PAP 874

Santa Cruz River Bank Stabilization At San Xavier Riparian Area

by

Rodney J. Wittler
and
The Fluvial Hydraulics and Geomorphology Team

U.S. Bureau of Reclamation

June 19, 2001

TECHNICAL SERVICE CENTER
DENVER, COLORADO

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FLUVIAL HYDRAULICS & GEOMORPHOLOGY TEAM
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US Department of the Interior
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REVISED JUNE 19, 2001

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

DEPARTMENT OF THE INTERIOR'S MISSION

The mission of the Department of Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

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ACKNOWLEDGEMENTS

The Fluvial Hydraulics & Geomorphology Team from the Technical Service Center conducts fluvial geomorphology studies for the US Bureau of Reclamation. The team consists of geomorphologists, engineers, and biologists. The members have expertise in water resources management, fluvial geomorphology, paleohydrology, hydraulics, sedimentation, photogrammetry, mapping, fisheries biology, wildlife biology, and riparian vegetation management.

The team members are:

- Dr. Rodney J. Wittler, Hydraulic Engineer. (Hydraulics, Water Resources Management)
- Dr. Daniel R. Levish, Geologist. (Paleohydrology, Fluvial Geomorphology)
- Ms. Jeanne E. Klawon, Geologist. (Fluvial Geomorphology, Geology)
- Dr. Ralph E. Klinger, Geologist. ((Paleohydrology, Fluvial Geomorphology)
- Dr. Blair P. Greimann, Hydraulic Engineer. (Hydraulics, Sediment Transport)
- Mr. Matt B. Jones, Computer Specialist. (Photogrammetry, Mapping)
- Ms. Susan C. Broderick, Fisheries Biologist. (Fisheries Biology, Endangered Species Recovery)
- Mr. Larry H. White, Wildlife Biologist. (Wildlife Biology, Riparian Vegetation Management)

CONCEPT

EXECUTIVE SUMMARY

Reclamation proposes to assist with the Santa Cruz River bank stabilization at the San Xavier riparian area, near Tucson, Arizona. The bank in question is the left bank (looking downstream) to the east of I-19 and the west of Tucscon International Airport, opposite of Martinez Hill (Elev. 2854). This document outlines the conceptual design of a trench-fill revetment. The design follows guidelines EM 1110-2-1601 (USACE-1994) executed by the "Chanlpro" PC Program For Channel Protection Design (USACE-1997) provided by the US Army Corps of Engineers, Waterways Experiment Station.

The intent of the concept is to stabilize the bank of the upper surface in the riparian area during relatively small floods. In particular, the design conceptualized herein is valid for main channel flow depths of one meter (3.0 feet) or less, average channel velocity of 2.1 m/s (seven feet per second) or less, local maximum velocity of 3.4 m/s (11.1 feet per second) or less, and a safety factor of 1.1.

There was no hydraulic modeling, either physical or numerical, of the reach for estimating design parameters. Input into ChannlPro came from two field visits, one by Wittler, the other by Levish, both of the Reclamation Technical Service Center Fluvial Hydraulics and Geomorphology Team. Figures 1-5 show the location and views of the riparian area.

The conceptual design calls for a trench fill revetment. The alignment of the trench occupies the surface of the riparian area, above two surfaces that formerly were the low flow channel and the main channel bed. The triangular shaped trench will be six feet deep and twelve feet wide. The riprap design is the standard ETL #10 mix, with a D_{100} of 0.91 m (36 inches), a D_{15} between 0.12 m and 0.16m (14 and 19 inches); one D_{100} thick, as a minimum. The cumulative length of the trench is roughly 286 m (938 feet). This corresponds to a volume of roughly 1.9 tons/ft (5,700kg/m) or a total of 1,800 tons (1,636,000 kg) at 120 lb/ft^3.

LOCATION

The project is within the San Xavier District of the Tohono O'Odham Nation, Pima County, Arizona. Figure 1 shows the general location of the project area south of central Tucson, Arizona. Figure 2 shows the riparian area in the San Xavier District, south of Tucson and west of Tucson International airport.

DESCRIPTION OF RIPARIAN AREA

Figure 3 is an aerial photograph of the project area (circled) just upstream of the I-19 bridges. Figure 4 and Figure 5 are panoramic photographs of the riparian area from the opposite bank. Figure 4 shows the entire project reach, albeit slightly distorted. Figure 5 shows the upstream portion of the riparian area, near the large tree at the present bank line.

Figure 1. Riparian area is near the San Xavier Mission, on I-19 south of downtown Tucson, east of Tucson International airport.

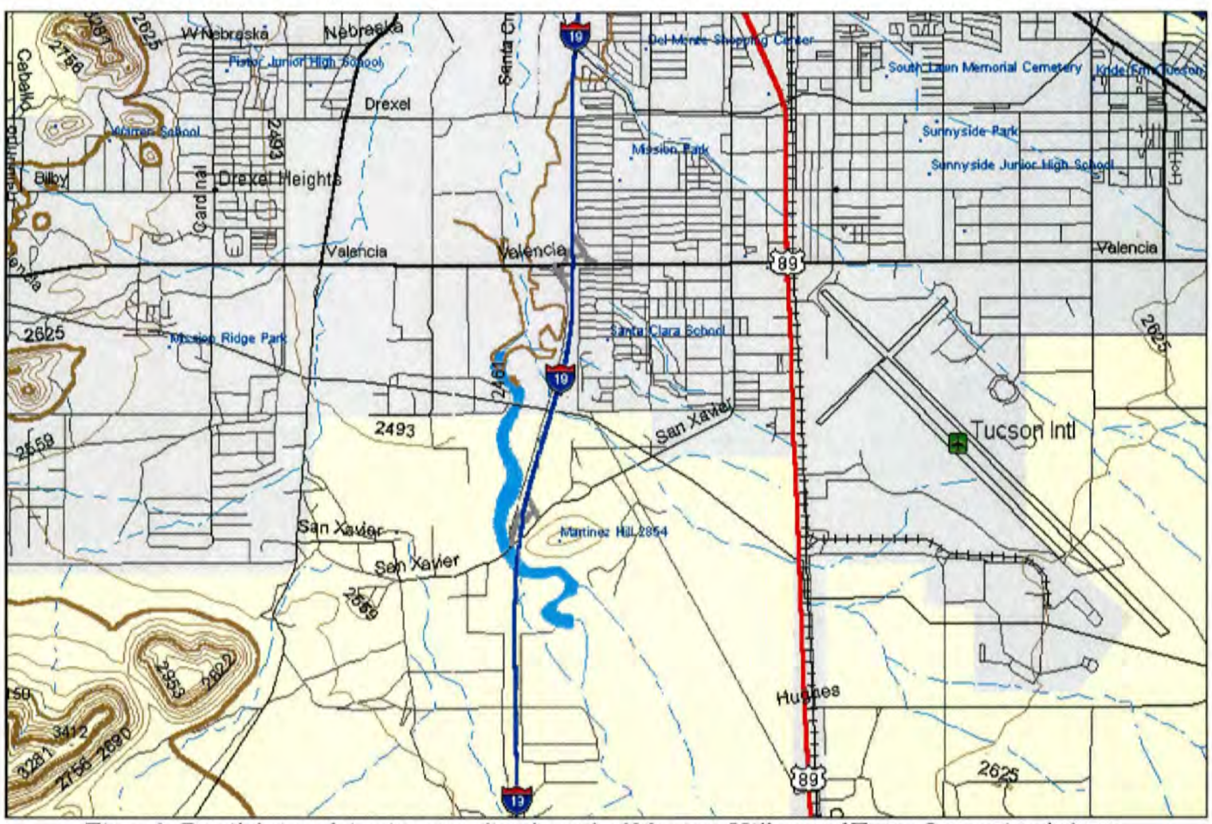

Figure 2. Detailed view of riparian area, directly south of Martinez Hill, east of Tucson International airport.

Figure 3. Riparian area and project area on left bank of Santa Cruz River, upstream of I-19 bridges.

Figure 4. Panoramic view of riparian area from opposite (east) bank. Flow is left to right, and the photograph is distorted.

Figure 5. Panoramic of upstream end of riparian area. Flow is left to right, and the photograph is distorted.

DESIGN CONCEPT

The Santa Cruz River upstream of Tucson is an ephemeral (flowing only following rain that produces runoff) sand bed channel. The riparian area that constitutes the project area occupies a low surface roughly 4 feet above the channel invert. The scallop shaped area comprises roughly 25 acres of riparian vegetation. The Santa Cruz River excavated this riparian area during a medium to large flood. The design concept for protecting the riparian area is to stabilize the bank during low to medium flows using a trench fill rock revetment. This design is probably not competent to withstand medium to large floods. The riparian area is on the inside of the bend where shear stresses are least, compared with other portions of the channel section.

The conceptual design calls for a trench fill revetment. The alignment of the trench occupies the surface of the riparian area, above two surfaces that formerly were the low flow channel and the main channel bed. The triangular shaped trench will be six feet deep and twelve feet wide. The riprap design is the standard ETL #10 mix, with a D_{100} of 0.91 m (36 inches), a D_{15} between 0.12 m and 0.16m (14 and 19 inches); one D_{100} thick, as a minimum. The cumulative length of the trench is roughly 286 m (938 feet). This corresponds to a volume of roughly 1.9 tons/ft (5,700kg/m) or a total of 1,800 tons (1,636,000 kg) at 120 lb/ft^3.

DESIGN LIMITATIONS

There was no hydraulic modeling, either physical or numerical, of the reach estimating design parameters. Input into ChannlPro came from two field visits, one by Wittler, the other by Levish, both of the Reclamation Technical Service Center Fluvial Hydraulics and Geomorphology Team. Figures 1-5 show the location and views of the riparian area. There are no controlled drawings of the project area. The basis of the specification volumes and distances is a 2000 aerial photograph at a 1:100 scale (rough).

The conceptual design herein is valid for main channel flow depths of one meter (3.0 feet) or less, average channel velocity of 2.1 m/s (seven feet per second) or less, local maximum velocity of 3.4 m/s (11.1 feet per second) or less, and a safety factor of 1.1.

DESIGN ASSUMPTIONS

The following output from ChannlPro (USACE 1997) lists the design assumptions. This concept attempts to use conservative, but reasonable values. For instance, the bank stabilization is on the inside of the bendway, not the outside. The design assumes a centerline bend radius of 1000 feet (305m).

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PROGRAM OUTPUT FOR A NATURAL CHANNEL SIDE SLOPE RIPRAP

BENDWAY

                   INPUT PARAMETERS
    SPECIFIC WEIGHT OF STONE,PCF                 165.0
    MINIMUM CENTER LINE BEND RADIUS,FT          1000.0
    WATER SURFACE WIDTH,FT                       700.0
    LOCAL FLOW DEPTH,FT                            3.0
    CHANNEL SIDE SLOPE,1 VER: 1.50 HORZ
    AVERAGE CHANNEL VELOCITY,FPS                  7.00
    COMPUTED LOCAL DEPTH AVG VEL,FPS             11.08
    (LOCAL VELOCITY)/(AVG CHANNEL VEL)            1.58
    SIDE SLOPE CORRECTION FACTOR K1                .71
    CORRECTION FOR VELOCITY PROFILE IN BEND       1.22
    RIPRAP DESIGN SAFETY FACTOR                   1.10
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SELECTED STABLE GRADATIONS
ETL GRADATION

NAME	COMPUTED D30 FT	D30(MIN) FT	D100(MAX) IN	D85/D15	N=THICKNESS/ D100(MAX)	CT	THICKNESS IN
7		1.10	27.00	1.70	NOT STABLE		
8	1.22	1.22	30.00	1.70	1.42	.91	42.5
9	1.34	1.34	33.00	1.70	1.01	1.00	33.5
10	1.34	1.46	36.00	1.70	1.00	1.00	36.0

D100(MAX) IN	LIMITS OF STONE WEIGHT, LB FOR PERCENT LIGHTER BY WEIGHT						D30(MIN) FT	D90(MIN) FT
	100		50		15			
30.00	1350	540	400	270	200	84	1.22	1.77
33.00	1797	719	532	359	266	112	1.34	1.94
36.00	2333	933	690	467	345	146	1.46	2.11

EQUIVALENT SPHERICAL DIAMETERS IN INCHES

D100(MAX)	D100(MIN)	D50(MAX)	D50(MIN)	D15(MAX)	D15(MIN)
30.0	22.1	20.0	17.5	15.9	11.9
33.0	24.3	22.0	19.3	17.5	13.1
36.0	26.5	24.0	21.1	19.0	14.3

PROJECT LAYOUT

Figure 6 is an aerial photograph of the riparian area and project area. The trench alignment and dimensions are superimposed on the aerial photograph.

Key elements to the alignment include:
1. Simple field layout
2. Key into high bank at upstream of revetment trench
3. Inclusion of large tree within protected area
4. Proximity to existing bank-line
5. Termination upstream of intersection with downstream high surface

The trench layout is simple, allowing easy location of points in the field. Begin by locating the two large trees in the photograph, one within the riparian area, the other on the opposite bank at the foot of Martinez Hill. A line between the trunks of those two trees forms the construction baseline. Extend the baseline 70m to the south, beyond the large tree in the riparian area. This end-point will be convenient to set up surveying instruments for layout of the trench alignment. The first segment extends 70m, 8° CW from the baseline terminus at the instrument location. The second segment extends 151m, 130° CW from segment 1. The third and final segment extends 65m, 170° CW from segment 2.

The trench will key into the high bank. This key will require excavation for placement of the riprap. Following placement of the rock, the high bank should be filled and compacted at the original grade.

The trench should extend around the root zone of the large tree in the riparian area. Care should be taken to first, not disturb existing roots, and second to rehabilitate exposed roots with the fill of top-soil. A vegetation specialist may be consulted on the proper methods for rehabilitating the exposed roots.

The trench is relatively straight. Discretion may be used in the field to align with the existing bank minimizing potential loss of riparian area surface.

The terminus of the trench occurs before intersection with the high bank at the downstream end of the riparian area: Wittler and Levish observed scour holes greater than roughly 3 feet in depth in this area. Potential scour of this magnitude would complicate this design especially the total rock volume and single design concept. This area experiences erosive velocities on the ascending and descending limbs of the flow hydrograph. The judgement of the designers is that leaving this area unprotected facilitates drainage of flood flows from the riparian area, alleviates potential large scour holes downstream of a rock revetment, and preserves the simplicity of this design while not jeopardizing the overall stabilization goal.

BANK STABILIZATION CONCEPT

Figure 7 shows Section A-A from Figure 6. Figure 8 details Section A-A. Figure 7 indicates optional bank armor land-wise and stream-wise from the trench. Use excess rock following completion of rock placement to form this optional armor layer. Figure 9 shows Section B-B from Figure 6. Section B-B details the relationship between the trench and the tree near the upstream end of the riparian area.

The trench is 12 feet wide, 6 feet deep. The bank slopes are 1.5H:1V land side, 0.5H:1V stream side. The intent of this trench shape is two-fold. First, the triangular shape lends itself to quick excavation using an excavator. Second, the purpose of a trench fill revetment is to intercept a laterally migrating stream, exposed only upon migration of the stream into the trench fill. Upon exposure, the stones within the original boundary ABC "launch" into the scour at the face of the trench, eventually achieving the secondary shape ADEC, shown in the figures. The launched stone forms a true blanket, or revetment, that meets the specifications of CHANLPRO (USACE 1997) and EM1610 (USACE 1994). The volume of stone within ADEC is 10% less than that within ABC, accounting for loss of fines during launching.

VOLUME ESTIMATE

The triangular shaped trench will be 6 feet deep and 12 feet wide. The riprap design is the standard ETL #10 mix, with a D_{100} of 0.91 m (36 inches), a D_{15} between 0.12 m and 0.16m (14 and 19 inches); one D_{100} thick, as a minimum. The cumulative length of the trench is roughly 938 feet. This corresponds to a volume of roughly 1.9 tons/ft or a total of 1,800 tons at 120 lb/ft^3.

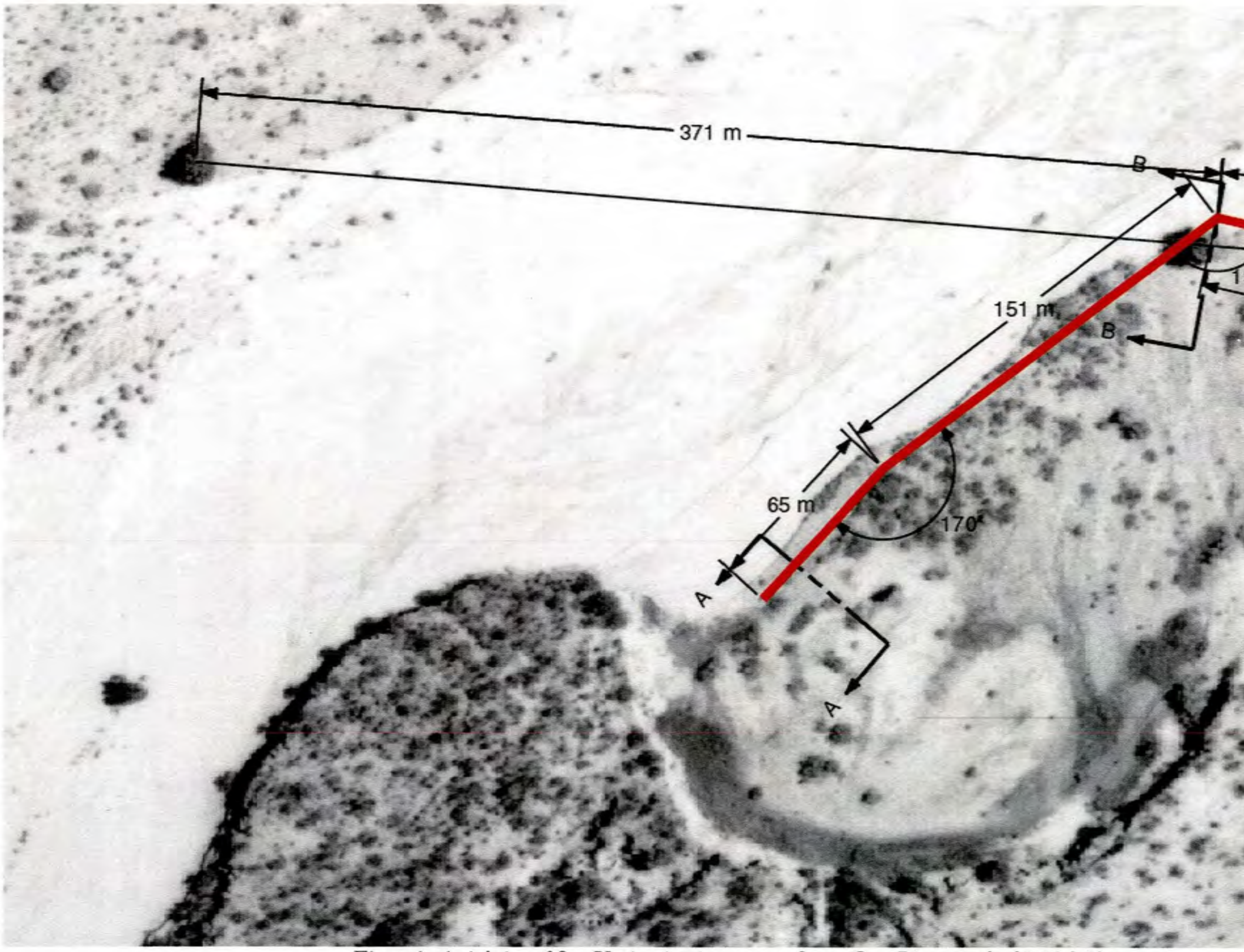


Figure 6. Aerial view of San Xavier riparian area on Santa Cruz River, south of 1-19 bridges.

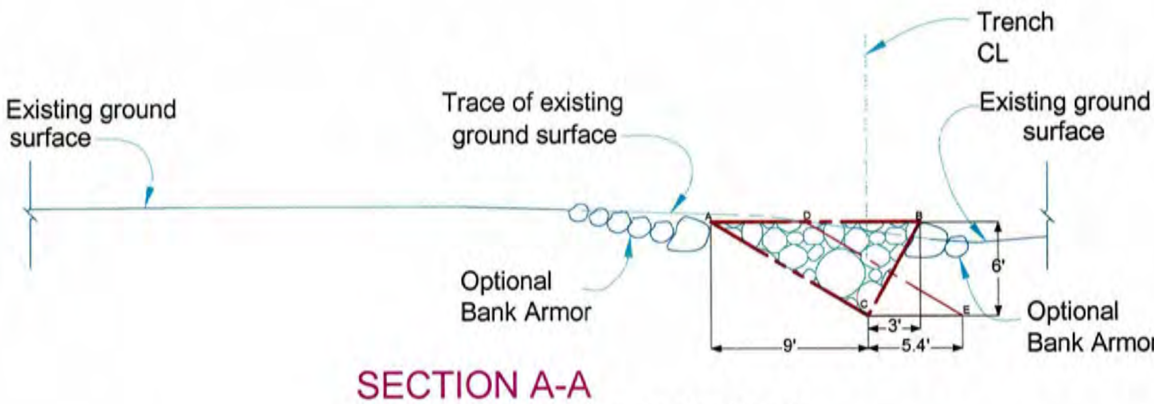


Figure 7. Section of trench and surrounding area.

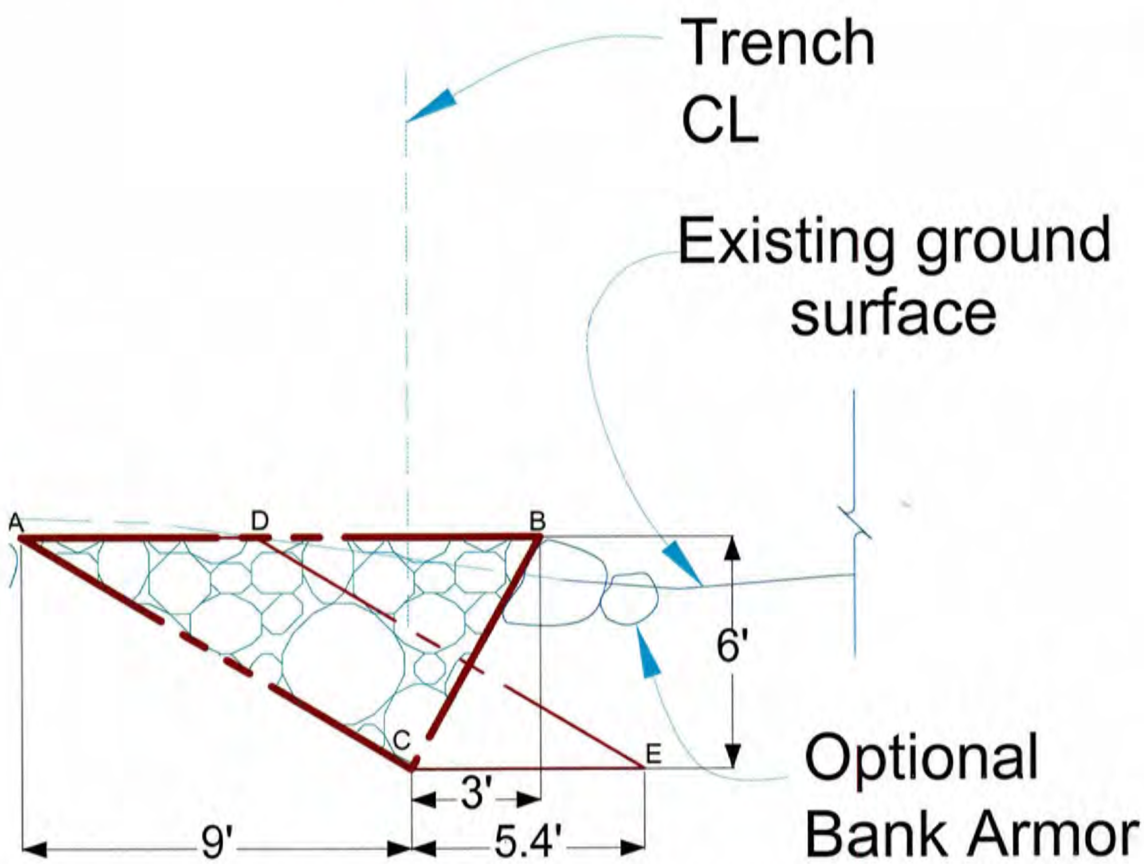
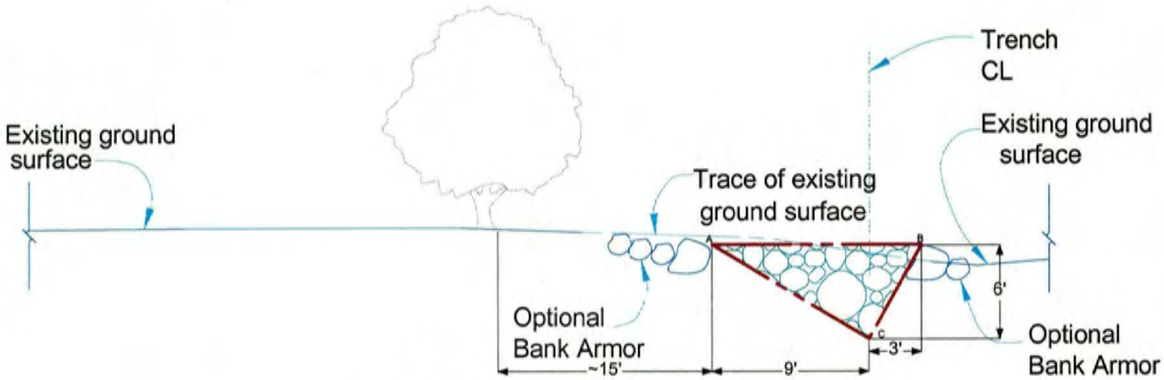


Figure 8. Detail of trench section, A-A. Original placement ADBC. Launched configuration ADEC.



SECTION B-B

Figure 9. Section B-B, showing relationship of trench to tree.

REFERENCES

US Army Corps of Engineers. 1994. "Hydraulic design of flood control channels," EM 1110-2-1601, US Government Printing Office, Washington, DC.

US Army Corps of Engineers. 1997. User's Manual For "Chanlpro", PC Program For Channel Protection Design. Stephen T. Maynord, Martin T. Hebler, and Sheila F. Knight. Coastal and Hydraulics Laboratory, Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS.