Chapter 4
Assembly of Information for Stability Evaluation

4-1. General

a. Evaluation of channel stability (see Chapter 5) requires assembly of relevant information on the channel and drainage basin. This chapter provides guidance on collection and assembly of information. Many of the information items may also be required for other project purposes, such as hydraulic and geotechnical design and environmental assessment.

b. Guidance is provided below under a number of headings, corresponding more or less to separate steps appropriate to a project of substantial scope. In the case of small projects, information assembly may be consolidated in accordance with the time and resources available.

4-2. Review of Historical Developments

a. In assessing an existing stream system, it is important to identify historical developments that may have affected its morphology and stability. In some areas the present characteristics of many streams are partly a result of past developments and interferences. Documentary on historical alterations may be difficult to find. However, comparisons of historical maps and of ground and aerial photographs can provide clues as to when significant changes occurred. It may then be possible to obtain information on what actually happened to cause the changes.

b. Historical information is needed for the project stream itself and also for the upstream basin. Large-scale changes in land use often affect channel stability by altering runoff, drainage conditions, and sediment supply. Information on major historical floods predating gage records is often useful. Past diversions into or out of the stream for flood control, irrigation, or other purposes may be key factors. Repairs and modifications to bridge crossings and other river structures may be significant.

c. Information can be summarized in the form of a brief calendar of the most significant administrative, social, and technical changes known to have occurred. An example is shown in Table 4-1. Suggested sources of historical information are listed in Table 4-2. See also Appendix E of EM 1110-2-4000.

Table 4-1
Example of Historical Development Calendar

Date	Development	Agency
1880-1900	Agricultural settlement: conversion from forest to farmland	--
1907	Extreme flood (not measured): extensive damage to farms and communities	--
1910-1925	Channelization and straightening of parts of stream system	Local drainage district
1934-1938	Construction of few soil conservation dams in upper basin	Soil Conservation Service
1955	Hydraulic study followed by limited dredging and bank protection work over lower 10 miles of main stream	Corps of Engineers
1950-1970	General intensification of agricultural development	--
1967	Highest gaged flood	U.S. Geological Survey
1972	Flood control study with recommendations for channel improvements	Corps of Engineers
1977	Environmental study: recommended halt to channel improvement plans	U.S. Environmental Protection Agency

Table 4-2
Suggested Sources of Historical Information

Previous studies and reports: Corps of Engineers, Soil Conservation Service, U.S. Bureau of Reclamation, consultants, etc.
U.S. Geological Survey Quadrangle Sheets: old and new series
Aerial photographs: for some areas AAA photos from the 1920's are available
Topographic maps by Army Map Service and others
County maps and city plots
Offices of county, state, highway, and railroad engineers
Local newspapers
Older inhabitants, especially farmers
U.S. Geological Survey: gauge histories and descriptions, gauging notes, rating curves through period of record; water supply papers; provisional discharge records
National Weather Service: storm and flood records
Municipal water and power plants: gauge records
Irrigation and drainage districts: gauge records

4-3. Map and Aerial Photo Interpretation

a. Topographic maps of various scales can indicate the nature of the drainage basin and stream system, the planform of the channel and its relation to the floodplain, and such physiographic controls as valley walls and intersecting ridges. Maps of different dates can sometimes be used to examine planform changes, and approximate longitudinal profiles and slopes can be developed from contour maps. For smaller streams, however, standard topographic maps may be of limited use.

b. Aerial photographs, stereoscopic if possible, are usually the most practical remote-sensing tool for study of stream channels and their changes (Figure 4-1). They are good for most cases except perhaps smaller streams in heavily wooded terrain. Frequently a number of series dating back to the 1950's or even the 1920's are available. Aerial photos permit examination of sediment deposits and bars, rapids, erosion sites, ice-formed features, and the general characteristics, location, and planform of the channel at various times. Extensive examples of aerial photo interpretation of channel patterns and features can be found in several publications (Mollard and Janes 1984; Cornell University 1952).

c. Quality of photography and suitability of scales may vary greatly between different dates. Low-level, large-scale photographs are not always the best for showing channel features, especially in wooded terrain, because morphologic features tend to be obscured by vegetation, and tone contrasts between different sediments and ground covers tend to be suppressed. For medium-sized streams, scales in the range of 1:10,000 to 1:30,000 are often best. Experienced interpreters generally use a pocket stereoscope for viewing.

d. When aerial photos of different dates are compared, account should be taken of water-level differences, which may be obtainable from hydrometric gage records. Care is also required in horizontal registration of overlays of different dates, with attention to fixed control points and the edge distortion inherent in uncorrected vertical photographs.

e. In a case study in Mississippi, aerial photos of 1986 were compared with presettlement maps of 1830 to examine major changes in channel location that had been initiated by agricultural development and subsequent basinwide erosion and sedimentation. In some reaches the mapped location of the 1830 channel was detectable from stereo viewing of the 1986 photos, being marked by contrasts in vegetation, edges of tree belts, and terrace scarps (Figure 4-2).

f. Satellite imagery, generally available since 1972, is useful for examining basin characteristics and land use changes. The coarse resolution of most early imagery limits its usefulness for channel studies. This limitation has improved dramatically in recent years with 30-meter (m) digital thematic mapper (TM) data and 10-m panchromatic data. With the most recent remote sensing/ Geographic Information System (GIS) software, engineers/scientists can conduct detailed analysis of basin land use changes, point bar formation, bank movement, meander migration, and flood overflow changes, and subsequently compile these data in a structured database that allows for multilevel queries. Imagery, whether it be from a satellite or scanned aerial photography, can be geo-corrected to a particular map projection, resampled to a particular scale, and overlaid in a multiple-layer GIS. The ability to query the database allows study managers to make decisions with a high degree of confidence. Queries may entail computations of linear measurements, area, and land use and visual methods of overlaying layers of the database. Past manual methods of planimetric river analysis can be supplemented or in some cases replaced by remote sensing/GIS technology.

4-4. Field Inspection

a. In the evaluation of the stability of an existing stream and basin, field observation is very important. Field inspection should be done after a review of maps and aerial photos. Further visits may be required at later stages. Both ground and aerial inspections are advisable where possible. Photographs (panoramic where appropriate) and notes or audio records should be taken of all significant features. Photographs should be mounted and annotated to show key features, and numbered for ease of retrieval. Video records may be useful in some cases.

b. Inspection should be done by persons experienced in river hydraulics and stability problems. The main inspection should normally be done under low to moderate flow conditions when the bed and banks of the streams are more easily seen, and preferably when foliage is absent. Additional observations under storm or flood conditions may be appropriate. In cold regions, the main inspection must be done when channels are free of ice and snow, but additional observations under ice conditions may be appropriate.

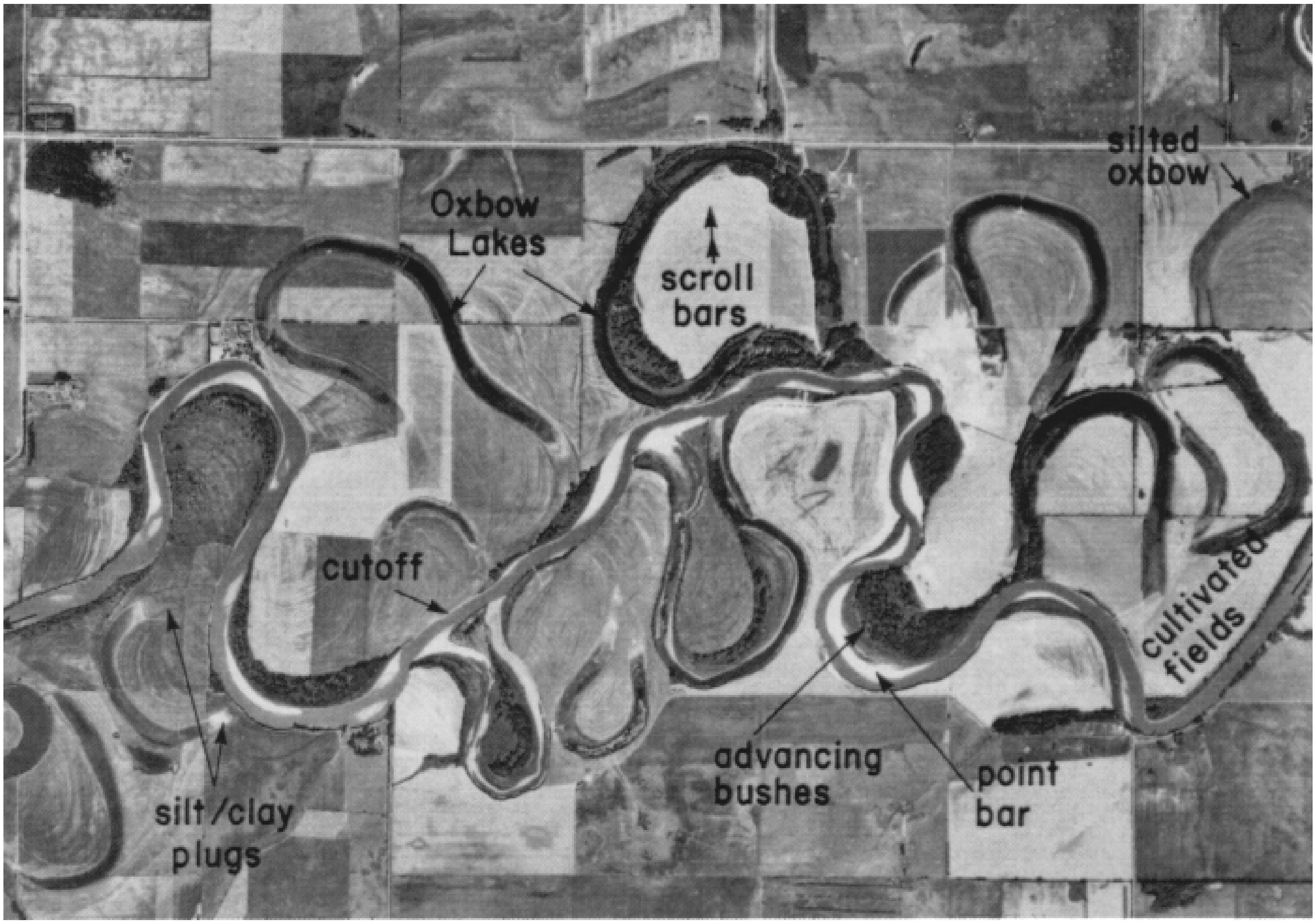


Figure 4-1. Aerial photograph of meandering river illustrating channel features

c. Electronic means of note taking such as tape recordings are favored by some observers, but they can require a troublesome amount of subsequent processing and interpretation. Excessive photography poses similar problems. Recording of information should be guided by considerations of necessity and sufficiency.

d. Excessive reliance should not be placed on observations from bridge crossings. In many cases, bridges tend to be built at special sites that are not typical of the stream as a whole. Also, bridges may create hydraulic anomalies in the course of time. On the other hand, evidence of extensions, underpinning, and remedial work at bridges may reveal instability problems.

e. The guidance provided here applies particularly to hydrotechnical aspects of stability. Joint inspections with geotechnical and environmental evaluation personnel may offer technical and economic advantages.

4-5. Key Points and Features

Points and features to be particularly looked for in field inspections are listed below under several heads. For background on the significance of points listed, reference should be made to Chapter 2, particularly paragraphs 2-3 and 2-8. The list does not necessarily include all features that may be significant in a particular case. Table 4-3 provides a summary checklist. If the channel has been subject to past works and interferences, efforts should be made during the field inspection to detect response in the form of changes to cross sections, slopes, planform, channel shifting, sedimentation, etc.

a. Upstream basin conditions.

(1) Topography, soils, vegetation, land use, and ongoing changes that may impact on channel stability.

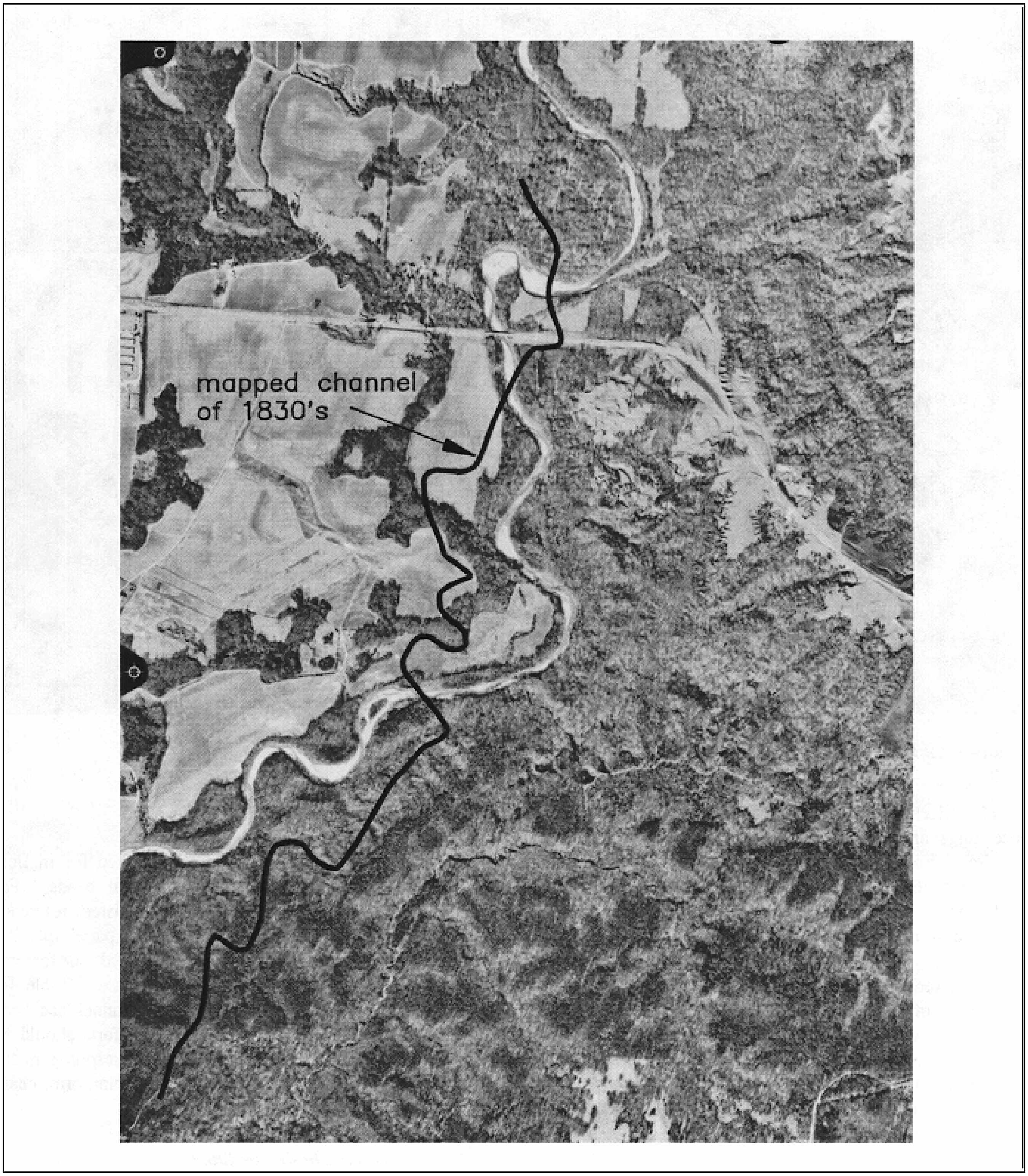


Figure 4-2. Comparison of modern (1986) and presettlement (1830) channel locations, Fannegusha Creek, Mississippi

Table 4-3
Checklist for Field Inspection

Upstream Basin and Channel Conditions

- Topography, soils, vegetation, land use, ongoing changes
- Erosion/deposition zones, sediment sources
- Drainage/irrigation systems, diversions
- Geomorphic controls and boundaries

Channel Planform and Banks

- Geological and structural controls
- Channel shifting and migration
- Bank soils, stratigraphy, failures, ice, seepage
- Vegetation, bank protection, floodplain conditions

Channel Profile and Bed

- Profile control points, irregularities
- Sediment deposits and stratigraphy
- Sizes and movement of bed material
- Degradation and aggradation

Water Surface Profile and Hydraulics

- High-water marks, debris/ice jams, flood conditions
- Velocities and roughness

Downstream Reaches

- Prior interference
- Features susceptible to upstream changes

General

- Photographs
- Overflight
- Witnesses to past floods
- Past interferences and responses

Note: Also see Appendix E of EM 1110-2-4000.

(Some items may be more easily obtainable from reports, maps, and aerial photos.)

(2) Active zones of erosion and deposition and evident sediment sources: sheet, rill, and gully erosion, etc. (Figure 4-3).

(3) Drainage and irrigation systems and diverted inflows and outflows.

(4) Tributary instability: gullying, headcutting, etc. (Figure 4-4).

(5) Dominant geomorphic controls: ridges, scarps, landform and channel type boundaries, etc. (see paragraphs 2-1 and 2-2). (May require specialist input.)

Figure 4-3. Major sediment source: valley landslide

Figure 4-4. Tributary gully

b. Channel planform and banks.

(1) Geological and structural controls on stream migration: valley walls, outcrops of rock and clay, clay plugs, bridges and dams, etc.

(2) Channel shifting and migration processes: meandering, cutoffs, braiding, etc.

(3) Bank soils and stratigraphy (Figure 4-5): composition, grain size ranges, layering, lensing, etc.

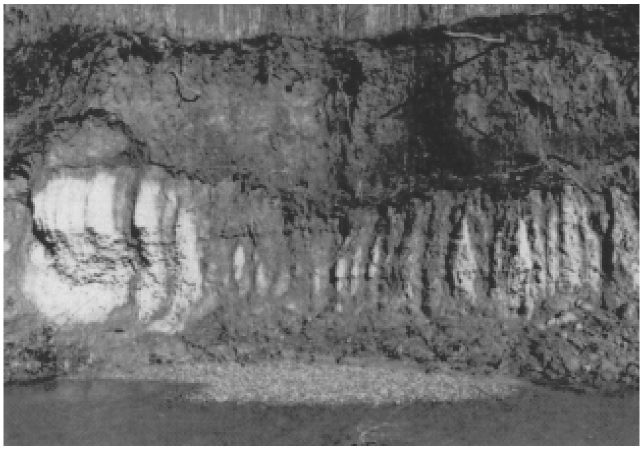


Figure 4-5. Stratification of bank soils

(4) Bank failures and erosion (Figure 4-6): locations, causes, and mechanisms (see paragraph 2-8).

Figure 4-6. Bank failure

(5) Drainage and seepage conditions especially after high flows (Figure 4-7), adjacent impoundments, irrigation, and cultivation practices.

(6) Types and densities of vegetation and root systems on banks and floodplain, and their significance with respect to erosion, slope stability, hydraulic roughness, trapping of sediment and debris, channel shifting, etc. Age and succession of vegetation on channel banks and bars can sometimes indicate rates of shifting and heights of flooding.

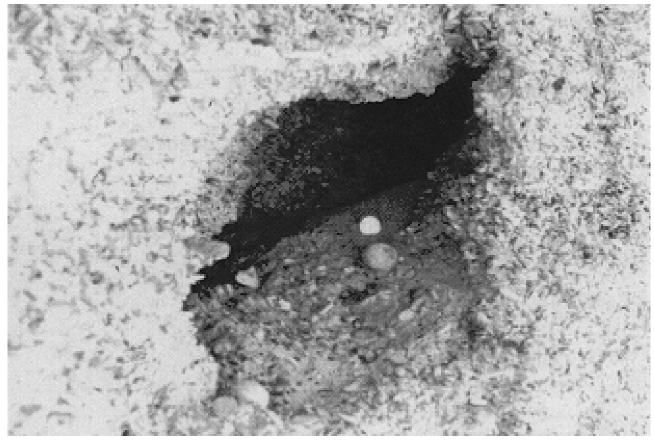


Figure 4-7. Piping and seepage in bank

(7) In cold regions: ice action on banks and vegetation, freeze-thaw action, frozen ground and ice lenses (see Figures 2-27 and 2-28; geotechnical input may be required).

(8) Existing and past bank protection work, damage, and failures and their causes.

(9) Floodplain conditions: natural and artificial levees, obstructions to flow, presence and clearing of vegetation, hydraulic roughness, local drainage inflow points, etc.

c. Channel profile and bed.

(1) Profile controls: outcrops, falls and rapids, nick points and zones (Figure 4-8), culverts, weirs, beaver dams, etc.

(2) Irregularity of streambed, occurrence of scour holes and shoals, alluvial bed forms, etc.

(3) Locations, forms, and grain size distributions of sediment deposits and bars (Figure 4-9).

(4) Thicknesses of active bed sediment, where probing or excavation to substratum is practicable.

(5) Indications of frequency of bed sediment movement; largest bed sediment sizes moved in past floods; relative intensity of bed sediment transport in the context of streams generally or of the region in question.

Figure 4-8. Nick zone in degrading channel (clay layer)

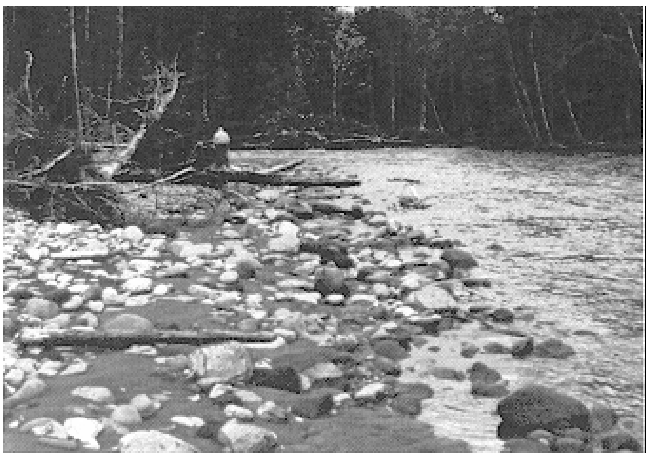


Figure 4-9. Channel bar with various sediment classes and debris

(6) Evidence of degradation: perched tributaries (Figure 4-10), exposed bridge piling (Figure 4-11), banks undercut both sides, etc.

(7) Evidence of aggradation; reduced bridge clearances, overtopped levees, buried intakes, etc.

d. Water surface profile and hydraulics.

(1) Recent high-water marks and probable dates.

(2) Water marks of afflux and drawdown around bridge piers (Figure 4-12). (Can sometimes be used to infer flood velocities.)

(3) Debris jams and accumulations.

Figure 4-10. Mouth of perched tributary

Figure 4-11. Exposed bridge piling

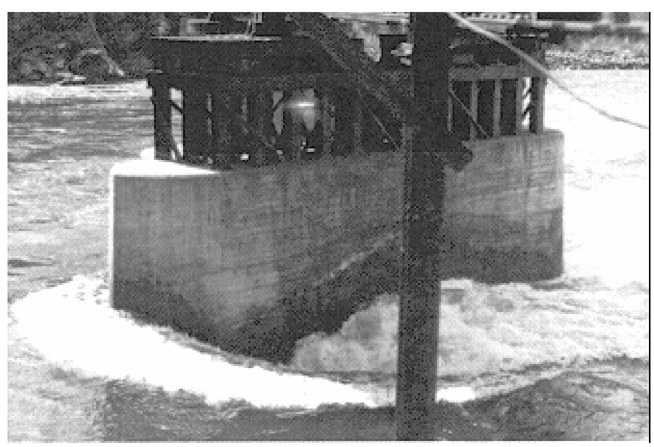


Figure 4-12. Flood stain marks on piers

(4) Evidence of ice jams and accumulations: tree scars, stripped vegetation, etc.

(5) Local photographs or witnesses' descriptions of flood conditions: depths of overbank flooding, standing waves, directions of attack on banks, overflow and escape routes, etc.

(6) Approximate velocities as observed.

(7) Estimates of hydraulic roughness based on general experience of channels (for confirmation purposes when other means of estimating are available).

e. Upstream and downstream reaches. Channel conditions should be inspected for some distance upstream and downstream of the project reach, with particular attention to features likely to impact on the project or susceptible to project-induced changes. Points to consider include how all the flood flows will be guided into the project channel at the upstream end; existing and potential upstream debris production; and downstream degradation as evidenced by headcuts (see paragraphs 3-18 through 3-23). Upstream and downstream reaches may require further attention at a later project stage.

4-6. Channel and Floodplain Surveys

a. Topography.

(1) Topographic or photogrammetric surveys to provide ground contours, channel and floodplain cross sections, and longitudinal profiles are normally required for the basic flood control aspects of the project. Attention to a number of points can improve the usefulness of survey information for stability evaluation.

(2) Cross sections should show margins and significant changes of vegetation cover, elevations of visible changes in bank soils, bank protection, water levels at time of survey, and detectable high-water marks. Section locations should be selected to cover a representative range of planform types - bends, straights, points of inflection, etc. - and a range of channel widths. If recent aerial photographs or a photomosaic plan is available, they can be used to select cross-section locations in advance and then to identify the locations on the ground. An example cross section is shown in Figure 4-13.

(3) The longitudinal profile should show bed levels, low or ordinary water levels, top of banks, and high-water

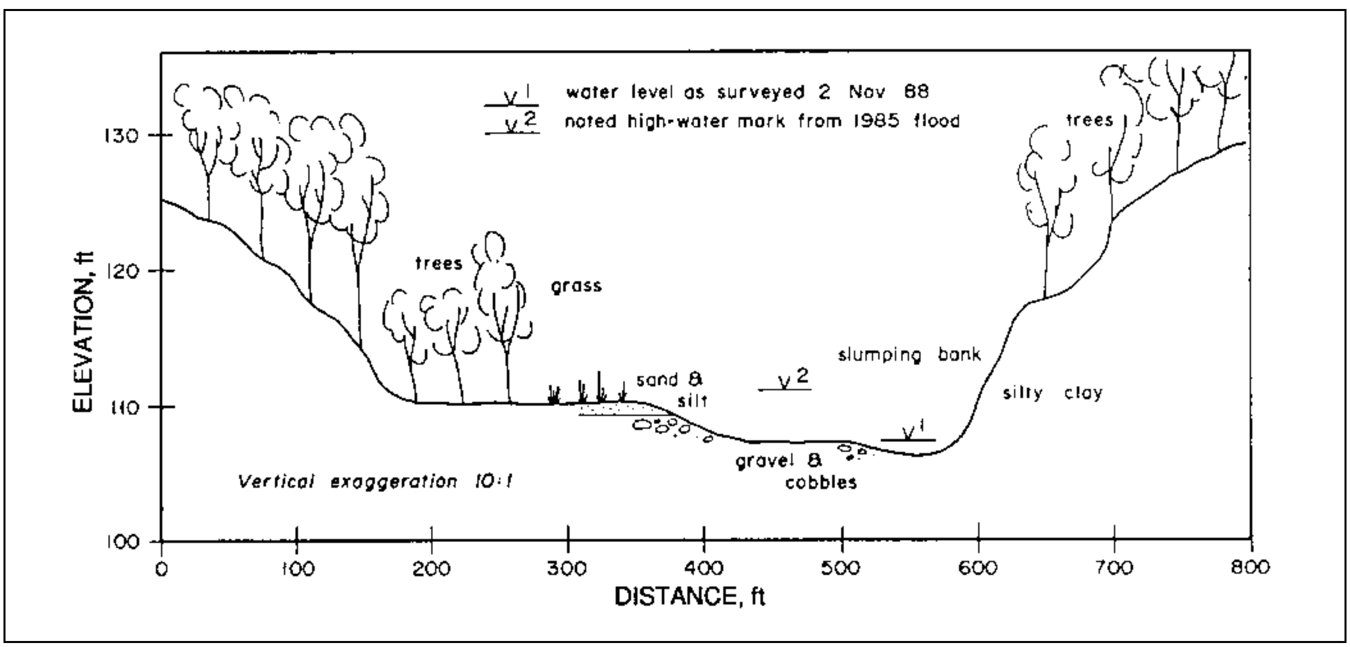


Figure 4-13. Example survey cross section

levels. Various bases for these delineations can be used. The bed levels may be along center line or along the thalweg (locus of deepest points). The low or ordinary water level may be a surveyed line on a specific date or a computed line corresponding to mean annual flow or other hydrologic parameter. The high-water level may be a surveyed high-water mark or a computed line corresponding to a flood of specified return period. For streams with definite floodplains, tops of bank lines should correspond more or less to floodplain levels unless there are bank levees. Notable discontinuities in the bed such as nick points, rapids and falls, and structures should be shown. An example profile is shown in Figure 4-14.

(4) Distances shown in profiles of single-channel streams should normally be measured along the channel center line. Where the stream splits into two or more channels, the main or largest channel should be used. In fully braided systems it is more practical to measure along the center of the braided belt. The basis for distance measurement should be clearly stated. Fixed points such as road crossings and tributary confluences should be shown. Quoted slopes should be based on fall divided by distance. When a stream has been shortened by previous channelization work and superimposed profiles are to be shown, it is best to superimpose fixed points such as bridges and show different distance scales; otherwise, false impressions of degradation and aggradation may be conveyed. Furthermore, exercise care when evaluating cross-section and profile data taken over time, i.e., low water, rising hydrograph, falling hydrograph, etc., when assessing aggradation and degradation trends.

b. Soils and materials.

(1) Samples of bed and bank materials should be taken for analysis of grain size distributions and for determination of other properties as required. The locations and frequency of sampling should be selected on the basis of previous field inspection and aerial photo interpretation.

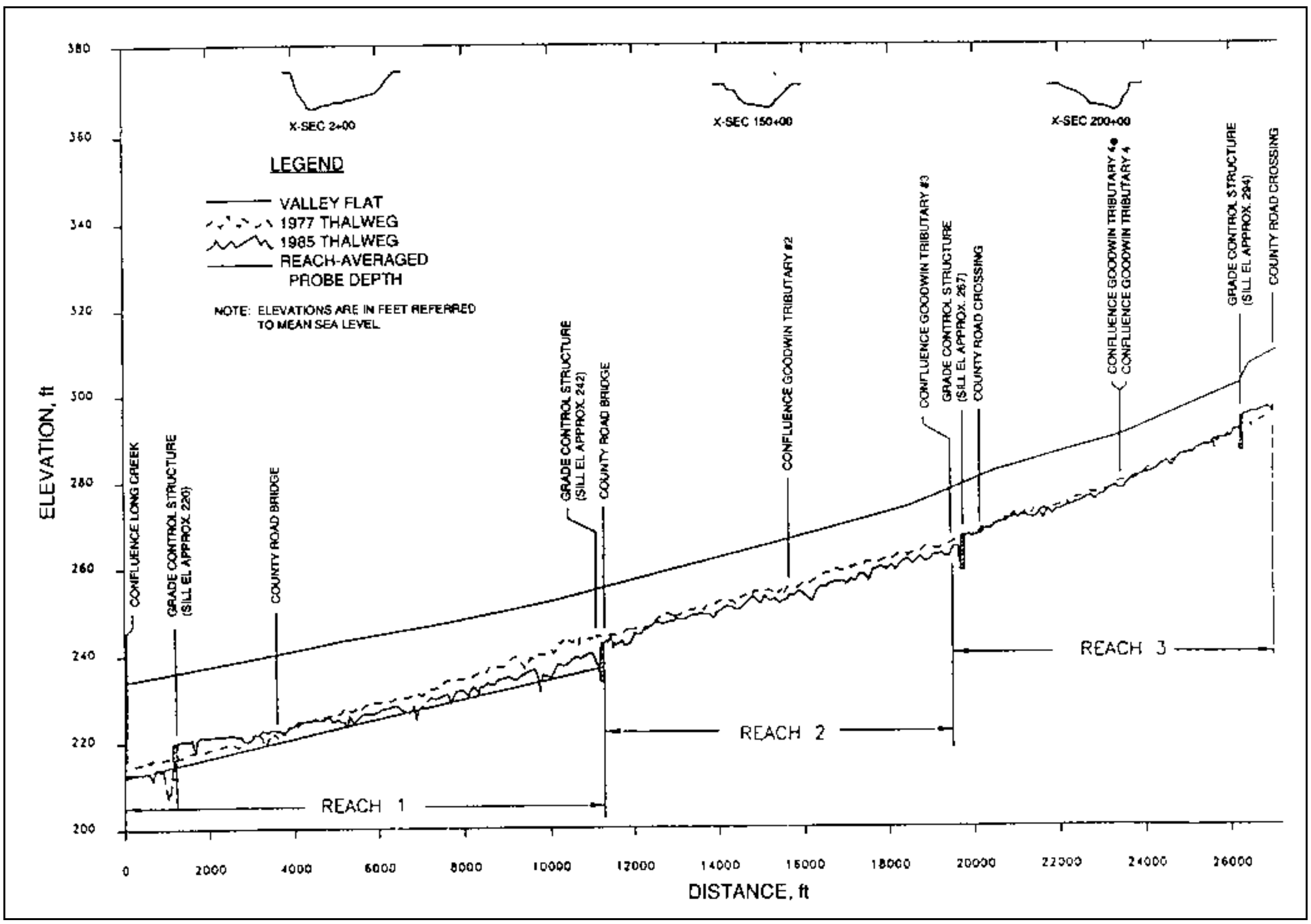
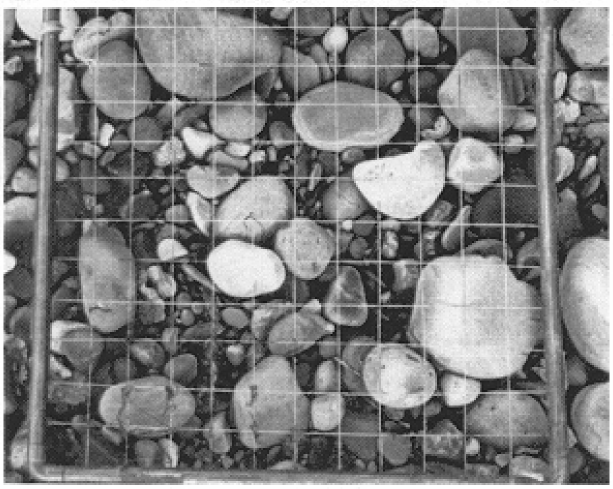


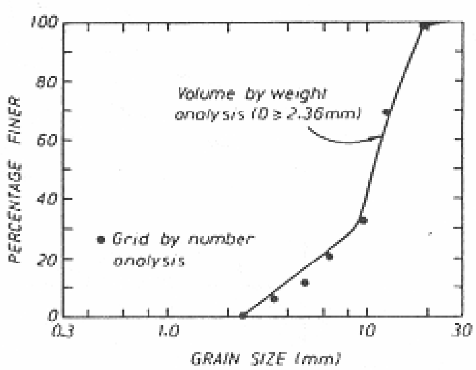
Figure 4-14. Example of stream profile

Due account should be taken of variation of soils and sediments along and across the stream, below the streambed, and up the banks.

(2) With coarse bed materials, collection of samples large enough for meaningful grain size analysis may be inconvenient. An alternative is to photograph the surface of channel bars though a wire grid, and to analyze the surface distribution from the photographs (Figure 4-15). If the surface material is similar to the underlying material, a surface distribution by number is more or less equivalent to a bulk distribution by weight (see Kellerhals and Bray 1971; Hey and Thorne 1983; Diplas and Sutherland 1988). In some coarse-bed streams, however, surface and underlying distributions of bed material are considerably different because of armoring effects. Armoring is more likely in streams where the bed is relatively inactive than in streams with frequent bed transport. If armoring is present, it is preferable to collect bulk samples that include subsurface material as well as the larger sizes in the armor layer.



a. Typical grid photograph



b. Comparison of grid by number analysis with volume by weight analysis-laboratory tests (Diplas and Sutherland 1988; courtesy of American Society of Civil Engineers)

Figure 4-15. Grid photograph of coarse sediment and comparison of analysis methods

(3) In streams with relatively fine or loose bed material of limited thickness overlying more consolidated materials, the bed can be probed at intervals with a metal rod to determine thicknesses of active sediment. Such determinations are particularly valuable in considering potential for bed degradation. Geophysical methods of determining sediment thickness are feasible in some cases. With very loose estuarial and coastal sediments, some form of echo sounding may be feasible. Where probing or indirect methods of investigating stratigraphy are not feasible, soil borings or excavations may be advisable.

c. Bank failure and erosion. The general characteristics of bank failure and erosion will be noted in the field inspection (see paragraph 4-4). In some cases a detailed survey of erosional sites may be required to relate erosional severity to bank soils, heights and slopes, etc. Related technical background is outlined in Section 5-3.

4-7. Streamflow and Related Data

a. General. Streamflow data are basic to engineering analysis of channel stability (see Section 5-3). Normally these data are analyzed for flood control aspects of the project. Data presentations required include discharge records, flood-frequency relationship, flow-duration relationship, and stage-discharge relationship. Where there is a hydrometric gauge in the basin, the first three can usually be generated for the project length without great difficulty. A gauge stage-discharge relationship, however, may be difficult to transfer to the project reach. In ungauged basins, synthetic discharge estimates may be generated from hydrologic analogy or from watershed modelling. In small flood control projects, lack of streamflow data often limits the practicability of stability analysis. If reliable streamflow information is not available, experienced judgment may be more useful than analysis.

b. Discharge records.

(1) The historical sequence of annual maxima is useful for interpreting field inspection and surveys. Especially in small basins, attention should be paid to peak instantaneous discharges rather than maximum daily discharges. If there has not been a large flood for many

years, the channel may convey a false impression of longterm stability. On the other hand, a recent extreme flood might have severely destabilized the channel, presenting an exaggerated impression of long-term instability.

(2) If the flood sequence exhibits peculiar features or anomalies, it is advisable to examine the gage history to assess possible changes due to subsidence or uplift or to shifts in gage location or datum.

c. Flood-frequency relationship. A graphical relationship using any standard method of plotting is usually sufficient. Extrapolation to return periods far beyond the length of the record should be regarded skeptically. Efforts should be made to determine the frequency of the bank-full discharge. If the stream has a definable bank-full condition and its return period appears to fall outside the range of 1 to 5 years, there may be a case for reviewing the hydrologic data, especially if they are synthesized.

d. Flow-duration relationship. A flow-duration relationship may be useful for a rough assessment of how frequently the streambed material is in motion, if used in conjunction with a beginning-of-motion analysis (see Section 5-3). It is also needed for estimating annual volumes of sediment transport. In small streams, it is particularly important to define the portion of the flow-duration curve with exceedances of 1 percent or less.

e. Stage-discharge relationship.

(1) A reliable stage-discharge relationship is needed for quantitative stability analysis. An incorrect stage-discharge relation may be quite misleading, especially if velocities are used as a stability criterion.

(2) Specific gage records, which plot stages versus time (usually in years) for fixed values of discharges, can be developed from the historical record of stage-discharge data for a particular gage. These are often valuable tools in assessing the vertical stability of the channel (see Figure 3-17).

(3) Where there is no suitable gage record, stage-discharge relationships are normally synthesized either by nonuniform flow analysis using HEC-2 or similar programs, or by uniform flow analysis of cross-section and slope data. The limitations of fixed-bed flow analysis as applied to mobile-boundary channels are not always sufficiently appreciated. Sections based on low-water surveys may be incorrect for high-water stages, because of channel scour and fill. If the channel is relatively uniform in cross section and slope, uniform flow analysis in which the Manning or similar equation is applied to an average cross section and slope may be sufficient and in some cases as reliable as nonuniform analysis.

(4) The greatest difficulty in synthesizing a stage-discharge relationship is correct estimation of hydraulic roughness, especially during the large floods that are critical for stability. Every effort should be made to check computed stages against observed or indicated water levels in past floods of known or estimated discharge.

4-8. Geologic and Geotechnical Information

a. Geologic and geotechnical information is important in evaluating channel stability. It is valuable to understand the geologic origins and geotechnical properties of soils and sediments that interact with the channel processes. Information may be obtained from previous reports or involvement of a specialist.

b. In a dynamic channel system, rock outcrops, cemented gravels, tills, and clay plugs may form hard points that resist erosion and constitute more or less fixed nodes in the plan form. Some cohesive or cemented deposits and soft rocks, however, break down fairly rapidly into cohesionless sediments under the influence of weathering, particularly freeze-thaw and wet-dry cycles.

c. Geotechnical conditions that often result in bank failure in alluvial and glacial outwash soils include internal erosion of dispersive clay, silt, and fine sand through piping; tension crack formation and displacements; saturation and drawdown with flood rise and recession; and surface slaking and soil flows due to temperature and moisture changes.

d. Lacustrine and glaciolacustrine soils and low-flow deposits may be layered or “varved.” Many banks in such soils exhibit slope instability.

e. Wind-deposited soils such as loess, composed of silt and clay-size particles, can stand on very steep slopes when dry, but are susceptible to loss of cementation when wetted and to erosion by overland flows.

f. Colluvial soils, derived from weathering of underlying rocks and subsequent gravity movement, are often found on steep river valley slopes. In wet periods they are subject to reduction in strengths and increases in unit weight, which tend to initiate bank failures. They may contain silty clay and weathered rock fragments.

Erosion of the silty clay may leave a temporary layer of rock fragments, too thin to act as a stabilizing berm, that becomes covered by subsequent landslides.

g. Glacial till is generally a compact mixture of clay, silt, sand, gravel, and boulder sizes. Most deposits are fairly resistant to erosion, and most streams in a till environment exhibit relatively low rates of erosion and channel shifting. Long-term incision of streams in till soils often leaves a surficial armor layer of cobbles or boulders that is resistant to movement by the stream.

4-9. Sediment Transport

Data needs for analysis of sediment transport are covered in EM 1110-2-4000, to which reference should be made if a full sedimentation analysis is judged advisable. In many small to medium flood control projects the necessary time and resources are not available; yet some qualitative assessment is desirable. The following points may assist such an assessment:

a. The relative degree of bed material transport - for example, low, medium, or high - can be judged to some extent by experienced observers from the aerial and ground features of the channel under relatively low flow conditions. Channels with high transport have large areas of exposed bars exhibiting clean rounded bed material without growths and vegetation. Channels with low transport tend to have few exposed bars, stable banks, and individual grains or stones covered with algae.

b. The degree of wash load can be similarly judged from recent silt and clay deposits in slack-water areas and on the upper banks and floodplain. Channels with high wash load will exhibit substantial thicknesses of silt/clay not yet colonized by vegetation. Channels with low wash load will have clean granular sediments on the upper banks and floodplain.

c. Notwithstanding *a* and *b* above, appearances are sometimes deceptive in the absence of local or regional experience. For example, the appearance of a medium-transport channel may vary considerably from arid to humid regions and from cold to hot regions. Description of bed material transport as low, medium, or high refers essentially to high-flow conditions, for example, discharges like the mean annual flood. Such a scheme may not be useful for ephemeral streams in arid regions, where floods capable of transport may occur at rare intervals and the channel is dry much of the time.

d. In meandering streams exhibiting systematic migration through an alluvial floodplain, the degree of bed-sediment transport is linked to the rate of meander shifting. The severity of bank recession can be visualized in terms of channel widths; for example, a rate of one channel width per year would be very high, whereas a rate of 1 percent of channel width per year would be quite low.

e. A braided planform usually but not always indicates high bed material transport. A contorted meander planform without visible point bars usually indicates low bed material transport, although wash load may be high. More generalized relationships of this type are discussed in paragraph 2-3.