SECTION 6 – OPEN CHANNELS

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6.1.0 GENERAL

Open channels for use in a major drainage system have significant advantages related to cost, capacity, multiple use for recreational and aesthetic purposes and potential for detention storage. Disadvantages include right of way needs and maintenance costs. Careful planning and design are needed to minimize the disadvantages and to increase the benefits.

The general classifications for open channels are: (1) Natural channels, which include all watercourses that have been carved by nature through erosion; and (2) New or altered channels, which are constructed or existing channels that have been significantly altered by human effort. New or altered channels can be lined with grass, concrete, mortared rocks or other materials. The channels should be designed for the 25 year storm with provisions for the 100 year storm within dedicated easements or right of way.

6.1.1 Natural Channels

The ideal natural channel has the following benefits:

A. Velocities are usually low, resulting in longer concentration times and lower downstream peak flows.

B. Maintenance needs are usually low because the channel is somewhat stabilized.

C. The channel provides a desirable green belt and recreational area adding significant social benefits.

6.1.2 New or Altered Channels

Grass channels are the most desirable of the various types of new channels for the following reasons:

A. The grass can stabilize the body of the channel.

B. The grass consolidates the soil mass of the bed.

C. The grass controls the movement of soil particles along the channel bottom.

Concrete lined channels are designed to protect the channel body from the erosive potential of high velocities. In addition to concrete-lined channels, other methods to combat erosive velocities in channels may be available and should be submitted to the City Engineer for review.

6.1.3 Section 404 Permit

When a project to modify a natural channel is proposed, the design engineer should check the requirements of Section 404, Permits for Dredged or Fill Material, of the Clean Water Act. If required, a permit should be obtained from the U.S. Army Corps of Engineers by the design engineer.

6.2.0 OPEN CHANNEL HYDRAULICS

An open channel is a conduit in which water flows with a free surface. The classification of open channel flow is made according to the change in flow depth with respect to time and space.

Flow in an open channel is said to be "steady" if the depth of flow does not change or if it can be assumed to be constant during the time interval under consideration. The flow is "unsteady" if the depth changes with time.

Open channel flow is said to be "uniform" if the depth of flow is the same at every section of the channel. A uniform flow may theoretically be steady or unsteady, depending on whether or not the depth changes with time. The establishment of unsteady uniform flow requires that the water surface fluctuate with time while remaining parallel to the channel bottom. Since it is impossible for this condition to occur within a channel, steady uniform flow is the fundamental type of flow treated in open channel hydraulics.

Flow is "varied" if the depth of flow changes along the length of the channel. Varied flow may be either steady or unsteady. Since unsteady uniform flow is rare, the term "unsteady flow" is used to designate unsteady varied flow exclusively.

Varied flow may be further classified as either "rapidly" or "gradually" varied. The flow is rapidly varied if the depth changes abruptly over a comparatively short distance; otherwise, it is gradually varied. Rapidly varied flow is also known as a local phenomenon; an example of which is the hydraulic jump.

With these varying conditions, open channel hydraulics can be very complex, encompassing many different flow conditions from steady uniform flow to unsteady rapidly varied flow. Most of the problems in stormwater drainage involve uniform, gradually varied or rapidly varied flow situations. In this Section, the basic equation and computational procedures for uniform, gradually varied and rapidly varied flows are presented.

6.2.1 Uniform Flow

For a given channel condition of roughness, discharge and slope, there is only one (1) possible depth for maintaining a uniform flow. This depth is referred to as normal depth.

The Manning's Equation is used to determine the normal depth for a given discharge.

$$Q = (1.49/n)\, A\, R^{2/3}\, S^{1/2} \qquad \text{(Eq. 6-1)}$$

where,

- Q = Total discharge, cfs
- n = Roughness coefficient
- A = Cross-sectional area of channel, ft^2
- R = Hydraulic radius of channel, feet (R=A/P)
- S = Slope of the frictional gradient, ft/ft
- P = Wetted perimeter, feet

Uniform flow is more often a theoretical abstraction than an actuality. True uniform flow is difficult to find in nature or to obtain in the laboratory. The Engineer must be aware of the fact that uniform flow computations provide only an approximation of what will occur but that such computations are usually adequate and useful and, therefore, necessary for planning.

The computation of normal depth for trapezoidal sections can be performed by using Figure 6-1 in Appendix B of this Manual.

6.2.2 Gradually Varied Flow

The most common example of gradually varied flow in urban drainage systems occurs in the backwater of bridge openings, culverts, storm sewer inlets and channel constrictions. Under these conditions, gradually varied flow will be created and the flow depth will be greater than normal depth in the channel. Backwater techniques would need to be applied to determine the water surface profile.

Calculations of water surface profiles can be accomplished by using standard backwater methods or acceptable computer routines, which take into consideration all losses due to changes in velocity, drops, bridge openings and other obstructions in open channels.

There are several acceptable methods for backwater calculations. The most common hand calculation method for prismatic channels and irregular-uniform channels is the Standard Step Method. The most widely used backwater analysis computer program is HEC-2, developed by the U.S. Army Corps of Engineers. This program can compute water surface profiles for natural and new channels.

6.2.3 Rapidly Varied Flow

Rapidly varied flow is characterized by abrupt changes in the water surface elevation for a constant flow. The change in elevation may become so abrupt that the flow profile is virtually broken, resulting in a state of high turbulence. Some common causes of rapidly varied flow in urban drainage systems are side-spill weirs, weirs and spillways of detention basins.

6.3.0 MANNING'S ROUGHNESS COEFFICIENTS

6.3.1 Existing and Natural Channels

Because several primary factors affect the roughness coefficient, a procedure has been developed to estimate this value, n. By this procedure, the value of n may be computed by:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m \qquad \text{(Eq. 6-2)}$$

where n_0 is a basic n value for a straight, uniform, smooth channel in the natural materials involved, n_1 is a value added to n_0 to correct for the effect of surface irregularities; n_2 is a value for variations in shape and size of the channel cross section; n_3 is a value for obstructions; n_4 is a value for vegetation and flow conditions; and m is a correction factor for meandering of the channel. Proper values of n_0 to n_4 and m may be selected from Table 6-1 according to the given conditions.

In selecting the value of n_1, the degree of irregularity is considered smooth for surfaces comparable to the best attainable for the materials involved; minor for good dredged channels, slightly eroded or scoured side slopes of canals or drainage channels; moderate for fair to poor dredged channels, moderately sloughed or eroded side slopes of canals or drainage channels; and severe for badly sloughed banks of natural streams, badly eroded or sloughed sides of canals or drainage channels, and unshaped, jagged and irregular surfaces of channels excavated in rock.

In selecting the value of n_2, the character of variations in size and shape of cross section is considered gradual when the change in size or shape occurs gradually; alternating occasionally when large and small sections alternate occasionally or when shape changes cause occasional shifting of main flow from side to side; and alternating frequently when large and small sections alternate frequently or when shape changes cause frequent shifting of main flow from side to side.

The selection of the value of n_3 is based on the presence and characteristics of obstructions such as debris deposits, stumps, exposed roots, boulders and fallen and lodged logs. One should recall that conditions considered in other steps must not be re-evaluated or double-counted in this selection. In judging the relative effect of obstructions, consider the following: the extent to which the obstructions occupy or reduce the average water area, the obstruction characteristics (sharp-edged or angular objects induce greater turbulence than curved, smooth-surfaced objects) and the position and spacing of obstructions transversely and longitudinally in the reach under consideration.

Table 6-1
Computation of Composite Roughness Coefficient
For Excavated and Natural Channels

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m$$

Channel Conditions		Values
n_0 Material Involved	Earth React Fine Gravel Coarse Gravel	0.020 0.025 0.024 0.028
n_1 Degree of Irregularity	Smooth Minor Moderate Severe	0.000 0.005 0.010 0.020
n_2 Relative Effect of Channel Cross Section	Gradual Alternating Occasionally Alternating Frequently	0.000 0.005 0.013
n_3 Relative Effect of Obstructions	Negligible Minor Appreciable Severe	0.000 0.013 0.025 0.050
n_4 Vegetation	Low Medium High Very High	0.008 0.018 0.038 0.075
m Degree of Meandering	Minor Appreciable Severe	1.000 1.150 1.300
Source: Chow, V.T. Open Channel Hydraulics, 1959.		

In selecting the value of n_4, the degree of effect of vegetation is considered in the following way:

A. Low for conditions comparable to the following: (a) dense growths of flexible turf grasses or weeds, of which Bermuda and blue grasses are examples, where the average depth of flow is two (2) to three (3) times the height of vegetation; and (b) supple seedling tree switches, such as willow, cottonwood or salt cedar where the average depth of flow is three (3) to four (4) times the height of the vegetation.

B. Medium for conditions comparable to the following: (a) turf grasses where the average depth of flow is one (1) to two (2) times the height of vegetation; and (b) stemmy grasses, weeds or tree seedlings with moderate cover where the average depth of flow is two (2) to three (3) times the height of vegetation and brush growths, moderately dense, similar to willows one (1) to two (2) years old, dormant season, along side slopes of a channel with no significant vegetation along the channel bottom, where the hydraulic radius is greater than two (2) feet.

C. High for conditions comparable to the following: (a) turf grasses where the average depth of flow is about equal to the height of vegetation, (b) dormant season -- willow or cottonwood trees eight (8) to ten (10) years old, intergrown with some weeds and brush, where none of the vegetation is in foliage, where the hydraulic radius is greater than two (2) feet; and (c) growing season -- bushy willows about one (1) year old intergrown with some weeds in full foliage along side slopes, no significant vegetation along channel bottom, where hydraulic radius is greater than two (2) feet.

D. Very high for conditions comparable to the following: (a) turf grasses where the average depth of flow is less than half (½) the height of vegetation, (b) growing season -- bushy willows about 1 year old, intergrown with weeds in full foliage along side slopes, or dense growth of cattails along channel bottom, with any value of hydraulic radius up to ten (10) or fifteen (15) feet and (c) growing season--trees intergrown with weeds and brush, all in full foliage, with any value of hydraulic radius up to ten (10) or fifteen (15) feet.

In selecting the value of m, the degree of meandering depends on the ratio of the meander length to the straight length of the channel reach. The meandering is considered minor for ratios of one (1.0) to one and two tenths (1.2), appreciable for ratios of one and two tenths (1.2) to one and five tenths (1.5), and severe for ratios of one and five tenths (1.5) and greater.

In applying the above method for determining the n value, several things should be noted. The method does not consider the effect of suspended and bed loads. The values given in Table 6-2 were developed from a study of some forty (40) to fifty (50) cases of small and moderate channels. Therefore, the method is questionable when applied to large channels whose hydraulic radii exceed fifteen (15) feet. The method applies only to unlined natural streams, floodways, and drainage channels and shows a minimum value of 0.02 for the n value of such channels. The minimum value of n in general, however, may be as low as 0.012 in lined channels and as low as 0.008 in artificial laboratory flumes.

6.3.2 New or Altered Channels

The Manning's Roughness Coefficients (n) for new or altered channels are shown in Table 6-2.

6.4.0 DESIGN REQUIREMENTS

Channel design involves the determination of the channel cross-section required to accommodate a given design discharge. The design requirements for open channels are discussed in the sections below and apply to channels or waterways that are proposed to be modified or constructed.

6.4.1 Grass-Lined Channels and Waterways

Key parameters in grass-lined channel or waterway design include permissible velocity, roughness coefficient, side slope, curvature, bottom width, and freeboard. The grass species selected shall be suitable for permanent application based upon the anticipated operation and maintenance of the channel or waterway.

A. **Velocity**. The maximum permissible velocity for the 100 year storm is six (6) feet per second and includes all transitions to or from channels and waterways with similar or different materials. In all cases, the velocity for the 100 year storm must be non-erosive. The minimum permissible velocity for the 2 year storm is two (2) feet per second.

B. **Roughness Coefficient.** The roughness coefficients selected shall be based on the degree of retardance of vegetation. Table 6-2 provides minimum Manning's Coefficients for channel design. The roughness coefficient shall be adjusted to reflect the relationship between the depth of flow and the typical height of the design vegetation, especially for shallow depths of flow, as well as other factors affecting channel conveyance.

C. **Slope.** The flow line slope of the channel shall be a minimum of two (2) percent unless the velocity for the 2 year storm flow is greater than two (2) feet per second, in which case the channel slope may be a minimum of one (1) percent. Compliance with this requirement must take into account the variation in channel flow due to distributed inflows to the channel. A reinforced concrete pilot channel must be used if the channel slope is less than one (1) percent. The pilot channel must be at least four (4) feet wide, two (2) inches deep, and be capable of withstanding vehicular loading. Any grass-lined portion of the channel bottom must have a slope of at least two (2) percent from that portion to the concrete-lined pilot channel. However, no open channel flow line slope may be less than one-half (0.5) percent.

D. **Side Slopes.** Side slopes shall be four (4) to one (1) or flatter for channels equal to or over four (4) feet deep and three (3) to one (1) or flatter for channels less than four (4) feet deep.

E. **Curvature.** The center line curvature shall have a minimum radius of twice the top width of the 100 year storm flow.

F. **Bottom Width.** The minimum flat bottom width of the channel is three (3) feet.

G. **Freeboard.** All grass-lined channels shall be designed to convey the one hundred (100) year storm event. The freeboard for the channel shall be the velocity head for the one hundred (100) year storm.

6.4.2 Concrete-Lined Channels

Concrete-lined channels may be needed in channel reaches where the velocities are excessive (See Section 6.4.1A. of this Manual) or where the channel characteristics require such use.

A. **Velocity.** In concrete-lined channels the probability of achieving supercritical flow is greatly increased. The designer must take care to insure against the possibility of unanticipated hydraulic jumps forming in the channel in considering the 25 and 100 year storms. Flow with a Froude number equal to one (1) is unstable and should be avoided. If supercritical flow does occur, then freeboard and superelevation must be determined. In addition, all channels carrying supercritical flow shall be continuously lined with reinforced concrete.

B. **Roughness Coefficient.** Table 6-2 provides the Manning's Coefficients for concrete-lined channels.

C. **Freeboard.** Adequate channel freeboard shall be provided for the 100 year storm in reaches flowing at critical depth by Equation 6-3 or using the energy grade line, whichever is less.

$$H_{FB} = 2.0 + 0.025V\,(d)^{1/3} \qquad \text{(Eq. 6-3)}$$

where,

H_{FB} = Freeboard height, ft
V = Velocity, ft/sec
d = Depth of flow, ft

Freeboard shall be in addition to superelevation, standing waves and/or other water surface disturbances. Concrete sideslopes shall be extended to provide freeboard. Freeboard shall not be obtained by the construction of levees.

D. **Superelevation.** Superelevation of the water surface shall be determined at all horizontal curves which deviate more than forty-five (45) degrees off the projected centerline. An approximation of the superelevation at a channel bend can be obtained from the following equation:

$$h = V^2 T_W / g r_c \qquad \text{(Eq. 6-4)}$$

where

h = Superelevation, ft
V = Flow velocity, ft/sec
T_W = Top width of channel, ft
r_c = Centerline radius of curvature, ft
g = Acceleration due to gravity, ft/sec^2

The freeboard shall be measured above the superelevation water surface.

E. **Side Slopes.** Since concrete lined channels do not require slope maintenance, the side slopes may be as steep as vertical with appropriate structural methods applied.

F. **Slope.** The flow line slope of the channel shall be no less than five tenths (0.5) percent and must also be sufficient to produce a velocity for the two (2) year storm flow of at least two (2) feet per second. Compliance with this requirement must take into account the variation in channel flow due to distributed inflows to the channel.

6.4.3 OTHER CHANNELS

Channels composed of materials other than vegetation or concrete shall be designed so that sediment deposition does not occur for the 2 year storm (except for channel drop structures and energy dissipators as approved by the City) and velocities for the 100 year storm are not erosive, using methods as approved by the City Engineer.

6.5.0 CHANNEL DROP STRUCTURES

The function of a drop structure is to reduce channel velocities by allowing for flatter upstream and downstream channel slopes. Two commonly used drop structures are shown in Figure 6-2 in Appendix B of this Manual.

The flow velocities in the upstream and downstream channels of the drop structure need to satisfy the permissible velocities allowed for channels. The design parameters for the sloping channel drop and the vertical channel drop are given below.

6.5.1 Sloping Channel Drop

A. **Approach Apron.** A minimum ten (10) foot long riprap apron should be constructed immediately upstream of the drop to protect against the increasing velocities and turbulence which result as the water approaches the sloping portion of the drop structure. The same riprap and bedding design should be used as specified for the portion of the drop structure immediately downstream of the drop.

B. **Chute.** The chute shall have roughened faces and shall be no steeper than 2:1. The length, L, of the chute depends upon the hydraulic characteristics of the channel and drop. For a unit discharge, q, of thirty (30) cubic feet per second per foot, L would be about fifteen (15) feet, that is, about one-half (½) of the q value. The L should not be less than ten (10) feet, even for low q values.

C. **Downstream Apron.** The length of the downstream apron shall be sized according to Table 6-3 and shall be constructed of reinforced concrete or riprap depending on structural requirements.

Table 6-2 **Minimum Roughness Coefficients of New or Altered Channels**	
Type of Channel and Description	Manning's Coefficients
1. Grass lined a. Bermuda (with regular mowing) b. St. Augustine (with regular mowing) c. Native grasses and vegetation not	 .040 .045 .060
2. Concrete a. Concrete lined (rough finish) b. Concrete lined (smooth finish-culverts) c. Concrete rip-rap (exposed rubble)	 .020 .015 .025
3. Gabion	.035
4. Rock-cut	.025
Source: 1. Chow, V.T. Open Channel Hydraulics. 1959. 2. WRC Engineering, Inc. Boulder County Storm Drainage Criteria Manual. 1984.	

Table 6-3 **Length of Downstream Apron**	
Maximum Unit Discharge, q (cfs/ft)	Length of Downstream Apron, L_B (ft)
0-14	10
15	15
20	20
25	20
30	25
Source: City of Austin, Watershed Engineering Division.	

6.5.2 Vertical Channel Drops

The design criteria for the vertical channel drop is based upon the height of the drop and the normal depth and velocity of the approach and exit channels. The channel must be prismatic throughout, from the upstream channel through the drop to the downstream channel.

The steepest allowable sideslope for the riprap stilling basin is 4:1. The riprap should extend up the side slopes to a depth equal to one (1) foot above the normal depth projected upstream from the downstream channel. The maximum fall allowed at any one drop structure is four (4) feet from the upper channel bottom to the lower channel bottom.

A description of the drop structure and the design procedure, going from upstream to downstream, is given below and shown on Figure 6-2 in Appendix B of this Manual.

A. Approach Channel: The upstream and downstream channels will normally be grass-lined trapezoidal channels.

B. Approach Apron: A minimum ten (10) foot long riprap apron is provided upstream of the drop to protect against the increasing velocities and turbulence which result as the water approaches the vertical drop.

C. Chute Apron: The riprap stilling basin is designed to force the hydraulic jump to occur within the basin and is designed for essentially zero scour.

6.6.0 ENERGY DISSIPATORS

Energy dissipators are used to dissipate excessive kinetic energy in flowing water that could promote erosion. An effective energy dissipator must be able to retard the flow of fast moving water without damage to the structure or to the channel below the structure.

Impact-type energy dissipators direct the water into an obstruction that diverts the flow in many directions and in this manner dissipates the energy in the flow. Baffled outlets and baffled aprons are two (2) impact-type energy dissipators.

Other energy dissipators use the hydraulic jump to dissipate the excess head. In this type of structure, water flowing at a higher than critical velocity is forced into a hydraulic jump, and energy is dissipated in the resulting turbulence. Stilling basins are this type of dissipator, where energy is diffused as flow plunges into a pool of water.

Generally, the impact-type of energy dissipator is considered to be more efficient than the hydraulic jump-type. Also the impact-type energy dissipator results in smaller and more economical structures.

The design of energy dissipators is based on the empirical data resulting from a comprehensive series of model structure studies by the U.S. Bureau of Reclamation, as detailed in its book Hydraulic Design of Stilling Basins and Energy Dissipators, 1984. Two (2) impact-type energy dissipators are briefly explained here.

6.6.1 Baffled Apron (U.S. Bureau of Reclamation Type IX)

Baffled aprons are used to dissipate the energy in the flow at a drop. They require no initial tailwater to be effective, although channel bed scour is not as deep and is less extensive when the tailwater forms a pool into which the flow discharges. The chutes are constructed on a slope that is 2:1 or flatter and extends below the channel bottom. Backfill is placed over one (1) or more bottom rows of baffles to restore the original streambed elevation. When scour or downstream channel degradation occurs, successive rows of baffle piers are exposed to prevent excessive acceleration of the flow entering the channel. If degradation does not occur, the scour creates a stilling pool at the downstream end of the chute, stabilizing the scour pattern. The simplified hydraulic design of the baffled apron is shown in Figure 6-3 in Appendix B of this Manual.

The general rules of hydraulic design of a baffled apron are as follows:

A. **Design Discharge.** The chute should be designed for the full capacity expected to be passed through the structure. The maximum unit discharge may be as high as sixty (60) cfs per foot for the 100 year storm.

B. **Chute Entrance.** The flow entering into the chute should be well distributed laterally across the width of the chute. The velocity should be well below the critical velocity, preferably the value shown in the curve D of Figure 6-3 in Appendix B of this Manual. The curve C in Figure 6-3 in Appendix B of this Manual is the critical velocity in a rectangular channel, $V_C=(gq)^{1/3}$.

C. **Chute Design.** The chute is usually constructed on a 2:1 slope. The upstream end of the chute floor should be joined to the horizontal floor by a curve to prevent excessive vertical contraction of the flow. The upstream face of the first row should be no more than one (1) foot (vertically) below the high point of the chute.

Based on the results of U.S. Bureau of Reclamation experiments, the greatest tendency to overtop the training walls occurs in the vicinity of the second and third rows of baffles. To prevent this overtopping, a partial baffle (1/3 to 2/3 of the width of a full baffle) should be placed against the training walls in the first row. This will place a space of the same width adjacent to the walls in the second row. Alternate rows are then made identical (i.e., rows 1, 3, 5, 7, etc., are identical; rows 2, 4, 6, 8, etc., are identical). Four (4) rows of baffles are necessary to establish the expected flow pattern at the base of the chute.

The height of the training walls on the chute should be three (3) or more times the baffle height, measured normal to the chute floor. Several rows of baffle piers are usually constructed below the channel grade to establish full control of the flow. At least one (1) row of baffles should be buried in the backfill which is used to restore the original bottom topography.

D. **Heights and Spacing of Baffle Pier.** Baffle pier height, H, should be about eight tenths (0.8) D_c to nine tenths (0.9) D_c, as shown in Curve B in Figure 6-3 in Appendix B of this Manual. D_c is the critical depth in a rectangular channel and determined by:

$$D_c = (q^2/g)^{1/3} \qquad \text{(Eq. 6-5)}$$

Baffle pier widths and spaces should be equal, up to 1.5 H but no less than H. The slope distance between rows of baffle piers should be 2H, twice the baffle height.

6.6.2 Baffled Outlet

Baffled outlets are used to dissipate the discharge energy from flow in a pipe. They are normally used at outlets from detention ponds or storm drainage systems. The baffles are intended to decrease the discharge velocities and subsequent erosion of the receiving system.

6.7.0 STRUCTURE AESTHETICS

The design of hydraulic structures in the urban environment requires an approach not encountered elsewhere because appearance must be an integral part of the design. The treatment of the exterior appearance should not be considered of minor importance.

Parks. Hydraulic structures should not detract from the pleasures enjoyed in an urban park. Furthermore, parks and green belts may later be developed in an urban area in which the structure will play a dominant environmental role.

Play Areas. An important consideration is that drainage structures often are an attraction for neighborhood children. It is almost impossible to make drainage works inaccessible to children, and therefore what is constructed should be made as safe as is reasonably possible. Hazards to children's safety should be avoided whenever possible.

Concrete Surface Treatment. The use of textured concrete presents a pleasing appearance and removes form marks. Exposed aggregate concrete is also attractive but may require special control of the aggregate used in the concrete.

Rails and Fences. The use of rails and fences along concrete walls provides a pleasing topping to an otherwise stark wall, yet provides a safety measure against the hazard of falling from an unprotected wall.

6.8.0 SUPPLEMENTAL SECTION

6.8.1 Alternative New Channel Design

The following is a description of the cross-sectional characteristics of an alternative channel design to be applied at the engineer's discretion but is in no way a requirement.

A. A pilot channel designed to carry the 10 year storm shall be calculated with Manning's "n" values in accordance with Tables 6-2 and 6-3. This channel is designed to separate the more frequent 10 year storm via an unobstructed pilot channel. Side slopes of the pilot channel shall not exceed 3:1 slope gradient and shall have a bottom width of no less than six (6) feet. The remaining cross-sectional area is designed to convey the additional storm flows up to the 100 year storm. This upper platform will accommodate vegetation with minimal maintenance requirements.

B. The ultimate 100 year floodplain shall be contained within overbanks on each side of the pilot channel. These overbanks shall be a minimum width of ten (10) feet and have a slope gradient not to exceed 6:1. The overbanks shall be stabilized with the seeds of grasses, native wildflowers and native woody species appropriate to riparian habitat and with blanket products. In calculating Manning's "n" values for the overbanks, reference must be made to Tables 6-2 and 6-3 with the following assumptions:

1. Heavily wooded and brushy overbanks; and
2. Bank irregularities, which can be reasonably expected from occasional, moderate erosion.

Figure 6-4 in Appendix B of this Manual depicts the conceptual idea of the alternative channel design.