CHAPTER IV

DESIGN GUIDELINES AND DETAILS

A. General

In this chapter, general design guidelines are provided for various bank stabilization methodologies introduced in Chapter II. Selection criteria for any of these erosion control methods is outlined in Chapter III. Details for the stabilization and erosion control methods discussed in this chapter are found in Appendix A.

WEST PITTMAN CREEK DOWNSTREAM OF DIAMONDHEAD DRIVE, PLANO, TEXAS

B. Structural and Armor Methods

1. Concrete-Lined Channel.

Concrete-lined channels are a common drainage feature of small, urban streams in North Central Texas, especially in areas where right-of-way for drainage purposes is minimal. In addition to flood flow capacity, concrete lined channels should be designed to maintain scour velocities (>2 fps) throughout the expected flow regime. Supercritical flow will not be allowed. Minimum bottom width shall be 10 feet. Channel intersections shall be at an angle not exceeding

15 degrees. The minimum radius of centerline curvature shall be three times the top width of the channel unless superelevation computations are submitted for review. Subsurface drainage should be provided to prevent scour under the slabs and relieve pressures behind protected slopes. Uplift forces on the slabs should be evaluated. Joint location and frequency should be carefully considered by the design engineer (USACE, 1991). A typical concrete lined channel section is shown in Plate 1 of Appendix A. The designer is also referred to the standard details of the community in which they are working.

2. Rock Riprap Revetment.

Rock or stone can be an effective erosion control measure if properly designed. Extensive research by such organizations as the Corps of Engineers has resulted in good design procedures. These design features have been incorporated into commercially available software packages to assist the design engineer (WEST, 1996). Usually, the design procedure selects a representative stone size, $D_{\%,}$, where % denotes the percentage of the total weight of the graded material that contains stones of less weight. Other issues to consider in the design of rock riprap include:

- limit slopes to 2h to 1v
- provide a well-graded layer of rock
- provide filter material underneath the riprap to prevent washout
- provide a riprap blanket thickness of at least 1.5 times D_{50}.
- properly terminate all ends of riprap blankets.

A typical riprap blanket section is shown in Plate 2 of Appendix A.

3. Gabion Lined Channel.

Gabions are a popular erosion control method because of their flexibility. Gabion lined channels can adjust to conform to minor changes in stream bed and bank conditions. Any gabion basket that is in frequent contact with water should be PVC coated. Gabion baskets that are exposed to high velocity flows with large debris such as trees should be protected with a surface layer of grout. Aids such as design manuals and computer programs are available from gabion basket manufacturers. A typical section for a gabion lined channel is shown in Plate 3.

4. Concrete Pilot Channels.

Design guidelines for concrete pilot channels are similar to those for concrete-lined channels. If the pilot channel's side slopes are vertical, access ramps must be provided at regular intervals for channel maintenance. If concrete pilot channels are used in conjunction with grass-lined side slopes, supplemental measures such as rock riprap or a soil retention blanket may be necessary at the concrete-grass transition to prevent erosion and undermining of the pilot channel. An example combination pilot channel is shown in Plate 4.

5. Articulated Concrete Blocks.

Use of this method is normally not economically justified for small streams locally because of the specialized construction equipment required. Utilization of any product of this nature should be as per manufacturer's direction.

6. Walls and U-shaped Channels.

Walls must often be used to form channel banks because of right-of-way or other bank geometry restrictions. This usually results in special engineering issues which should be evaluated by a licensed professional engineer experienced in structural design.

a) Reinforced concrete.

Channel walls can be formed by reinforced concrete retaining walls. Design guidelines for such walls are beyond the scope of this manual. Some guidance can be found in the Standard Details published by each city. Reinforced concrete walls should be designed by a licensed professional engineer experienced in structural design.

b) Gabion Tiebacks.

Gabion walls can be constructed to function as channel banks. In this application, the structural walls can either be gravity (Plate 5) or incorporate an anchoring system for minimal right-of-way and bank disturbance (Plate 6).

c) Stone.

Stone masonry walls can be used for low channel banks. Stone walls should not exceed 4 feet in height and should be provided with adequate weepholes for subsurface drainage. Mortar strengths should be a minimum of 2500 psi (28 days). Walls greater than four feet should be designed, signed and sealed by a licensed professional engineer. An example stone wall is shown in Plate 7.

d) Crib Walls.

Structurally, crib walls are gravity walls, constructed of timber, precast concrete or steel beams. In addition to overturning, crib walls should be analyzed for internal stability. The front face should be battered for economy and appearance. Designs should be supervised by a licensed professional engineer experienced in structural design. The Federal Highway Administration has published standards for log cribbing (Gray, 1996).

e) Bulkheads.

Bulkheads should be constructed of durable materials such as treated lumber, metal or concrete. Sections above normal pool or adjacent to variable level ponds must provide for seepage through the wall. Tieback systems designed by qualified structural engineers should be provided. Plate 8 shows a typical bulkhead installation.

7. Sand-Cement Bag Revetment.

Sand-cement bag revetments are not uncommon in North Central Texas. Design considerations are similar as those for concrete and other types of revetments. Designers should provide against undermining of the toe and erosion at ends of the revetment. Sand-cement bag revetments are best suited to mild (2h to 1v or flatter) slopes and/or short walls in areas of low velocity. Steeper and/or taller walls must include supplemental measures such as tiebacks to withstand structural forces. Design guidelines can be seen in Plate 9.

8. Fabric Formed Concrete Systems.

Fabric Formed Concrete Systems are similar in application to sand-cement bag revetments and are usually proprietary systems. Installation should be in accordance with manufacturer's recommendations.

9. Dikes, Jetties and Jacks.

Dikes, jetties and jack systems are typically for control of large river systems and will not be presented in detail in this manual. One possible exception are vane dikes. Vane dikes are low elevation structures designed to guide flows away from eroding banks. They can also be used to evenly distribute flood flows through bridges and culverts when the upstream stream channel may be meandering or skewed to the crossing. An example of this application of vane dikes is shown on Plate 10A. Vane dikes can also be used with debris fins to reduce potential blockage of culverts (Plate 10B).

10. Soil Cement.

Use of in-place soil combined with cement provides a practical alternative to rock and concrete riprap. The resulting mixture, soil cement, has been successfully used as bank protection in many areas of the Southwest. Soil cement in a stair-step construction can be used on slopes as steep as 1:1. If properly constructed, soil cement can provide an aesthetically pleasing erosion control solution. A variation of this technical, Roller Compacted Concrete (RCC), has been used successfully on relatively large dam spillways. Most stream bank stability problems are too small in scope to be candidates for cost effective applications of RCC. As with all erosion control methods, soil cement applications should be designed by an experienced engineer. See Plate 11.

11. Bendway Weirs

Bendway weirs were developed by the engineers of the US Army Engineer Waterways Experiment Station to protect stream banks along the Mississippi River. These low weirs redirect the force of the river away from the outer bank toward the inner part of the bend and can be used to direct flow towards bridge structures. Most design criteria is based on field experience supplemented by model testing. A conceptual layout is shown on Plate 11A.

C. Grade Control Structures

Often, it is necessary to make abrupt changes in channel grade for the purpose of maintaining non-erosive flow conditions. This can be accomplished through the use of check dams, drop structures, and channel transition structures. Generally speaking, design of these structures should be performed by an experienced hydraulic engineer.

1. Check Dams.

The positioning of check dams along a stream course is an effective means of arresting the incising and downcutting that can occur as an urban stream attempts to achieve stability. Check dams should be made of durable materials such as concrete or gabions. Designs should extend sufficiently upstream and downstream to prevent undercutting. Normally, protection should extend up the adjoining slope to protect against any locally elevated velocity created by the structure. Stream hydraulics should be tested to ensure that design flood levels are not increased. Plate 12 shows a typical check dam in section.

2. Drop Structures.

Drop structures are utilized to check erosion by controlling energy gradients and to provide for large changes in flowline elevation over short distances. The changes in flowline elevation can be accomplished by means of a vertical drop or by constructing a fairly steep chute. A stilling basin is usually part of the drop structure design (Peterka,1984). To be effective, drop structures must be located so as to create stable channel conditions upstream and downstream from the structure. Details and design charts for a typical drop structure are shown on Plate 13.

3. Channel Transitions.

Channel transitions should be designed to accomplish the necessary change in cross section with as little flow disturbance as possible within the limits of ROW and economy. There is little guidance for transitions from improved, regular channel sections to natural stream sections. In general, detailed water surface profiles should be computed throughout the transition and velocity changes from section to section should not exceed 20 percent. Changes in flow line elevation should be minimized. The transition itself can take the general forms shown on Plate 14. The resulting water surface profile should be as smooth and straight as possible. Transitions involving high velocity (supercritical) flows should follow the rules of thumb as shown on Plate 14(USACE, 1991).

D. Storm Sewer Outfalls

Storm sewer outfalls are a chronic erosion problem in urban drainage systems. Often, the storm sewer system is terminated well short of the stream bank itself and at an elevation well above the receiving stream's flowline. The usual result of this practice is a headcut which eventually reaches the storm sewer headwall. Sometimes, the headwall itself is undermined to the point of failure. Even if the storm sewer outfall is extended to the stream bank, erosion can occur as a result of storm sewer flows between the headwall and the stream channel itself or even as a result of stream bank erosion due to urbanization.

There are three general types of storm sewer outfalls:

- the traditional Type A and B headwall found in most municipal standard drainage details
- the sloped end section headwall (sometimes called Type C)
- the impact type stilling basin outfall .

STORM SEWER OUTFALL ON RUSSELL CREEK UPSTREAM OF ALMA ROAD, PLANO, TEXAS

Generally speaking, the Type A, Type B and sloped end section headwalls will provide adequate protection for outfall velocities (in the pipe or box) of 8 ft/sec or less. This is provided that the outfall extends fully to the stream channel and adequate erosion protection is provided in the form of rock riprap and/or a reinforced concrete flume to prevent erosion around the headwall and between the headwall and the stream channel. Plate 15 shows suggested protection for standard headwalls. A good detail for sloped end sections is found in the City of Plano's standard details, sheet SD-14.

If the intervening area between the last inlet and the top of stream bank is more than one acre, surface erosion of the bank at the outfall often occurs. A wye or grate inlet should be situated at the top of bank to prevent this erosion. This can also serve as a vent to relieve capacity-robbing pressure fluctuations which can occur when the upstream pipe is flowing full and the downstream end is submerged.

The impact-type stilling basin outfall should be used when outfall velocities (in the pipe or box) are in excess of 8 ft/sec. The basic dimensions of the basin (Plate 16) are a function of the design discharge (Plate 17). Columns 1 and 2 of Plate 17 give pipe sizes used in field installations and assume a maximum velocity for the design flow of 12 ft/sec. Other pipe sizes may be used, but the relationship between structure size and discharge should remain as shown in the table. Conduit slope at the outlet should be limited to 3%. If the conduit slope must exceed 3%, use a mild(less than 2%) slope for at least two diameters upstream of the basin (Peterka, 1984).

E. Soil Bioengineering Practices

Soil Bioengineering Practices (SBP) are thoroughly covered in *Biotechnical Slope Protection and Erosion Control* (Gray and Leiser, 1982). Excerpts and summaries of the various methods from that text are presented here for general guidance to those considering SBP's for stream bank stabilization.

1. Live Stakes*.*

Live staking, the planting or driving of unrooted cuttings to control soil erosion and shallow sliding, should be from plant species that will root easily and grow with minimal maintenance. Species should have long straight stems for ease of driving. Willow and desert aphyll can be used in our region for live staking. Stakes should be cut and planted when the species is dormant.

2. Wattles*.*

Wattle spacing should range from 3 feet on severely eroded slopes to 20 feet on slopes subject to moderate uniform sheet erosion. Wattling bundles should be composed of plant materials that root easily, are long, straight and flexible and are in plentiful supply near the project site. If easily rooted plant material is in short supply, bundles should be live staked. Placement should occur in late October or in the month of November after the fall rains . Wattle details and installation guidance is shown in Plates 18 and 19.

3. Brush Layering*.*

Branches should be 3-4 feet long, ¾-2 inches in diameter, and spaced 8-12 inches apart. Vertical spacing can range from 3 to 10 feet depending on the erosion potential of the slope. Spacing should be closer at the bottom of long slopes and increase as one moves up the slope. Brush Layering details and installation guidance is shown in Plates 20 through 22.

4. Brush Matting*.*

Brush matting or mattressing, mulches of hardwood, should be placed after planting in a shingle fashion with the butt ends pointed upstream. Mats should be a minimum of 4 inches thick constructed of 1 inch thick stems. Stakes should be 3 feet long and placed at 3-ft centers. Brush matting details and installation guidance is shown in Plates 23 through 26.

5. Coir.

This product is a very strong organic geotextile in mats or rolls, used to confine and stabilize soil until vegetation can be established. Coir is often used in conjunction with other SBP's and is commercially available.

6. Live Cribwalls.

Crib walls are hollow box -like interlocking arrangement of logs, timbers or concrete beams filled with soil or rock. These function as gravity walls as far as design is concerned. Typically, timber is rough cut, structural grade Douglas Fir. Heights should be limited to 4 feet unless designed by a Professional Engineer experienced in structures of this nature. Backfill should be free-draining, granular material. A typical crib wall design is shown in Plate 27.

7. Stream Bank Toe Protection

Type III- Pre-Vegetated Blankets, shown in Plate 28, are useful in establishing vegetation at stream and lake edges.

8. Combinations.

Various Soil Bioengineering Practices can be combined to solve problems such as gully and rill erosion as shown in Plate 29.

F. Other Nonstructural Methods

1. Grassed-Lined Channels

Key parameters in grass-lined channel design include permissible velocity, roughness coefficient, side slope, curvature, bottom width, and freeboard. The roughness coefficient for bare earth should only be used for checking maximum permissible velocity. Since bare earth channels will normally collect sediment and encourage undesirable vegetative growth, they will not be permitted for proposed improvements, unless written approval is obtained from the City Engineer. Design for grass-lined channels must include adequate temporary erosion controls for the construction period and final acceptance is conditional upon full vegetation coverage. If a variance is granted, the capacity of proposed bare earth channels will be determined using the grass-lined Manning's coefficient.

Small roadside-type ditches may be designed using normal depth, uniform flow methods as long as the flow rate does not exceed 100 cubic feet per second and the flow area does not exceed 20 square feet. Ditches and channels which exceed these limits must be designed with the standard-step method and will require the submittal of a HEC-2 (or equivalent) hydraulic model.

The maximum permissible velocity for grass-lined channels is as shown in Table II-1. To verify the channel velocities, the designer shall use uniform depth (for small channels) and a HEC-2 (or equivalent) hydraulic model (for large channels). Flow velocities shall not exceed allowable limits for the design storm when exiting a riprap section or culvert apron back onto grass-lined or bare earth channels. Appropriate energy dissipater designs shall be used if these velocities are exceeded.

Side slopes for earthen or grass-lined channels shall be four (4) horizontal to one (1) vertical side slopes or flatter if the slopes are to be maintained by the City. Steeper side slopes will be allowed only upon the approval of the City Engineer. The channel side slopes, along with the channel invert (to be approved by the City Engineer and Parks Department), must otherwise be stabilized in a manner approved by the City Engineer.

Channel intersections and minimum curvature criteria are the same for Grass-lined channels as for concrete-lined channels

If a greenbelt is incorporated into the overall plan for development, as a channel or as a buffer zone around a channel, then the greenbelt shall be landscaped, yet <u>still retain the required hydraulic capacity</u>. Landscaping requirements and maintenance responsibilities will be determined at the plat stage.

In North Central Texas, the Texas Department of Transportation uses the following grasses:

- Bermuda grass
- Buffalo grass
- Green Spangletop
- Little Bluestem
- Indian grass
- Switchgrass
- Sideoats Grama
- Sand Dropseed

The chances of establishment of newly seeded channels can be improved through the use of hydraulic mulch, synthetic blankets, emulsifiers and tackifiers. All channels must include the use of an approved soil retention blanket (see section D.3 of this chapter) for the lower two feet of the channel. Channels with erosion design velocities exceeding 5 feet per second but less than 8 feet per second shall include use of an approved soil retention blanket throughout the channel section. Channels with erosion design velocities equal to or greater than 8 feet per second must be armored (see IV.B)

2. Geogrids/Geotextiles/Cellular Confinement.

Most of these systems are proprietary and should be installed per the manufacturer's recommendations.

3. Blankets, Mats, Netting.

Excellent guidance is provided by the Texas Department of Transportation concerning synthetic blankets and mats for use as slope protection and flexible channel liners. Annually, these products are tested and a list of acceptable products is published (TXDOT, 1997). It is recommended that applications in the project area be limited to those products on TxDOT's approved list. The current list is included in Appendix B.

A soil retention blanket is used for short and/or long-term protection of seeded and sodded slopes, ditches, and channels. Soil retention blankets can be manufactured out of wood, straw or coconut fiber mat, synthetic mat, paper mat, jute mesh or other material. The soil retention blanket shall be one of the following classes and types:

- TXDOT Class 1. "Slope Protection"
  - Type A. Slopes 3(h):1(v) or flatter - Clay soils
  - Type B. Slopes 3(h):1(v) or flatter - Sandy soils
  - Type C. Slopes steeper than 3(h):1(v) - Clay soils
  - Type D. Slopes steeper than 3(h):1(v) - Sandy soils
- TXDOT Class 2. "Flexible Channel Liner"
  - Type E. Short-term duration (Up to 2 years) Shear Stress (t_d) < 48 Pa
  - Type F. Short-term duration (Up to 2 years) Shear Stress (t_d) 48 to 96 Pa
  - Type G. Long-term duration (Longer than 2 years) Shear Stress (t_d) > 96 to <239 Pa
  - Type H. Long-term duration (Longer than 2 years) Shear Stress (t_d) $\geq$ 239 Pa

4. Removal of Obstructions

Obstructions in a stream channel can alter flow characteristics and contribute to bank instability. Logs and other debris can block bridges and culverts worsening flood levels. Common obstructions in urban areas include fallen trees and sediment deposition.

Streams should be inspected at least annually, prior to spring rains to locate obstructions and schedule their removal. Removal typically involves cutting the tree into manageable pieces for removal and safe disposal. Sediment removal is more difficult and may involve dredging and/or mechanical removal. Sometimes, point bars at stream meanders can be removed by excavating a pilot channel across the bar and allowing the stream flow to erode the accumulated sediments. This practice should not be undertaken without the approval of the City Engineer.

CHAPTER V

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