CHAPTER 4

CHANNEL SIZE AND ALIGNMENT

Section I. General

4-1. Channel Characteristics. The type and amount of traffic that can be accommodated by a waterway will depend to a considerable extent on the available width, depth, and alignment of the channel in addition to other factors. Most shallow-draft waterways utilize most or part of an existing stream which consists of alternate bends and straight reaches or crossings between bends. Even canals have bends as required to take advantage of existing lakes or low areas and/or bypassing existing structures or highly developed areas. Because of the characteristics of the equipment using the waterways, the channel dimensions required will vary depending on the alignment of the channel.

* 4-2. Channel Dimensions. Section 5 of the Rivers and Harbors Appropriation Act approved 4 March 1915 outlines the basis for channel dimensions as follows:

> "That in the preparation of projects under this and subsequent river and harbor Acts, unless otherwise expressed, the channel depths referred to shall be understood to signify the depth at mean low water in tidal waters tributary to the Atlantic and Gulf coasts and at mean lower low water in tidal waters tributary to the Pacific coast and the mean depth for a continuous period of fifteen days of the lowest water in the navigation season of any year in rivers and nontidal channels, and the channel dimensions specified shall be understood to admit of such increase at the entrances, bends, sidings, and turning places as may be necessary to allow of the free movement of boats."

Note the statement "unless otherwise expressed" means, specific project authorization takes precedence over the Section 5 general authorization. Where rivers have been canalized, the channel depth referred to will usually be the depth at normal pool. When a width of channel is specified it will be understood to mean the bottom width at project depth in straight segments. Widening on bends is generally needed to allow safe vessel transit. *

4-3. Channel Requirements. Channel dimensions required for navigation will depend on channel alignment, size of tow, and whether one-way or two-way traffic is to be accommodated. One-way traffic can be justified on segments of some waterways when there is a low volume of traffic, passing lanes are provided on long reaches, and close traffic control and communication are maintained. Providing for two-way unrestricted traffic would result in a much safer and more efficient waterway. Channel dimensions and alignment provided can affect construction and maintenance cost and the development of traffic on the waterway. Providing a straight channel can reduce the length of the waterway and require less channel width than with a sinuous channel. However, channels in natural streams tend to meander with most of the length of the low-water channel occurring in bends of various curvature. In streams carrying sediment, long straight reaches would tend to be unstable and difficult to maintain.

Section II. Channel Design

4-4. Channel Cross Section. In determining the channel size, some of the basic criteria used are the sectional area ratio, draft-depth ratio, and maneuverability requirements. Tests have indicated that the resistance to tow movement in a restricted channel decreases rapidly as the sectional area ratio (ratio of the channel area to the submerged tow area) is increased to a value of 6 or 7 and then decreases less rapidly as the ratio is further increased. Resistance to tow movement and power required to move the tow are increased if the draft is more than about 75 percent of the available depth, particularly if the channel has restricted width, such as a canal or a lock.

Section III. Channel in Straight Reaches

4-5. Minimum Width. The minimum channel widths required for safe navigation in straight reaches depend on the type and size of equipment in general use on the waterway, alignment and velocity of currents, intensity of the prevailing wind, how well the channel limits are defined, navigation aids provided, and whether one-way or two-way traffic is permitted. The minimum channel width should provide for the width occupied by the tow, clearance between the tow and channel limits, and clearance between tows for two-way traffic. Operating experience has indicated that the minimum clearance required for reasonably safe navigation in straight reaches should be at least 20 feet between tow and channel limits for two-way traffic, 40 feet for one-way traffic, and at least 50 feet between tows when passing. When structures or mooring areas that could constitute a hazard are located along the channel limit line, greater clearances should be provided. Also, additional clearance should be provided in channels with restricted cross-sectional area or where adverse currents would be encountered. Because of the larger cross section of channels designed for two-way traffic and passing occurs in a relatively short reach, the clearance required between tows and channel limit is less than for channels designed for one-way traffic. As a guide the minimum channel widths required for tows of various sizes are as follows:

Tow Width, Feet	Channel Width, Feet Two-Way Traffic	Channel Width, Feet One-Way Traffic
105	300	185
70	230	150
50	190	130*

* Channel widths of less than 130 feet are not recommended for commercial traffic.

* 4-6. Minimum Crossing Distance. Crossings are straight reaches between alternate bends and are common in meandering streams. Tows leaving one bend, usually from along the concave bank, have to cross toward the opposite bank to approach the concave bank of the next alternate bend. The distance required for a downbound tow to make the crossing without flanking or excessive maneuvering will depend on the size of tow, the width of channel, and the alignment and velocity of currents. The average length of channel required for various sized tows to cross from one side of the channel to the opposite side under varying conditions as determined from the results of model studies is shown in Figure 4-1. These results are based on moving minimum-powered tows located adjacent and parallel to one side of the channel crossing to the opposite side with currents generally parallel to the bank lines. In most crossings, currents will tend to move from along the concave bank of one bend toward the concave bank of the next bend downstream, particularly during the lower flows. In such cases, tows can make the crossing in a shorter distance than indicated. Also, tows with greater power and controllability or tows flanking can make the crossing in a somewhat shorter length of channel than that indicated by the results of the model study. Although not exact, the information in Figure 4-1 provides a good general indication of the length of straight reach that should be provided between alternate bends, particularly when short radius bends and limited channel widths are involved. *

Section IV. Channel Widths in Bends

4-7. Orientation of Tows in Bends. The need for additional widths in bends has been known and recognized but little or no information has been available on the amount required. Recent model studies have provided a basis for computing channel widths occupied by tows of various sizes navigating in bends of different curvature. In making a turn, the stern of a tow is moved laterally in a direction opposite to the direction of the turn (figs. 4-2 and 4-3). In negotiating a bend, the tow *

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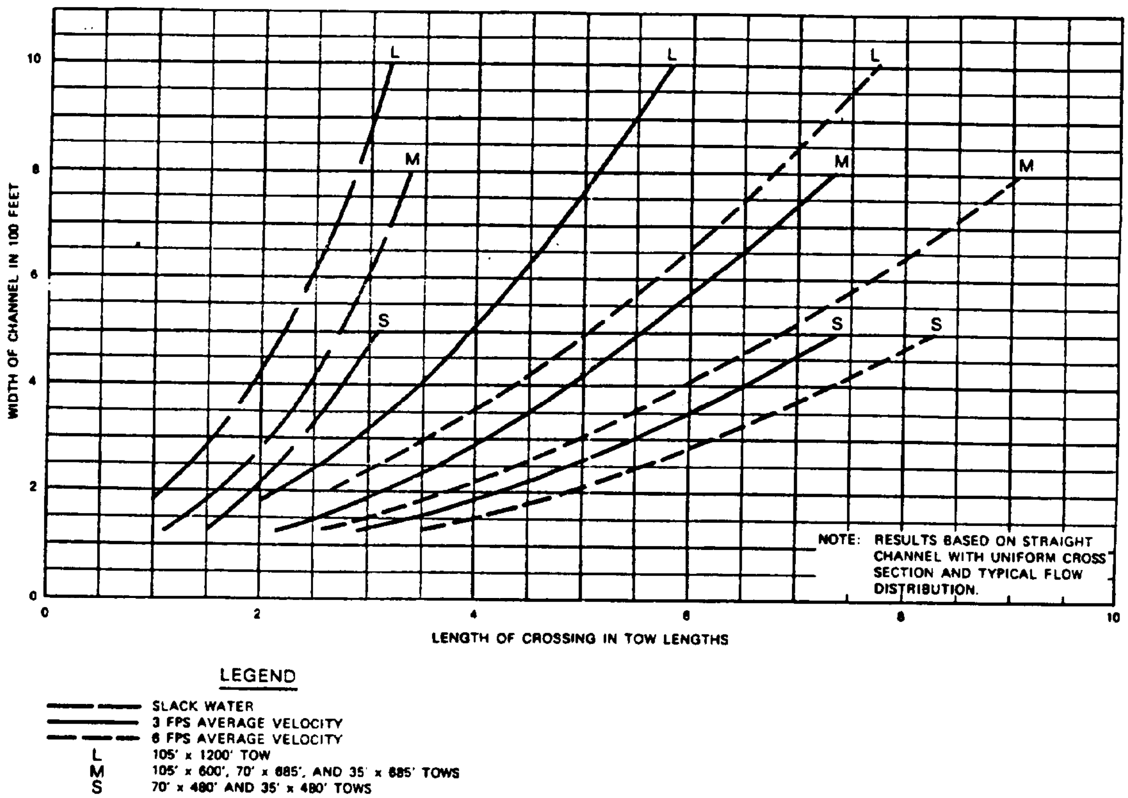
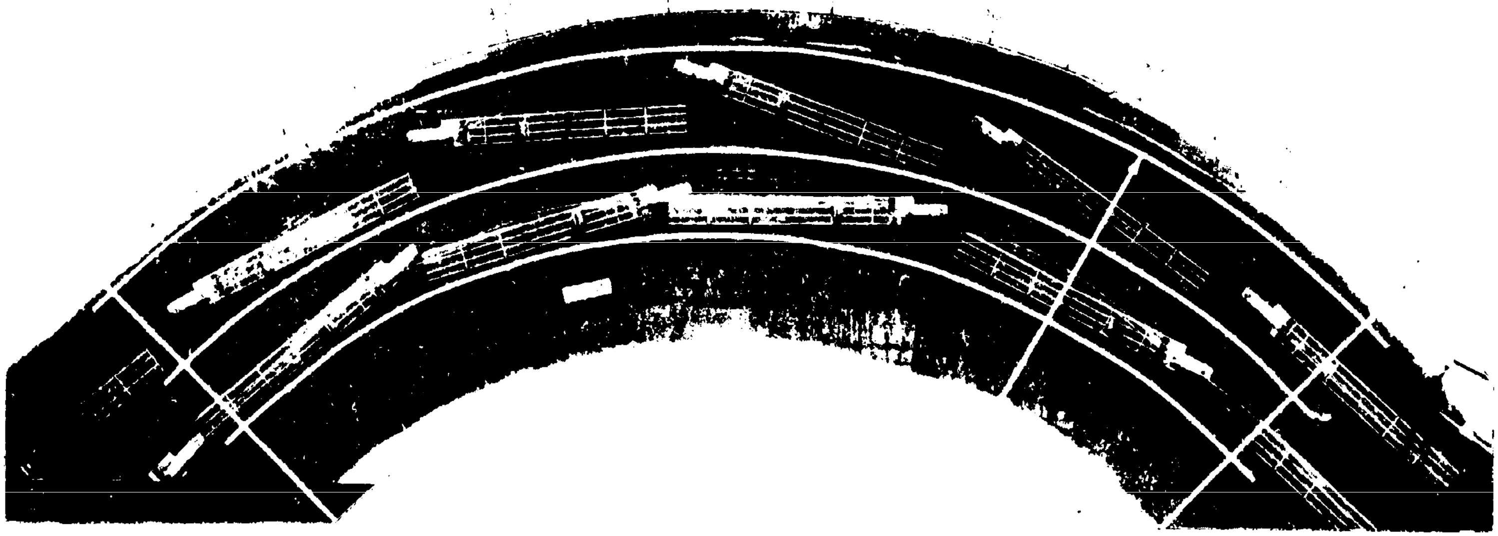


Figure 4-1. Length of channel required between alternate bends *

assumes and maintains an angle to the channel alignment which is referred to as the deflection angle (also referred to as drift angle). The width of the channel required is a direct function of the deflection * angle assumed by the tow and the length and width of the tow (fig. 4-4). The deflection angle assumed by a tow is dependent on many factors, the most important of which are radius of bend, size of tow, and the length of the bend up to about 90 degrees. Other factors affecting the deflection angle include current alignment and velocity, speed of tow with respect to that of the currents, draft of the tow with respect to channel depth, direction of travel (upstream or downstream), tow driving or flanking when downbound, and alignment and position of tow entering the bend. As a general rule, the deflection angle assumed by a tow increases rapidly as the radius of the bend decreases to less than about four or five times the length of the tow.

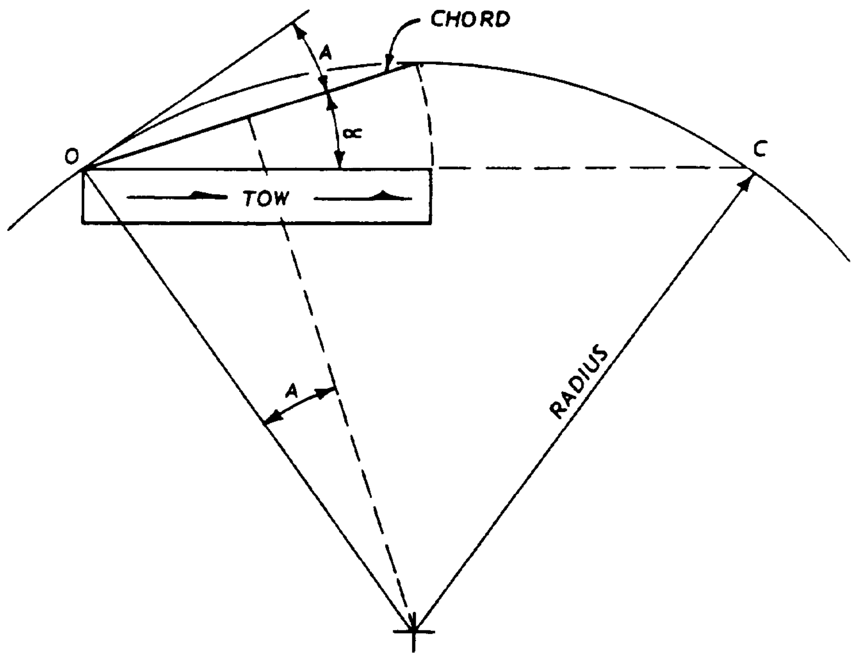
4-8. <u>Determining Channel Widths Required in Bends.</u> If the deflection angle assumed by a tow is known, a reasonably accurate channel width

* Figure 4-2. Mosaic showing progressive location and orientation of a downbound 70-foot by 515-foot tow negotiating an actual river bend with low-velocity currents



DOWNSTREAM AND UPSTREAM NAVIGATION

* Figure 4-3. Model reproducing a bend of uniform curvature and radius of 3500 feet with average velocity of 3.0 feet per second. Multiexposure photograph shows progressive movement of each of two 105-foot by 1200-foot model tows with two-way traffic



LEGEND

CHORD = LENGTH OF TOW
A = CHORD ANGLE
α = DEFLECTION ANGLE
O - C = CHORD BASED ON TOW ALIGNMENT MOVING THROUGH THE BENDWAY

* Figure 4-4. Description of deflection angle α

required can be determined from one of the following two equations:

a. $CW_1 = (\sin \alpha_d \times L_1) + W_1 + 2C$

b. $CW_2 = (\sin \alpha_u \times L_1) + W_1 + (\sin \alpha_d \times L_2) + W_2 + 2C + C_t$

where

CW_1 = channel width required for one-way traffic, feet

CW_2 = channel width required for two-way traffic, feet

α_d = maximum deflection angle of a downbound tow, degrees

α_u = maximum deflection angle of an upbound tow, degrees

L = length of tow, feet

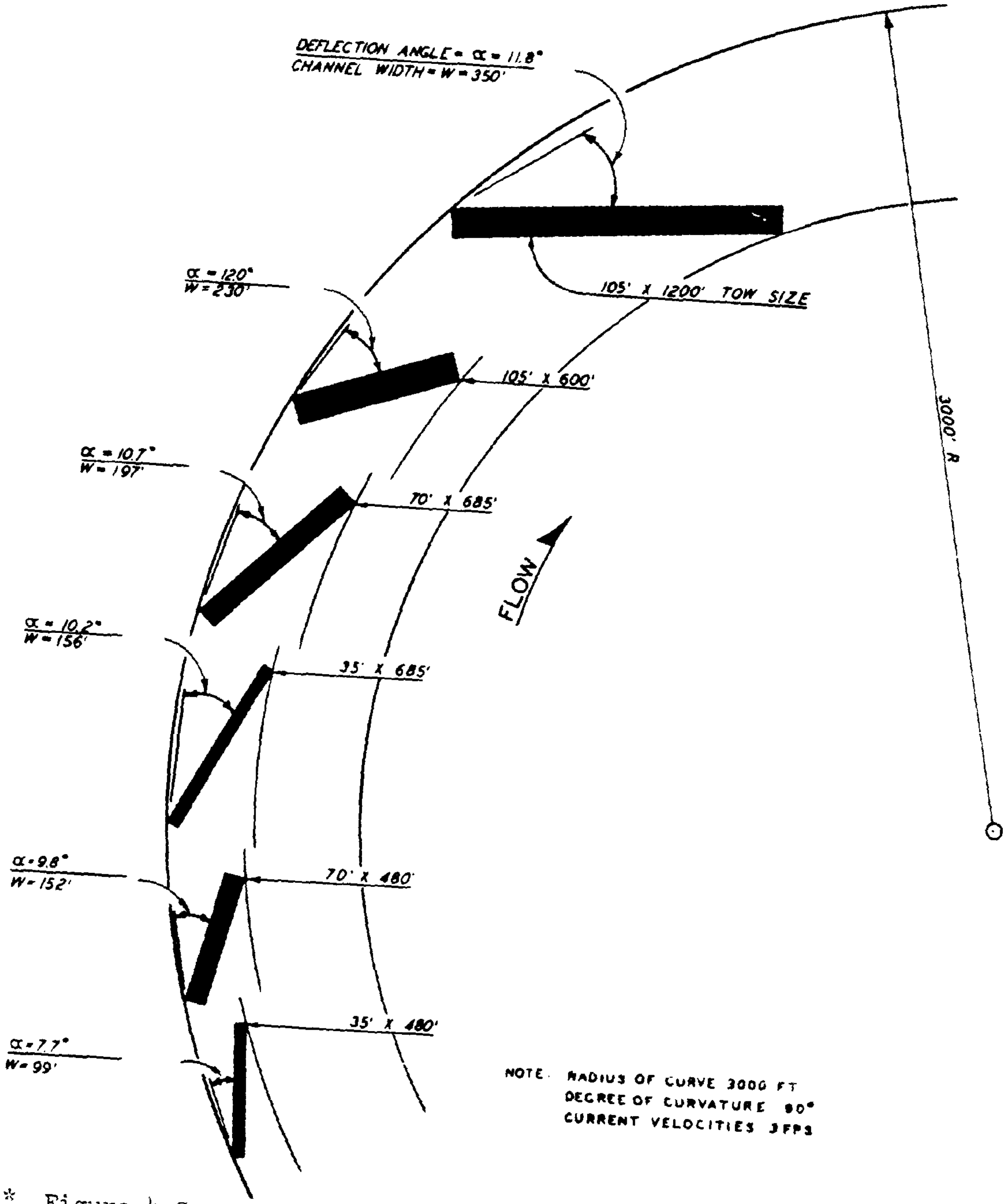
W = width of tow, feet

C = clearance required between tow and channel limit for safe navigation, feet

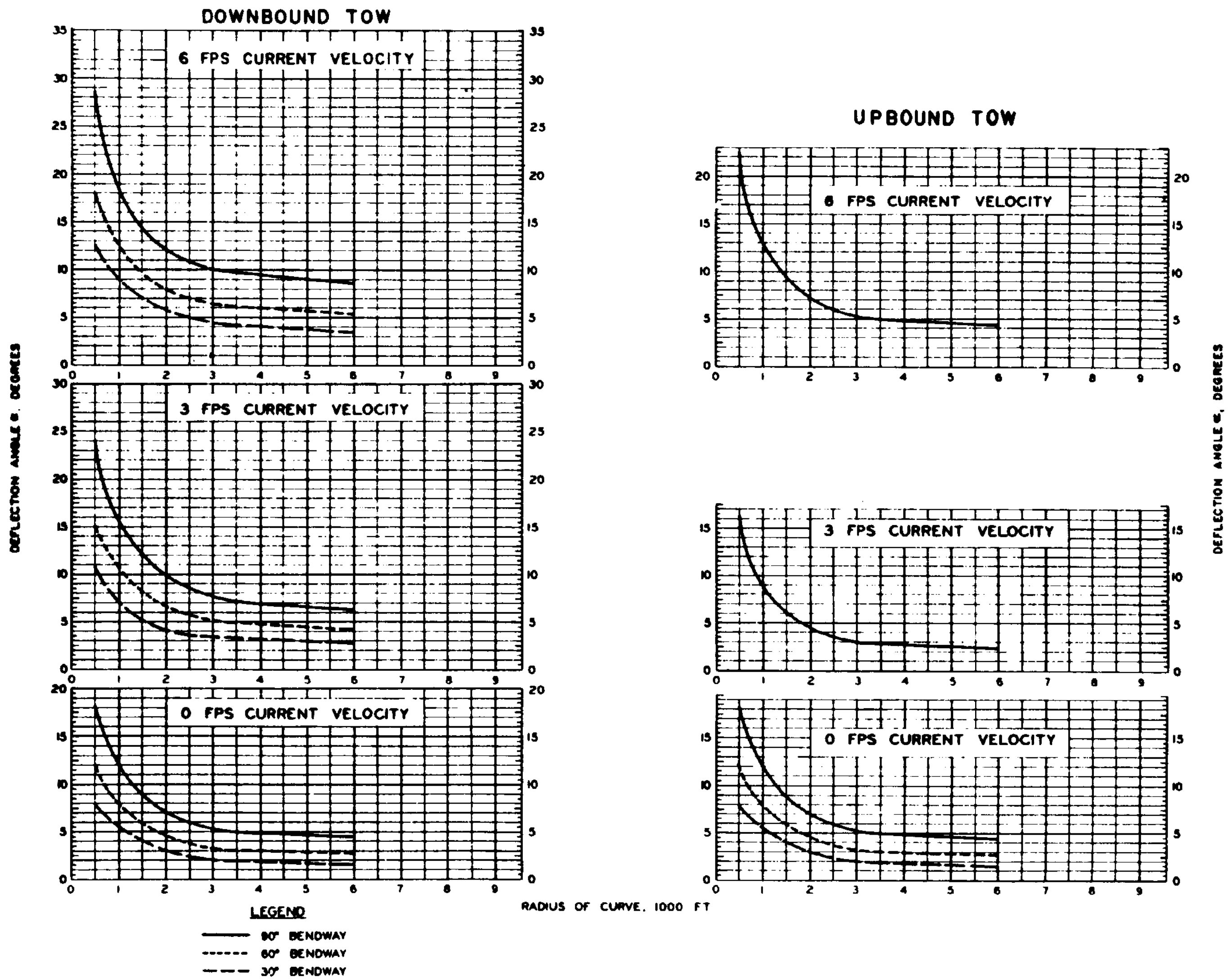
C_t = minimum clearance required between passing tows for safe two-way navigation, feet

* 4-9. Deflection Angles. The deflection angle assumed by different size tows in bends of various curvature based on results of model studies are shown in figures 4-6 to 4-11. These results are based on tests with tows having the minimum power required to navigate the waterway under the conditions indicated. Results for downbound tows are based on driving the bend. Channel dimensions for downbound tows flanking can be approximated by using the deflection angle for an upbound tow. Tows with greater power for the load can develop more rudder control and would assume a smaller deflection angle and require less channel width. Also, tows with greater maneuverability because of independent operation of their screws, specially designed rudders, or auxiliary steering devices will require less channel width than would be indicated by the results of the model tests.

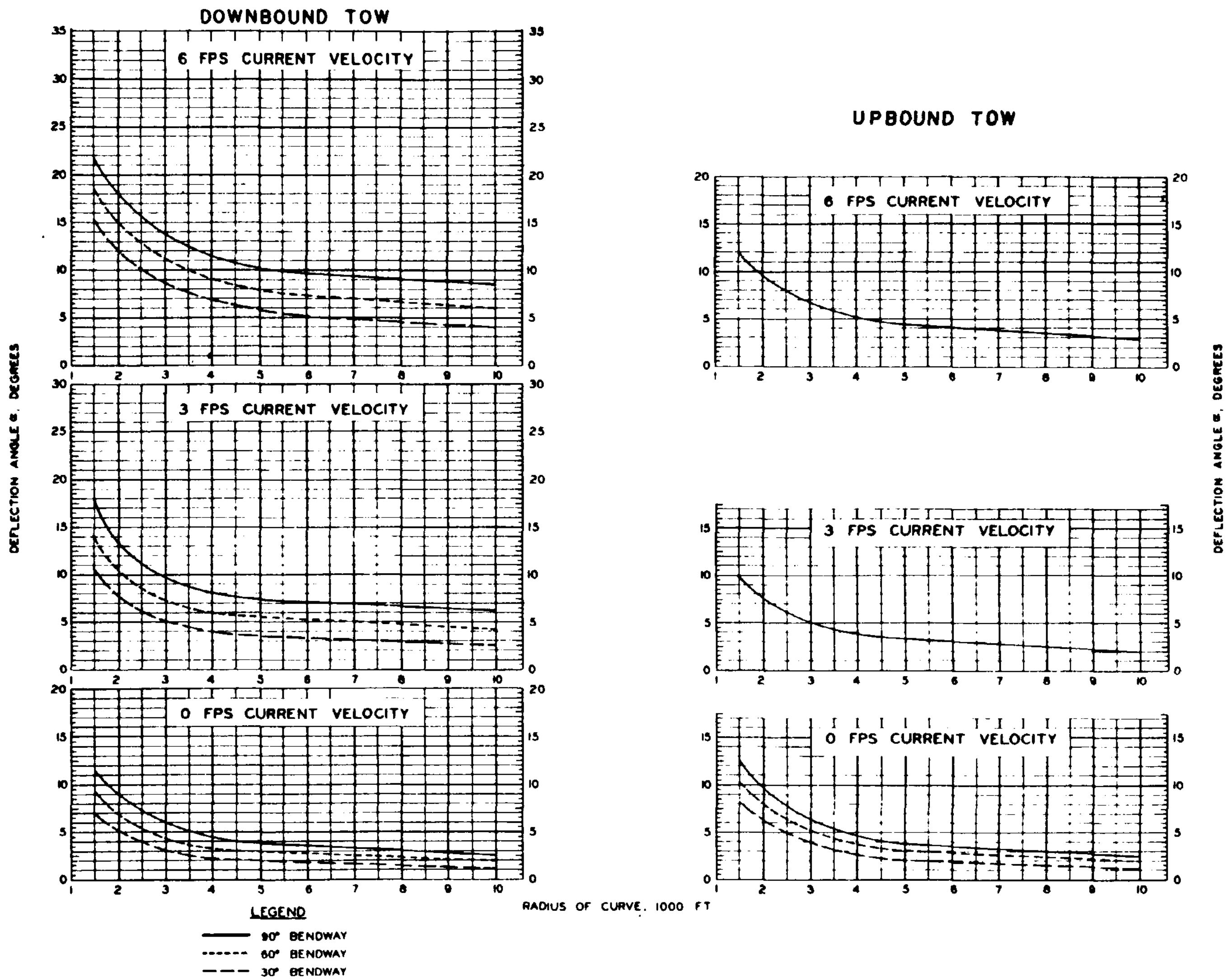
* 4-10. Irregular Bank Line. The preceding information on navigation in bends is based on bends having continuous concave banks. In natural streams having erodible beds and banks, the alignment of the concave banks might include scallops or landward indentations caused by erosion or local bank failures. These irregularities could have an adverse effect on tows navigating the bends and should be considered in the design of the projects. Model studies have indicated that small irregularities in the bank lines would have little or no effect on navigation but that longer irregularities in the downstream one-third of bends would generally have a significant adverse effect. These studies indicate that scallops in the bank line could be hazardous, particularly for downbound tows, when the length of a scallop along the bank is a minimum of one tow length and extends into the bank at least the width of the tow at a depth of 75 percent of the draft of the tow. This type of hazard is caused by currents moving into the scalloped area having a tendency to ground downbound tows moving close along the concave bank or causing them to hit the bank near the lower end of the scallop. In reaches *



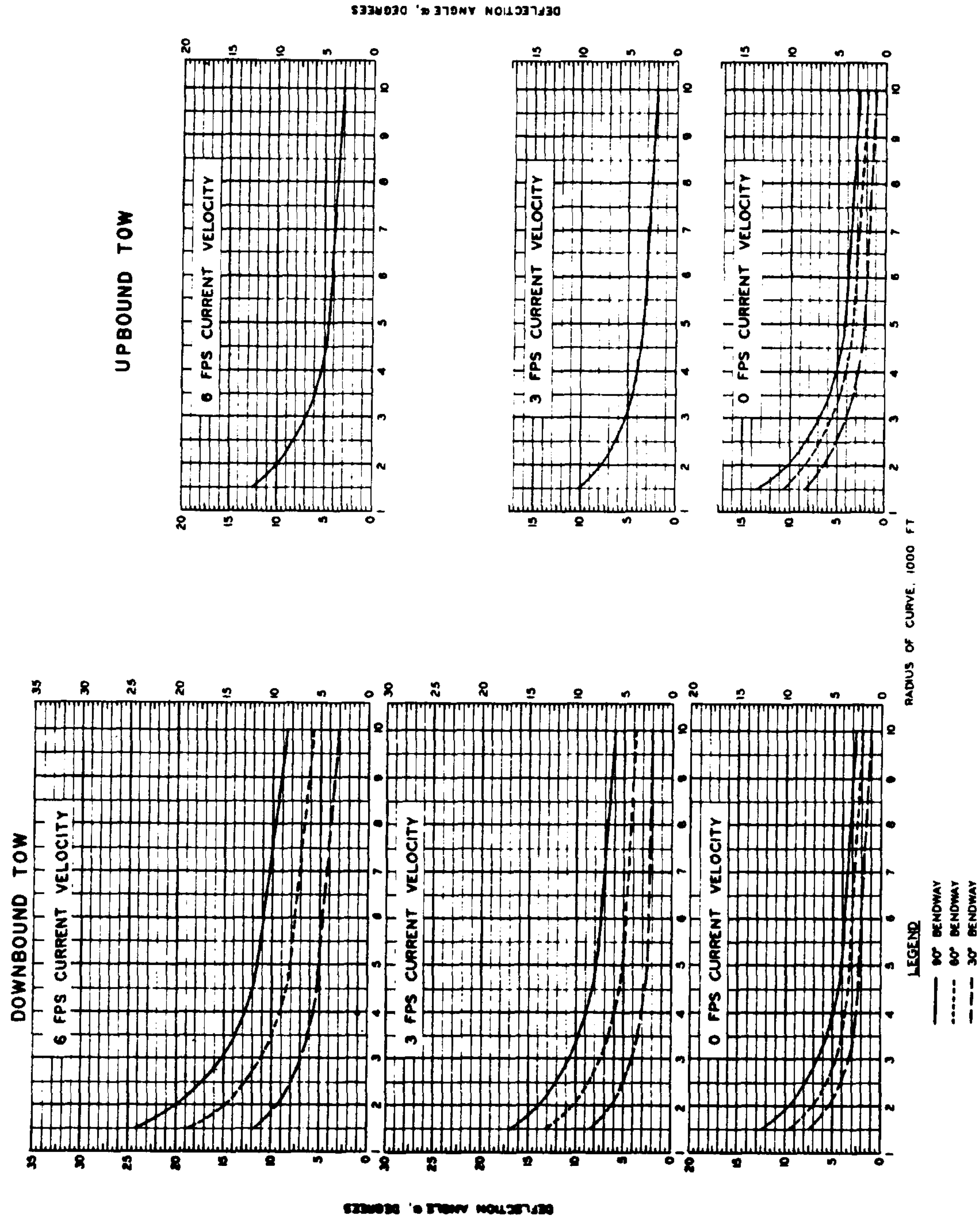
* Figure 4-5. Variation in deflection angle and channel widths occupied by tows of different sizes



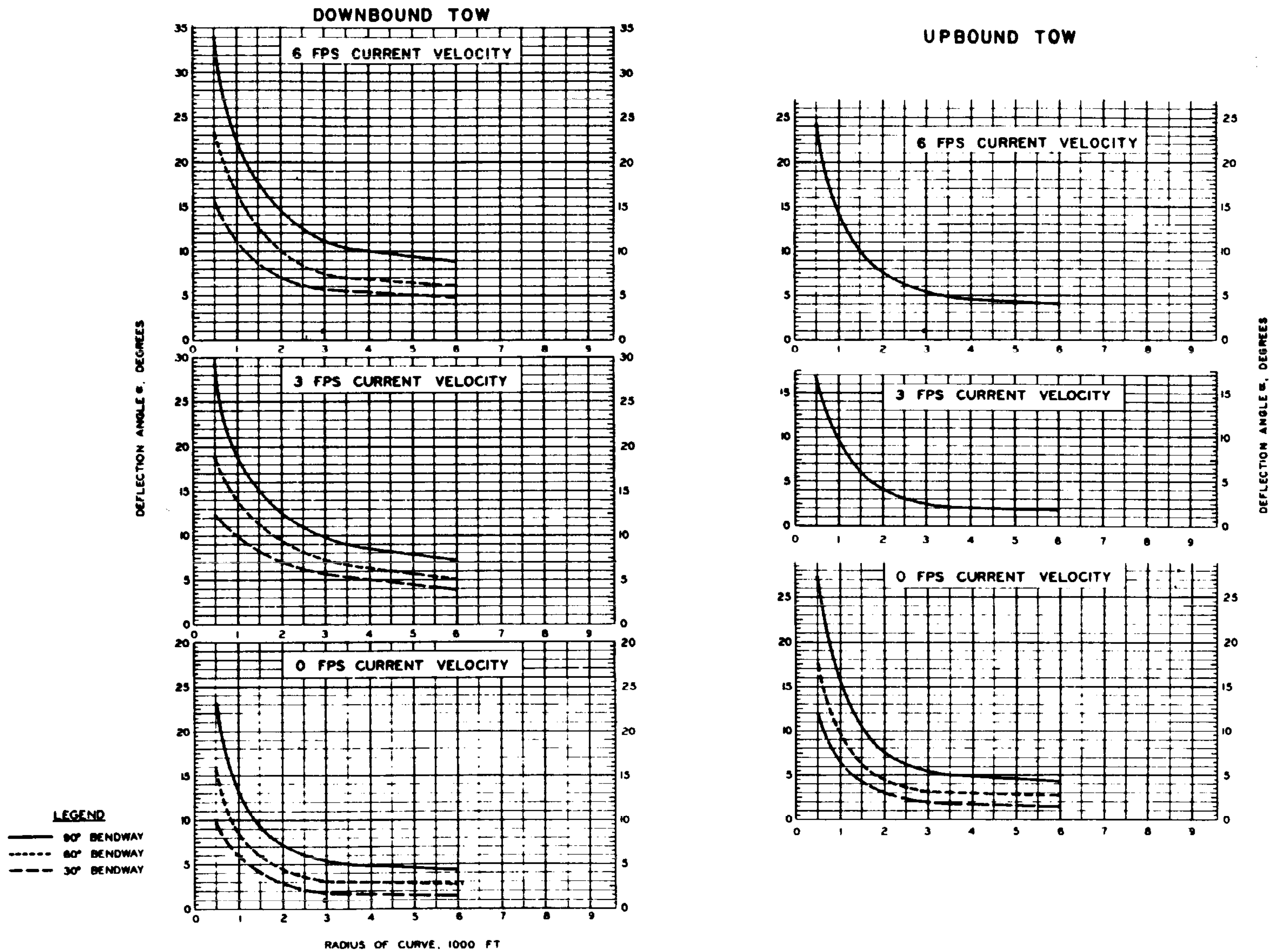
* Figure 4-6. Deflection angle for tows driving through bends forming uniform curves. Tow size: 35 feet wide by 480 feet long, submerged 8 feet



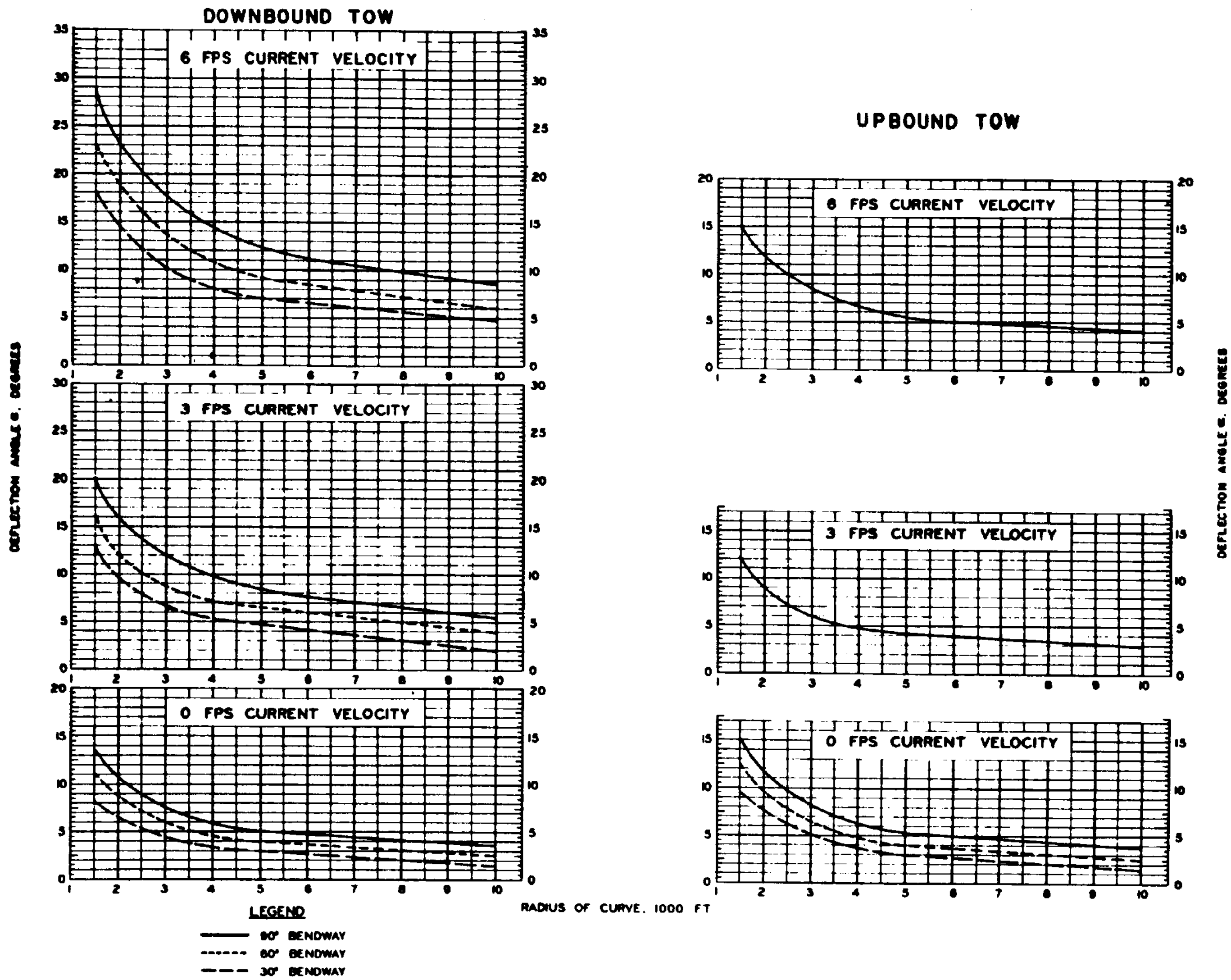
* Figure 4-7. Deflection angle for tows driving through bends forming uniform curves. Tow size: 35 feet wide by 685 feet long, submerged 8 feet



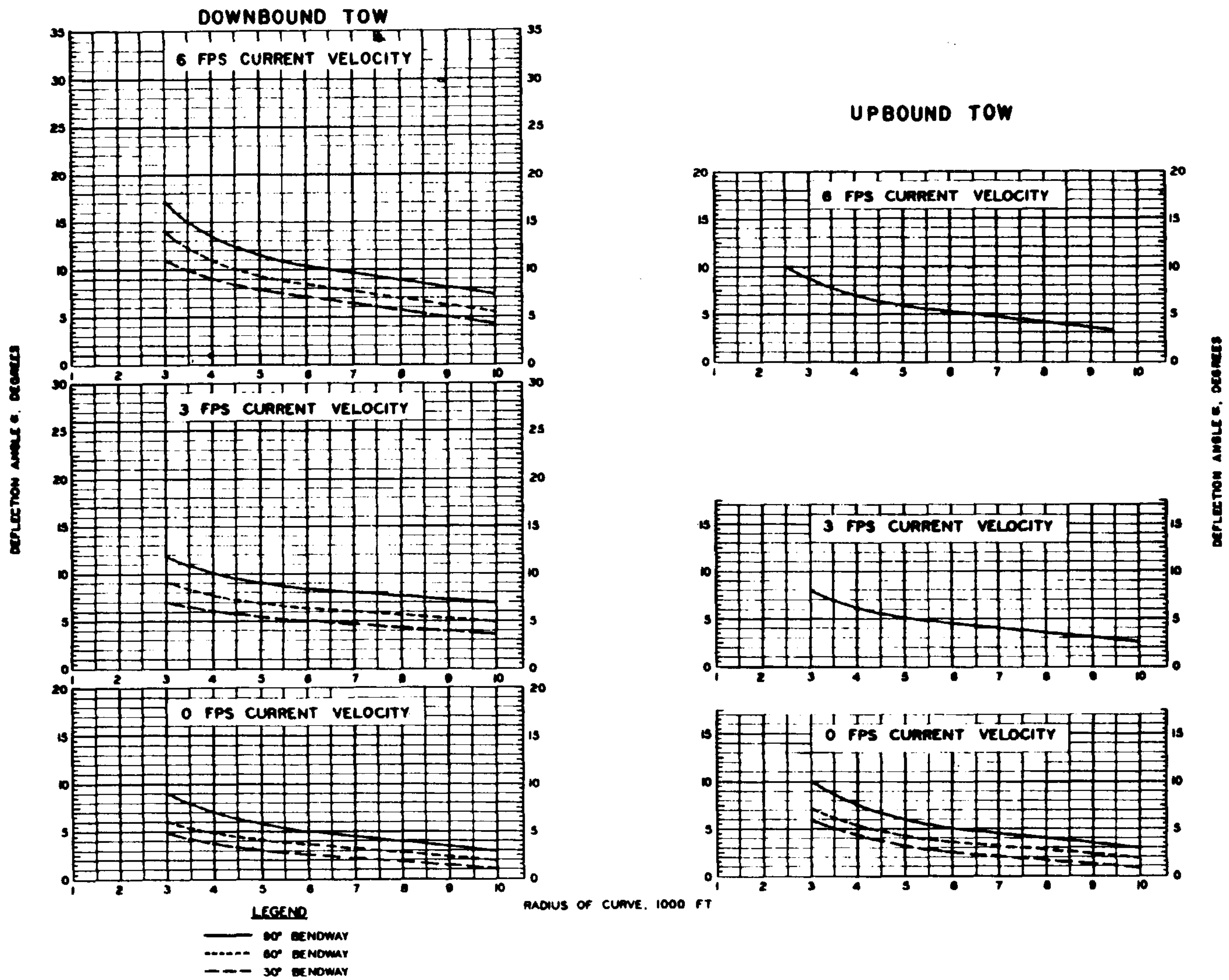
* Figure 4-8. Deflection angle for tows driving through bends forming uniform curves.
Tow size: 70 feet wide by 685 feet long, submerged 8 feet



* Figure 4-9. Deflection angle for tows driving through bends forming uniform curves. Tow size: 70 feet wide by 480 feet long, submerged 8 feet



* Figure 4-10. Deflection angle for tows driving through bends forming uniform curves. Tow size: 105 feet wide by 600 feet long, submerged 8 feet



* Figure 4-11. Deflection angle for tows driving through bends forming uniform curves. Tow size: 105 feet wide by 1200 feet long, submerged 8 feet

* where bank failure or erosion of this magnitude can be expected, the bank should be protected along a selected alignment. Existing scallops might require some remedial measures such as filling in the affected areas, adding dikes to prevent or reduce the movement of currents into the areas, or increasing the width of the channels to permit tows to move a sufficient distance from the affected bank lines. *

* 4-11. Basis of Design. The design of a channel for one-way traffic has to be based on the channel width required for downbound tows. For two-way traffic, it is assumed that downbound traffic would move along the concave bank of the bend and upbound along the convex bank. The radius of the bend used for upbound traffic in the figures is that of the concave limit line, same as for downbound tows as shown in figure 4-5. The clearance between tows and between the tow and channel limit lines is a matter of judgment, skill of the pilot, and how well the limit lines are defined. During the model tests the minimum clearance between the channel limit lines and the tow was assumed to be 20 feet and between tows, 50 feet for two-way traffic. For one-way traffic a minimum clearance of 40 feet should be provided between tow and channel limit lines. Improvement of natural streams for navigation will in most cases involve some modification in channel alignment, width, and depth. In streams carrying little or no sediment, it might be more economical to increase the width of the channel in bends than to increase the radius of curvature. In streams where there is a sizable sediment load, a wider channel in bends would not be self-maintaining and could require considerable maintenance dredging.

Section V. Bridge Location and Clearances

* 4-12. Location. Numerous accidents involving collision with bridge piers have occurred on inland waterways with considerable damage to property and, in some cases, loss of life. It is important, therefore, that the location and orientation of bridges and clearances provided for navigation be such as to eliminate as far as practicable any danger of collision with the bridge structure. As a general rule, bridges should not be located in a bend, just downstream of a sharp bend, or where crosscurrents can be expected. When more than one bridge is required in a given locality, the bridges should either be close together with the piers in line or far enough apart to permit tows passing one bridge to become properly aligned for passage through the next bridge.

* 4-13. Clearances. The navigation span (horizontal clearance between piers) should be somewhat greater than the designed width of the channel in the reach depending on the alignment and velocity of currents in the reach, alignment of the channel approaching the bridge particularly from

upstream, and the probable effects of the prevailing winds. The vertical clearance should be sufficient to permit tows to clear the low members of the bridge within the navigation span at the maximum navigable flow. Bridge clearances, both horizontally and vertically, are the responsibility of the U. S. Coast Guard and planning should be coordinated with the local district of that organization.