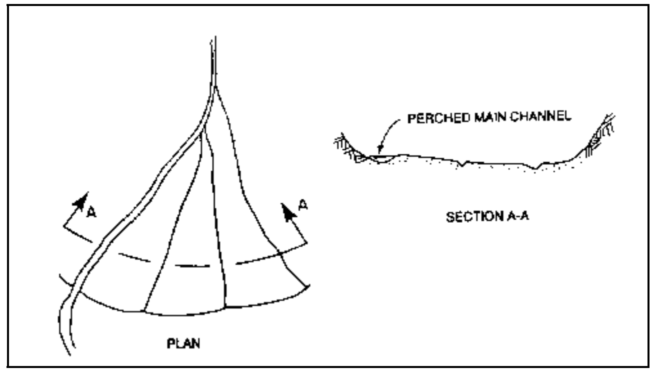


Figure 6-5. Perched channel on aggrading alluvial fan

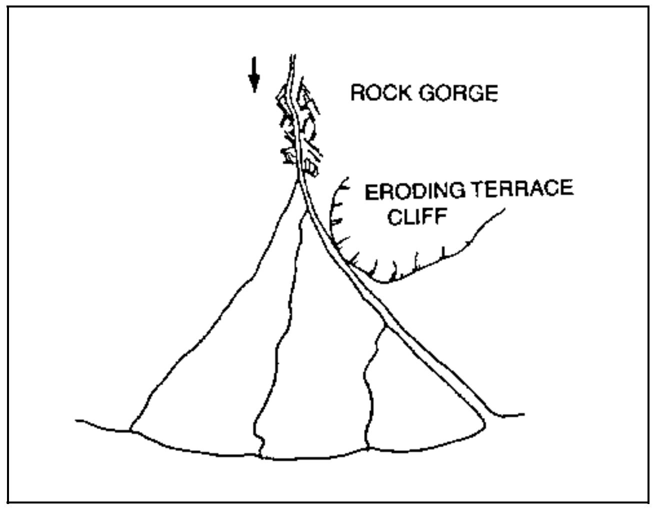


Figure 6-6. Principal active source of fan bed load may be downstream of apex

a series of fans and lead them to the main channels (Figure 6-7). In the case illustrated, debris basins are located at the head of each fan (see paragraph 6-7*c*).

6-7. Longitudinal Profile and Grade Controls

a. Causes of profile instability.

(1) In most cases the basic longitudinal profile of a flood control channel is determined by the slope of the existing channel. Most problems of longitudinal instability arise because the existing slope is too steep for equilibrium under the modified sedimentation, hydraulic, or hydrologic conditions of the flood control channel. The bed of the project channel then begins to degrade within and upstream of the project length, and perhaps to aggrade downstream.

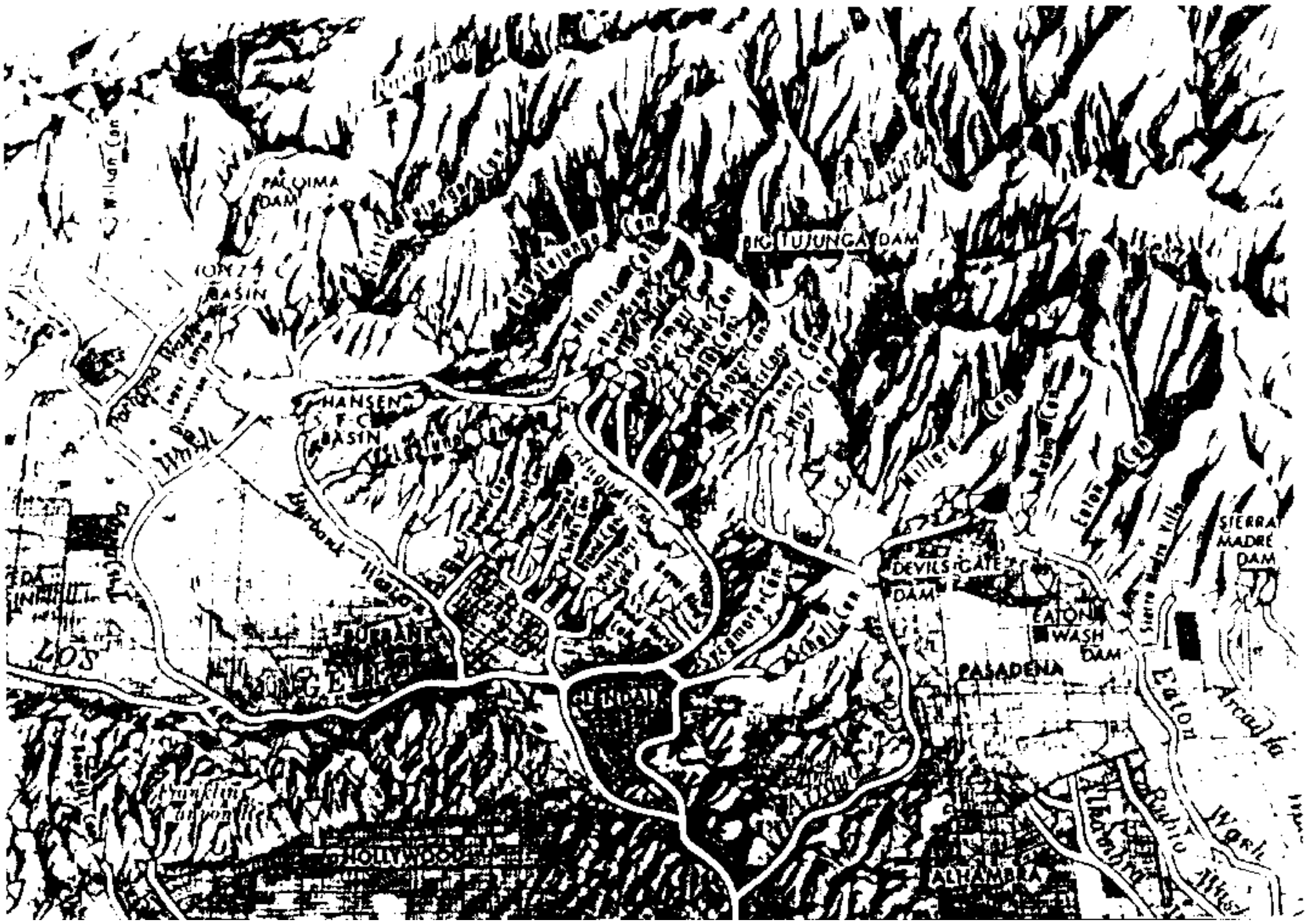


Figure 6-7. Cross-slope interceptor channels collecting flood flows from adjacent alluvial fans

(2) There are two main reasons the existing gradient may be too steep for the project channel. The first reason is that discharges in the project channel may be significantly larger than in the existing channel. As explained in Chapter 2, larger discharges require flatter slopes to maintain equilibrium with equivalent bed material transport; see also Figure 5-11. A second reason is shortening through realignment, which was a common problem in earlier flood control projects but is now discouraged, as discussed in paragraph 6-4. A third, less common reason may be the addition of a basin or reservoir that traps bed material upstream of the project channel (paragraph 6-6).

(3) Problems of profile degradation are most common and severe in channels with beds of sand or other easily eroded fine-grained materials. Examples include many of the bluff-line streams of northern Mississippi, which as a result of land-use changes and channel alterations are generally degrading into fine-grained deposits of sand, loess, silt, and clay. In gravel-bed channels, the ability of the stream to armor the surface of the bed with the coarser fraction of the bed load tends to retard rates of degradation.

(4) An opposite type of longitudinal stability problem arises when the project channel slope is too flat and begins to steepen (aggrade) by accumulation of bed material. This can occur in diversion and bypass projects if flows in the existing channel are thereby reduced but the channel continues to take a substantial part of the bed material load (see also Chapter 3, Section I). This type of problem may also arise in new channel projects if the slope provided is insufficient to transport all the inflowing bed material.

b. Grade control structures.

(1) Channel profile degradation can be controlled by the use of grade control structures at intervals along the channel. Grade control structures provide local hard points or controlled drops so that an equilibrium slope can develop or be constructed between structures (Figure 6-8). The spacing is determined so that the local degradation or drop below each structure is within acceptable limits. Acceptable limits depend on economic, environmental, and other considerations.

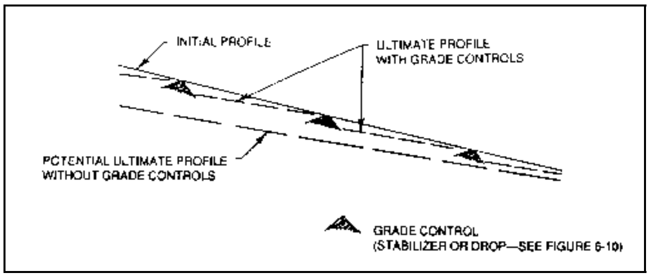


Figure 6-8. Use of grade controls to limit profile degradation and downstream sedimentation

(2) The basinwide evaluation approach referred to in paragraph 5-10 can be used to assess the need for grade control and to determine the appropriate design for achieving stable channel slopes and bank heights.

(3) The rating curve of a grade control structure should normally be designed to match that of the upstream channel as closely as possible over the full range of discharges. In some cases, stepped sill crests are used to achieve a match (Figure 6-9). It may be desirable in incised streams to construct the grade control to act as a weir at an elevation above the preproject channel bottom. Such a structure would tend to trap sediments, flatten channel gradients, lessen bank heights, and promote the overall stability of the channel system.

(4) The decision as to whether grade controls or drops should be part of the project design or whether they should be deferred until problems develop depends partly on economic and political considerations and partly on the expected severity of profile response. Previous local experience is generally valuable in making this determination. However, the entire channel system should be reviewed, including tributaries and their expected reaction to flood control on the main stem. If degradation of the main stem or tributaries is projected, grade control features should be used as part of the initial project. Construction should be phased so that tributary grade control features are completed before flow line lowering on the main stem.

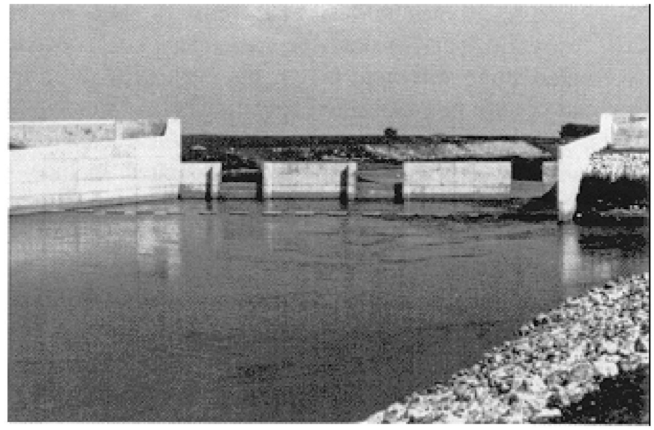


Figure 6-9. Use of stepped sill on grade control structure to match upstream rating curve

(5) Grade control structures are generally classified into two types: stabilizers and drop structures (Figure 6-10). The distinction between the two types is not always clearcut. Design guidelines for both types are given in EM 1110-2-1601 and in Hydraulic Design Criteria 623/624, and have been expanded by Robles (1983).

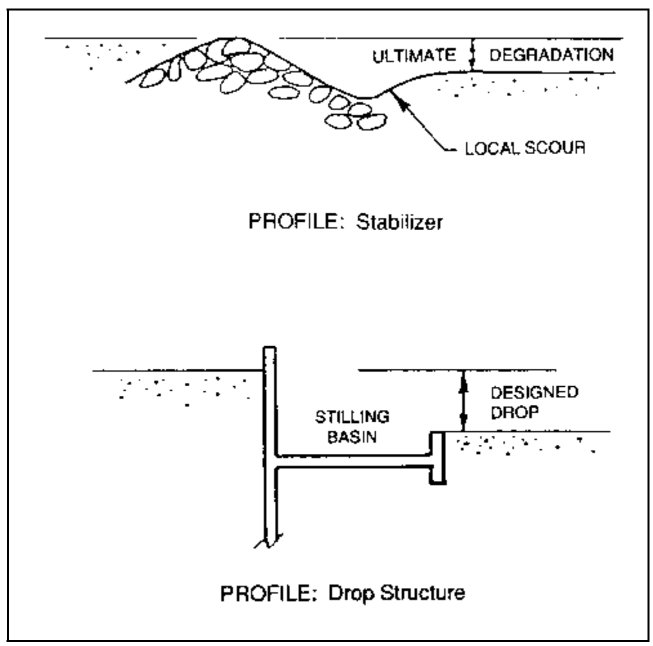


Figure 6-10. Classification of grade control structures

According to Robles (1983), stabilizers as used in the U.S. Army Engineer District, Los Angeles, are “concrete or grouted stone sills built across the channel to form an artificial control point.” Stabilizers may be of three types: weirs, chutes, or flumes, and may be constructed of a wide variety of materials. Types illustrated include a simple sheet pile weir (Figure 6-11) and a special flume type developed in Mississippi (Figure 6-12). If the drop that develops below a stabilizer is too great—normally 2 to 4 ft depending on type—energy dissipation becomes a problem and more elaborate drop structures must be used. Drop structures are normally provided with some form of stilling basin or armored plunge pool for energy dissipation (Figure 6-13). They have been used as remedial measures in cases of severe degradation, or as elements of project design where substantial slope flattening is expected. Whether to use stabilizers at relatively close spacing or drop structures at wider spacing is partly an economic question.

(6) Where existing slopes are only marginally excessive, it may be possible to achieve longitudinal stability by increasing channel roughness, for example using scattered boulders placed in a manner to prevent them from sinking into their own scour hole. Such a solution is often favored by fisheries interests as it provides useful resting places and shelter.

c. Control of sediment inflows.

(1) Some flood control channel projects may require special features for control of sediment inflows, in order to reduce the need for future dredging to maintain flood capacities and tributary access. Channels on aggrading alluvial fans, as referred to in paragraph 6-3, provide one example. Increases in sediment inflow due to expected degradation of the upstream channel or tributaries can often be controlled through grade control structures as described in paragraph 6-2 above. However, other means to control sediment inflows, such as sediment or debris basins, may also be desirable. Sediment basins are commonly used at the heads of alluvial fans (Figure 6-14).

(2) In the Yazoo Basin in Mississippi, combinations of grade control structures, artificial sediment basins, and natural sediment trapping areas have been used for effective control of anticipated maintenance dredging requirements. The grade control structures have raised sills to build up existing degraded channel beds. Sediment basins within the leveed floodway also provide a source of levee borrow material. Sediment trapping areas are naturally low lands in or near certain reaches of channel. All these features provide incidental environmental benefits by improving water quality, reducing disturbance by future maintenance work, and enhancing fish and wildlife habitat.

(3) Another means of controlling sediment inflows in small watersheds is to provide grade control or riser pipe structures on the small tributaries. These structures detain small volumes of flood water and allow deposition of coarser sediments in a designated area. They can also prevent the upstream migration of head cuts and gullies. A typical riser pipe structure as used in the Yazoo Basin is shown in Figure 6-15.

(4) Where an unlined flood control channel is expected to lose capacity due to deposition of bed material from sediment inflows, and where sediment basins or maintenance dredging appear impracticable, it may be advisable to consider a lined channel for high-velocity flow and sediment flushing. Lined channels may also be used downstream of a debris basin to prevent bed degradation (Figure 6-16). Some data on sediment transport and self-cleaning velocities in lined channels are provided by Mayerle, Nalluri and Novak (1991). However, lined channels are not always free from sediment problems. In Corte Madera Creek, California, where gravel deposited in the downstream reaches of the concrete-lined channel, the Manning roughness coefficient was found to be 0.028 (Copeland and Thomas 1989).

(5) Recent flume experiments at WES showed that near-bottom coarse sediment concentrations of 3,000 ppm increased roughness values by about 10 percent (Stonestreet, Copeland, and McVan 1991).

6-8. Cross Sections and Hydraulic Capacities

a. Range of cross-sectional types. A wide variety of cross-sectional types and modifications have been used in flood control channel projects. The following types are illustrated in Figure 6-17:

(1) Existing channel retained, with wide setback levees on floodplain.

(2) Existing channel retained, with levees close to channel banks.

(3) Channel widened on one or both sides to full depth.

(4) Channel deepened and widened on one side.

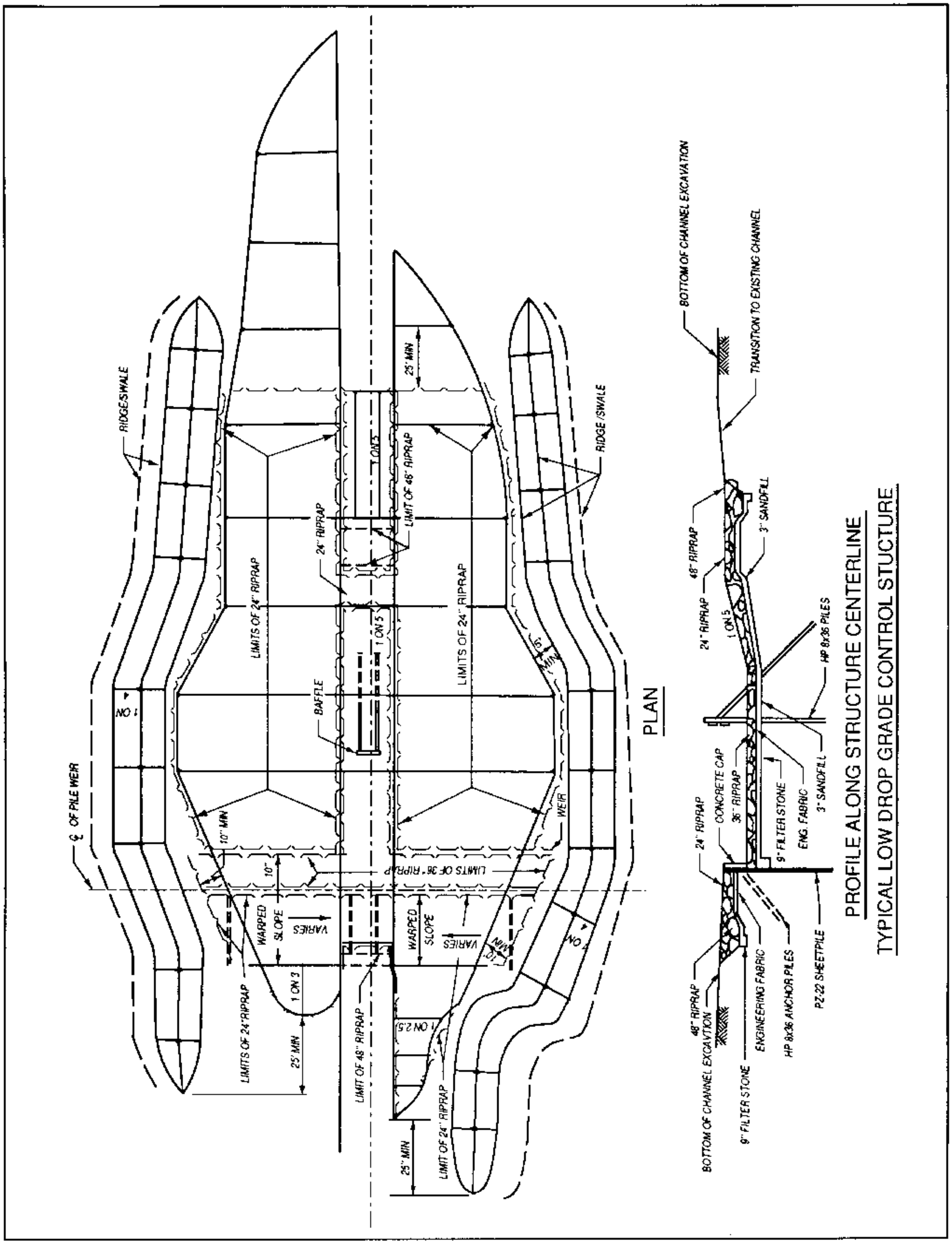


Figure 6-11. Sheet pile weir stabilizer

Figure 6-12. Flume-type grade control/gauging structure

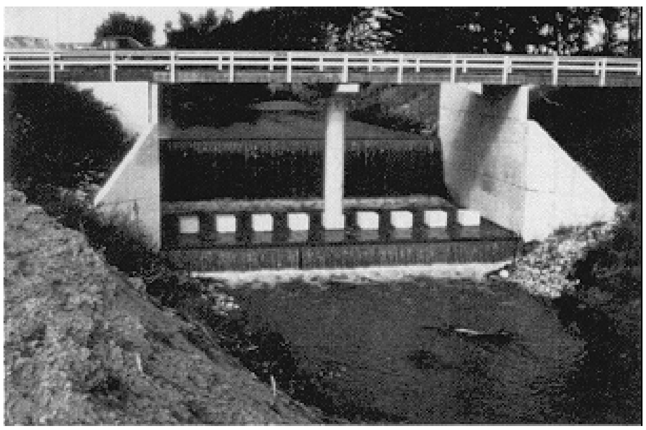


Figure 6-13. Drop structure with energy dissipator

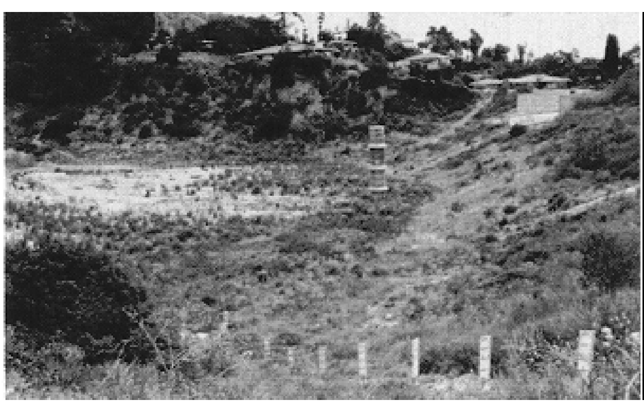


Figure 6-14. Debris basin and dam at head of alluvial fan

(5) Channel deepened and widened to part depth (with berm).

(6) Major enlargement with retention of inner low-flow channel (Figure 6-18).

(7) Existing channel paralleled by separate floodway or bypass channel.

b. A number of these alternatives are also discussed in paragraphs 3-1 and 6-2. From a stability viewpoint Type a is generally preferable, but in many cases other considerations will predominate. Type g is also attractive if sedimentation is not a problem (paragraph 3-7). Generally, widened and deepened sections are the most susceptible to problems of bank erosion, channel shifting, and profile degradation.

c. A wide variety of practices exist for determining channel capacity and frequency of the bank-full condition, depending on the overall requirements of the project. In compound cross sections such as type *e*, the berm level normally corresponds to the annual summer flood. In type *f*, the low-flow channel may be sized for dry-season flows only.

d. Increasing channel capacity in environmentally sensitive areas.

(1) A problem facing many Corps Districts is design of flood control projects in river basins or specific reaches of river basins that are extremely environmentally sensitive. Increased channel conveyance can often be achieved in these areas through either clearing and snagging or channel cleanout alternatives. These alternative channel improvement methods, both of which are generally much less destructive to the environment than conventional channel enlargement, are defined in (2) and (3) below. (See also paragraphs 3-2 and 3-3.)

(2) Clearing and snagging. Channel clearing and snagging (Figure 6-19) involves the removal of trees, brush, logjams, and other material from the channel. Channel capacity is increased as roughness is reduced and blockages removed. Work is typically limited to within the top bank of the channel but may be extended to the overbank if significant overbank flow occurs and the work is environmentally acceptable. The degree of improvement can range from total clearing where all woody vegetation is removed from the channel to selective clearing

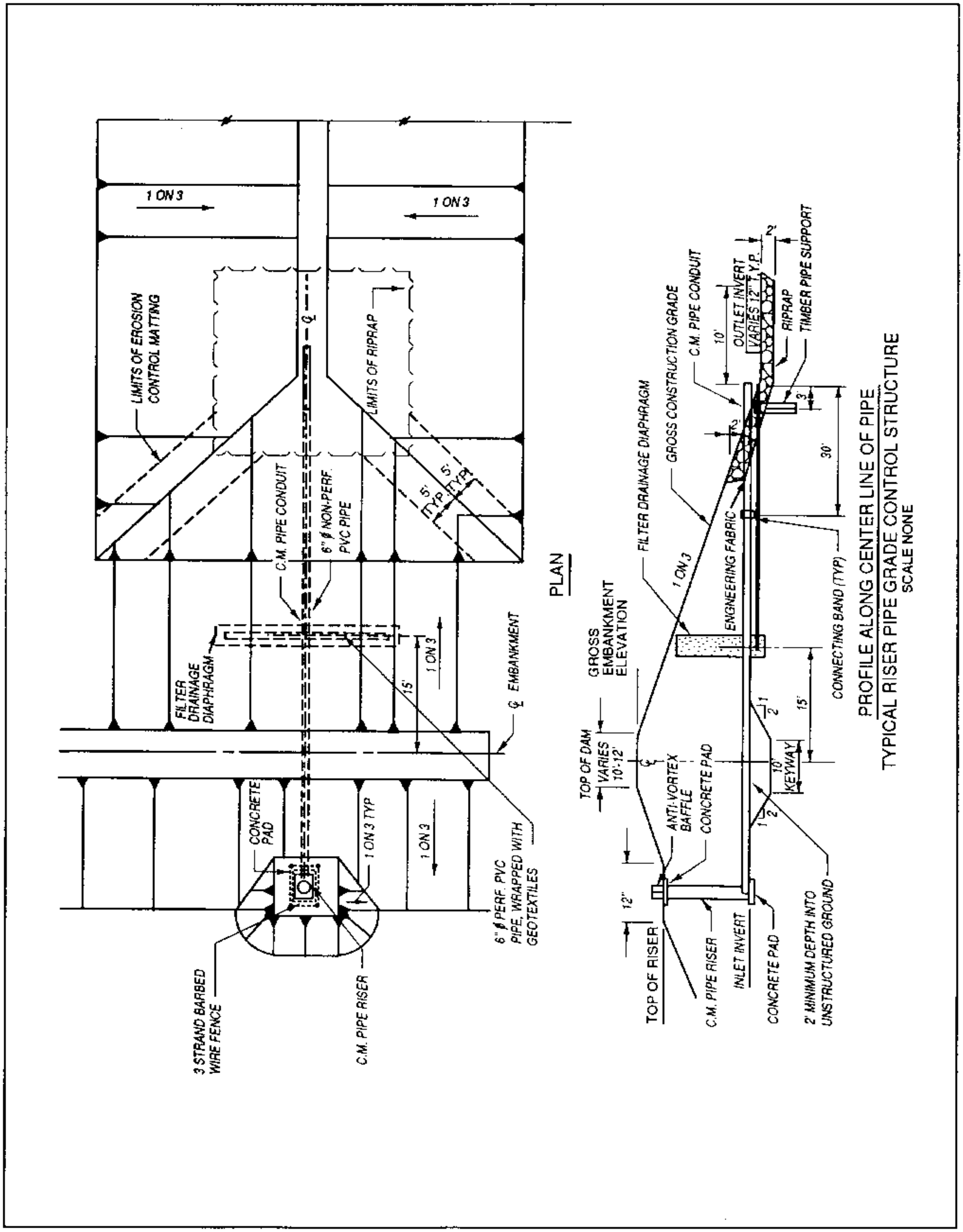


Figure 6-15. Typical riser pipe grade control structure

Figure 6-16. Concrete-lined channel on alluvial fan below debris dam (looking downstream)

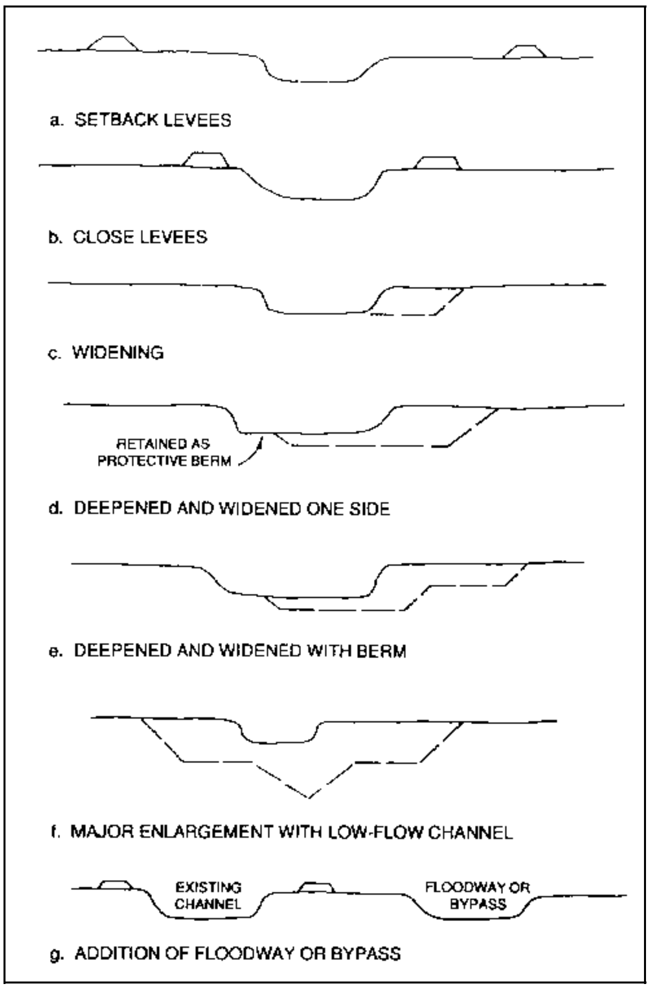


Figure 6-17. Various types of modified cross sections

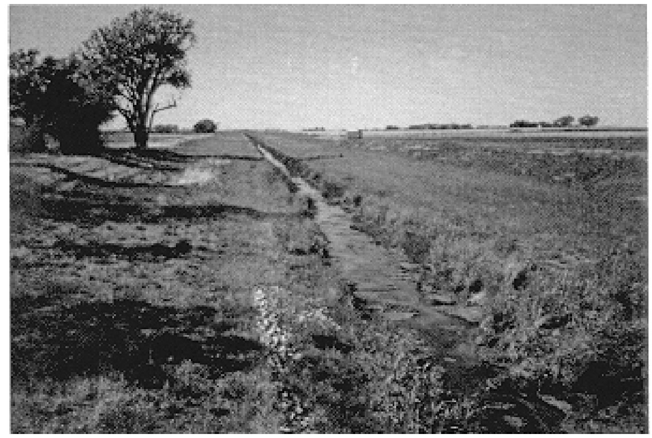


Figure 6-18. Compound cross section with low-flow channel, grassed berms, and leaves

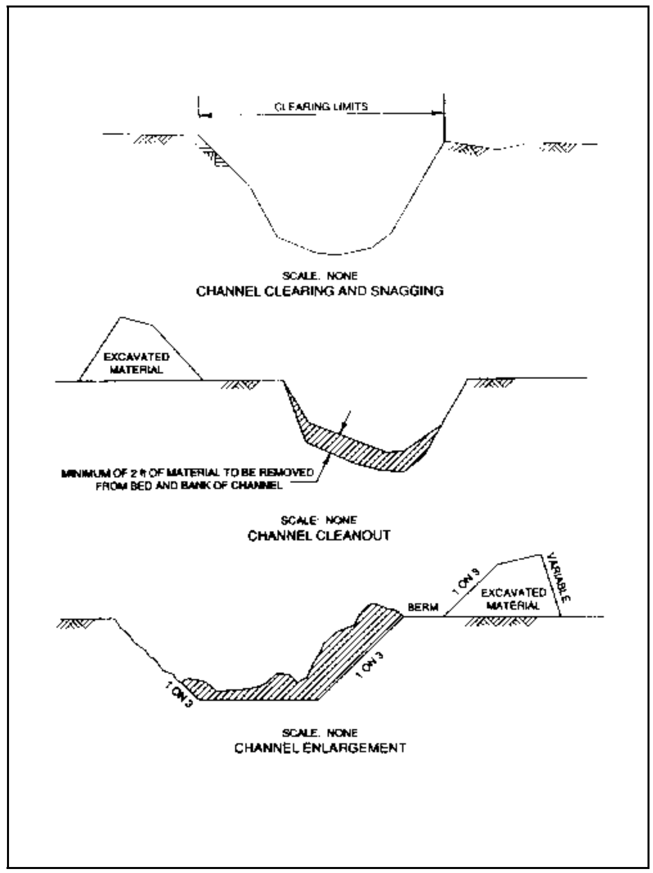


Figure 6-19. Increasing channel capacity in environmentally sensitive areas

(Figure 6-20) where only selected vegetation is removed. Selective clearing will in many cases allow desirable vegetation to remain with only minor losses in channel capacity over total clearing. An example is leaving selected larger trees on a spacing that does not seriously hamper the flow capacity of the channel. The channel bottom is cleared of all woody vegetation while the bank is selectively cleared.

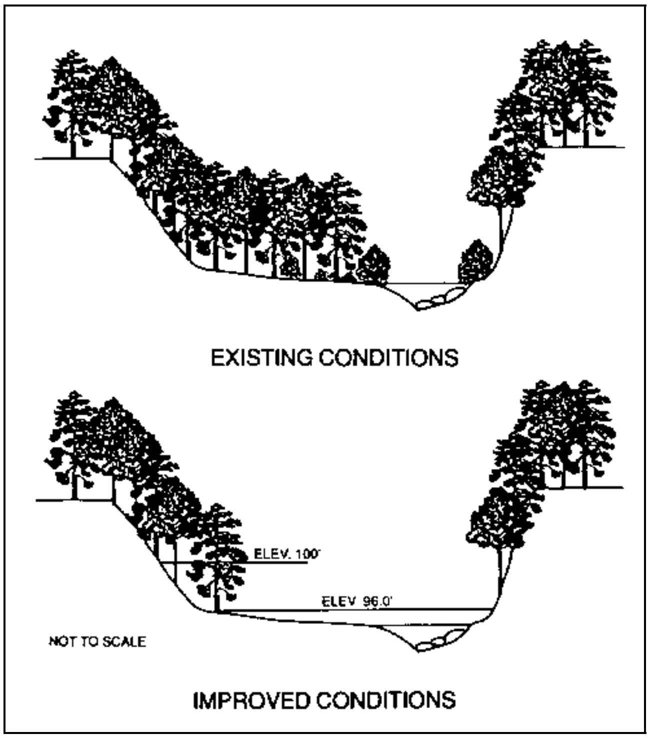


Figure 6-20. Selective clearing and snagging

(3) Channel cleanout. Channel cleanout (Figure 6-19) is similar to clearing and snagging in that all vegetation is removed from the channel bottom and at least one bank. However, the improvement is carried farther in that material is excavated from the channel also. Typically a given thickness of material, 2-3 ft in most cases, is excavated from the channel bottom. The excavation depth is tapered to near zero at top bank of the channel. In many cases all work is performed from one bank only, which allows the opposite bank to remain undisturbed. The top width of the channel remains essentially unchanged. Figure 6-19 shows a typical cross section of a channel cleanout compared to clearing and snagging and conventional channel enlargement.

(4) Projects such as the Upper Steele Bayou Basin in the U.S. Army Engineer District, Vicksburg, have been designed using this concept. The project area contains a particularly sensitive area through which additional flows must pass for the project to operate. Conventional channel enlargement downstream of the sensitive area resulted in sufficient lowering of flood flow lines to permit the use of a selective clearing and snagging alternative within the sensitive reach. Selective clearing and snagging of the environmentally sensitive reach was sufficient to offset the increase in peak flow resulting from conventional channel enlargement upstream of the area. This allowed areas adjacent to the sensitive area to achieve some flood stage reductions and provided a sufficient outlet for the conventional channel enlargement in the upstream areas.

(5) While not providing the degree of flood stage reduction attainable through conventional channel enlargement, selective clearing and snagging of environmentally sensitive reaches may provide a means by which an otherwise unacceptable project can be constructed. This concept has met the approval of both environmental and flood control proponents as an acceptable compromise between protecting the environment and providing flood control.

6-9. Control of Meandering

a. Development and migration of meanders is a major stability problem in many flood control projects. This often results from continuation or aggravation of a pre-existing situation. Tolerable pre-existing meander migration may become troublesome in a project context because it threatens flood control levees. Pre-existing meandering may be aggravated because increased channel-forming discharge tends to increase the meander wavelength and amplitude and rate of migration, or because natural bank protection has been disturbed by project works or accompanying land-use changes. For example, clearing and snagging or channel enlargement often reduces the erosion resistance of stream banks and leads to accelerated meandering. Redevelopment of meanders is a common problem in streams that have been straightened or realigned (Figures 3-6 and 6-21). If a channel is made too wide, the low-water channel may develop submeanders (Figure 3-21) that can gradually progress to full meanders by erosive attack on the banks.

b. There is an apparent paradox about certain aspects of meandering. It might seem logical that high slopes and velocities would cause more rapid meander shifting. However, it is noticeable that streams with flat slopes and relatively low velocities often have very active meanders, and that meandering tends to be more extreme in backwater zones, for example, upstream of confluences and reservoirs.

Figure 6-21. Redevelopment of meanders in straightened channel following side bar development

c. Several points about dealing with meandering in project design and maintenance are discussed in (11-(5)) below.

(1) The best solution is to locate levees outside the meander belt. This is not always possible, however. In some cases the meander belt may occupy the entire valley bottom. In other cases the meander belt may widen after construction due to factors mentioned in *a* above. Sometimes the pattern of future meander shifting is difficult to predict.

(2) Levees can be set back as far as possible from the existing channel, and a minimum distance between the levees and eroding riverbanks can be specified, with an understanding that protection works will be initiated when this minimum is reached at any point. In the case of the Tanana River at Fairbanks, Alaska, a deferred construction agreement provides for construction of groins when the specified minimum setback is encroached upon.

(3) Short lengths of bank revetment at points of active river attack are not usually effective in the long term. The attack usually shifts to other points and tends to outflank the short revetments. As these are extended, the end result is protection of the entire project length.

(4) An intermittent form of bank protection, such as groins, is usually more economical than continuous revetment. Although groins tend to cause flow disturbances that are sometimes unacceptable for navigational reasons, they appear to be beneficial to fisheries because they provide diversity of flow depths and shelter zones of low velocity during high flows.

(5) Bank vegetation and root systems provide effective protection against rapid meander shifting in many natural streams. Vegetation should not be disturbed unless there is no reasonable alternative. In the case of channel enlargement, excavation on the inner bank only (see Figure 3-3) enables retention of protective vegetation on outer banks. Where existing vegetation has to be removed, it may be feasible to replant. However, biological restorative techniques that are successful in small streams are not always transferable to larger channels. EM 1110-2-1205 should be consulted for guidance.

6-10. Bank Protection

a. Artificial bank protection is used to control meandering, to protect channel banks and levees against velocities and shear stresses that are too high for the bank materials, or to prevent toe scour and removal of berms that would encourage progressive bank failure due to geotechnical factors such as gravity slumping and seepage (Figure 6-22).

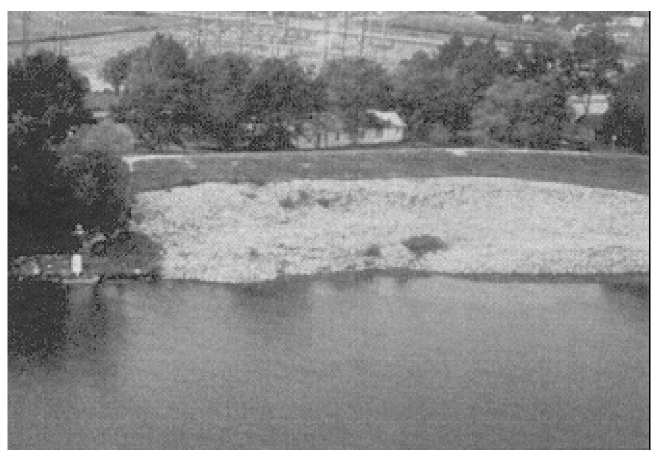


Figure 6-22. Revetment necessitated by encroachment of bank caving on levee

b. Only general comments on bank protection are made herein. More extensive information is given in Petersen (1986), and riprap bank protection is covered in EM 1110-2-1601. EM 1110-2-1205 discusses various methods from an environmental viewpoint. Ports (1989) discusses various aspects of bank erosion and protection.

c. Methods of bank protection can be divided into continuous types such as revetment and discontinuous types such as groins (Figure 6-23). Materials include rock riprap, natural or planted vegetation, concrete, and fabricated or patented systems.

Figure 6-23. Combined use of continuous toe protection and intermittent groins

d. Failure of riprap bank protection is often due to underscouring at the toe. Galay, Yaremko, and Quazi (1987) give a detailed discussion of riprap protection in relation to toe scour. EM 1110-2-1601 provides guidance on weighed toe construction details.

e. In meandering streams, bank protection is usually provided initially only on the outer banks. The protection should be extended far enough upstream and downstream to avoid outflanking (Figure 6-24).

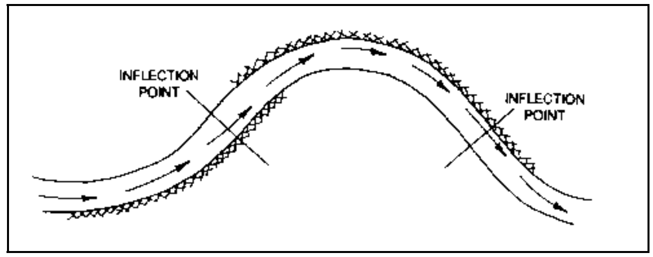


Figure 6-24. Extension of outer bank protection downstream of inflection points

6-11. Control of Sediment Deposition

a. Loss of designed flood conveyance by sediment deposition is a common problem. It often occurs as a result of longitudinal instability (see paragraphs 6-3 through 6-6), or as a result of enlargements that reduce the capacity of the channel to transport sediment arriving from upstream through the project length. Flood diversions, high-level bypasses, or offstream detention reservoirs may also reduce the sediment transport capacity of the main channel. Deposition may occur in unmodified channel reaches downstream from the project because of increased sediment delivery from bank erosion or bed degradation within the project length.

b. Most commonly, deposition is a problem of sandy materials deposited from bed load or suspended load or both. Deposition of fine sand and silt from suspended load may be a problem on berms and in slackwater areas, as well as in estuarial and deltaic channels. Loss of conveyance due to deposition of gravel is less common generally, but is a special problem with alluvial fans in hilly terrain (see paragraph 6-6). Alteration of the nature and location of sediment deposits due to upstream works may adversely affect fish habitat in gravel-bed rivers (Milhous 1982).

c. Methods of controlling sedimentation include the following:

(1) Design of flood control channels that are capable of properly conveying the postproject sediment loads that will be imposed on the system.

(2) Debris basin at the upstream end of project, designed to capture part of the bed material load. It must be evacuated periodically. See EM 1110-2-1601 for details.

(3) Sediment retention structures, grade control structures, etc., in the headwaters and tributaries.

(4) Soil conservation measures in the watershed, including legislation to control sediment production from land use and developments.

(5) Periodic excavation or dredging of the project channel. It is necessary to ensure that a single flood

cannot deposit enough material to compromise the flood protection. The cleanout zone can be localized by excavating a sediment trap at one or more points. This approach may be necessary when the problem involves sedimentation downstream of the project.

d. In the case of levee projects, certain types of vegetation cover on the overbank (berm) areas between the channel and the levees may encourage deposition of fine sediments from suspended load. It may be necessary to keep these areas free of dense vegetation. On the other hand, overbank vegetation may sometimes reduce sediment deposition problems in the main channel.