Memo for the Record

Skunk Creek, New and Agua Fria Rivers, Phase II

General Design Memorandum

Depth of Toe Protection for Bank Stabilization and Levee Design

U.S. Corps of Engineers-COE

1986

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REMARKS

REPLY TO
ATTENTION OF:

November 4, 1986

Office of the Chief
Hydrology & Hydraulics Branch

Mr. Nicholas P. Karan
Chief, Engineering Division
Flood Control District of Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

Dear Mr. Karan:

In your letter, dated September 18, 1986, you requested our levee toe-down design criteria and calculations. This District's design practice calls for a nominal depth of toe protection of 10 feet below the river thalweg. This valve is increased or decreased depending on physical characteristics of the watercourse (natural and man-made) as well as flood characteristics occurring in the watershed. Also, per your request, we are enclosing two Hydraulic Section Memorandums for Record in which are detailed the rationale for development of depth of toe protection used in the Phoenix, Arizona and Vicinity (Including New River); General Design Memorandum for the Skunk Creek and the New and Agua Fria Rivers Feature.

With regard to use of about 8.5 feet of toe protection below an equilibrium slope gradient, we understand that this is incorporated within a channel reach that includes several grade stabilizers, soil cement parallel banks with gentle curvature bends, and a relatively flat excavated invert. In contrast, the reach downstream of Buckeye Road, which contains the Corps' single levee system, remains a natural river bed with several braided channels that project toward the levees at relatively high angles of attack. Because of the high potential for river bed thalweg meander in a medium composed of fine material, 10 to 15 feet of toe protection was deemed necessary for this reach.

If you have any further questions concerning our response, please contact Mr. Rene Vermeeren of Hydraulics Section, at (213) 894-6995.

Sincerely,

Robert C. Kyle

Norman Arno
for Chief, Engineering Division

Enclosure

SPLED-HH

9 October 1985

MEMORANDUM FOR RECORD

SUBJECT: Skunk Creek, New and Agua Fria Rivers Phase II General Design Memorandum. Depth of Toe Protection for Bank Stabilization and Levee Design

1. On 12 September 1985, a meeting was held in Hydraulics Section to discuss the depth of toe protection for the subject project reach. Present at the meeting were the following section personnel: Robert Schaetzel, Glenn Mashburn, Rene Vermeeren, and Joe Evelyn. Two separate analyses were conducted on this subject and documented in Memorandums for Record by Mr. Schaetzel, dated 12 August 1985, and by Mr. Vermeeren dated, 16 September 1985. Based on the results of both analyses and subsequent discussions, the following depths of toe protection were established by Mr. Evelyn:

Bank Station From	Bank Station To	Approximate River Station From	Approximate River Station To	Depth of Toe Protection Below Thalwag (ft.)
Skunk Creek East Bank				
26+52	39+00	26+52	39+00	10
39+00	51+00	39+00	51+00	13
51+00	71+50	51+00	71+50	10
New River East Bank				
224+74	230+00	232+60	238+00	10
230+00	240+00	238+00	246+00	13
240+00	302+00	246+00	309+00	10
302+00	324+00	309+00	325+00	13

Enclosure

9 October 1985

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SUBJECT: Skunk Creek, New and Agua Fria Rivers Phase II General Design Memorandum. Depth of Toe Protection for Bank Stabilization and Levee Design

324+00 - 334+00	325+00 - 334+00	10
334+00 - 345+00	334+00 - 345+00	15
349+00 - 361+00	349+00 - 361+00	15
West Bank		
231+50 - 255+00	232+60 - 255+00	10
255+00 - 268+00	255+00 - 267+00	13
268+00 - 334+00	267+00 - 334+00	10
334+00 - 345+00	334+00 - 345+00	15
349+00 - 361+00	349+00 - 361+00	15
Agua Fria River East Bank		
7+86 - 26+27	162+50 - 149+00	13
West Bank		
17+72 - 75+00	111+00 - 168+00	10
75+00 - 103+75	168+00 - 199+00	13
103+75 - 104+75	199+00 - 200+20	15

Rene Vermeeren
RENE VERMEEREN
Hydraulic Engineer

Joseph B. Evelyn
JOSEPH B. EVELYN
Chief, Hydraulics Section

CF: SPLED-DB
(Karakawa)

16 September 1985

MEMORANDUM FOR RECORD

SUBJECT: Toe Protection for the Proposed Levee and Bank Protection Works on Skunk Creek, New and Agua Fria Rivers from ACDC to Gila River

1. Purpose: The purpose of this study is to determine toe depth protection for the project noted above.

2. Introduction. In general, the depth of toe protection for either levees or bank protection works is based on estimates of general degradation and maximum local scour that would occur during the design flood. The general scour can be determined from a detailed sediment transport analysis conducted for the subject reaches. However, in the case where the protection runs along the natural stream bank without the use of groins or spur dikes, a literature search uncovered no theoretical or empirical relationship applicable to determine the local scour due to crossflows impinging against the protection works. For this reason, the depth of toe protection should be based on past performance of COE projects and past experience of the engineer.

In this study, the river characteristics of several projects that have failed due to flow impingement will be examined to aid in determining the appropriate toe depth required for this project.

3. Existing Projects.

A review was made of various reports (listed in the references) published by the Los Angeles District describing past projects in which the protection works failed due to floodflows that were less than design flows. The review revealed that there are several projects which appear to be similar to the proposed project from a standpoint that they are in wide meandering stream. These projects are on the Santa Maria River, Santa Clara River, and San Jacinto River. The mode of failure was common among these projects in that the protection works, consisting of revetted levees, were damaged by meandering flows that undermined the stone protection and by crossflows that eroded parts of the levee. The types of remedial measures taken to restore these projects to their original design protection include lowering the toe depth, constructing training dikes to reduce flow meanders, constructing or rebuilding groins in areas of flow impingement, and grouting of the revetment.

4. Proposed Project.

In order to establish an appropriate depth of toe protection for the proposed project, the existing projects noted above were selected for general comparison of design features and river characteristics. It is thought that a comparison might reveal trends or factors that should be considered in making

Incl 2.

judgment on the project toe depth. The current design practice within the Los Angeles District calls for toe depth to extend a minimum of 10 feet below the thalweg, unless some other predominant factor prevails in resisting erosion whereby the toe depth may be reduced. Table 1 provides the pertinent information of both the existing and the proposed projects. Any judgments drawn from this table will be discussed in the conclusions.

TABLE 1. COMPARISON OF RIVER CHARACTERISTICS

Element	EXISTING PROJECTS			PROPOSED PROJECTS		
	Santa Maria River	Santa Clara River	San Jacinto River	Skunk Creek	New River	Agua Fria River
River slope	.003	.003	.005 to .009	.0031	.00325	.003
Design (cfs) Discharge	150,000 to 160,000	225,000	86,000	35,000	41,000	90,000
Design depth of flow (ft)	6.3 to 12.6	11 to 20	6 to 13	13 to 20	10 to 19	8 to 15
Design velocities (fps)	6.2 to 16	7.8 to 17.1	7 to 15	4 to 15	6 to 14	5 to 9
Approximate						
Floodflow width (ft)	2000	1000 to 2000	1000	150 to 1100	210 to 1600	1200 to 3300
Floodway width (ft)				500 to 600	400 to 500	2000 to 2200
Original toe depth (ft)						
below backfill line	13 to 19	5 to 7	10 to 15			
below thalweg	10 to 12	8	5 to 10			
Thickness of riprap (ft)	1.5	1.5 2.0 at toe	1.5			
Protection	Riprap	Riprap	Riprap	Grouted rock	Soil cement	Soil cement
Flood Damage Information						
Approximate Damaging Discharge (cfs)	25,000	35,000 1/ 165,000	25,000			
Est. depth of erosion below streambed (ft)	12	13	2/			
Impingement flow velocity (fps)	16 to 18	N/A	N/A			

1/ No levee damage at 35,000 cfs, but severe erosion. 165,000 cfs was the peak discharge during flood event.
2/ At or below existing levee toe.
N/A - Not available

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SUBJECT: Toe Protection for the Proposed Levee and Bank Protection Works on Skunk Creek, New and Agua Fria Rivers from ACDC to Gila River

5. Other Considerations.

Other notable factors in determining toe depth would be the river alignment, bed material, historical bank erosion, and gravel mining. Accounting for these factors along with the general comparison trends would provide a basis for recommending the toe depths.

6. In locations where the banks may be subject to severe angles of attack, such as on the outside of bends, additional toe depth will be recommended. The amount will be based on the maximum scour that occurred on the existing projects (shown in previous table).

7. The type of bed materials is an important factor in the degradation trends since finer sand materials will generally erode easier than coarser materials. To determine the potential for scour a qualitative comparison of bed materials was made between the existing and proposed projects. The bed materials on the existing projects were noted as sand-bed streams, whereas, on the proposed projects, the bed materials consist mainly of sands on the Agua Fria River with significantly more gravels and cobbles on the New River and Skunk Creek. This would generally indicate that the potential for scour for the proposed projects would not worsen since the bed materials are coarser.

8. Because of the lack of data on historical bank erosion, this discussion will be limited to a qualitative viewpoint using aerial photos. Unfortunately, the only flood aerial photographs available were on the Agua Fria River during the 1980 flood for part of the subject reach and immediately after the 1980 flood for the entire subject reach. Examination of the aerial photographs indicate that some bank erosion occurred on the right bank downstream of Buckeye Road and that low flows did meander. However, due to the limitations of the photographs, it was not possible to determine if the bank erosion was due directly to the meander of low flows. It should be noted that the alignment of the right bank of the proposed project corresponds with the natural right bank. On the left bank, the proposed project does not encroach within the post-flood bank line.

9. Although gravel mining operations will be permitted in or near the subject reaches, strict control of the operations should be established to avoid harmful effects such as a large gravel pit inducing degradation of the streambed or stockpiling of materials inducing meandering of the floodflows toward a bank.

10. Conclusions

General: Past experiences with existing Corps of Engineers' projects have provided invaluable information into the mechanism of failure of protection works in which the floodflows were less than the peak design discharge. For the project reaches, the depth of the protection will be designed to resist failure from undermining from both low flows as well as design flows. The

recommended toe depths, as discussed in subsequent paragraphs for each reach, are based on past experiences, current design practices, and other considerations mentioned herein. Table 2 summarizes the recommended toe depths of each reach. It should be noted that the use of prediction type equation-Lui (Ref. 11) should be applied to the situation for which it was intended for. Deviation of Lui's equation may result in misleading scour depths. However, in this study, it may be possible to apply the equation on the left bank of the Agua Fria River at lower Buckeye Road.

11. Skunk Creek.

In comparing Skunk Creek to the existing projects, the elements which appear similar are the river slopes, design velocities, and depths. The elements that are not similar are the design floodway width and design discharge. The factor that appears significant is the flow width. It can be concluded that since the flow widths in this reach are much less than that of the existing projects, the tendencies for low flows to meander are reduced. Hence, the banks are less subject to severe angles of attack, which results in less local scour occurring due to flow impingement. The results of the sediment transport analysis indicate that general degradation would be less than one foot. Therefore, the minimum toe depth below the streambed of 10 feet is recommended in the straight reach and 13 feet on the outside bank of the curved reach. The 13 feet is based on the maximum scour that occurred on the Santa Maria and Santa Clara River Projects.

12. New River.

The design elements and river characteristics in the reach from just upstream of Peoria to just downstream of Olive are very similar to the Skunk Creek reach with the exception that both sides of the channel will be stabilized. Also, the results were the same of the sediment transport analysis. Therefore, a minimum of 10 feet below the thalweg is recommended except on the outside of bends where toe depth should be increased to 13 feet, and near the drop structure where toe depth should be increased to 15 feet. The 15 feet is based on past experience and engineering judgment of local scour at a stabilizer.

13. Agua Fria River.

A comparison of the design elements and river characteristics indicate that they are very similar to the existing projects except for the flow velocities, which are slightly lower. The results of the sediment transport analysis indicate that general degradation would be less than one-foot for the design flood. In this reach, the river is very wide and conducive to low flow meanders; which could attack the bank protection at a severe angle. Considering this flow pattern plus all the factors, which are generally similar to the existing projects, it is reasonable to conclude that the maximum toe scour could be as deep as what occurred on the existing projects. Therefore, toe depth protection of 13 feet is recommended on both banks.

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TABLE 2. TOE DEPTH RECOMMENDATION

BANK STATION 1/	DEPTH OF TOE PROTECTION BELOW THALWEG (ft)
Skunk Creek	
East Bank	
26+52 - 38+50	10
38+50 - 48+50	13
48+50 - 71+50	10
New River	
Upstream Reach	
(East Bank)	
321+78 - 332+00	10
(West Bank)	
324+80 - 332+00	10
(Both Sides)	
332+00 - 361+00	15
Downstream Reach	
(East Bank)	
224+74 (Olive) - 232+75	10
232+75 - 249+50	13
249+50 - 302+44	10
(West Bank)	
231+50 - 253+50	10
253+50 - 263+50	13
263+50 - 309+50	10
Agua Fria River	
(East Bank)	
7+86 - 26+27	13
(West Bank)	
17+72 - 104+75	13

1/Stations from plan view map, scale 1" = 500'
Stations approximated in curved reaches.

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SUBJECT: Toe Protection for the Proposed Levee and Bank Protection Works on Skunk Creek, New and Agua Fria Rivers from ACDC to Gila River

14. References

(1) U.S. Army Engineer District Los Angeles, "Report on Engineering Aspects, Floods of January and February 1969 in Southern California," 1974, Los Angeles, California.

(2) U.S. Army Engineer District, Los Angeles, "Report on Levee Failures and Distress, San Jacinto River Levee and Bautista Creek Channel, Riverside County, Santa Ana River Basin, California," August 1980, Los Angeles, California.

(3) Gildea, A. P., U.S. Army Engineer District, Los Angeles, "Design Practice for Levee Revetment on West Coast Intermediate Streams," 1963, Los Angeles, California.

(4) U.S. Army Engineer District, Los Angeles, "Skunk Creek and the New and Agua Fria Rivers, GDM Phase II - Draft", July 1985, Los Angeles, California.

(5) U.S. Army Engineer District, Los Angeles, "Supplemental to Design Memorandum No. 1 for Santa Maria Valley Levees and Channel Improvements", March 1980, Los Angeles, California.

(6) U.S. Army Engineer District, Los Angeles, "Santa Maria Levees Investigation Report", August 1970.

(7) U.S. Army Engineer District, Los Angeles, "Letter-Type Report on Project Design Deficiencies and Remedial Measures for Santa Clara River Levee", January 1982, Los Angeles, California.

(8) Miscellaneous Paper, "Santa Clara River Levee", no date.

(9) Simons, Li, & Asso., "Final Sediment Transport Report for the New River and Skunk Creek", January, 1985.

(10) Simons, Li, & Asso., "Final Report, Standard Project Flood Analysis and Conceptual Design of Channelization in the Agua Fria River", May 1984.

(11) Schaetzel, Robert, Memorandum for Record, SPLED-HH, U.S. Army Engineer District, "Toe Depth Calculations for Levees and Bank Protection from Gila River to ACDC Outlet," 26 August 1985.

Rene Vermeeren

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