Chapter 17
Channel Capacity Studies

17-1. Introduction

a. *General*. Channel capacity studies tend to focus on high flows. Flood operations for a reservoir will require operational downstream targets for nondamaging flows when excess water must be released. Nondamaging channel capacity may be defined at several locations, and the target flow may be defined at several levels. There may be lower targets for small flood events and, under extreme flood situations, the nondamaging target may cause some minor damage. Also, the nondamaging flow target may vary seasonally and depend on floodplain land use.

b. *Withstanding release rates*. Channel capacity is also concerned with the capability of the channel to withstand reservoir release rates. Of particular concern is the reach immediately downstream from the reservoir. High release rates for hydropower or flood control could damage channel banks and cause local scour and channel degradation.

c. *Channel capacity*. While flood operation may focus on maximum channel capacity, planning studies usually require stage-discharge information over the entire range of expected operations. Also, low-flow targets may be concerned with maintaining minimum downstream flow depth for navigation, recreation, or environmental goals. Channel capacity studies typically provide information on safe channel capacity and stage-discharge (rating) curves for key locations.

17-2. Downstream Channel Capacity

a. *Downstream channel erosion*. Water flowing over a spillway or through a sluiceway is capable of causing severe erosion of the stream bed and banks below the dam. Consequently, the dam and its appurtenant works must be so designed that harmful erosion is minimized. The outlet works for a dam usually require an energy-dissipating structure. The design may vary from an elaborate multiple-basin arrangement to a simple head wall design, depending on the number of conduits involved, the erosion resistance of the exit channel bed material, and the duration, intensity, and frequency of outlet flows. A stilling basin may be provided for outlet works when such downstream uses as navigation, irrigation, and water supply, require frequent operation or when the channel immediately downstream is easily eroded. Sections 4-2b and 4-3j of EM 1110-2-3600 provide a general discussion of energy dissipators for spillways and outlet works, respectively.

b. *Adequate capacity*. The channel downstream should have adequate capacity to carry most flows from reservoir releases. After the water has lost most of its energy in the energy-dissipating devices, it is usually transported downstream through the natural channel to its destination points. With the expected release rates, the channel should be able to resist excessive erosion and scour, and have a large enough capacity to prevent downstream flooding except during large floods.

c. *River surveys*. River surveys of various types provide the basic physical information on which river engineering planning and design are based. Survey data include information on the horizontal configuration (planform) of streams; characteristics of the cross sections (channel and overbank); stream slope; bed and bank materials; water discharge; sediment characteristics and discharge; water quality; and natural and cultural resources.

d. *Evaluating bank stability*. To evaluate bank stability, it is essential to understand the complex historical pattern of channel migration and bank recession of the stream and the relationship of channel changes to streamflow. Studies of bank caving, based on survey data and aerial photographs, provide information on the progressively shifting alignment of a stream and are basic to laying out a rectified channel alignment. The concepts and evaluation procedures presented in “Stability of Flood Control Channels” (USACE 1990) are applicable to the channel capacity evaluation.

e. *Interrupted sediment flow*. A dam and reservoir project tends to interrupt the flow of sediment, which can have a significant impact on the downstream channel capacity. If the project is relatively new, the affect may not be seen by evaluating historic information or current channel conditions. The future channel capacity will depend on the long-term trends in aggradation and degradation along the river. General concepts on sediment analysis are presented in Chapter 9. *Sediment Investigations of Rivers and Reservoirs*, EM 1110-2-4000, is the primary reference for defining potential problems and analyses procedures.

f. *Downstream floodplain land use*. Channel capacity also depends on the long-term trends in downstream floodplain land use. While it is not a hydrologic problem, channel capacity studies should recognize the impact of floodplain encroachments on what is considered the nondamaging channel capacity. Anecdotal history has shown that many Corps' projects are not able to make planned channel-capacity releases due to development and encroachments downstream.

17-3. Stream Rating Curve

a. *Stage-discharge relationship*. The relationship between stage and discharge, the "rating" at a gauging station, is based on field measurements with a curve fitted to plotted data of stage versus discharge. For subcritical flow, the stage-discharge relationship is controlled by the stream reach downstream of the gauge; for supercritical flow, the control is upstream of the gauge. The stage-discharge relationship is closely tied to the rate of change of discharge with time, and the rating curve for a rising stage can be different from that for the falling stage in alluvial rivers.

b. *Tailwater rating curve*. The tailwater rating curve, which gives the stage-discharge relationship of the natural stream below the dam, is dependent on the natural conditions along the stream and ordinarily cannot be altered by the spillway design or by the release characteristics. Degradation or aggradation of the river below the dam, which will affect the ultimate stage-discharge conditions, must be recognized in selecting the tailwater rating curves to be used for design. Usually, river flows which approach the maximum design discharges have never occurred, and an estimate of the tailwater rating curve must either be extrapolated from known conditions or computed on the basis of assumed or empirical criteria. Thus, the tailwater rating curve at best is only approximate, and factors of safety to compensate for variations in tailwater must be included in dependent designs.

c. *Extrapolation*. Extrapolation of rating curves is necessary when a water level is recorded below the lowest or above the highest gauged level. Where the cross section is stable, a simple method is to extend the stage-area and stage-velocity curve and, for given stage values, take the product of velocity and cross-section area to give discharge values beyond the stage values that have been gauged. Generally, water-surface profiles should be computed to develop the rating beyond the range of observed data.

d. *Rating curve shifts*. The stage-discharge relationship can vary with time, in response to degradation, aggradation, or a change in channel shape at the control section, deposition of sediment causing increased approach velocities in a weir pond, vegetation growth, or ice accumulation. Shifts in rating curves are best detected from regular gauging and become evident when several gaugings deviate from the established curve. Sediment accumulation or vegetation growth at the control will cause deviations which increase with time, but a flood can flush away sediment and aquatic weed and cause a sudden reversal of the rating curve shift.

e. *Flow magnitude and bed material*. Stream bed configuration and roughness in alluvial channels are a function of the flow magnitude and bed material. Bed forms range from ripples and dunes in the lower regime (Froude number < 1.0) to a smooth plane bed, to antidunes with standing waves (bed and water surface waves in phase) and with breaking waves and, finally, to a series of alternative chutes and pools in the upper regime as the Froude number increases.

f. *Upper and lower rating portions*. The large changes in resistance to flow that occur as a result of changing bed roughness affect the stage-discharge relationship. The upper portion of the rating is relatively stable if it represents the upper regime (plane-bed, transition, standing wave, or antidune regime) of bed form. The lower portion of the rating is usually in the dune regime, and the stage-discharge relationship varies almost randomly with time. Continuous definition of the stage-discharge relationship at low flow is a very difficult problem, and a mean curve for the lower regime is frequently used for gauges with shifting control.

g. *Break up of surface material*. In gravel-bed rivers, a flood may break up the armoring of the surface gravel material, leading to general degradation until a new armoring layer becomes established and ratings tend to shift between states of quasi-equilibrium. It may then be possible to shift the rating curve up or down by the change in the mean-bed level, as indicated by plots of stage and bed level versus time.

h. *Ice*. Ice at the control section may also affect the normal stage-discharge relationship. Ice effects vary with the quantity and the type of ice (surface ice, frazil ice, or anchor ice). When ice forms a jam in the channel and submerges the control or collects in sufficient amounts between the control and the gauge to increase resistance to flow, the stage-discharge relationship is affected; however, ice may form so gradually that there is little indication of its initial effects. Surface ice is the most common form and affects station ratings more frequently than frazil ice or anchor ice. The major effect of ice on a rating curve is due to backwater and may vary from day to day.

17-4. Water Surface Profiles

a. *Appropriate methods*. For most channel-capacity studies, water surface profiles will be computed to develop the required information. Given the technical concerns described in the preceding section on rating curves, the selection of the appropriate method requires some evaluation of the physical system and the expected use of the information. The modeling methods are described in Chapter 8 and are presented in EM 1110-2-1416. While steady-flow water surface profiles are used in a majority of profile calculations, the unsteady flow aspects of reservoir operation or the long-term effects of changes in sediment transport may require the application of methods that capture those aspects.

b. *Further information*. The Corps, and other agencies, have accumulated considerable experience with river systems. Appendix D, "River Modeling - Lessons Learned" (EM 1110-2-1416), provides an overview of technical issues and modeling impacts that apply to profile calculations. *Stability of Flood Control Channels* (USACE 1990) provides case examples of stream stability problems, causes, and effects. While the focus is not on reservoirs, the experience reflects the high flow conditions that are a major concern with reservoir operation. And EM 1110-2-4000 provides procedures for problem assessment and modeling. All of these documents should be reviewed prior to formulating and performing technical studies.