State of Colorado
Streambank Erosion Study

Elk River
Routt County, Colorado
for the
Colorado State Soil Conservation Board
Colorado Association of Soil Conservation Districts
Routt County Soil Conservation District

Soil Conservation Service
Denver, Colorado

November 1988

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THE WATERSHED IN BRIEF

The portion of the Elk River involved in this study is the lower portion just upstream from the confluence with the Yampa River, in Routt County, Colorado [SEE ATTACHED MAP]. The drainage area of the Elk River (a part of the Colorado River Basin) is approximately 480 square miles. Elevations range from 6,515 feet at the confluence of the Yampa and Elk Rivers to 12,180 feet at the top of the watershed.

The annual precipitation in the study area is 18 to 25 inches and the average frost-free period is 40 to 65 days.

GEOLOGY

Glacial deposits of Pleistocene age are widespread in the Park Range and the White River Plateau. Moraines representing several intervals of glaciation are present along most of the major valleys in the higher portions of these areas. Several levels of Pleistocene stream terraces underlain by sandy and gravelly deposits occur along the Elk River. Recent alluvium occurs in floodplains of most smaller tributaries as well as along the larger streams.

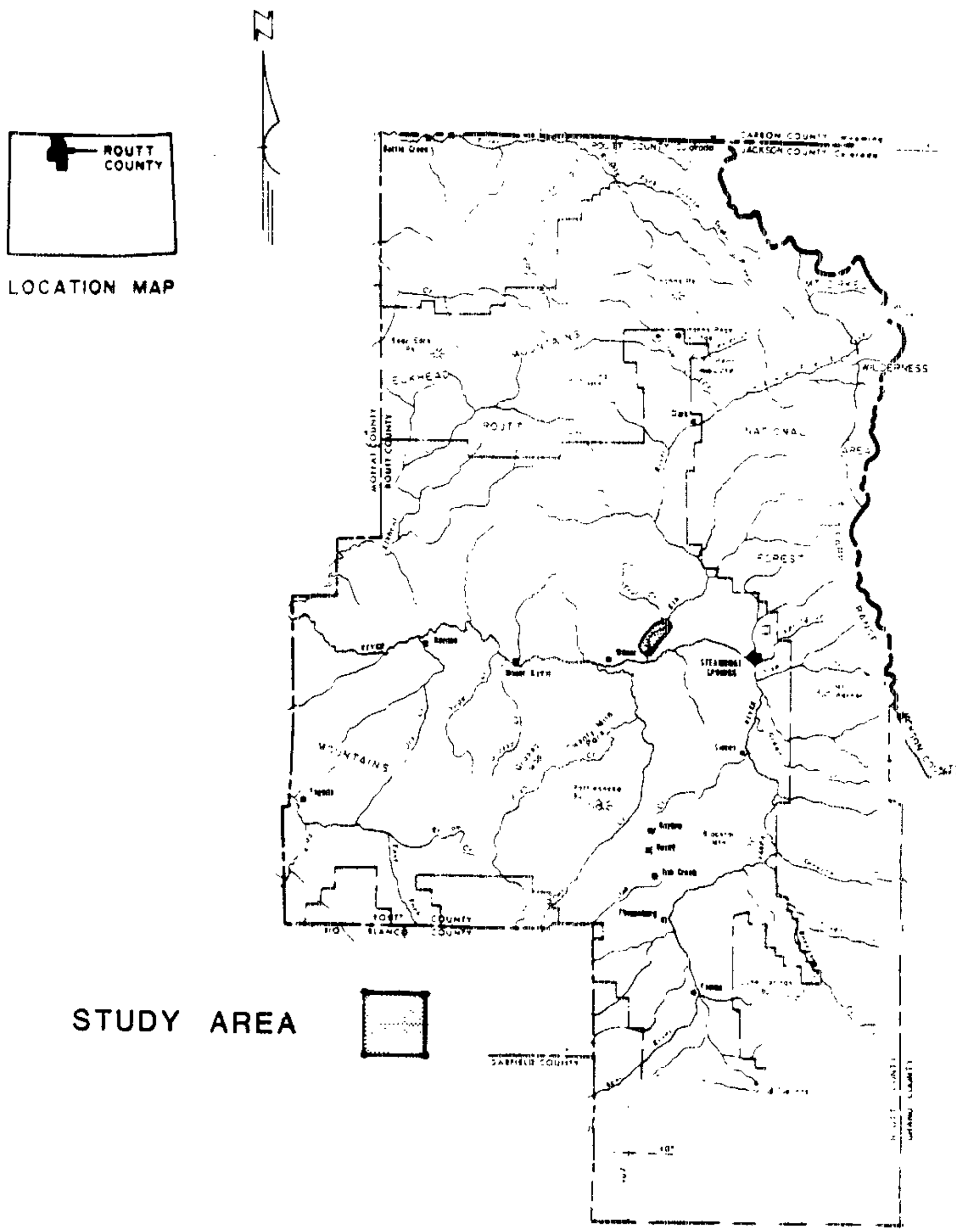
WATERSHED PROBLEMS AND NEEDS

Streambank erosion has been a continuing problem for this area. The loss of arable and farmed land, loss of riparian areas, loss of and damage to irrigation structures, and damage to bridge embankments are examples of types of damages occurring approximately 2 miles of the study area. Approximately 91 acres of pastureland, hayland, trees, homesteads, and riparian areas that are adjacent to the study areas, including 1 bridge, 1 house, and 1 diversion [SEE LOCATION MAP AND TABLE 1].

Earth moving equipment has been used in the past at several locations. This has disturbed the gravels and cobbles armoring the bottom and sides of the channel allowing materials to be moved downstream. These deposition areas also affect the stream wherever they occur. Streambank erosion also contributes to the loss of riparian habitat and vegetation as well as farmable land.

The new deposition areas are without vegetation. Older deposition areas are becoming slowly vegetated. Several landowners along the river have applied Dr. Donald R. Reichmuth's rock drop practices to control the rivers direction of flow. These rock drop practices are being used to keep the water turned away from eroding banks and have so far been effective at relatively low spring runoff flows.

There still is the need, along the streambanks, to control or stabilize the erosion and reduce the damages that have not been corrected as well as to protect the farmable lands, irrigation structures, bridges, riparian areas, and farmsteads.



ELK RIVER

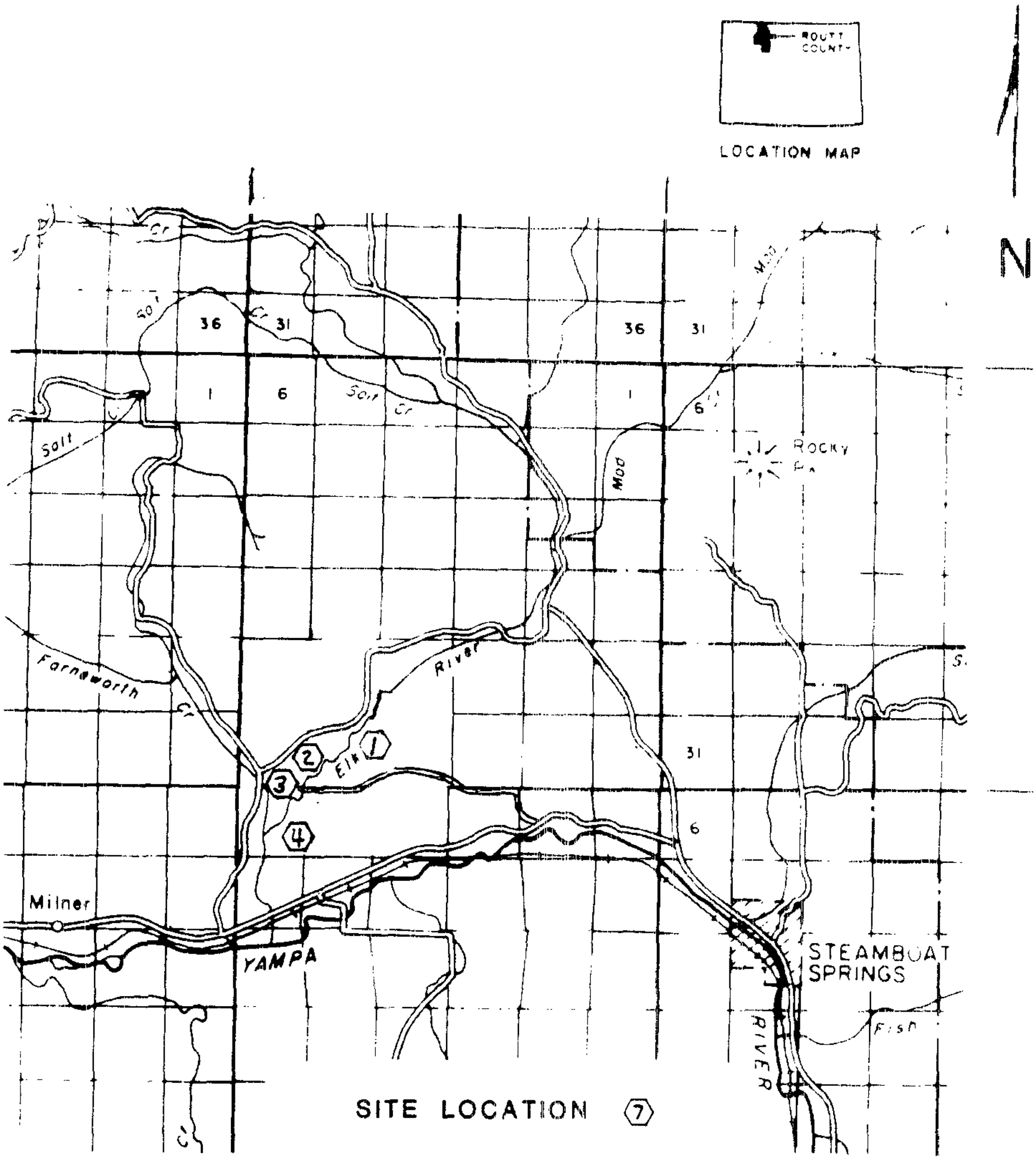
ROUTT COUNTY

COLORADO

STREAMBANK EROSION STUDY

TABLE 1
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
STUDY AREA

Site	Area to Protect					River Length Eroding	Average Streambank Loss per Year	
	Trees Riparian Area	Pasture and Hayland	Bridges	Houses and Outbuildings	Diversions			
	Ac	Ac	No	No	No	Ft	Ft	Ac Ft
1	9	0	0	0	0	1,900	5.0	0.33
2	0	0	0	0	0	0	0.0	0.00
3	20	10	0	0	1	3,200	3.8	1.10
4	5	1	0	1	0	2,200	4.4	0.33
Total	34	11	0	1	1	7,300	-	-



ELK RIVER

ROUTT COUNTY

COLORADO

STREAMBANK EROSION STUDY

WORKS OF IMPROVEMENT FOR POTENTIAL DEVELOPMENT

Possible measures for improvement include rock riprap, anchored trees, rock jetties, jacks, vegetated buffer strips, vegetative sprig revetment, and riparian zones.

Rock riprap is an effective method of controlling streambank erosion on nearly all streams. Rock can be placed on straight to severely meandering streambanks.

Anchored trees can be used as an effective method of streambank protection on most streams. They can be used on streams with any degree of meandering.

Rock jetties are an effective method of controlling streambank erosion on slight to moderately meandering curves. Because jetties function by deflecting the flow away from the streambank they are not practical on sharp curves.

Jacks can be used to stabilize most eroding banks. They are especially useful in streams which have wide sections due to streambank meandering. The jacks can be located to allow eroded areas to silt in behind the row of jacks.

Vegetated buffer strips for bank protection is primarily related to cropland which is tilled up to the edge of stream channels without leaving a vegetative zone.

Vegetative sprig revetment is one of the most effective methods of controlling streambank erosion under natural conditions. It is also the least costly method available when the vegetation is maintained in good condition.

Riparian zones along the river banks will reduce much of the damage associated with streambank erosion. The root systems developed from trees and brush provide protection from the cutting action of water flowing against the banks. The rock drop practices introduced by Dr. Donald R. Reichmuth, PE/LS GEOMAX, PC in his "Living with Fluvial Systems a Short Course on River Mechanics," were not examined because of the lack of information on effectiveness, cost data, and design.

NATURE AND ESTIMATE OF COST AND IMPROVEMENT

USGS topographic maps as well as aerial photos were used in making field reconnaissance of the proposed study area and in determining problem areas.

Quantities, along with present costs, were used to develop an estimated engineers cost. Two percent was added for mobilization, and 15 percent was added for contingencies to obtain estimated construction cost. Engineering services and project administration are 14 and 17 percent, respectively, of the construction cost. The estimated installation cost is the total of these costs [SEE TABLES 2A, 2B, 2C, 2D, 2E, 2F, 2G]. Average annual cost includes operation and maintenance costs.

STRUCTURAL EFFECTS AND ECONOMIC FEASIBILITY

The use of rock riprap, anchored trees, rock jetties, jacks, vegetated buffer strips, vegetative sprig revetment, and riparian zones are some of the treatment measures that would be used to help stabilize the river banks. This will allow continued production on haylands, rangeland, and pasture lands. These measures could also protect established riparian areas from being destroyed. Bridges and diversion areas could be protected from the encroachment of the eroding riverbeds.

Feasibility analysis indicate that no alternatives were economically feasible for project-type action on any of the sites in which agricultural land alone was being protected. The costs to protect the sites were too excessive when compared with the benefits received using project-type methods of evaluation. Landowners or groups of landowners would not recoup their expenditures. Feasibility is shown by comparing the annual benefits to the annual cost for each alternative and for each site.

TABLE 2A
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Rock Riprap (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (2%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Cy	$	$	$	$	$	$	$	$	$
1	3,800	222,300	31,122	37,791	0	291,213	4,400	25,525	29,925	0
2	Existing bridge is in good condition									
3	6,400	374,400	52,416	63,648	0	490,464	7,500	42,989	50,489	970
4	4,400	257,400	36,036	43,758	0	337,194	5,100	29,555	34,655	3,330
Total	14,600	854,100	119,574	145,197	0	1,118,871	17,000	89,069	115,069	-

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) Installed (with base) 2 cy per foot bank at $50 per cy = $100 per foot with a life expectancy of 50 years
(3) Corps of Engineers 404 permit to work in river
(4) Includes cost for structural measures to protect riparian habitat and 2% O&M
(5) Benefits for riparian habitat protection were not analyzed

TABLE 2B
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Anchored Trees (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (1%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Ft	$	$	$	$	$	$	$	$	$
1	1,900	44,460	6,224	7,558	0	58,242	400	7,067	7,467	0
2	Existing bridge is in good condition									
3	3,200	74,880	10,483	12,730	0	98,093	700	11,902	12,602	970
4	2,200	54,480	7,207	8,752	0	67,439	500	8,182	8,682	3,330
Total	7,300	170,820	23,915	29,039	0	223,774	1,600	27,151	28,751	-

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) Installed at $20 per foot of bank protected with a life expectancy of 15 years
(3) Corps of Engineers 404 permit to work in river
(4) Includes cost for structural measures to protect riparian habitat and 1% O&M
(5) Benefits for riparian habitat protection were not analyzed

TABLE 2C
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Rock Jetty (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (4%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Cy	$	$	$	$	$	$	$	$	$
1	800	46,800	6,552	7,956	0	61,308	1,900	5,374	7,274	0
2	Existing bridge is in good condition									
3	1,280	74,880	10,483	12,730	0	98,093	3,000	8,598	11,598	970
4	880	51,480	7,207	8,752	0	67,439	2,100	5,911	8,011	3,330
Total	2,960	173,160	24,240	29,039	0	226,840	7,000	19,883	26,883	-

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) Installed (with base) 4 cy per foot at $50 per cy = $200 per foot with a life expectancy of 50 years
(3) Corps of Engineers 404 permit to work in river
(4) Includes cost for structural measures to protect riparian habitat and 4% O&M
(5) Benefits for riparian habitat protection were not analyzed

TABLE 2D
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Jacks (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (3%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Ft	$	$	$	$	$	$	$	$	$
1	1,900	23,230	3,112	3,779	0	29,121	700	2,610	3,310	0
2	Existing bridge is in good condition									
3	3,200	37,440	5,242	6,365	0	49,047	1,100	4,390	5,490	970
4	2,200	25,740	3,604	4,376	0	33,720	800	3,020	3,820	3,330
Total	7,300	85,410	11,957	14,520	0	111,887	2,600	10,020	12,620	-

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) Installed at $10 per foot bank protected with a life expectancy of 40 years
(3) Corps of Engineers 404 permit to work in river
(4) Includes cost for structural measures to protect riparian habitat and 3% O&M
(5) Benefits for riparian habitat protection were not analyzed

TABLE 2E
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Buffer Strips (Vegetated) (2) (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (2%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Ft	$	$	$	$	$	$	$	$	$
1	1,900	23,230	3,112	3,779	0	29,121	400	2,550	2,950	0
2	Existing bridge is in good condition									
3	3,200	37,440	5,242	6,365	0	49,047	700	4,300	5,000	0
4	2,200	25,740	3,604	4,376	0	33,720	500	2,960	3,460	0
Total	7,300	85,410	11,957	14,520	0	111,887	1,600	9,810	11,410	-

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) installed at $0.10 per sq. ft. (50 ft. on each side of stream or 100 ft. for one side)
for a total of 100 sq. ft. for each foot of stream or $10 per foot of stream with a life expectancy of 50 years
(3) Corps of Engineers 404 permit to work in river and easement from landowner
(4) Includes cost for structural measures to protect riparian habitat and 2% O&M
(5) Benefits for riparian habitat protection were not analyzed

TABLE 2F
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Vegetative Sprig Revetment (2) (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (5%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Ft	$	$	$	$	$	$	$	$	$
1	1,900	11,115	1,556	1,890	0	14,561	600	1,260	1,880	0
2	Existing bridge is in good condition									
3	3,200	18,720	2,621	3,182	0	24,523	900	2,150	3,050	0
4	2,200	12,870	1,802	2,188	0	16,860	600	1,480	2,080	0
Total	7,300	42,705	5,979	7,260	0	55,944	2,100	4,910	7,010	-

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) Installed at $5 per foot of bank protected (10 ft. on each side of stream channel or 20 ft. for one side - sprigs set at approximately two foot centers) with a life expectancy of 50 years
(3) Corps of Engineers 404 permit to work in river and easement from landowner
(4) Includes cost for structural measures to protect riparian habitat and 5% O&M
(5) *Benefits for riparian habitat protection were not analyzed*

TABLE 2G
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
COST ESTIMATE - COMPARISON OF BENEFITS AND COST (Dollars) (1)

Site	Structural Measures Riparian Zone (2)	Construction Cost	Engineering	Project Administration	Land Rights (3)	Total Installation	O & M (5%)	Average Annual Cost	Total Average Annual Cost with O&M (4)	Average Annual Benefits (5)
	Ft	$	$	$	$	$	$	$	$	$
1	1,900	4,446	622	756	0	5,824	200	510	710	0
2	Existing bridge is in good condition									
3	3,200	7,488	1,048	1,273	0	9,809	400	860	1,260	0
4	2,200	5,148	721	875	0	6,744	300	590	890	0
Total	7,300	17,082	2,391	2,904	0	22,377	900	1,960	2,860	0

(1) Price Base: September 1987 amortized at 8 5/8% for 50 years
(2) Zone to extend 50-100 feet up bank - $2 per foot of bank protected with a life expectancy of 50 years
(3) Corps of Engineers 404 permit to work in river and easement from landowner
(4) Includes cost for structural measures to protect riparian habitat and 5% O&M
(5) Benefits for riparian habitat protection were not analyzed

ENVIRONMENTAL CONDITIONS AND IMPACTS

A field review of the Elk River was conducted on May 1, 1987. Comparison of old maps/photos along with newer maps/photos was made to determine the movement of the stream. A good portion of the land adjacent to the river itself is used for hay production or livestock grazing.

Installing alternatives will effectively reduce the erosion and sediment problems for the erosive areas and to the river. The alternatives would also enable the landowner to maintain the present land use or change the land use as needed. In some areas, fish, wildlife, and wetland habitat may be maintained or in some cases improved. Installation may also help maintain the diversity of habitat in the basin area.

There are also aesthetic and social benefits to implementing practices. The area tends to look more pleasing to the eye. There is also pride of ownership that comes into play. Landowners like having their property look good and are willing to spend substantial amounts to make it more pleasing to the eye.

All of the alternative treatments analyzed in this study will improve riparian habitat by reducing damages caused by erosion and sedimentation. However, vegetated buffer strips, vegetative sprig revetment, and riparian zones will return the habitat to native conditions more completely and rapidly.

A comparison between the alternatives of the economic, environmental, and social factors are listed in TABLE 3. These factors are rated as to beneficial, adverse, or no effect due to the type of treatment used.

TABLE 3
ELK RIVER
ROUTT COUNTY, COLORADO
STREAMBANK EROSION STUDY
ANALYSIS OF ECONOMIC, ENVIRONMENTAL, AND SOCIAL FACTORS

Factors	Alternative Treatment (1)							Remarks
	Rock Riprap	Anchored Trees	Rock Jetties	Jacks	Buffer Strips	Sprig Revetment	Riparian Zone	
Erosion Reduced	++	+	+	+	+	+	++	Streambank
Sedimentation Reduced	++	+	+	+	+	+	++	
Floodwater Reduced	o	-	-	-	-	-	-	Roughness coefficient of stream
Wetlands	o	o	o	o	+	+	+	
Wildlife	o	+	o	+	++	+	++	Habitat
Groundwater	o	o	o	o	-	-	-	Recharge and water use
Water Quality	++	+	+	+	++	++	++	Reduces erosion and sedimentation
Irrigation	++	+	+	+	++	++	++	Protects irrigation structures
Endangered Plants and Animals	o	o	o	+	++	+	++	Increases habitat
Net Economic Benefits	--	-	-	-	-	-	-	High installation cost
Recreation	-	o	-	-	+	+	++	Reduces erosion and sedimentation
Transportation	++	+	+	+	+	++	++	Reduces damage to roads and bridges
Fish Habitat	-	+	-	+	+	+	+	Reduces sedimentation
Social Resources	o	o	o	o	o	o	o	
Visual Resources	-	-	-	-	+	+	+	Reduces cutbank areas

(1) Considered Value Ratings:
o No Effect
+ Beneficial Effect
++ Very Beneficial Effect
- Adverse Effect
-- Very Adverse Effect

CONCLUSIONS & RECOMMENDATIONS

Based upon the staffs field inspection of the total river reach and study of four sites, the following conclusions have been reached.

1. Dedication of riparian zones along river banks will reduce much of the damage associated with streambank erosion. The root system developed from trees and brush along the streambank provide protection from the cutting action of water flowing against the banks. Protection from bank sloughing will also be obtained.

Other benefits, such as increased wildlife habitat, increased numbers of all wildlife, and diversity of scenery, will also be realized from riparian zones. These zones will also move the high value agricultural crops away from the streambanks, therefore, reducing the likelihood of damage to these crops.

Where eligible, landowners can receive assistance through the Conservation Reserve Program (CRP) administered by the Agricultural Stabilization and Conservation Service (ASCS) to develop a 66 to 99 foot wide riparian zone along streams or water bodies. To be eligible, the land would have had to be used to produce agricultural commodities 2 of the 5 years between 1981 and 1985. Rental payments for 10 years are offered as an incentive to convert the cropland to grass or trees.

Riparian zones will provide protection from the lower frequency flows. However, large flows can produce bank erosion which will destroy them. When this happens, the uprooted trees can block the channel and cause additional bank cutting.

2. This study recommends the formation of a state coordinator position. The need for a person to coordinate activities relating to stream channel improvements was identified. Many examples of work being done without consideration of the effects, both upstream and downstream, were noted during the study. This showed the lack of knowledge about river mechanics and flow patterns by the people doing the work.

The coordinator should be someone that landowners could ask for advice about the effects of work in streams before construction is started. The coordinator could provide the assistance or direct the landowner to an agency that could help. This would not replace the U.S. Army, Corps of Engineers, Section 404 permitting process, but the coordinator could provide assistance to streamline the process.

The coordinator could work with landowners to solve problems along a stream reach. By working in the total reach, the problem solutions could be coordinated for maximum efficiency. Development of riparian zones which include areas owned by several people could also be addressed by the coordinator.

This type of "streambank erosion coordinator" should be assigned to a state agency such as the CSSCB, to provide assistance state wide, and act as a moderator in the argument between development and environmental preservation.

3. When individual streambank erosion control projects are undertaken, a thorough study of the total stream reach is needed to predict the effects of the project action upstream and downstream from the site of construction. If work is to be carried on in the riverbed the damage to the rivers armor needs to be considered as to what will take place upstream and downstream. A Section 404 permit to work in the river needs to be obtained from the Corps of Engineers to assure all persons involved have had an opportunity to respond. In areas where blanket permits have been granted a review system may need to be established to prevent unneeded damage to the river system.

4. It is not cost effective to use rock riprap or rock jetties to protect agricultural land. These types of bank protection may be cost effective where structures such as roads, homes, bridges, irrigation diversions, or other high value improvements are threatened. Anchored trees and jacks are in general the most cost effective structural control measures and may be viable only in some specific locations.

5. Vegetated buffer strips, vegetative sprig revetment (bank sloping and revegetation), and riparian zones were considered viable alternatives in this study. High velocity flows on the river may require structural practices such as jacks in conjunction with a vegetative practice.

6. Angled rock structures (placing of large rocks with approximately 1 to 1.5 feet of drop in the river) as introduced by Dr. Donald R. Reichmuth, PE/LS GEOMAX, PC, in his short course "Living With Fluvial Systems a Short Course on River Mechanics," were not considered in the analysis because of the lack of specific cost data, effectiveness, and design.

These type structures are possible for the landowners to install at their own initiative with the use of technical assistance from consultants. They have a high maintenance and may not be as effective during high flows.

7. In the early 1960's an Agricultural Conservation Program (ACP) was available to provide financial and technical assistance to landowners who applied treatment to streambank erosion problems. This approach might be possible again. It would encourage proper designed treatment measures as well as financial incentive.

STREAMBANK PROTECTION EXAMPLES

Streambank protection practices are generally used in reaches of a stream which have a stable channel bottom. If the channel bottom is not stable, other types of practices may be more beneficial. Streambank protection practices are used to keep a streambank from eroding and causing meanders in a stream. Some of these types of practices can also be used to help heal existing meanders by slowing the velocity and allowing sedimentations to occur in the eroded area.

The practices described in the following pages **(see "Summary of Practices")** are some types of measures which can be used to protect streambanks. Also included are measures that were not considered, in this study, yet may be a possible solution to streambank problems.

A few requirements are common to all types of streambank protection. The toe of any kind of bank protection must extend below the cannel to a depth which will ensure that scouring will not undercut the toe of the practice. The upstream and downstream ends of the bank protection must be stable. This can be accomplished by tying the ends of the practice into stable reaches of the top of the bank. However, it is usually acceptable to extend it only up the bank to one foot above the high water elevation. This elevation must be determined by a detailed hydrologic and hydraulic analysis of the stream.

SUMMARY OF PRACTICES
Streambank Protection Practice

Structural Practices 1/	Cost Per Foot	Expected Life (yrs)	O&M
Rock Riprap	100	50	2
Anchored Trees	20	15	1
Rock Jetty	200	50	4
Jacks	10	40	3
Vegetative Practices			
Vegetated Buffer Strips	10	50	2
Vegetative Sprig Revetment	5	50	5
Riparian Zone	2	50	5

1/ O&M is expressed as a percentage of the original construction cost.

Structural Practices

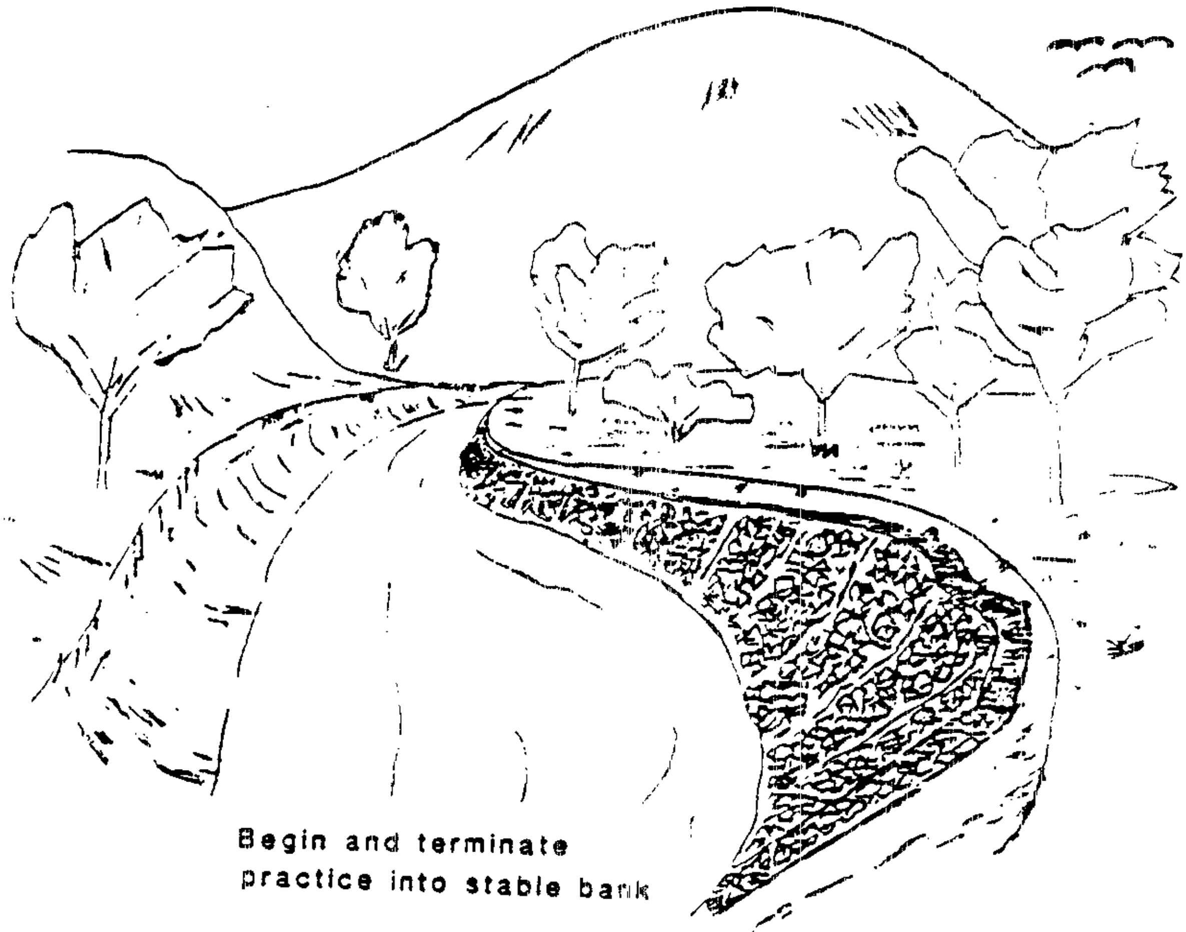
Rock Riprap

Rock riprap is an effective method of controlling stream bank erosion on nearly all streams. Rock can be placed on stream banks which are straight to severely meandering. Rock for riprap should be material which is dense, angular, and durable. Rock should be well graded to minimize air voids in the riprap blanket. The rock should be sized to withstand the force of the water in a stream without displacing the rock. Depending on the type of soil in the bank, a riprap blanket may require a filter of sand and/or gravel. The filter will prevent the piping of soil particles from the bank through the riprap blanket due to groundwater movement. The stream bank is shaped to a slope no steeper than 2.0 horizontal to 1.0 vertical prior to placement of the rock. The toe of a riprap blanket must be deep enough to prevent the stream from undercutting the bank below the riprap and causing the bank to fail. The upstream and downstream ends of the riprap blanket must be tied into the bank at a stable point.

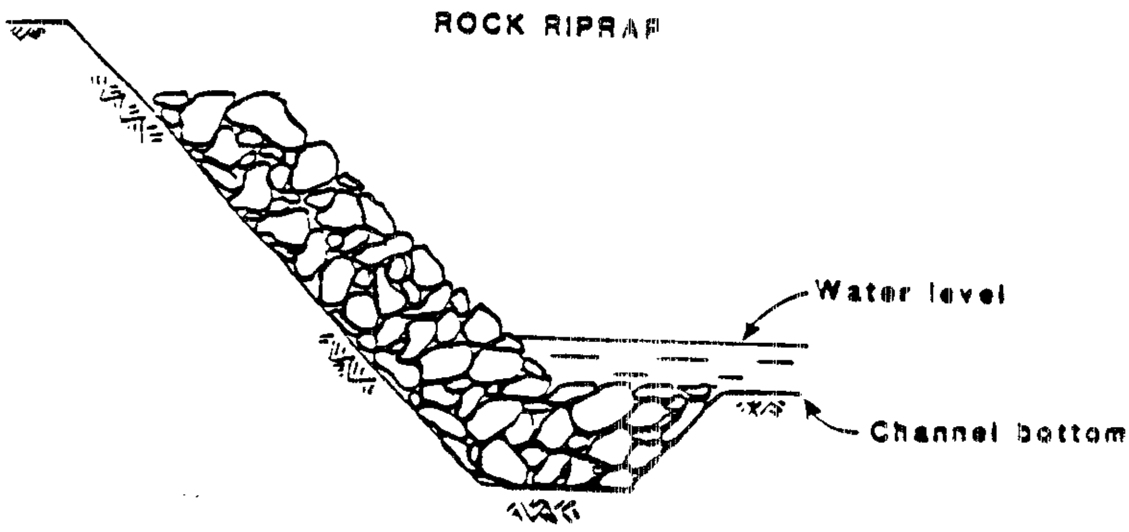
Some stream banks may not require the riprap blanket to extend to the top of the bank. An example of this could be if the bank on one side of the stream is significantly higher than the bank on the other side. The blanket should extend up the bank to a height of one foot above the high water elevation. The area above the rock should be shaped and seeded with appropriate vegetation.

A variation of this practice is to use **wire-bound rock.** The cross section would be similar to the rock riprap cross section. However, since the rock is held in place with anchored, wire-fencing material, the rock can be a smaller size. This will allow the thickness of the blanket to be reduced. Wire-bound rock is not recommended on channels with high banks or streams with a high flow velocity.

Maintenance requirements for a riprap blanket include replacing or repositioning rock if it is displaced by high flows. The upstream and downstream ends of the blanket should be checked to make sure erosion is not occurring. If scour holes have developed, the eroded areas should be filled and protected with additional riprap.



ROCK RIPRAP



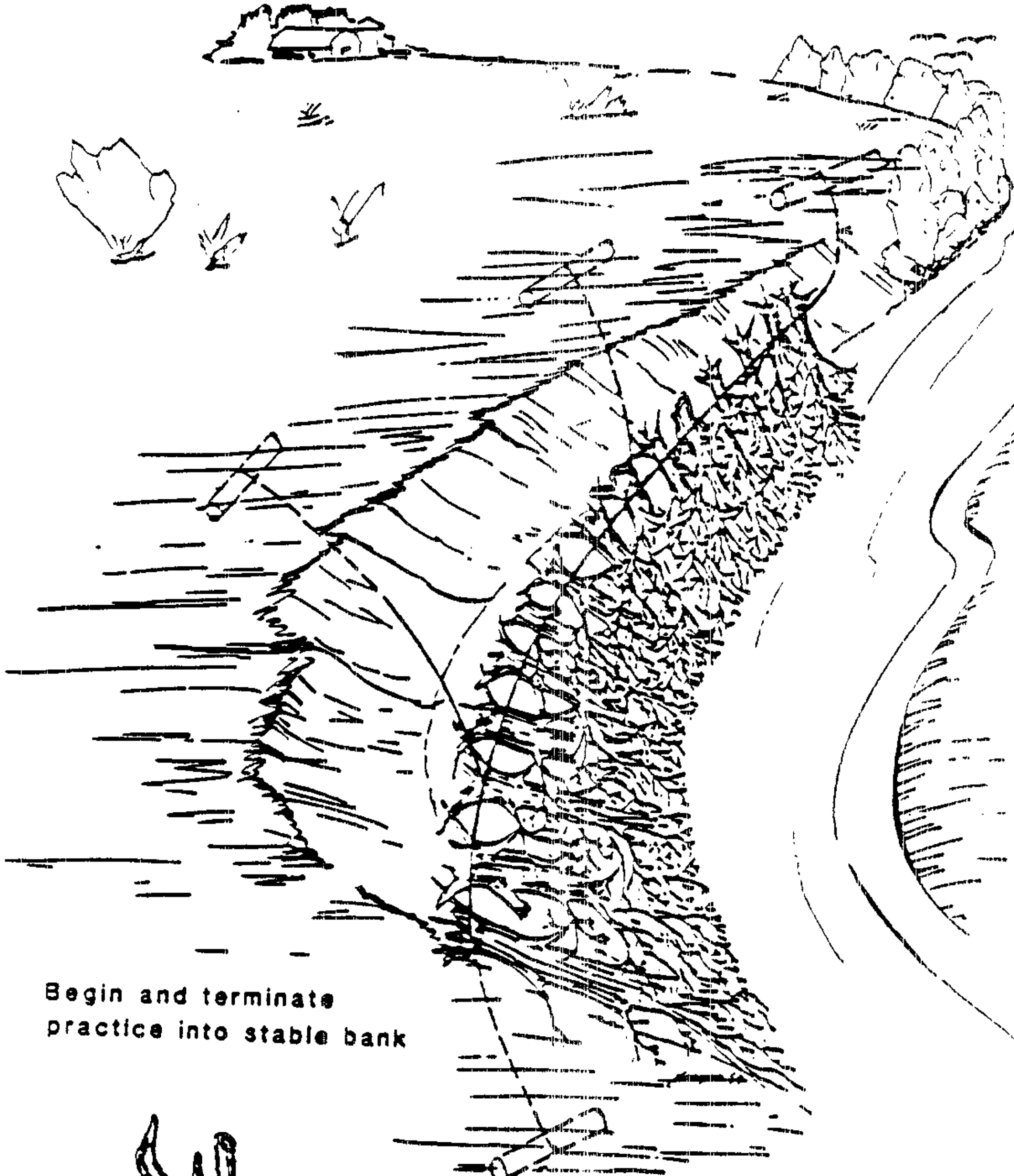
TYPICAL RIPRAP SECTION

ROCK RIPRAP

Anchored Tree Revetment

Anchored trees can be used as an effective method of stream bank protection on most streams. They can be used on streams with any degree of meandering. The trees can be placed perpendicular or parallel to the bank. The trees should be as bushy as possible. Juniper and brushy willow work well. The trees are placed with the butt end of the tree against the bank and/or upstream. The trees are anchored with cable and deadmen to hold them in place. The anchors are located on the bank at least 10 feet from the edge of the bank. The area behind the trees is sometimes filled with gravel or other material. This helps hold the trees in place and also provides a surface which can be seeded. Even when the area behind the trees is not backfilled, some type of vegetation should be established. The upstream and downstream end of the reach must be protected to minimize the chance of water getting behind the trees and causing erosion. The most effective long-term result from this practice occurs when vegetation has been established along the entire reach.

Maintenance requirements for this practice include repairing damaged cable or anchors. Disturbed spots or scour holes behind the trees or on the ends should be repaired and protected.



ANCHORED TREE REVETMENT

TREE TYING DETAIL

ANCHORED TREES

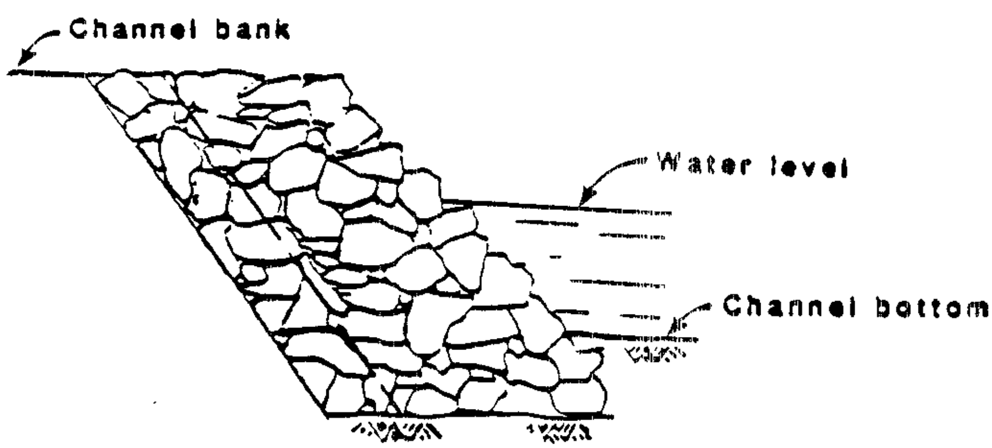
Jetty Stream Bank Erosion Control

Jetties are an effective method of controlling stream bank erosion on slight to moderately meandering curves. Jetties typically are not feasible on sharp curves. Jetties function by deflecting the flow from the stream away from the stream bank. Jetties can be constructed completely from rock or they can have a dirt, sand or gravel core with rock on the surface for erosion protection. Rock must be large enough to withstand the force of the water without being displaced. The size and spacing of the jetties depends on the physical characteristics of the stream; for example, the channel width and the sharpness of the curve. A jetty should not extend into the stream from the bank more than 20 percent of the channel width. The design of jetties requires an evaluation of the downstream channel and bank conditions to avoid causing erosion and other problems.

Jetties can be used to protect a stream bank without using any other practices. However, it is generally recommended to shape and seed the bank reaches between jetties.

Maintenance requirements for this practice include replacing or repositioning any rock which has been displaced. Over a period of a few years, sediment bars may develop near the downstream end of the jetty. These gravel bars should be removed to keep the jetty system functioning properly. A maintenance inspection should include a look at the downstream bank to check for erosion which could have been caused as a result of the jetties.

JETTY STREAMBANK EROSION CONTROL



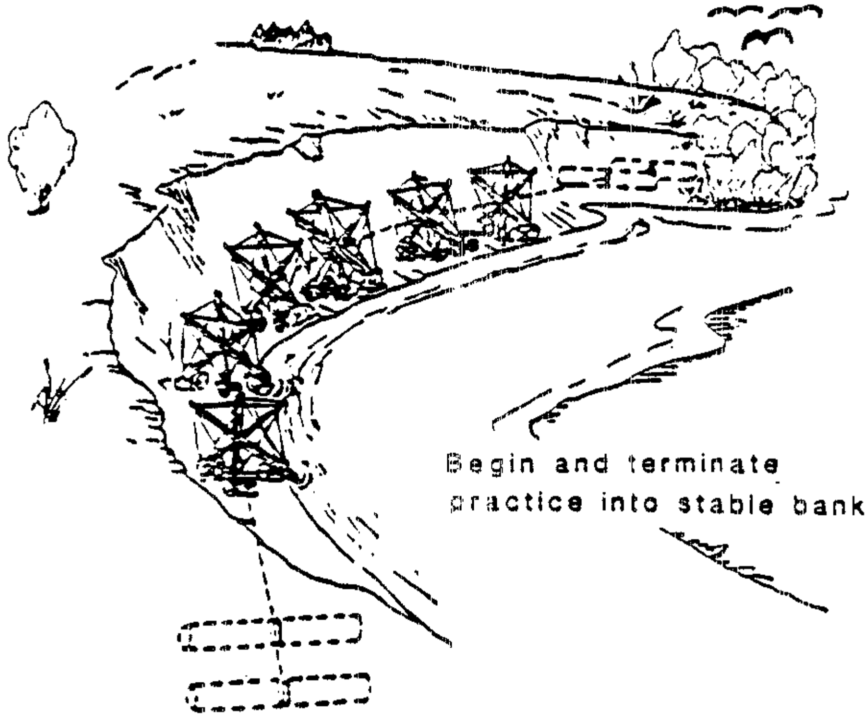
TYPICAL JETTY SECTION

JETTIES

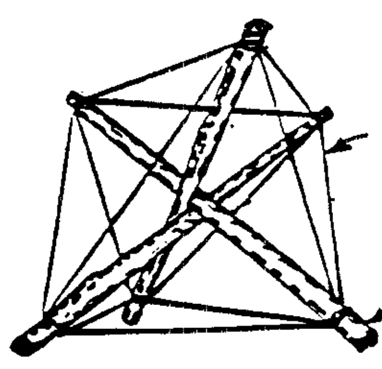
Stream Bank Erosion Control With Jacks

Jacks can be used to stabilize most eroding banks. Jacks are especially useful in streams which have wide sections due to stream bank meandering. The jacks can be located to allow eroded areas to silt in behind the row of jacks. On smaller streams and streams with fairly low flow velocities, a single row of jacks is all that would be required. The jacks can be fabricated from wood, concrete or metal. Individual jacks are fabricated by tying three posts or beams in a cross shape with wire. The jacks are placed along the toe of the bank. Rock is placed on and around the base of wood jacks to keep them from floating. The jacks are anchored to the bank with cable and deadman anchors. Vegetation should be established in the area behind the jacks.

Maintenance requirements for this practice include inspecting the jacks and repairing any loose or broken wires. Any movement of the jacks or rock should be corrected by returning it to its original location. Any scour holes or other erosion which has occurred behind the jacks should be reshaped and revegetated.



STREAMBANK EROSION CONTROL WITH JACKS



JACK DETAIL

STREAMBANK JACKS

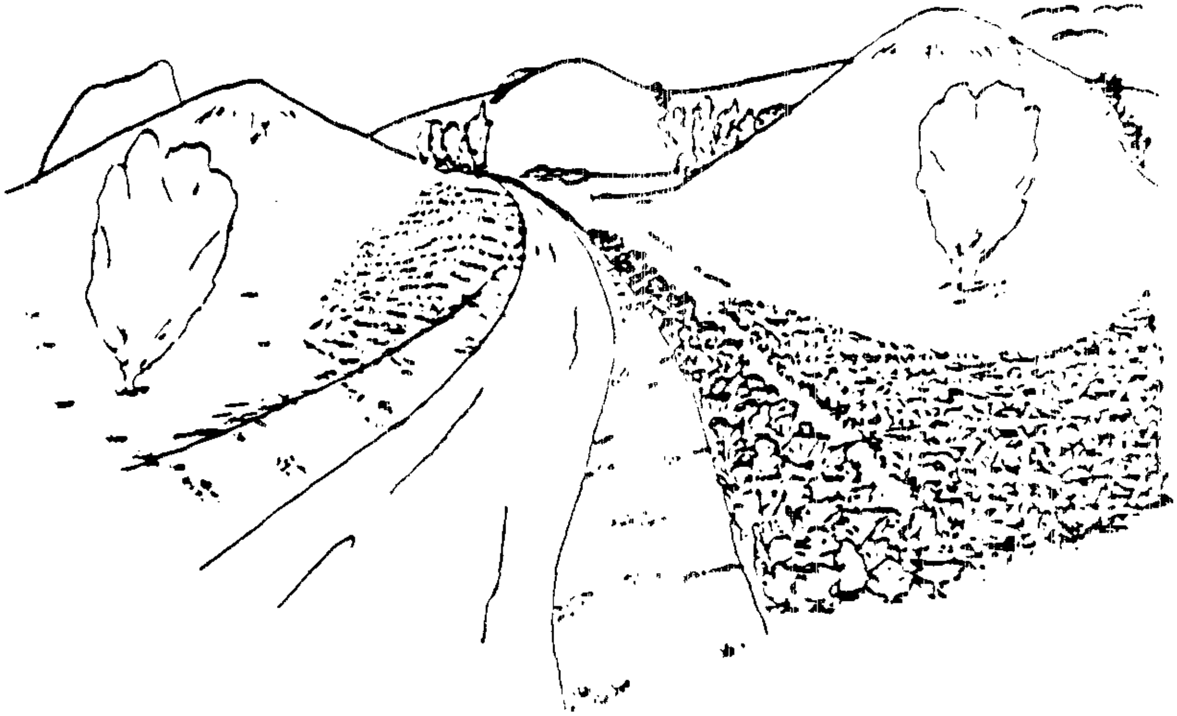
Vegetative Practices

Vegetated Buffer Strip Bank Protection

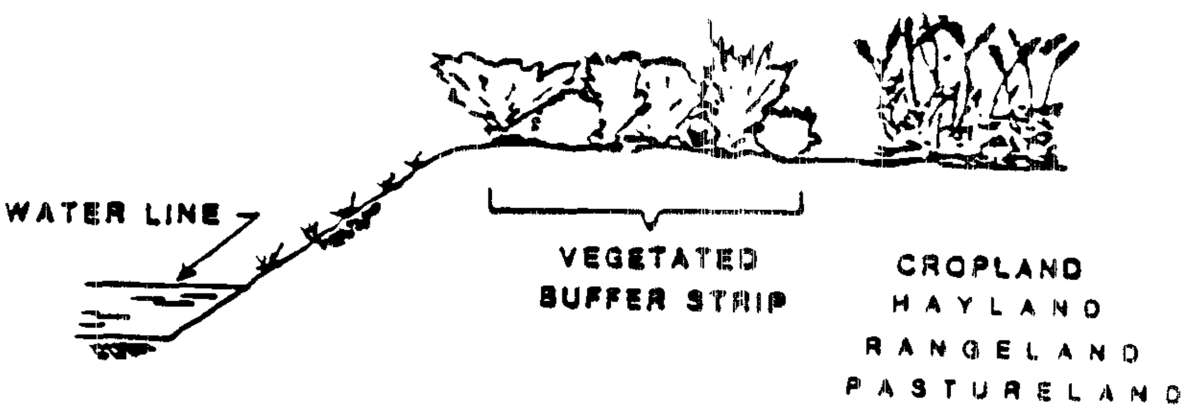
This practice is primarily related to cropland which is tilled up to the edge of stream channels without leaving a vegetative zone. These areas commonly contribute to stream bank erosion because the perennial vegetation needed for protection and stabilization is not present.

This practice would leave at least a 50 foot, and preferably a 100 foot wide, strip on each side of the stream channel. This would effectively create a buffer strip for trapping sediment coming from off channel sites and reduce erosion along the stream bank. In no case should overstory brush and tree vegetation along or within 50 feet of the stream channel be elimiated to increase crop or livestock forage production.

Maintenance requirements for this practice include brush removal in channel and periodic checks of vegetation to ensure understory vegetation is perennial. If understory vegetation is annual species, the area should be farmed and reseeded to adapted perennial species.



VEGETATED BUFFER STRIP BANK PROTECTION



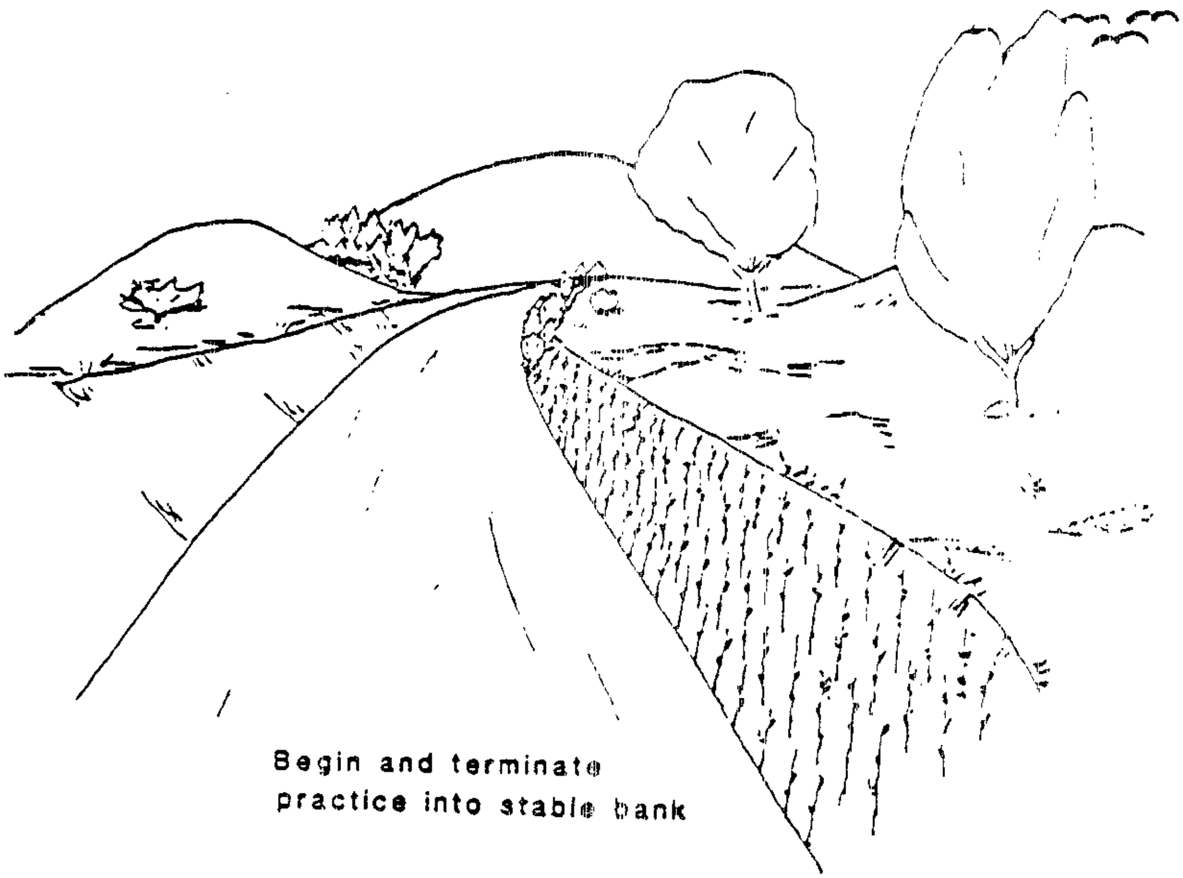
VEGETATED BUFFER STRIP

Willow/Alder/Dogwood Sprigs Revetment

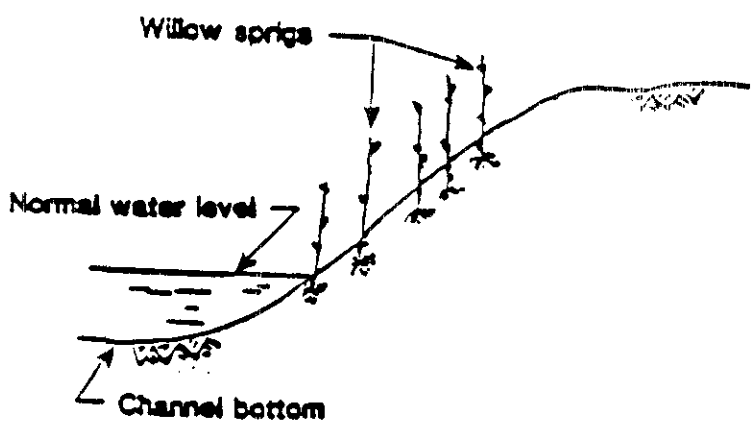
Stream bank vegetation is one of the most effective methods of controlling stream bank erosion under natural conditions. It is also the least costly method available when maintained in good condition. When streams begin to meander, bank erosion can occur if the vegetative protection is not in proper condition.

When this occurs, sprigs of adapted woody species such as willows, alders, and dogwood can be used in the wetter zone of the stream bank. This method works best on the straight stream sections where water pressure is not attempting to scour the banks. A critical requirement of this method is to sprig the cuttings deep enough or close enough to ground water to ensure moisture for at least 60 days. If water levels decrease too fast for the cuttings to root and follow the declining water table, they will die. The stream banks above the sprigged cuttings should be seeded to grass and banks may require shaping to at least 1.5 to 1 slope.

Maintenance for this practice will require replacement of dead sprigs and reshaping and seeding banks which develop scour holes.



WILLOW SPRIG BANK REVETMENT



TYPICAL BANK SECTION

WILLOW SPRIGS

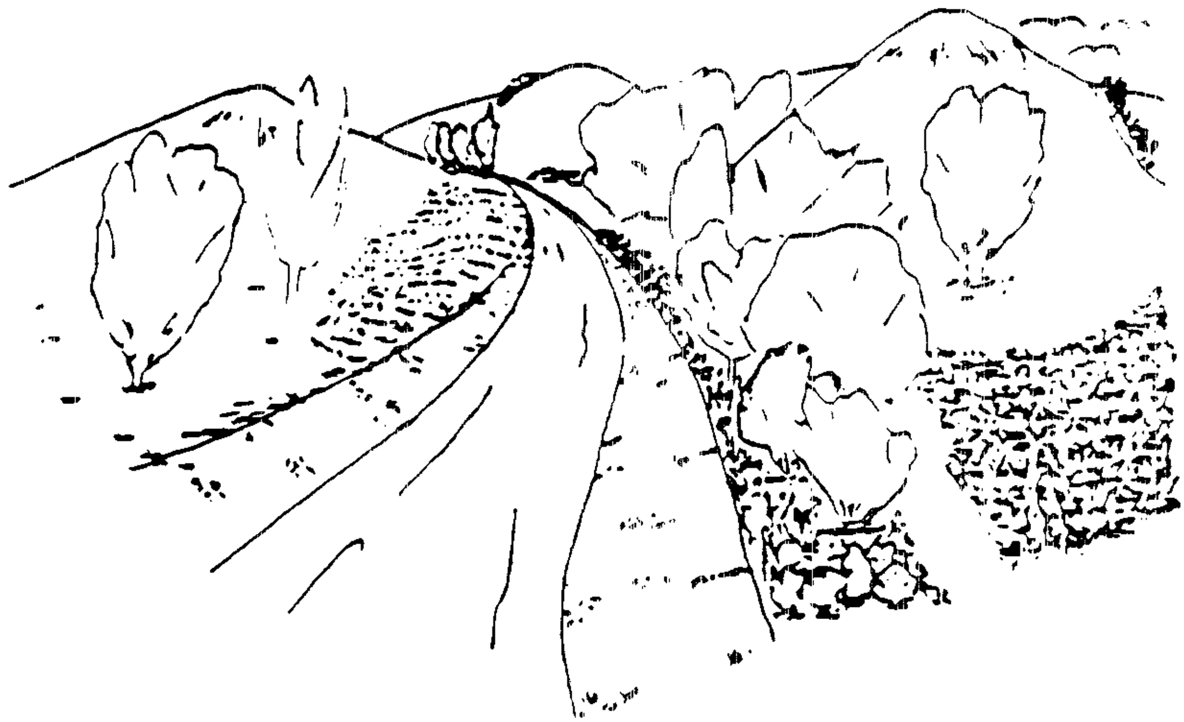
Riparian Zone

Dedication of riparian zones along the river banks will reduce much of the damage associated with streambank erosion. Riparian zones will provide protection from the lower frequency flows. However, large flows can produce bank erosion. Structural practices may be needed in some locations.

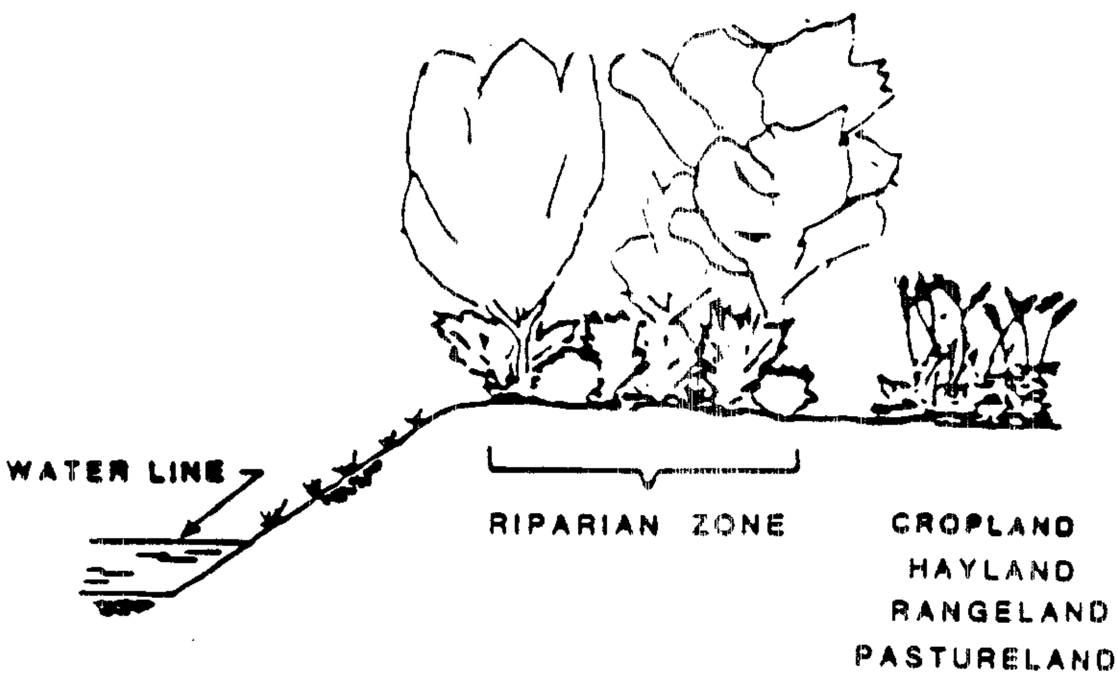
This practice would leave at least a 50 foot and preferably a 100 foot wide riparian zone along the stream. The root system developed from trees and brush along the streambank provide protection from the cutting action of water flowing against the banks. Protection from bank sloughing will also be obtained.

Other benefits, such as increased wildlife habitat, and diversity of scenery will be realized from riparian zones. These zones will also move the high value agricultural crops away from the streambanks, therefore reducing the likelihood of damage to these crops.

Maintenance requirements for this practice include tree and brush removal that can block channel and cause additional bank cutting. Fencing to keep livestock out of the riparian areas during certain times of plant growth.



RIPARIAN ZONE BANK PROTECTION

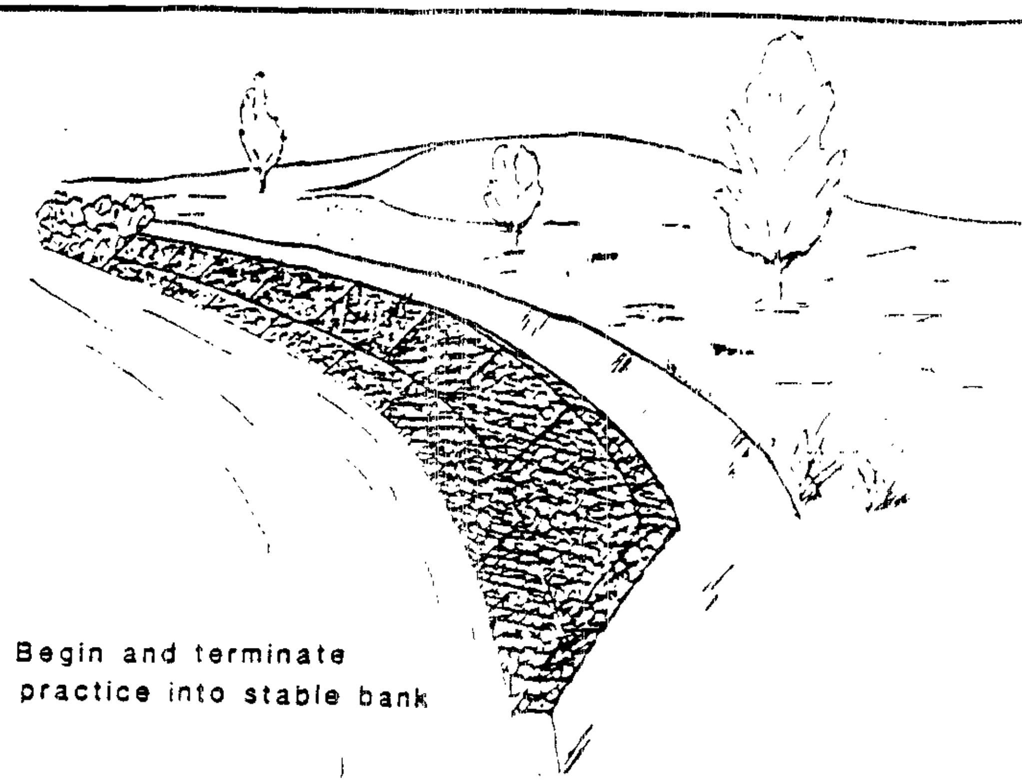


RIPARIAN ZONE

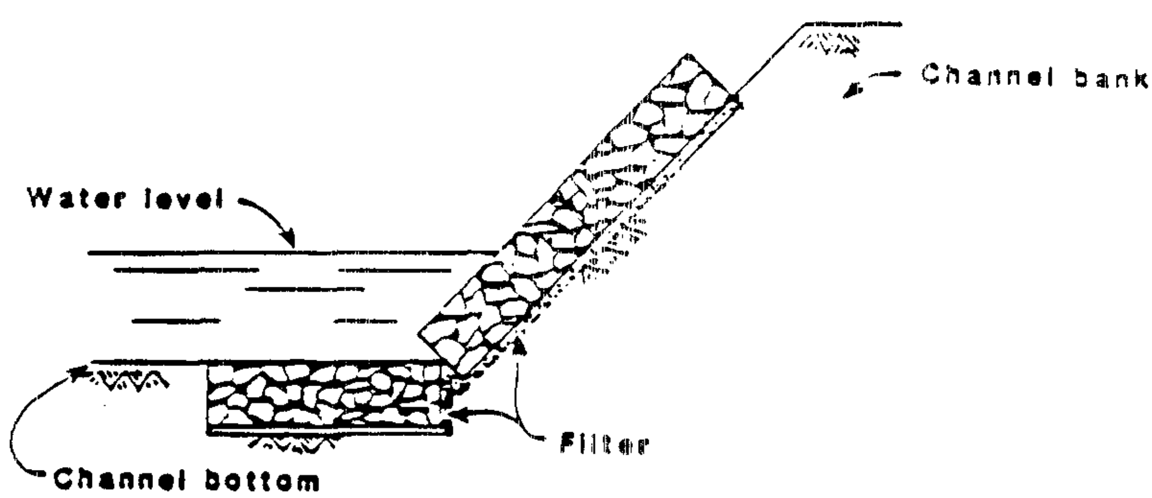
Gabion Revetment

Gabions can be used to stabilize stream banks in nearly every situation. Gabions consist of wire baskets filled with rock. Bank protection using gabions can be constructed using either a mattress revetment or a retaining wall. The installation of gabions must consider the potential scour depth in the channel. The gabion baskets usually require a filter between the baskets and the base material. The filter can be either a sand or gravel filter or a filter fabric. If a mattress revetment is used, the banks should be shaped to a slope no steeper than 1 horizonal to 1 vertical prior to placing the gabions. If a retaining wall is used, the banks may be vertical.

Maintenance requirements for this practice include inspecting the gabion baskets and repairing any broken wires.



GABION REVETMENT



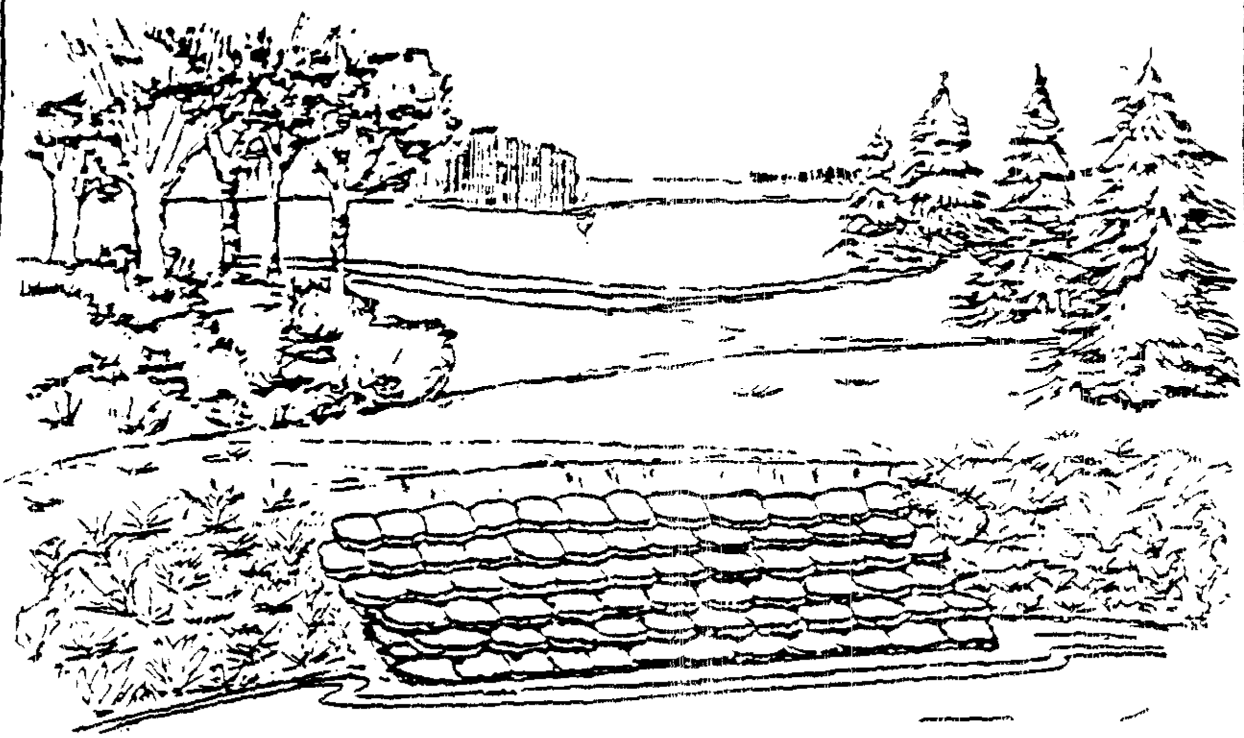
TYPICAL GABION SECTION

GABIONS

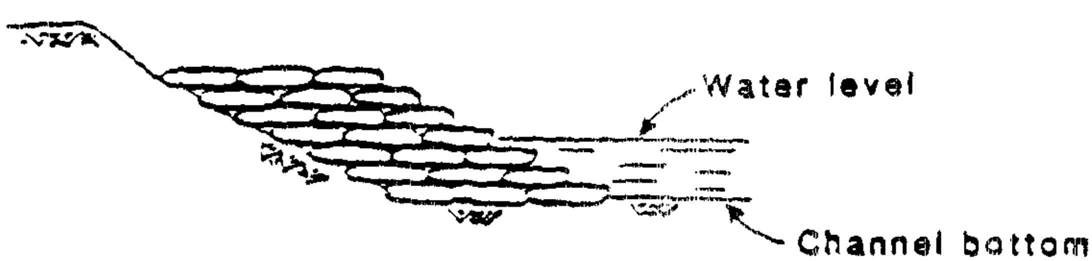
Sack Concrete Revetment

Sack concrete revetments can be used to control bank erosion in nearly every situation. The stream bank should be shaped to a slope no steeper than 1 horizontal to 1 vertical. Burlap or plastic sacks are filled with soil-cement or sand-cement mixtures. The sacks are then stacked along the bank. The toe for the sacks should be placed below the channel bottom to prevent any undercutting of the sacks. After the sacks have been placed, they can be hosed down to get a quick set or they can be left to harden from natural precipitation. The durability of this practice will depend on the quality and proportions of the mixture in the sacks. The sacks should extend up the bank to at least one foot above the high waterline. If the sacks do not extend to the top of the bank, the bank should be shaped and seeded.

This practice should be maintained by inspecting for broken-up concrete and erosion at the ends of the revetment. Any broken-up concrete should be patched. Scoured areas at either end of the revetment should be shaped and protected.



SACK CONCRETE REVETMENT



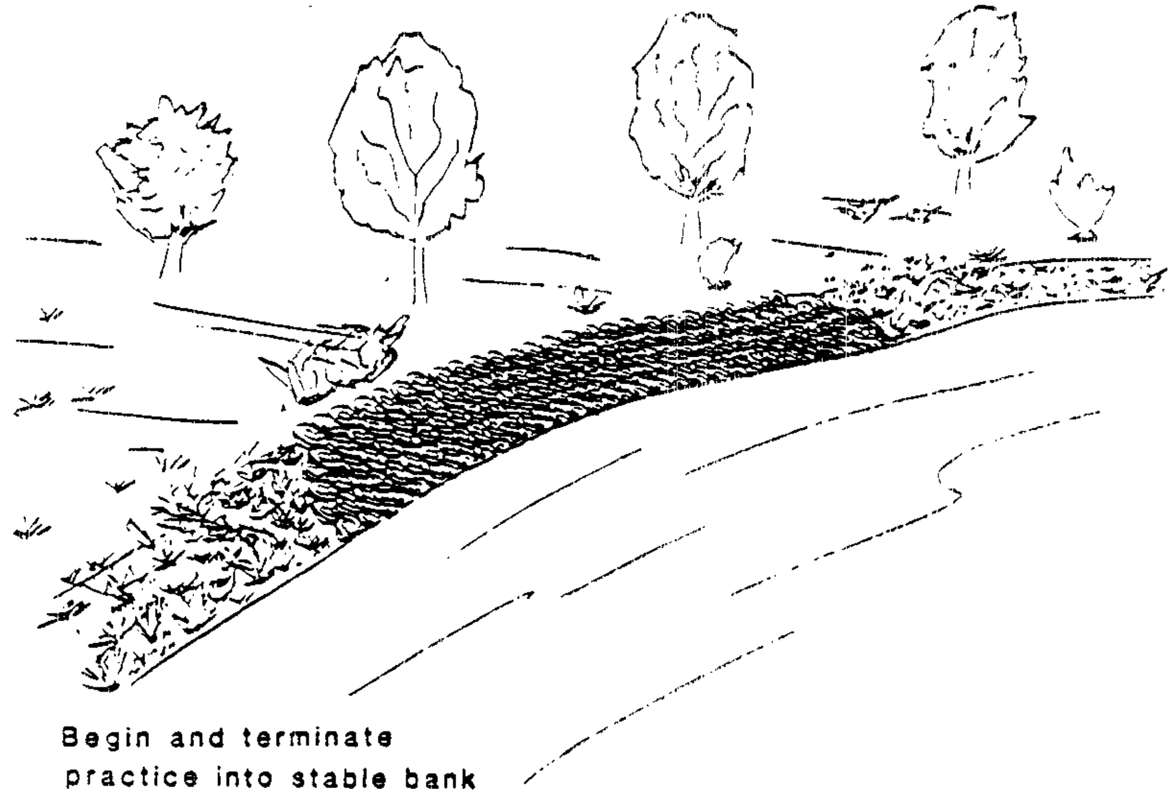
TYPICAL REVETMENT SECTION

SACK CONCRETE

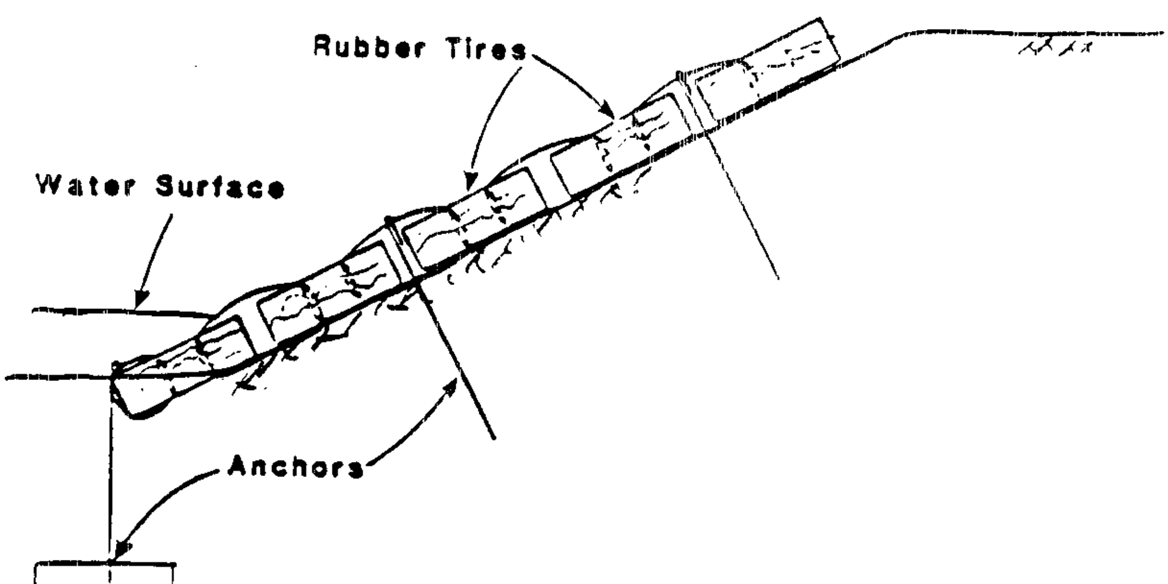
Anchored Tire Revetment

Anchored tires can be used to control bank erosion in streams which do not have high flow velocities. High flow velocities make it difficult to get vegetation established. High velocities also increase the chance of erosion occurring around the tires. The stream banks are shaped to a slope no steeper than 2 horizontal to 1 vertical. Tires are then tied together and placed on the slope. They should extend up the bank to a height of one foot above the high water elevation. The area above the tires should be shaped and seeded to appropriate vegetation. The mat of tires is anchored to the slope to keep it from floating when it is submerged. The toe of the tire mat should be protected with rock to prevent the stream from undercutting the tires. Vegetation should be established over the tire mat.

Maintenance requirements for this practice include replacement or repair of broken tire wires or anchors. Vegetation which has been damaged due to high flows should be reestablished.



ANCHORED TIRE REVETMENT



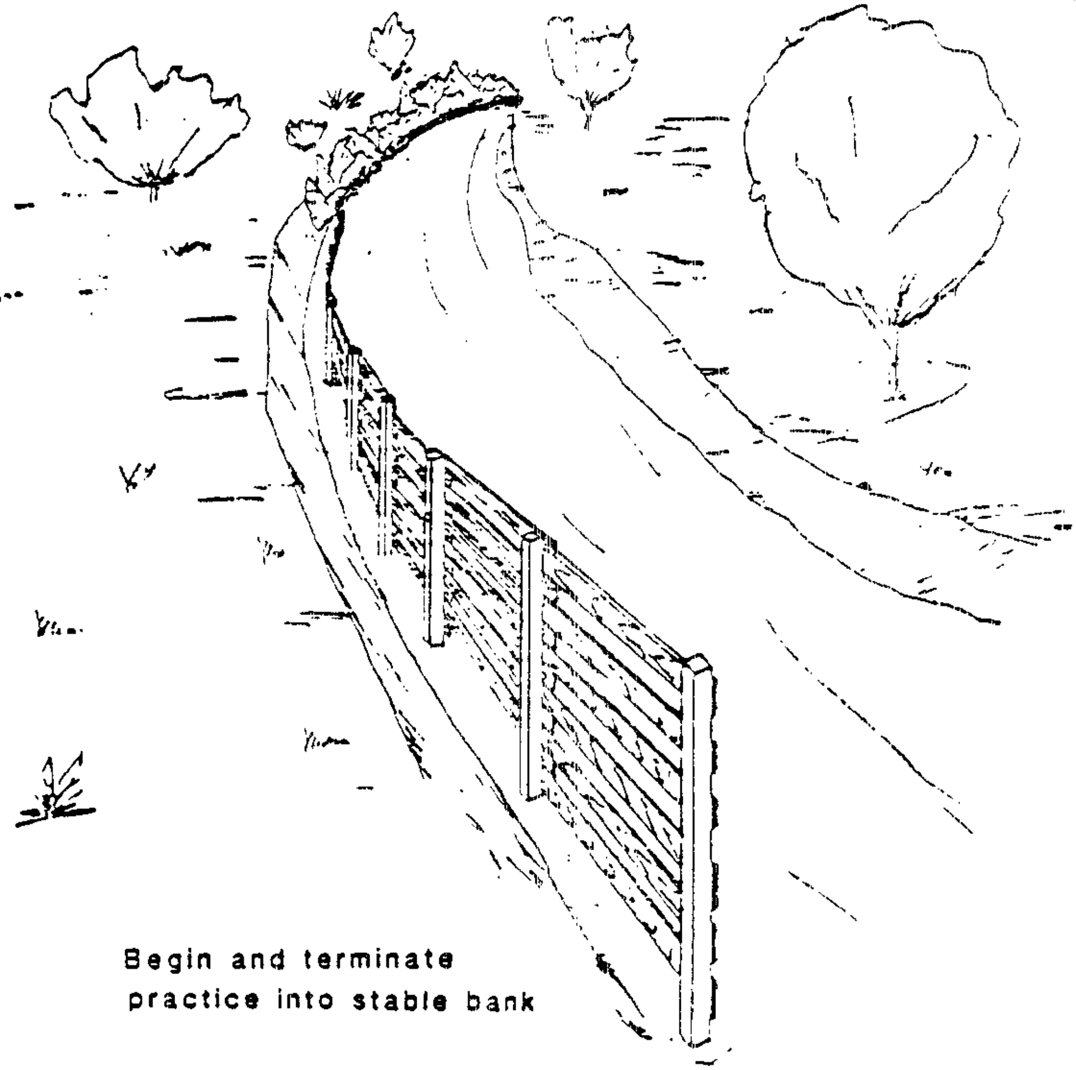
ANCHORED TIRE DETAIL

ANCHORED TIRES

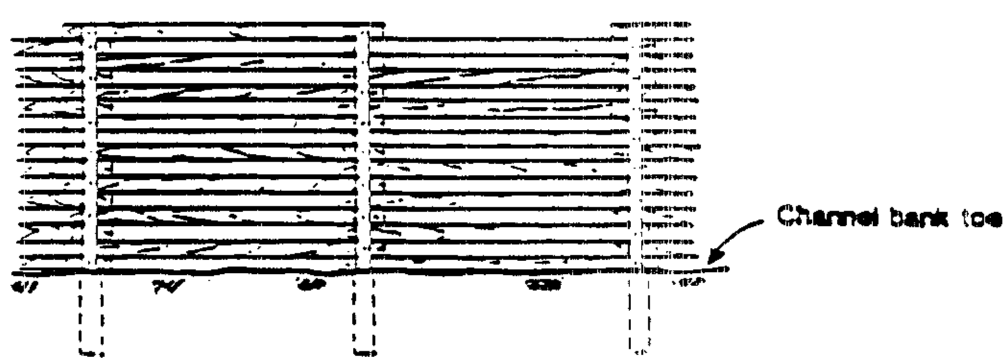
Posts and Planks Bank Protection

This practice consists of building a post and plank or pole barrier along the toe of the channel bank. This practice can be used on most streams with moderate to low flow velocities. It is especially useful in streams which have wide sections due to stream bank meandering. The post and plank or pole barriers can be located to allow eroded areas to silt in behind the barrier. Posts are placed at approximately a 12 foot spacing. Three-inch thick planks are bolted to the channel side of the posts. The bank behind the barrier should be shaped to a slope no steeper than 1.5 horizontal to 1 vertical and then seeded.

This practice is maintained by repairing or replacing any broken or loose planks. Eroded areas or scour holes should be reshaped and seeded.



POST AND PLANK BANK PROTECTION



POST AND PLANK DETAIL

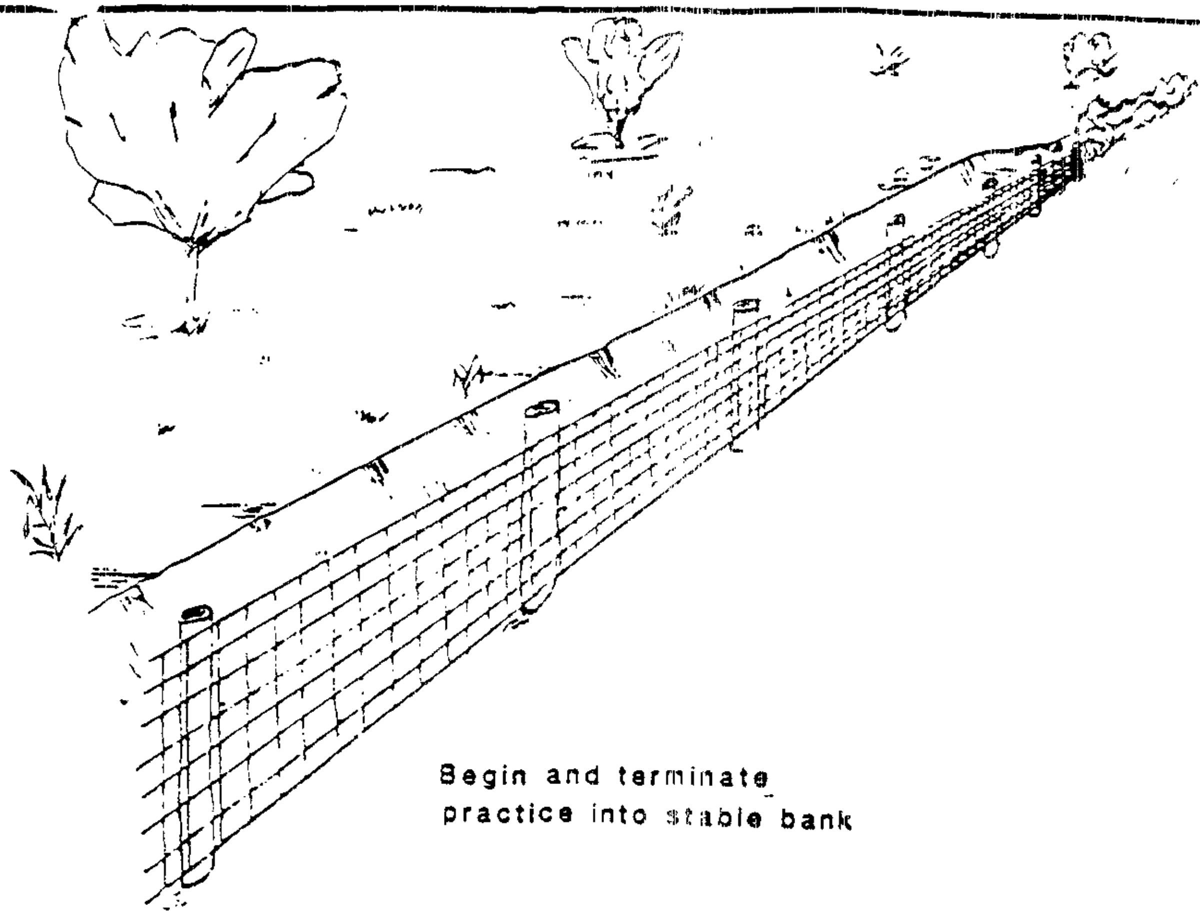
POST AND PLANK

Woven Wire Fence Revetment

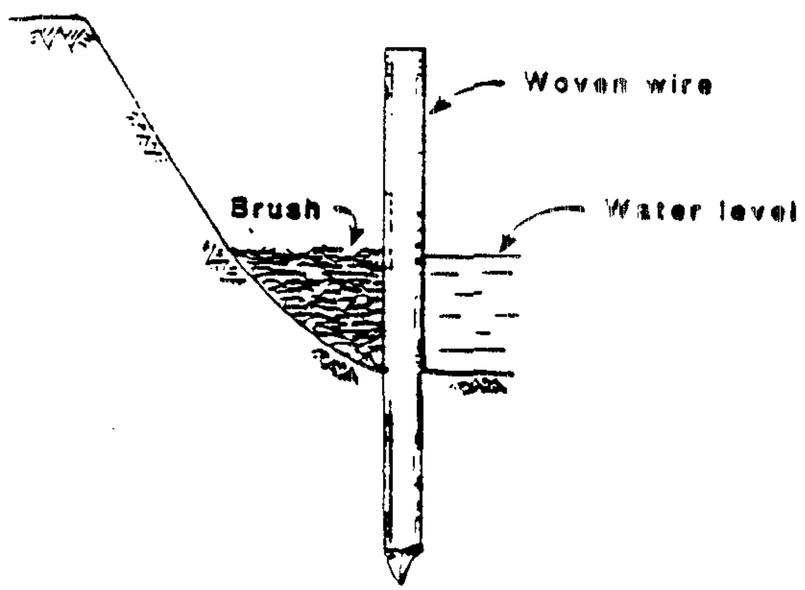
Woven wire fence can be used to stabilize stream banks with relatively low velocities. Posts are driven into the channel along the toe of the bank at six to eight feet spacings. Woven wire-fencing material is attached to the posts on the channel side of the posts. The bank behind the fencing should be shaped to a slope no steeper than 1.5 horizontal to 1 vertical and then seeded. This practice has achieved its intended results when the bank behind the fence has been completely stabilized with vegetation.

Another variation to this practice is to use live willow posts. These posts should be three to five inches diameter and spaced on a four foot spacing. Fiber netting is tied to the posts to provide protection at the toe until the willows get established. The bank behind the willow posts should be shaped and seeded.

Maintenance on these practices includes inspecting the fencing and vegetation. Any loose or broken wires should be repaired. Any seeded areas which have been eroded should be reshaped and seeded.



WOVEN WIRE FENCE REVETMENT



TYPICAL FENCE SECTION

WOVEN WIRE FENCE

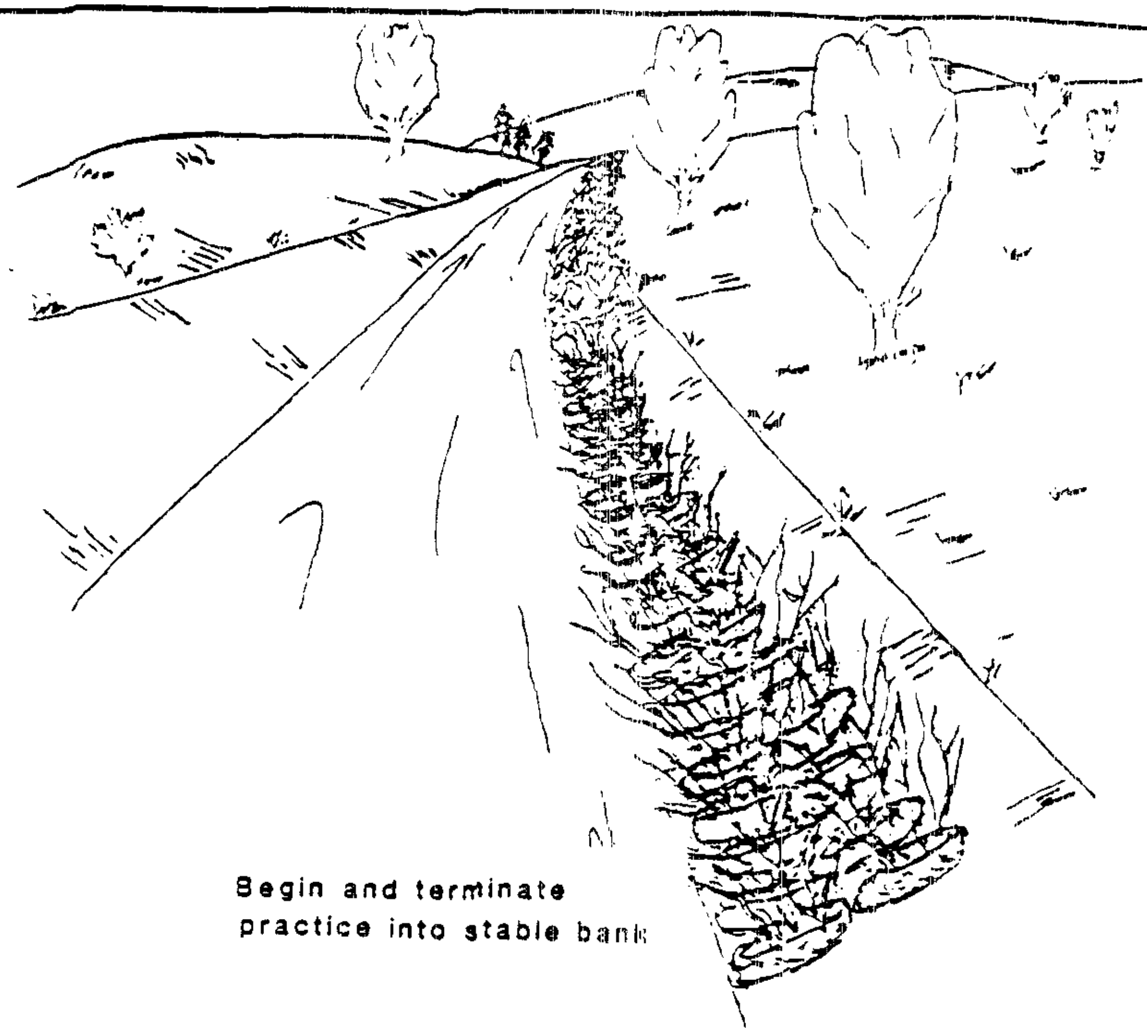
Willow Clump Revetment

When meander erosion is occurring, clumps of live willows can be relocated from local areas which have excess willows to protect either straight or meander type erosion.

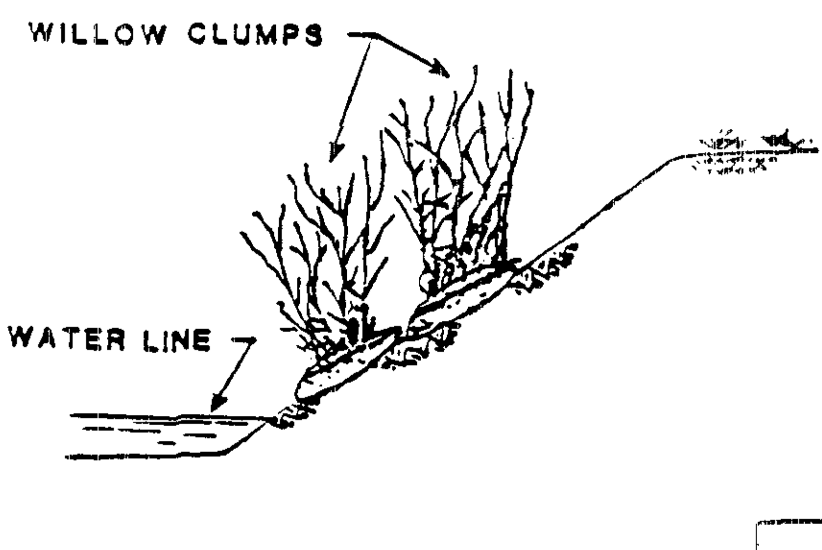
The clumps can be dug and transported using a front end loader or backhoe tractor and placed directly into the stream bottom against the bank. Willows should normally be placed in locations where they receive perennial water/moisture.

The clumps should be placed so stream flow can not get behind or between clumps. On meanders, clump protection such as steel posts with woven wire fence should be installed to ensure the clumps stay in place until well rooted (one year's protection is adequate). This protection may also be necessary on straight channel sections if stream flows are high enough to endanger washing out of freshly placed clumps. The woven wire should be installed high enough up bank on the ends to ensure the clumps and fence are not washed out the first season. The banks can then be sloped to 1.5 to 1 or greater slope and seeded with an adapted grass or local clumps of sod to speed up the total bank rehabilitation. This may not be necessary as the clump protected banks will slough and revegetate naturally, but will help in weed control.

Maintenance requirements for this practice include replacing sections that wash out and reseeding those sections that do not establish adequate grass stands.



WILLOW CLUMP BANK REVETMENT



WILLOW CLUMPS

Seeding With Fabric Mat Revetment

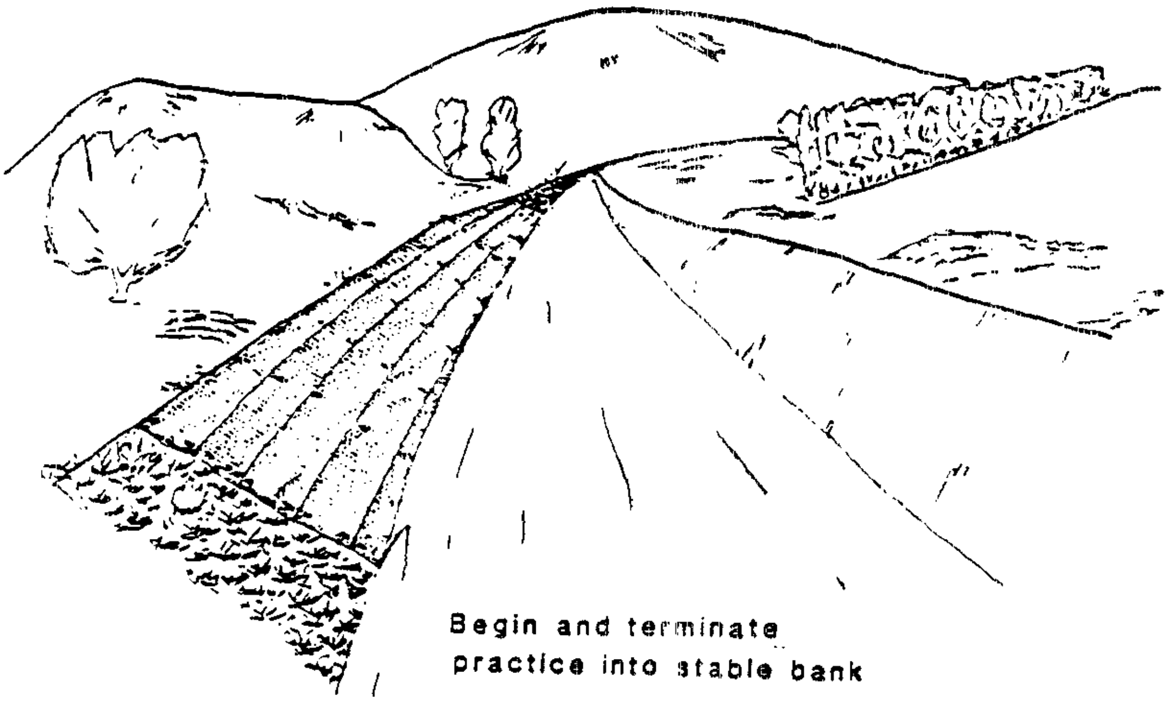
On disturbed stream sections where vegetative type protection is desirable without willows, seeding grasses with fabric mat protection may be the solution.

Stream banks should be shaped to a 3:1 slope or greater and seeded with a mix of adapted grasses. The mix should include species capable of withstanding excessive moisture to species which are quite drought tolerant (i.e. canarygrass/creeping foxtail - brome - wheatgrasses). The seeded section should then be covered with erosion control revegetation mat and staked down to stabilize the section until sod is established. This practice can be used below the temporary high water line, but not normally where perennial flows occur.

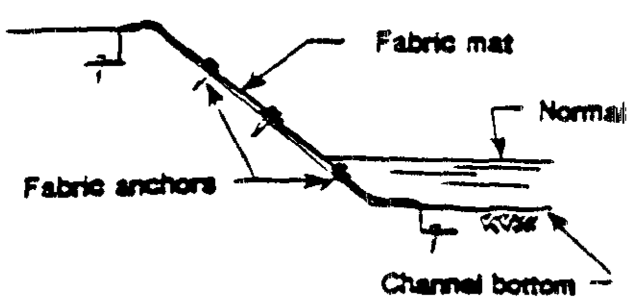
Some straight reaches and reaches with a slight meander can be protected by just shaping and seeding the banks. This can be done in channels above the water line and where the flow velocity is low.

Maintenance requirements for this practice include periodic checks to ensure fabric mat is adequately staked and additional seeding if necessary.

This practice may be applied along with structural stabilization projects.



FABRIC MAT WITH SEEDING BANK REVETMENT



TYPICAL BANK REVETMENT SECTION

FABRIC MAT
WITH SEEDING

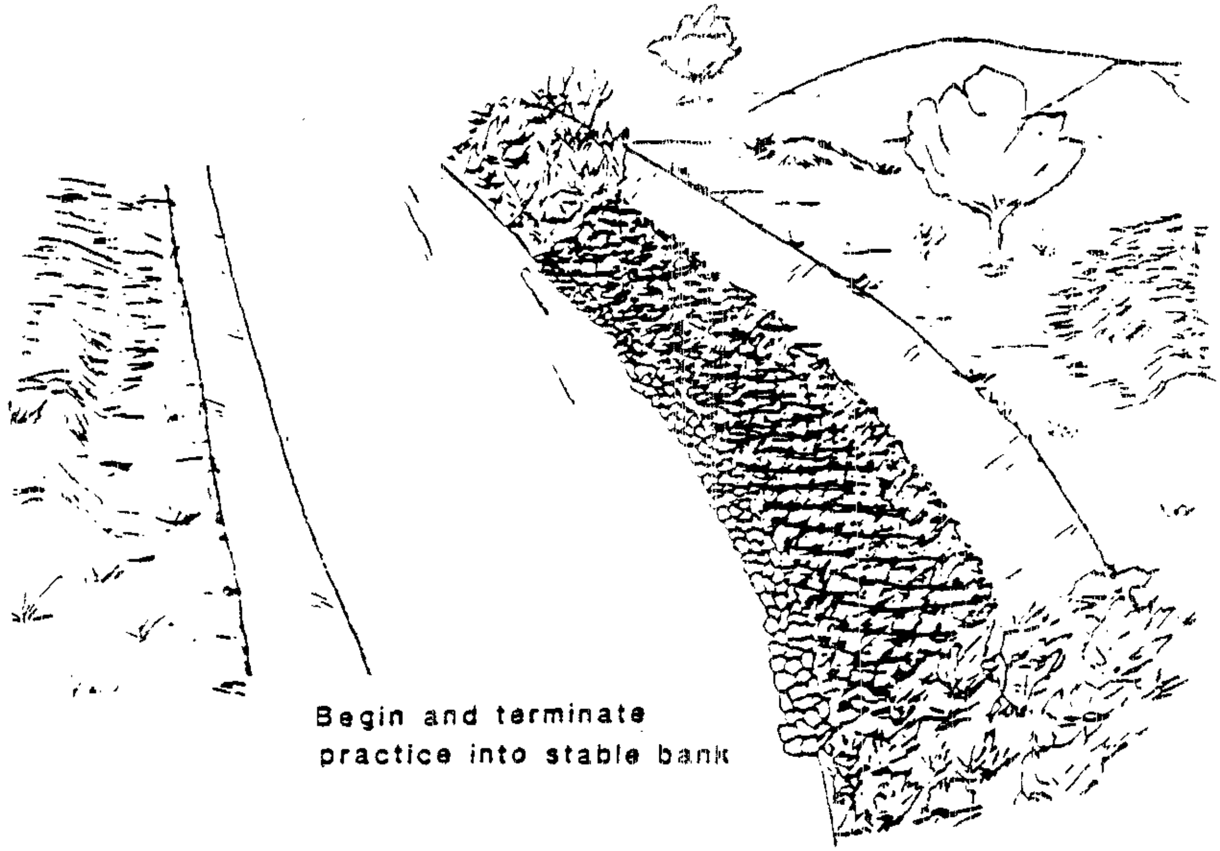
Rock and Brush Revetment

Rock and brush mat revetments can be used to control stream bank erosion in most areas where rock riprap can be used. There are two conditions when this practice would not be recommended. The first is on a sharp curve. The second is on reaches with large flows and a high velocity. The bank is sloped back to a slope not steeper than 1.5 horizontal to 1 vertical. A rock toe is placed at the bottom of the slope to protect the bank from undercutting. Brush is then laid with the butt ends up the slope and transverse to the stream bank. The brush is anchored in place with wire and stakes. If the mat does not extend to the top of the bank, the unprotected area should be seeded.

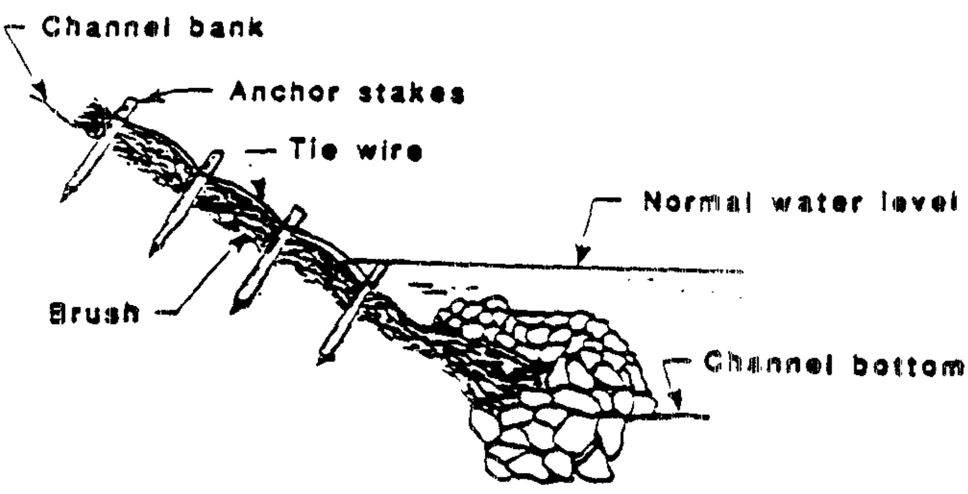
A variation to this practice is to use all **bundled brush or willows.** This would not be recommended on channels with high flow velocities. The brush would replace the rock in the toe and bottom part of the slope.

It is recommended to use live brush for the above practices. If live brush is used, loose dirt should be placed over or around the bundled brush. This will enable more of the brush to sprout faster and form vegetative protection for the bank.

These practices should be maintained by inspecting the wire anchors and the rock toe. Any wires which have been pulled loose should be repaired. Brush or rock which has been dislodged should be replaced.



BRUSH AND ROCK BANK REVETMENT



TYPICAL REVETMENT SECTION

BRUSH AND ROCK

GLOSSARY

A listing of terms commonly used to describe streambank erosion and instability mechanisms, as well as terms related to streambank protection and river mechanics, is provided below:

Abrasion - Removal of streambank material due to entrained sediment, ice or debris rubbing against the bank.

Angle of repose - The maximum angle (as measured from the horizontal) at which gravel or sand particles can stand.

Aggradation (bed) - A progressive buildup or raising of the channel bed due to sediment deposition. Aggradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place.

Alluvial fan - A cone-shaped deposit of sediment formed at the confluence of a stream and its tributary. If the sediment load of the tributary cannot be carried away by the stream, an alluvial fan forms.

Armoring - (a) Natural process whereby an erosion-resistant layer of relatively large particles is formed on a streambank due to the removal of finer products by streamflow. (b) Placement of a covering on a streambank or filter to prevent erosion.

Articulated concrete mattress - Rigid concrete slabs usually hinged together with corosion-resistant wire fasteners; primarily placed for lower bank protection.

Asphalt block - Precast or broken pieces of asphalt that can be hand-placed or dumped on a streambank or filter for protection against erosion.

Asphalt (bulk) - Mass uncompacted asphalt usually dumped from a truck (upper bank protection) or a barge (lower bank protection) that is placed to protect the bank against erosion.

Avulsion - A change in channel course that occurs when a stream suddenly breaks through its banks; usually associated with a catastrophic event.

Backfill - The material used to refill a ditch or other excavation, or the process of doing so.

Backwater area - The low-lying lands adjacent to a stream that may become flooded during periods of high water.

Bank - The side slopes of a channel between which the streamflow is normally confined.

Bed - The bottom of a channel

Bed load - Sediment that moves by saltation (jumping), rolling or sliding in the bed layer of a stream.

Bedrock - The solid rock underlying soils and overlying the mantle rock, ranging from surface exposure to depths of several hundred feet.

Bed slope - The inclination of the channel bottom.

Bituminous mattress - An impermeable rock-, mesh-, or metal-reinforced layer of asphalt or other bituminous material placed on a streambank to prevent erosion.

Blanket - Material covering all or portion of a streambank to prevent erosion.

Braided stream - A relatively wide and shallow stream with multiple channels formed by islands and bars in the waterway.

Buffer zones - Areas of trees, grass, or other vegetation located between top bank and adjacent pastures or cultivated fields (also called greenbelts).

Bulkhead - A vertical or nearly vertical retaining wall or structure supporting a natural or artificial streambank.

Cation-exchange capacity (CEC) - The sum total of exchangeable cations that a soil can absorb; expressed in *milliequivalents per gram or 100 grams of soil.

Caving - The collapse of a bank by undercutting due to wearing away of the toe or an erodible soil layer above the toe.

Cellular-block mattress - Regularly cavitated interconnected concrete blocks placed directly on a streambank or filter to prevent erosion. The cavities can permit bank drainage and the growth of either volunteer or planted vegetation when filter fabric is not used between the mattress and bank.

Channel - A natural or man-made waterway that continuously or periodically passes flow.

Chemical stabilization - Streambank protection technique involving the application of chemical substances to increase particle cohesiveness and to shift the size distribution toward the coarser fraction. The net effect is to improve the erosion resistance of the material.

Clay - Material passing the No. 200 (0.074 mm) U.S. Standard Sieve that exhibits plasticity (putty-like properties) within a range of water contents and has considerable strength when air-dry (Unified Soil Classification System).

Clay blanket - Layer of compacted clay placed over cohesionless bank soils to protect them against erosive streamflow.

Concrete block - Precast concrete material placed on a streambank or filter to prevent erosion.

Confluence - The junction of two or more streams.

Constriction (flow) - A reduction in channel cross-sectional area that results in greater stream velocities and/or water depth.

Crib - A frame structure, filled with earth or stone ballast, designed to absorb energy and to deflect streamflow away from a bank.

Critical shear stress - The minimum amount of shear stress exerted by passing stream currents required to initiate soil particle motion.

Cross section - A diagram or drawing cut across a channel that illustrates the banks, bed, and water surface.

Crossing - The relatively short and shallow reach of a stream between b ends; also called a crossover.

Current - Water flowing through a channel.

Cut bank - The concave wall of a meandering stream.

Cutoff - A new, relatively short channel (natural or artificial) formed when a stream cuts or is realigned through the neck of an oxbow or horseshoe bend. A cutoff can also develop as successive high-water flows develop a chute across the inside of a point bar.

Degradation (bed) - A progressive lowering of the channel bed due to scour. Degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place.

Dike (groin, spur, jetty) - A structure extending from a bank into a channel that is designed to (a) reduce the stream velocity as the current passes through the dike, thus encouraging sediment deposition along the bank (permeable dike) or (b) deflect erosive currents away from the streambank (impermeable dike).

Discharge - Volume of water passing through a channel during a given time, usually measured in cubic feet per second.

Drainage basin - An area confined by drainage divides, often having only one outlet for discharge.

Eddy current - A vortex-type motion of a fluid flowing contrary to the main current, such as the circular water movement that occurs when the main flow becomes separated for the bank.

Energy grade slope - An inclined representing the total energy of a stream flowing from a higher to a lower elevation.

Ephemeral stream - A stream that flows only in direct response to precipitation and receives little or now water from springs or no sustained supply from snowmelt or other sources. An ephemeral stream's channel is at all times above the water table.

Erosion - Removal of soil particles from the land surface due to water or wind action.

Erosion control matting - Fibrous matting (e.g. jute, paper, etc.) placed or sprayed on a streambank for the purpose of preventing erosion or providing temporary stabilization until vegetation is established.

Fabriform - Grout-filled fabric mattress used for streambank protection.

Fascine - A bundle of brush, sticks, or timber used to make a foundation mat or to construct a revetment to protect a streambank against erosion.

Fence - A streambank protection technique consisting of wire mesh or timber attached to a series of posts, sometimes in double rows; the space between the rows may be filled with rock, brush, or other materials. Fences may be placed either parallel to the bank or extended into the stream, in either case these structures decrease the stream velocity and encourage sediment deposition as the flow passes through the fence.

Fetch - The area in which waves are generated by wind having a rather constant direction and speed; sometimes used synonymously with fetch length.

Fetch length - The horizontal distance (in the direction of the wind) over which wind generates waves and wind setup.

Filter - Layer of fabric, sand, gravel, or graded rock placed, or developed naturally where suitable in-place materials exist, between the bank revetment and soil for one more of three purposes: to prevent the soil from moving through the revetment by piping, extrusion, or erosion; to prevent the revetment from sinking into the soil; and to permit natural seepage from the streambank, thus preventing buildup of excessive hydrostatic pressure.

Flanking - Erosion resulting from streamflow between the bank and the landward end of a river-training or a grade-control structure.

Flow slide - Saturation of a bank to the point where the soil material behaves more like a liquid than a solid; the soil/water mixture may then move downslope resulting in a bank failure.

Gabion - A wickerwork or wire mesh basket or cage filled with stone or other materials placed against a streambank to prevent erosion.

Gobi Block - Precast cellular concrete block often used as a substitute for riprap.

Geomorphology - That branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and in the buildup of erosional debris.

Grade-control structure (sill, check dam) - Structure placed bank to bank across a stream channel (usually with its central axis perpendicular to flow) for the purpose of controlling bed slope and preventing scour or head-cutting.

Gravel - Rounded or semirounded particles of stone.

Grout - A fluid mixture of cement and water or of cement, sand, and water used to fill joints and voids.

Hard point - A streambank protection technique whereby "soft" or erodible materials are removed from a bank and replaced by stone or compacted clay. Some hard points protrude a short distance into the channel to direct erosive currents away from the bank. Hard points also occur naturally along streambanks as passing currents remove erodible materials leaving nonerodible materials exposed.

Head-cutting - Channel bottom erosion moving upstream through a basin indicating that a readjustment of the basin's slope and its stream discharge and sediment load characteristics is taking place. Head-cutting is evidenced by the presence of waterfalls or rapidly moving water through an otherwise placid stream. Head-cutting often leaves streambanks in an unstable condition as it progresses through a reach.

Helical flow - Three-dimensional movement of water particles along a spiral path in the general direction of flow. These secondary-type currents are of most significance as flow passes through a bend; their net effect is to remove soil particles from the cut bank and deposit this material on the point bar.

Hydraulic radius - The cross-sectional area of a stream divided by its wetted perimeter.

Jack (jackstraw, Kellner jack) - A component of a river training structure consisting of wire or cable strung on three mutually perpendicular metal, wooden, or concrete struts.

Launching - Release of undercut material (stone riprap, rubble, slag, etc.) downslope; if sufficient material accumulates on the streambank face, the slope can become effectively armored.

Levee - An embankment generally landward of top bank that confines flow during highwater periods, thus preventing overflow into lowlands.

Longard tubing - Sand-filled tubes (synthetic material) placed either parallel or at an angle to the streamflow for streambank protection.

Lower bank - That portion of a streambank having a elevation less than the mean water level of the stream.

Mattress - A covering of concrete, wood, stone, or other material used to protect a streambank against erosion.

Meandering stream - A single channel waterway having a pattern of successive deviations in alignment and flow direction.

Middle bank - That portion of a streambank having an elevation approximately the same as that of the mean water level of the stream.

Natural levee - A low, alluvial ridge adjoining the channel of a stream formed by sediment deposited by floodwaters that have overflowed the channel banks.

Organic mixtures and mulches - Any of a number of agents (e.g. petrochemicals or vegetative matter) used to stabilize a streambank against erosion by providing protection and nutrients while vegetation becomes established. These agents, which may be in the form of liquids, emulsions, or slurries, are normally applied by mechanical broadcasters.

Overbank flow - Water movement over top bank either due to a rising stream stage or to inland surface-water runoff.

Oxbow - The abandoned bow-shaped or horseshoe-shaped reach of a former meander loop, that is left when the stream cuts a new shorter channel across the narrow neck between two closely approaching bends of the meander.

Pavement - Streambank surface covering, usually impermeable, designed to serve as protection against erosion. Common pavements used on streambanks are concrete, compacted asphalt, and soil cement.

Peaked stone dike - Riprap placed parallel to the toe of a streambank (at the natural angel or repose of the stone) to prevent erosion of the toe and induce sediment deposition behind the dike.

Perennial stream - A channel that has continuous flow.

Phreatic line - The upper boundary of the seepage water surface landward of a streambank.

Pile - An enlongated member, usually made of timber, concrete, or steel, that serves as a structural component of a river-training structure.

Piping - Removal of soil material through subsurface flow of seepage water that develops channels or "pipes" within the soil bank.

Point bar - The convex side of a bend that is built up due to sediment deposition.

Quarry-run stone - Natural material used for streambank protection as received from a quarry without regard to gradation requirements.

Rapid drawdown - Lowering the water against a bank more quickly than the bank can drain, which can leave the bank in an unstable condition.

Reach - A portion of a channel between any two points.

Refusal - Erosion-resistant material placed in a trench (excavated landward) at the upstream end of revetment ot prevent flanking.

Reinforced-earth bulkhead - A retaining structure consisting of vertical panels and attached to reinforcing elements embedded in compacted backfill for supporting a natural or artificial streambank (a specific type of retaining wall).

Retaining wall - A vertical structure used to maintain an elevation differential between the water surface and top bank while at the same time preventing bank erosion and instability.

Retard - Structure placed parallel to a streambank to prevent erosive currents from attacking the bank.

Revetment - Cover of erosion-resistant material placed to protect a streambank.

Riparian - Pertaining to anything connected with or adjacent to the banks of a stream.

Riprap - See stone riprap

River training structure - Any configuration constructed in a stream or placed on, adjacent to, or in the vicinity of a streambank that is intended to deflect currents, induce sediment deposition, induce scour, or in some other way alter the flow and sediment regimes of the stream

Rock-and-wire mattress - A flat or cylindrical wire cage or basket filled with stone or other suitable material placed on a streambank or filter as protection against erosion.

Rubble - Rough, irregular fragments of random size placed on a streambank to retard erosion. The fragments may consist of broken concrete slabs, masonry, or other suitable refuse.

Runout - See discharge.

Sack revetment - Streambank protection consisting of sacks (e.g. burlap, paper, or nylon) filled with mortar, concrete, sand, stone, or other available material placed on a bank to serve as protection against erosion.

Sand - Soil material that can pass the No. 4 (4.76 mm) U.S. Standard Sieve and be retained on the No. 200 (0.075 mm) sieve.

Scour - Erosion due to flowing water; usually considered as being localized as opposed to genera bed degradation.

Sediment load - The sediment carried through a channel by streamflow.

Sediment yield - The total sediment outflow from a drainage basin during a specific period of time. The outflow includes bed load as well as suspended load, and usually is expressed in terms of weight or volume per unit time.

Seepage - The slow movement of water through small cracks and pores of the bank material.

Sill - A structure built across the bed of a stream to prevent scour or head-cutting; see also grade-control structure.

Silt - Material passing No. 200 (0.074 mm) U.S. Standard Sieve that is nonplastic or very slightly plastic and exhibits little or no strength when air-dried (Unified Soil Classification System)

Sloughing - Shallow movement of a soil mass down a streambank as the result of an instability condition oat or near the surface (also called slumping). Conditions leading to sloughing are: bed degradation, attack at the bank toe, rapid drawdown, and slope erosion to an angle greater than the angle of repose of the material.

Soil-cement - A designed mixture of soil and portland cement compacted a a proper water content to form a veneer or structure that can prevent streambank erosion.

Spur dike - See dike.

Stable channel - A condition that exists when a stream has developed just the right bed slope and cross section for its channel to transport the water and sediment delivered from the upstream watershed without any of the sediment being deposited or without any soil particles being removed from the bed or bank.

Stage - Water-surface elevation of a stream with respect to a reference elevation.

Stone riprap - Natural cobbles, boulders, or rock dumped or placed on a streambank or filter as protection against erosion.

Streambank erosion - Removal of soil particles or a mass of particles from a bank surface due primarily to water action. Other factors such as weathering, ice and debris abrasion, chemical reactions, and land-use changes may also directly or indirectly lead to streambank erosion.

Streambank failure - Collapse of a bank due to an instability condition.

Streambank protection - Any technique used to prevent erosion or failure of a streambank.

Suspended-sediment load - That part of a stream's total sediment load which is transported within the body of fluid and has very little contact with the bed.

Synthetic mattress, matting, or tubing - A grout- or sand-filled, manufactured, semiflexible casing placed on a streambank to prevent erosion.

Tetrahedron - Component of river-training works made of six steel or concrete struts fabricated in the shape of a pyramid.

Tetrapod - Bank-protection component of precast concrete consisting of four legs joined at a central joint, with each leg making an angle of 109.5 deg with the other three.

Thalweg - The line extending down a channel that follows the lowest elevation of the bed.

Tieback - Structure placed between revetment and bank to prevent flanking.

Timber or brush mattress - A revetment made of brush, poles, logs, or lumber interwoven or otherwise lashed together. The completed mattress is then placed on the bank of stream and weighted with ballast.

Toe - That portion of a stream cross section where the lower bank terminates and the channel bottom or the opposite lower bank begins.

Toe-fill - Break in slope between the bank and the overbank area.

Tractive force - The drag on a streambank caused by passing water which tends to pull soil particles along with the streamflow.

Trench-fill revetment - Stone, concrete, or masonry material placed in a trench dug behind and parallel to an eroding streambank. When the erosive action of the stream reaches the trench, the material placed in the trench armors the bank and thus retards further erosion.

Turbulence - Motion of fluids in which local velocities and pressures fluctuate irregularly in a random manner as opposed to laminar flow where all particles of the fluid move in distinct and separate lines.

Upper bank - The portion of a streambank having an elevation greater than the mean water level of the stream.

Van dikes - Structures designed to direct streamflow away from an eroding bank line, but permitting limited amounts of both water and sediment to pass landward of the structure.

Vegetation - Woody or nonwoody plants used to stabilize a streambank and retard erosion.

Velocity (of water in a stream) - The speed that water travels in a given direction; expressed as a distance traveled during an interval of time.

Watershed - See drainage basin.

Wave attack - Impact of waves on a streambank.

Windrow revetment - A row of stone (called a windrow) placed on top bank landward of an eroding streambank. As erosion continues the windrow is eventually undercut, launching the stone downslope, thus armoring the bank face.