US Army Corps of Engineers

(Albuquerque District)

Floodwater Lesson Learned
Channel Stabilization in Santa Fe, NM

PDH: 2 Hours

Don Soards, P.E.

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Channel Stabilization
In Santa Fe, NM

1. Course Overview

I am proud to present this course. I was a young civil engineer with the Corp of Engineers when I was called out to investigate some minor flooding in Santa Fe, NM. The cause of that minor flood was a large branch caught in a concrete box culvert under St. Francis Drive. There I met the Santa Fe city engineer. He explained his long-range plan to reduce the number of residents in the 100-year floodplain. The challenge he faced was a large number of old (Santa Fe was started in 1607) structures that functioned as *de facto* grade controls. These structures had raised the channel bottom and robbed the channel of much-needed floodwater capacity. His plan was to remove these structures and let erosion wash out the accumulated sediment. It worked! Neighborhoods were removed from the 100-year floodplain. The erosion brought challenges to stabilize the channel at its new capacity. This course describes how those challenges were met. I was inspired to meet a public servant with the confidence and judgment to pursue a plan that benefited the citizens of his community.

This course satisfies 2-hours of engineering continuing education requirement for Professional Engineer license renewal.

One thing common to all engineering disciplines is protection against flooding. Our systems need to work when it rains.

This course in Floodwater Lessons Learned: Channel Stabilization in Santa Fe, NM is intended to encourage the engineer to consider the big-picture result of field performance of many projects over many decades.

The engineer's duty is to make things work. Following instructions, complying with the law, and using current best practices are usually good enough for the present. But the engineer's task to make things work in the future. This requires making projections about future conditions and use. While engineers prefer hard facts, we are sometimes forced to work with "soft data" that require evaluating many possible options. During this evaluation, we use legal requirements and best technology as tools.

When I headed the Albuquerque District's Inspection of Completed Works (one of three major programs I had as Chief of Emergency Management for a dozen years), I noticed the same design/construction errors being repeated. The US Army's version of Total Quality Management (TQM) was Total Army Quality (TAQ). Under TAQ, the process of continuous improvement was building, feedback, and improved building.

The problem was a lack of feedback because flood control structures may sit for decades without being tested by significant flooding. I strove to compensate for this lack of immediate feedback by having studies made of the histories of over one hundred projects constructed by the Albuquerque District Corps of Engineers since 1948. I selected Professor Richard J. Heggen, a hydrology/hydraulics teacher at UNM, to write many of these, including Channel Stabilization in Santa Fr, NM. His interesting and entertaining lecture style is reflected in his writing.

2. Learning Objectives

Upon successful completion of this course, the participants will be able to:

- Recognize many defects in existing flood control structures.
- Review plans to avoid those defects.
- Consider how the life of flood control structures may impact current engineering systems.
- Inspect flood control projects.
- Be able to consider making and implementing a long-range urban vision.

3. Summary

In this course, we examined key features of flood control and bank protection projects that worked over time and a number of those that faced challenges during their long life. Suggestions for improvement were made for many of the problems encountered.

Reference Socorro Diversion Channel Lessons Learned by Professor Richard J. Heggen

LESSONS LEARNED

CHANNEL STABILIZATION IN SANTA FE, NEW MEXICO

July 1997

By Richard J. Heggen, Professor of Civil Engineering, University of New Mexico

Channel Stabilization in Santa Fe, NM

Lessons Learned

The Projects

The U.S. Army Corps of Engineers has six channel stabilization projects on the Santa Fe River system:

Project	Emergency Flood Control Work, Mascaras Arroyo
Contract	DA-29-005 CIVENG-59-9
Final Inspection	1959
Project	Santa Fe Emergency Flood Control Project, Phase I
Contract	DACW47-70-C-0001
Final Inspection	2 April 1970
Project	Santa Fe Emergency Flood Control Project, Phase II
Contract	DACW47-71-C-0011
Final Inspection	17 March 1971
Project	Flood Protection of Capshaw Junior High School
Contract	DACW47-79-C-0064
Final Inspection	5 September 1979
Project	Streambank Protection on Alameda Street
Contract	DACW47-91-C-0007
Final Inspection	25 July 1991
Project	Emergency Bank Protection, County Road 62 Bridge
Contract	DACW47-94-C-0024
Final Inspection	27 January 1995

The Capshaw and County Road 62 projects are single structures isolated from other channel stabilization works. The other four projects consist of multiple sites and structures that cannot be meaningfully evaluated in isolation. Some sites contain construction from more than one Corps project, or a Corps project and previous or subsequent work by another agency.

All sites are similar in stabilization practice, relying extensively on gabion baskets for bank protection and grade control. Most structures are designed to blend into the natural channel morphology.

In 1970 the Corps noted, *"This method of bank protection is not common with the Corps ... This project is the first instance of gabion use in the Albuquerque District. It would appear that this method of bank protection is ideal to fill the gap between situations requiring mass concrete (or grouted riprap) and those where Kellner jacks perform so well."*

The Review

This review assesses the optimistic *ideal* of 1970.

This review covers approximately a dozen channel reaches, several having multiple improvements. This review covers structures inspected in the annual Corps field visits. In some cases these reports include non-Corps construction functioning in relation with Corps projects.

Because the improvements tend to be relatively small constructions at different locations, it is not uncommon to find an improvement that works in one place does not do as well in another.

With one exception, this review is topical, not specific to a particular site and not focused on detail. The exception is the *Sewer Line Crossing* case study.

The Short Answers

The following "short answers" are general themes drawn from the subsequent topics.

What Worked

The dramatic 20-year channel degradation has decelerated. While there is no assurance that the channel has stabilized for the long term, solutions are evolving. In terms of immediate problems, roughly 90 percent of the Corps construction seems to be productive.

Removal of grade control structures has increased local flood conveyance capacity. Much of the Santa Fe River overbank downstream of St. Francis Drive is no longer in the floodplain.

What Didn't Work

Removal of grade control structures has not rectified the City's flooding vulnerability. Neither floods nor sediment are well managed by arbitrary intervention.

Like ballerinas, hydraulic structures are no better than their toes. Most failures initiate with undercutting. The best structure can topple. Most successful structures owe their existence to a channel stabilized downstream.

Much Corps effort relates what might be called "Section 14 fixes". At risk of oversimplifying a body of law and procedures, the concept of "emergency response" permeates the engineering. In the spirit of military strategy, the Santa Fe River has been too-often seen as Granada. Unfortunately, it is Bosnia.

Coordination is woeful. Santa Fe River stakeholders lack understanding of causality, agreement on objectives, commitment to solutions, and a spirit of mutuality. Gabions cannot fill this void.

Sideslope Protection

What Worked

Fig. 1 shows floodwall gabions tiered at a 12-inch layback, not 18 inches as specified. Because the toe is stable, as indicated by the overgrowth, the construction error can be tolerated. If the toe begins to rotate, however, toppling may follow.

Sidewalls fail when the toe is undercut. The footing must extend below any conceivable scour. Fig. 2 illustrates trenching to this effect. While a practice of, say, 5-foot cover may reflect general experience, the depth is only meaningful when long-term trends are understood.

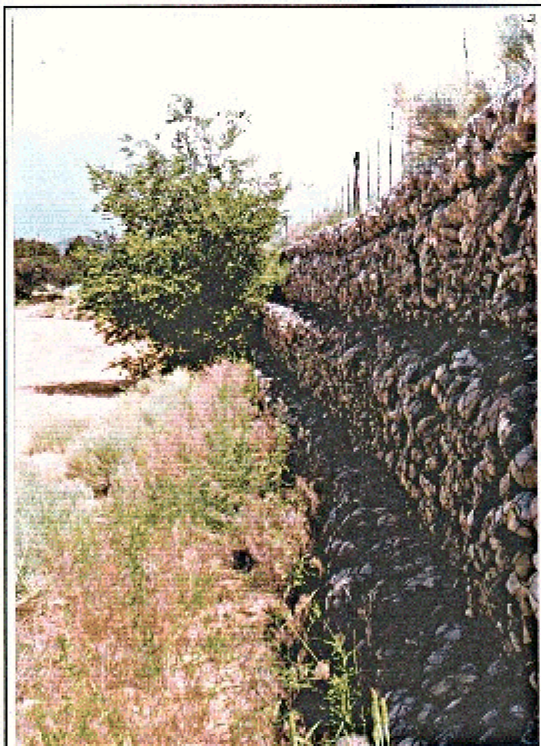

Figure 1. Stable sideslope protection.

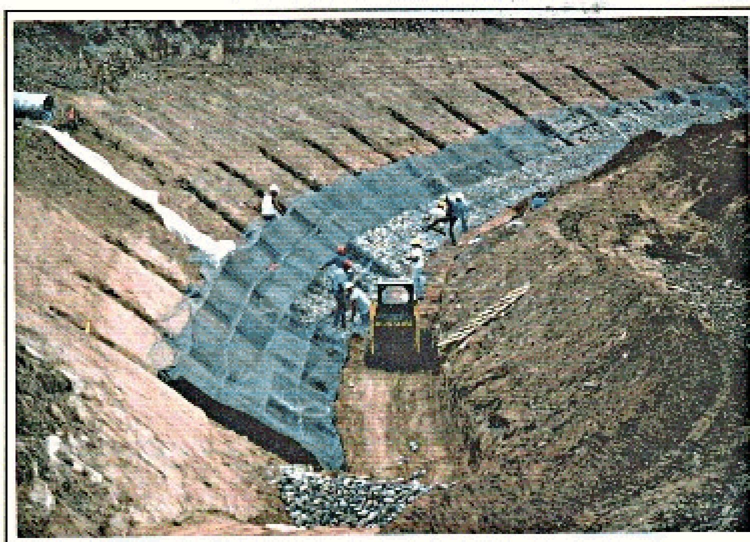

Figure 2. Trenched sideslope toe

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What Didn't Work

When a gabion or rock mattress is undercut, the wire bears the weight of the rockfill, as shown in Fig. 3. Rupture follows.

Figure 3. Eminent rupture

Fig. 4 illustrates a severely undercut wall footing. The bridge pier upstream already has been replaced. The wall will fail as scour continues.

Figure 4. Undercut footing

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The aesthetic rockwork in Fig. 5 appears to defy gravity. Undercut sidewalls must be retrofit with gabion toes.

Figure 5. Suspended rock wall

High velocities in Fig. 6 have pulled rocks from the sidewall.

Figure 6. Sidewall damage by high velocity flow

Fig. 7 illustrates the rotation of sidewall gabions into the channel as the bed degrades.

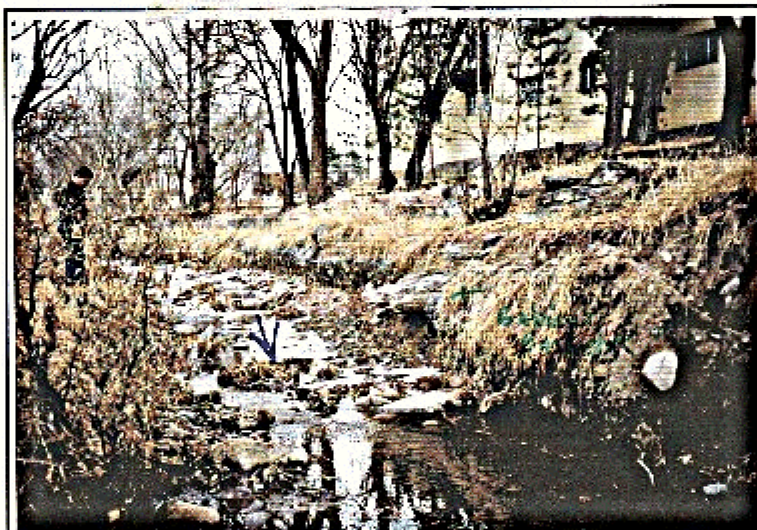

Figure 7. Rotated gabions

Endwalls are vulnerable to erosion. The wall in Fig. 8 needs a tieback.

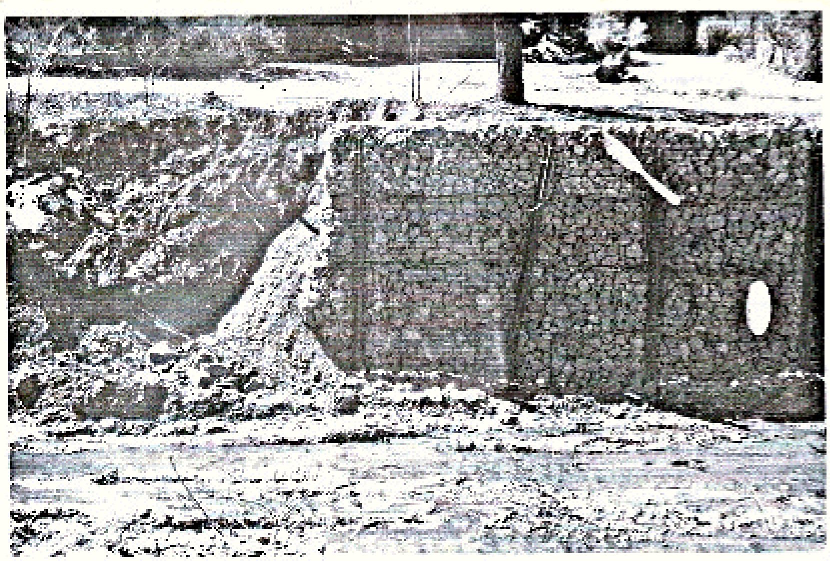

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Figure 8. Exposed endwall

Dumping extra rock at the end of a structure, the Fig. 9 effort, is not a satisfactory endwall termination.

Figure 9. Ineffective rock pile

Grade Control

What Worked

The weir of Fig. 10 has end protection, though it appears to be too surfacial

Figure 10. Weir with end protection

Figs. 11 and 12 show a recent grade control improvement, bearing little resemblance to Phase I and II improvements. This structure resembles a suggested Maccaferri configuration.

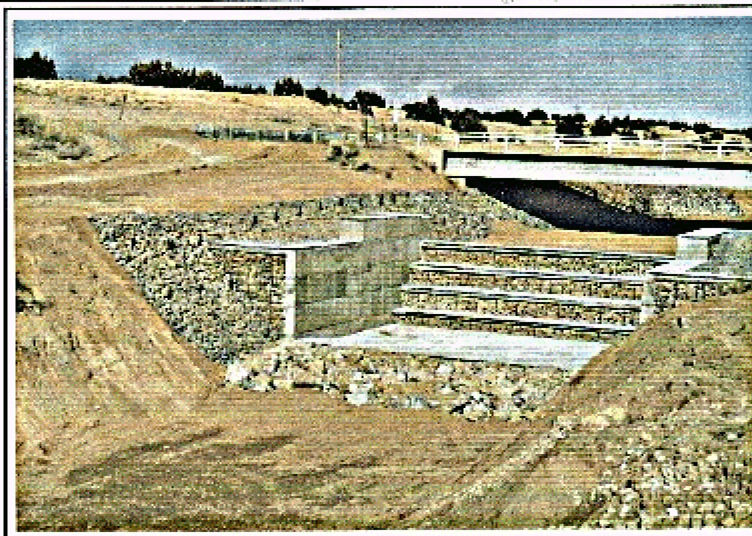

Figure 11. Design for permanence

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Figure 12. Tested by nature

What Didn't Work

While the grade control structure of Figs. 11 and 12 functions well hydraulically, its rock mattress wall is vulnerable to undercutting, as seen in Fig. 13. Specified toe burial was not done.

Figure 13. Potential unraveling

The City intentionally removed grade control structures to increase channel capacity. These structures include culverts replaced by bridges, sills constructed by before the 1960's and rock barriers which may date from the 1930's. Following are several inspection references.

30 July 1974. Several structures lowered or removed as part of City plan to increase capacity.

23 March 1976. Failed rail and gabion protection of sewer line. Scour action now able to progress upstream, the stated objective of the City Engineer.

19 May 1983. The City is still lowering stabilizer structures one rock at a time to increase channel capacity above Old Santa Fe Trail.

February 1996. Most old grade control structures are gone, contributing to the degradation of the low flow channel.

Fig. 14 is a breached check dam. The fitted masonry construction indicates that the construction is old. The channel has since degraded. From the perspective of increasing flood conveyance, this works well, although without much benefit to the community because of inconsistent employment.

Figure 14. Breached check dam

In a more encompassing management consideration, the grade control removal strategy is flawed. Scour knows not where to stop.

Older grade control structures not purposefully breached, such as the rock wall weir in the bottom of Fig. 15, need care. The slab rocks below this structure are undercut.

Figure 15. Undercutting below grade control

Fig. 16 illustrates the consequence of lateral migration around a grade control structure. End protection better than that of Fig. 10 is required.

Figure 16. End erosion

Crossings

What Worked

Visually, Fig. 17 seems an unlikely candidate for the "What Worked" category. The box culvert can arrest a headcut. Until they collapse into the void below, box culverts provide a line of defense.

Figure 17. One way to halt a headcut

Crossings that do not constrict the bed are less likely to induce scour, as shown by the 70-year stability in Fig. 18.

Figure 18. Wide crossing

What Didn't Work

Road crossings in degrading reaches require extensive channel protection. Unfortunately, such protection is does not satisfy all aesthetic tastes. Fig. 19 is the New Mexico State Highway and Transportation Department's solution to Fig. 17.

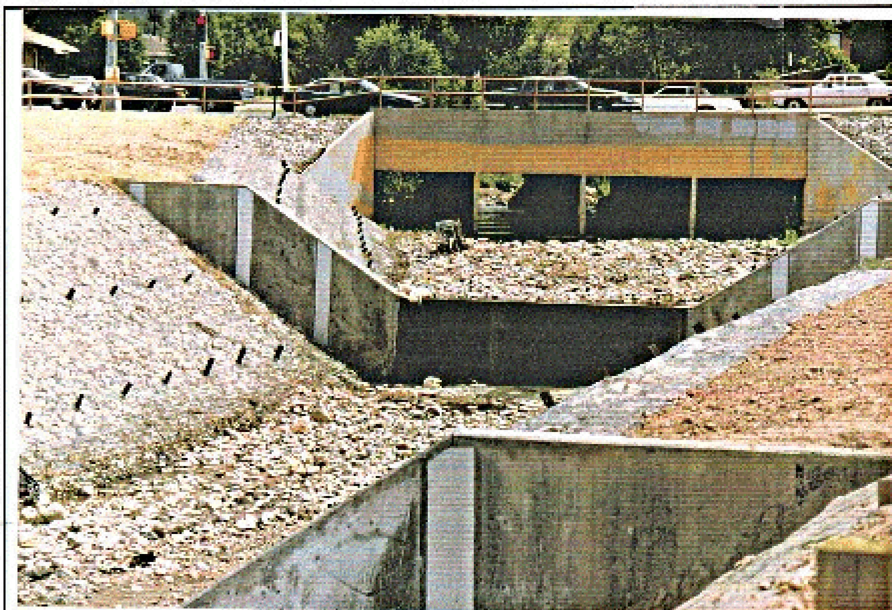

Figure 19. Beauty lies in the eye of the beholder.

Local fixes tend to fail. Figs. 20 and 21 show the beginning and end of a three-tier gabion drop at a crossing.

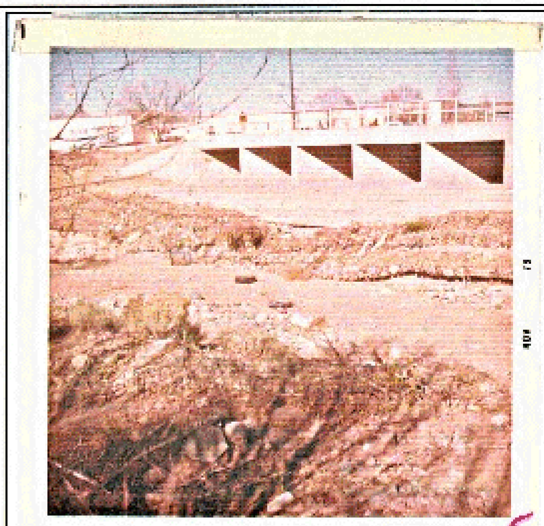

Figure 20. Gabion walls are flexible, ...

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Figure 21. ... but only so far.

Piers allow headcuts to march upstream, as seen in Fig. 22. While concrete casing around an I-beam may provide little structural strength, exposed steel is perceived as unsafe.

Figure 22. Public confidence can erode with the channel bed.

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A deep enough drop structure can protect a crossing from scour. More often, this strategy just moves the problem.

Figure 23. Another local fix

Vegetation

What Worked

Where general scour is absent, vegetation can protect sidewall footings. In Fig. 24, gabions protecting the older rock wall are successfully overgrown with grass.

Figure 24. Toe vegetation

Fig. 22 shows complementary vegetation and siltation covering a gabion toe after 25 years. The buried mesh has probably corroded, which is acceptable if general scour does not occur.

Figure 25. Vegetation and sedimentation

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Trees provide additional wall protection, as illustrated In Fig. 26.

Figure 26. Tree protection

What Didn't Work

Shrubs and saplings rooted within gabions will eventually compromise the structure. The City generally removes the type of growth shown in Fig. 27.

Figure 27. Growth in gabion wall

Fig. 28 shows wall damage by trees left to mature.

Figure 28. Tree damage

Channel overgrowth including several-inch diameter trees, seen in Fig. 29, has not always been removed in a timely manner.

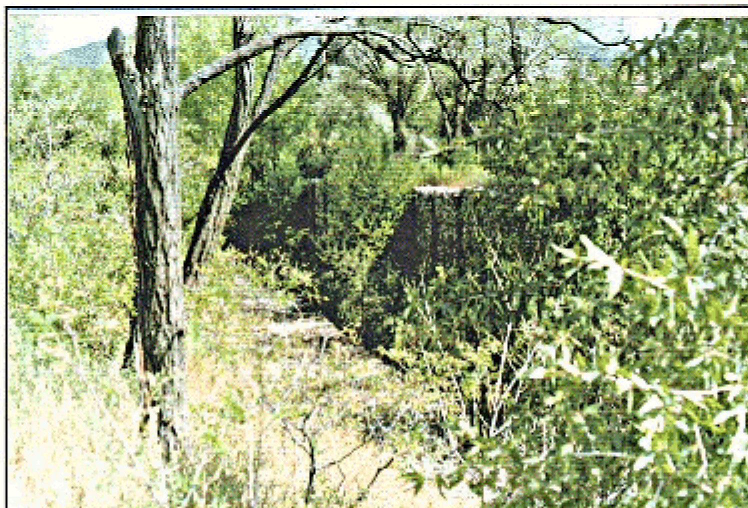

Figure 29. Overgrowth

Figs. 30 and 31 demonstrate an over-reliance on vegetation. Tree trunks can resist wall rotation and tree roots can hold up foundations. When the vegetation dies, however, so will the structure

Figure 30. Tree trunk wall

Figure 31. Root foundation

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Rundowns and Drains

What Worked

The Fig. 32 outfall serves its purpose, despite a crack in the concrete lip.

Figure 32. Stormwater rundown

What Didn't Work

Fig. 33 shows the consequence of a flowpath down the side of a rundown. The initial culprit was more likely local flow than the design discharge from the outfall.

Figure 33. Erosion along side of rundown

The stormwater outfall of Fig. 34 lacked a rundown.

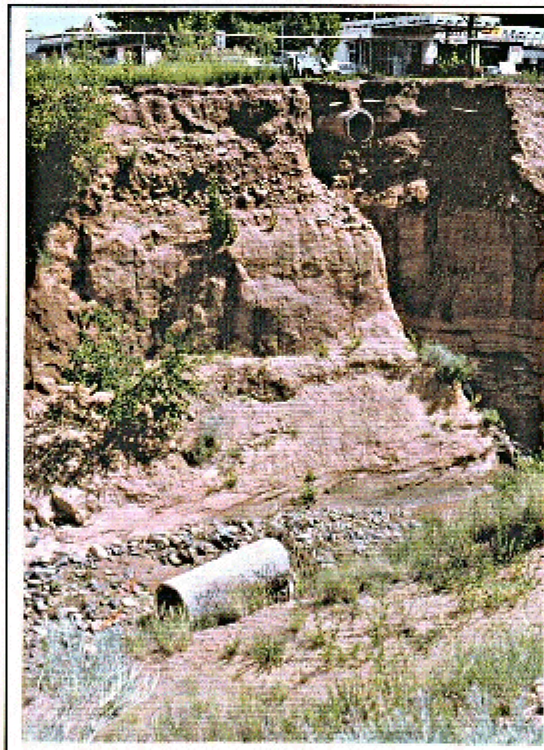

Figure 34. Self-consuming outfall

The source of the drain of Fig. 35 is unknown. A preconstruction survey should have identified the location.

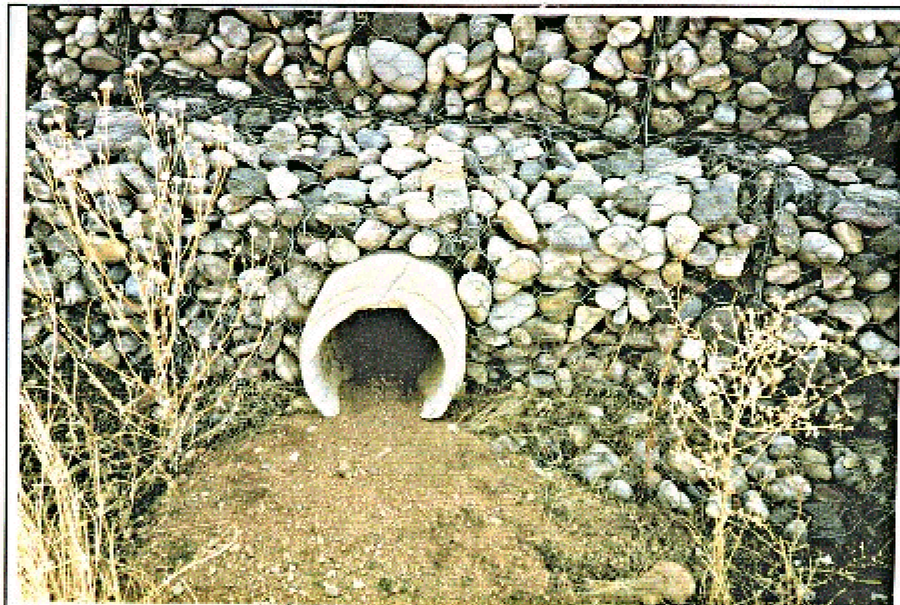

Figure 35. A mystery outlet

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Materials

What Worked

The gabion rockfill has proven to be satisfactory. Riprap wire in reaches with infrequent ephemeral flows looks almost new after 25 years, as seen in Fig. 36

Rails appear to be standard practice. Fig. 37 shows use of a double row.

Figure 36. 25-year gabions in "as built" condition

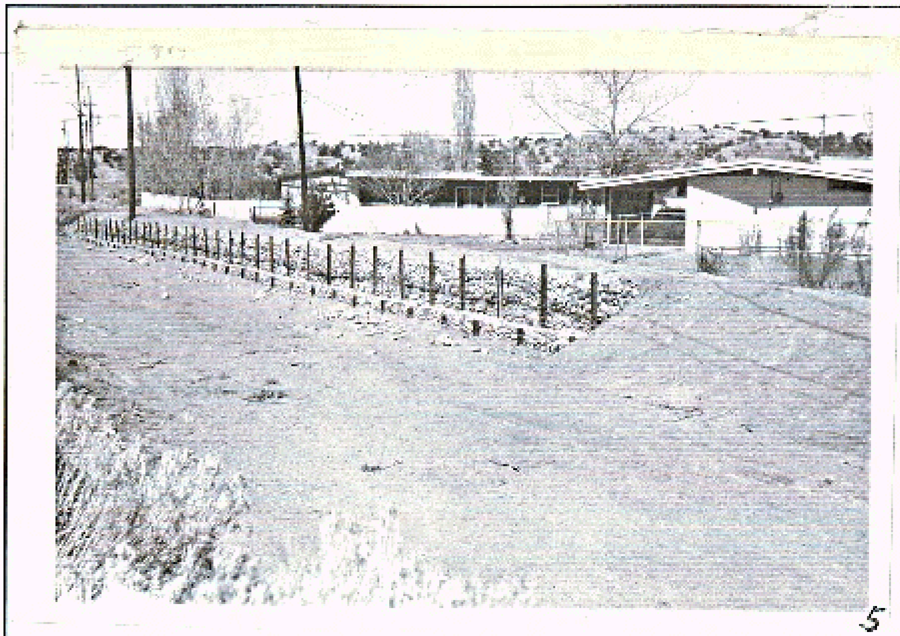

Figure 37. Double rail rows

The gabion wall in Fig. 38 is reinforced by rails in the far section and unreinforced in the near section. Note the bulging in the unreinforced section.

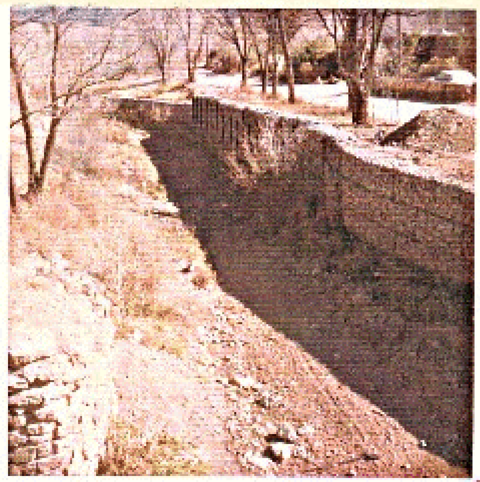

Figure 38. Bulged unreinforced gabions, straight reinforced gabions

What Didn't Work

Gabions in reaches with frequent flow may be approaching the end of their effective life. Galvanized wire corrodes in moist environments. When the channel bed degrades, compromised bottom wires (the term "rotten" is used in the inspections) are exposed. The wire suffers breakage due to abrasion and snagging by debris. Gabions appearing sound from above, particularly if their toes are overgrown, may be effectively open bottomed.

Many rockfill structures appear to push the lower end of the diameter specification. The rocks of Fig. 39 appear to be large gravel.

Figure 39. Gravel fill

Fig. 40 shows the consequence of small and rounded rockfill. When the wire corrodes, the contents escape.

Figure 40. Damaged gabions

Rockfill has washed out of the Fig. 41 gabion.

Figure 41. Lost rockfill

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While grouting slows some undercutting, the practice appears to be stop-gap at best. Grouting in Figs. 42 and 43 is undercut.

Figure 42. Grouting failure

Figure 43. Grouting failure

Abrasive sediment-laden flow can consume concrete. Fig 44 shows two years worth of wear.

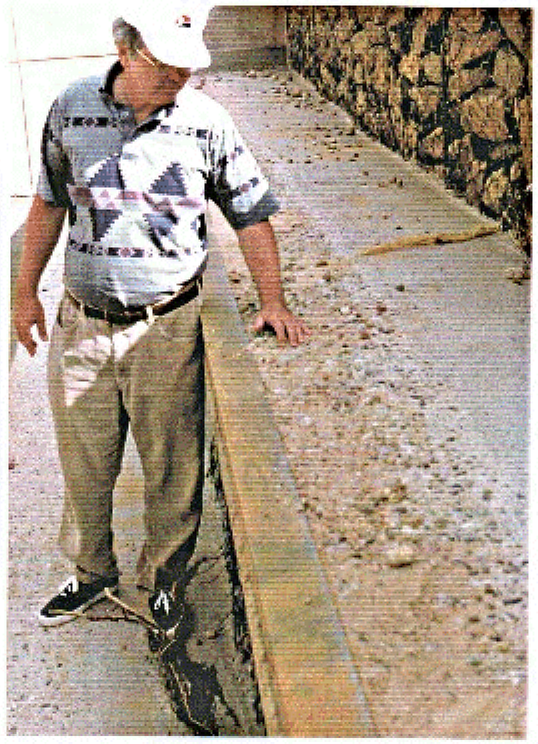


Figure 44. Worn concrete

Five years of Santa Fe ultraviolet light cannot degrade the "degradable" plastic mesh used for revegetation in Fig. 45.

Figure 45. Petrochemical groundcover

Assessment

What Worked

The record of channel change is adequate. The Corps inspection record provides a continuous history through the years of great change, a starting point for further planning.

What Didn't Work

As late as 1988, annual inspection reporting used the inappropriate Albuquerque District Levee Inspection form. The inspection format should be specific to the project. An improved example is the form developed for County Road 62. Good and bad inspection format examples are attached.

Gabions are not perpetual, an understandable oversight in Maccaferri literature. Corps maintenance manuals should quantify the maintenance effort based on experience.

Lack of consensus regarding cause leads to local, short-term, and inefficient engineering. Understanding may incorporate several factors and may vary by location. Following are some suggested factors for the scour history:

1. Parkway channalization (1968-71) reduced channel width and overbank storage area.
2. The City removed grade control structures
3. Paving and urbanization led to low permeability of compacted soil. The time of concentration decreased and the volume of runoff increased.
4. Exposure of soft sandstone with conglomerate lenses led to incising, narrowing, and increased the unit discharge.
5. Gravel mining initiated headcutting.
6. Upstream dams and water supply features cut off sediment sources.
7. Deposition in Arroyo Mascaras decreased the sediment supply.

Lack of scientific data stymies solutions. The Committee on Channel Stabilization (1990) proposed a plan for the data. Much of the data needs only to be compiled and unified. No authority, unfortunately, has carried through with the effort. Without a systematic specification of sediment sources, transport, and the geomorphic adjustment, it seems improbable that engineered solutions will substantially improve.

Lack of a sediment process model hinders solutions. The model need not necessarily be a computerized HEC-6 or a HEC-RAS extension. It could be a simplified set of scientific relationships that govern channel behavior. The science is available.

In addressing jurisdictional-perceived problems, the Corps, City of Santa Fe, Santa Fe County, and the New Mexico State Highway and Transportation Department are prone to autonomous solutions. The river remains unaware of the distinctions.

Project aesthetics loom central to decision making, seemingly more so than flood control. The public desires a "natural" waterway while hydrology and geomorphology ceased to be "natural" decades ago. Constituent politics has led to channel satisfying neither conveyance or beauty.

Inspection Note Summary

Positive general comments predominate in many inspection reports, *e.g.*, "Good condition", "Satisfactory", etc. The attached spreadsheet tabulates the problems noted, in most cases directed toward local irregularities.

Sewer Line Crossing

Introduction

A sewer line crosses the Santa Fe River between St. Francis Drive and the Arroyo Mascaras confluence. Fig. 1 shows the 1981 topography. The sewer line crossing is Site 5 of the Corps Santa Fe River Emergency Flood Control Project, Phase 1 and midpoint in the 1992 channel lining by others below St. Francis Drive.

Santa Fe River discharge is approximately 4800 cfs for the 100-year event, 3340 cfs for the 50-year event, 2320 cfs for the 25-year event and 2100 cfs for the 15-year event. Fig. 2 shows the 100-year event flood plain for current conditions.

The sewer line crossing is only a small part of Santa Fe River sediment control issues. Corps involvement is only as a small portion of its Phase I improvements. In an illustrative sense, however, the sewer line case study is pertinent to similar engineering challenges. Corps records document dramatic channel scour and efforts to control that degradation.

This report contains photographs from Corps annual inspections. Synopsized inspection and photograph notes are shaded.

Pre-1970

The sewer line was at channel grade, encased in a 3x3-foot concrete jacket. The channel reach was historically held in equilibrium by downstream grade control structures. The grade control structures had deteriorated and/or been removed by the City to increase flood conveyance capacity.

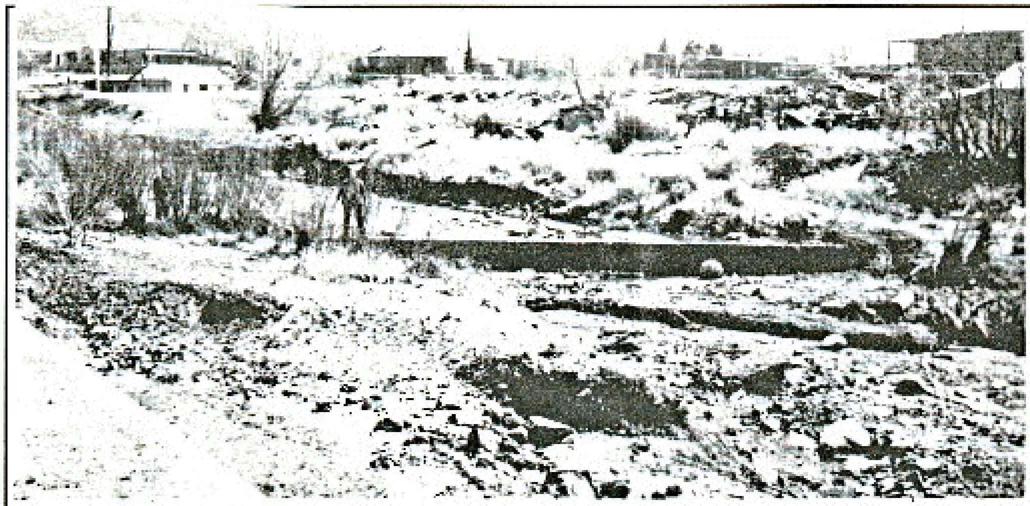


Photo 1. 20 August 1969

1970's

Site 5 was one of 10 channel and/or bank stabilization locations for the Santa Fe River Emergency Flood Control Project, Phase I. This was the only Corps construction at the sewer line crossing.

TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM VERTICAL AERIAL PHOTOGRAPHY EXPOSED IN A WILD HEERBRUGG RC10, LENS SERIAL NO. SAg II 2004, ON NOVEMBER 18, 1981.

SCALE: 1"=200' (1:2400)
CONTOUR INTERVAL: 1', 2' AND 5'
VERTICAL DATUM: MEAN SEA LEVEL DATUM OF 1929

Figure 1. Site topography, 1981

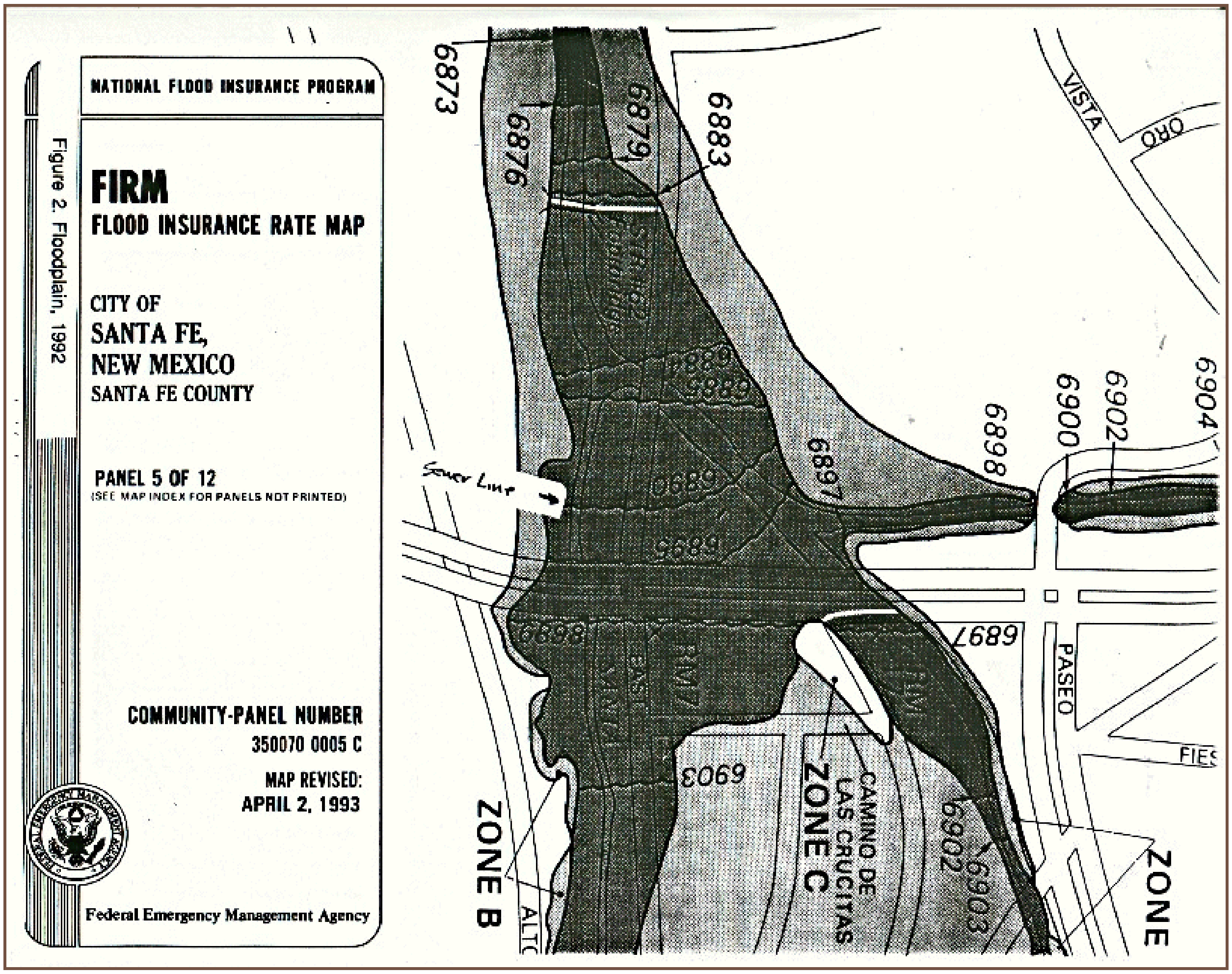


Figure 2. Floodplain, 1992

Local scour below St. Francis Drive was presumably identified in Phase I formulation, but there is no record of the prior degradational history.

Gabions and rails were added to form a 3-foot drop at the jacket. Site 5 specifications included:

84-foot row of 7 gabion baskets, L = 12 feet, H = 3 feet, W = 1 foot, 6 inches*
Maccaferri or Bekaert brand gabions, government furnished
Type F units, 3 C.Y. capacity*, 3 diaphragms
3.25 x 4.5 inch mesh, 3-mm heavily galvanized wire
4-12 inch field or rough unhewn quarry stone
60 to 90 pound rails, 10-foot height, 6 feet on center*
No filter fabric or graded backfill

* Slightly varied dimensions if metric gabions were employed.

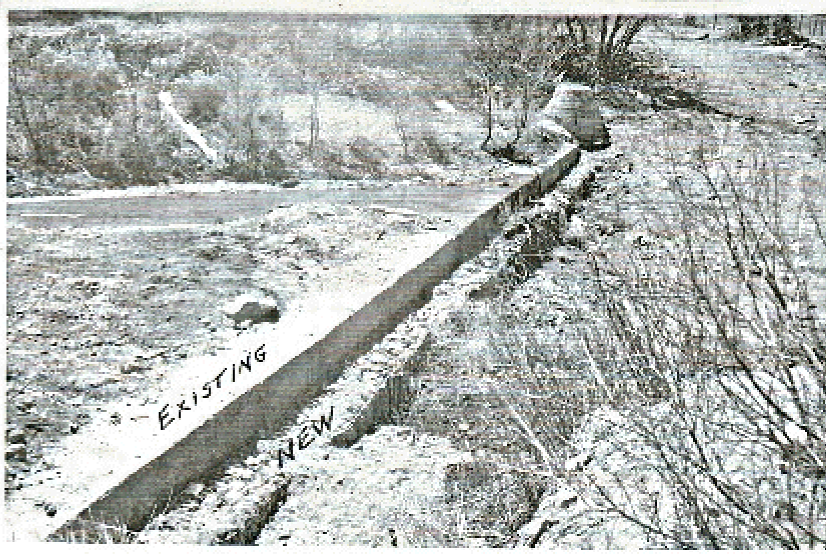


Photo 2. 2 April 1970

Design calculations and criteria are not archived in the inspection reports. Fig. 3 is the design drawing.

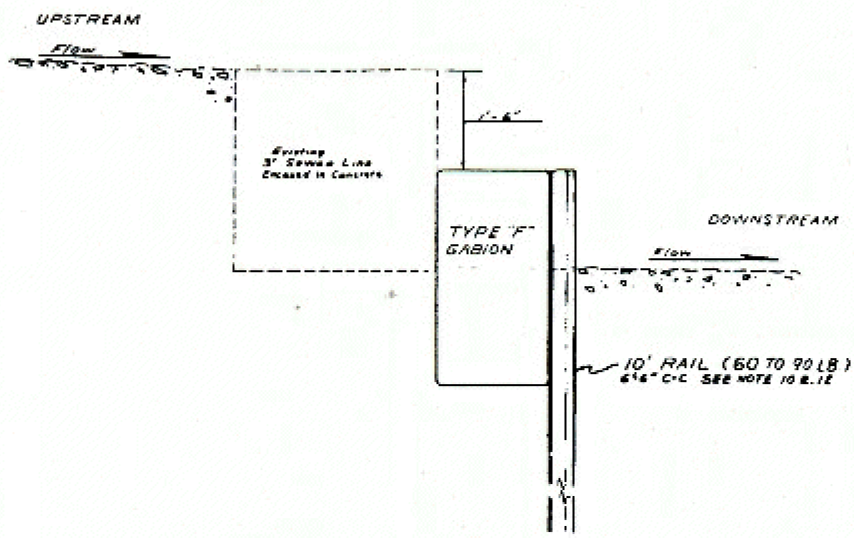


Figure 3. Phase I improvements

Phase I design is marginal. Maccaferri literature weir design commonly includes:

- Filter fabric
- At least one basket depth below downstream grade or a horizontal toe mattress
- End protection
- 3-foot square units where gabions interface with concrete

Figs. 4 and 5 are from Maccaferri literature.

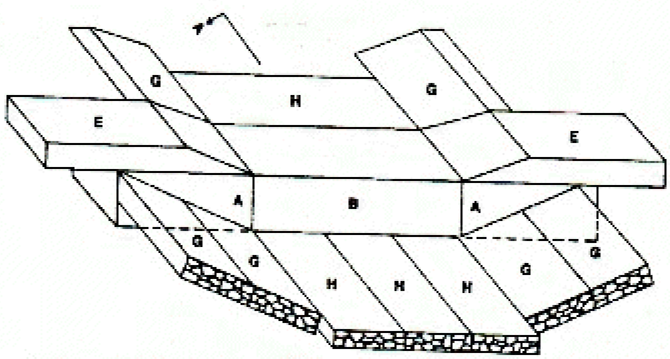


Figure 4. Illustrative Maccaferri 3-foot weir

Sewer Line Crossing 3

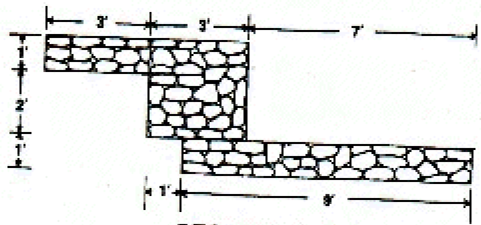


Figure 5. Illustrative Maccaferri cross-section, 3 foot drop

Maccaferri literature does not incorporate structural rails.

Despite Phase I, the channel continued to erode. Fig. 6 traces the subsequent degradation history.

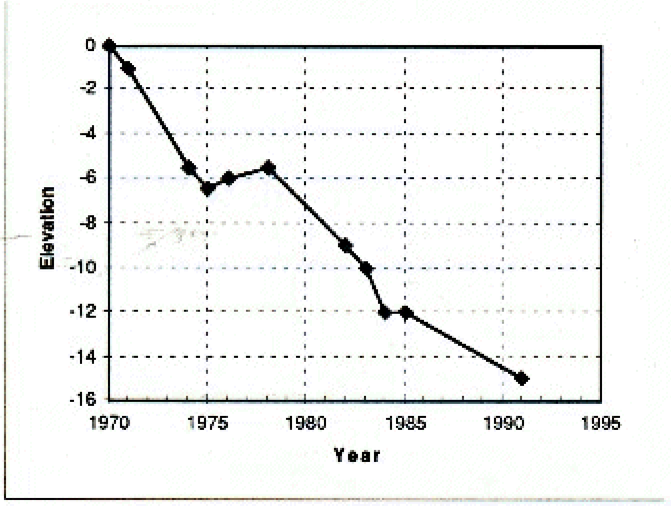


Figure 6. Channel elevation at sewer line crossing, 1970 = 0 feet

Persistent erosion may have been due to both plunge from the drop and headcut progression from general scour. As the Phase I toe was undermined, the gabion baskets sagged, rotated and ruptured.

There is no indication of lateral flow around the gabion ends, a failure mechanism seen elsewhere. The sewer line itself may have provided hardened abutments.

Four to 8-inch gabion rock fill is stable at 17.6 fps channel velocity; the gabion deforms at 23.2 fps. Respective velocities for 5 to 10-inch rocks are 19.5 and 24.3 fps. It is improbable that these velocities were exceeded.

Vertical rails provide little resistance to structural rotation and no protection against undercutting. After the baskets begin to settle and break apart, the rails remained to collect debris, plastic bag beacons to failed intervention.

Sewer Line Crossing 4

Had everything else functioned well, Phase I was doomed by toe erosion.

The 1971 Phase II Corps improvements included gabions at the Arroyo Mascaras confluence. It may have been thought that this would stabilize the upstream bed. As the Phase II gabion toe promptly failed and the baskets collapsed, Phase II did not benefit the sewer line site.

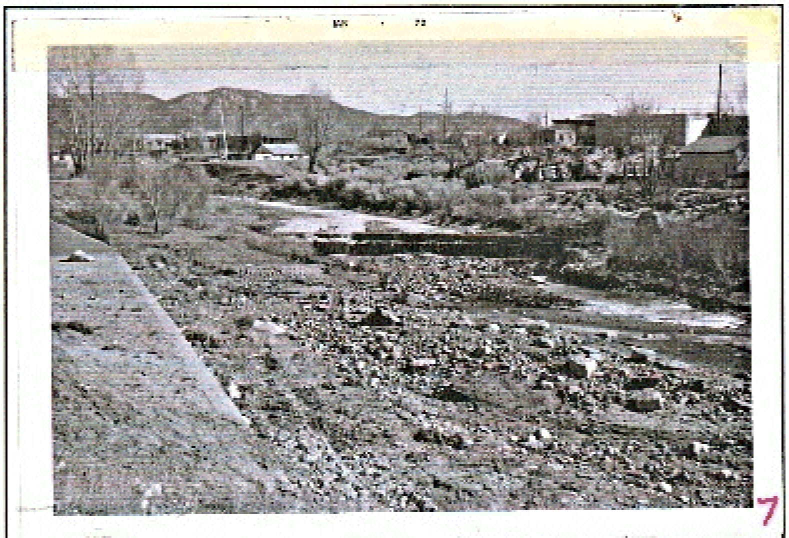


Photo 3. 19 January 1972

Inspection Report, 19 January 1972
Photo Note: River has scoured about 1 foot compared to 2 April 70.

Photo 4. 30 July 1974

Inspection Report, 30 July 1974
Photo Note: Single row of rail-braced gabions protecting sewer line. Scour 2 or 3 feet below bottom of gabions, but they have been held in place by rails and are not damaged

Sewer Line Crossing 5

Photo 5. 20 September 1974

Photo 6. 30 April 1975

Inspection Report, 30 April 1975

At the sewer line crossing Santa Fe River, the gabions placed to prevent undercutting of the sewer line are themselves undercut, up to 3 or 4 feet. They are now held only by the driven steel rails, and are beginning to slump and break up.

Photo Note: Vertical rails have caught a lot of trash and partly obscure the row of gabions.

In 1976, the drop-structure solution was abandoned. Others added a concrete pier beneath the jacket, allowing flow to pass below the pipe.

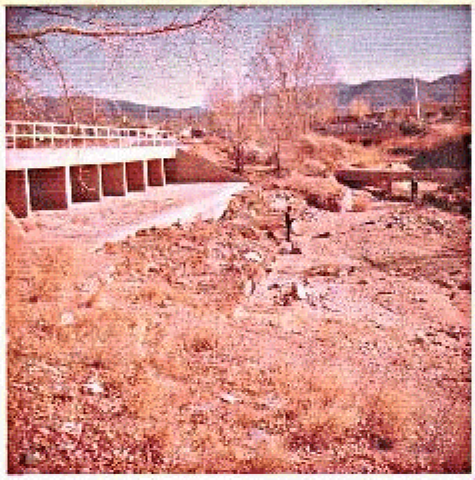


Photo 7. 23 November 1976

Inspection Report, 23 November 1976

Scour action continued in 1976, causing total failure and removal of much of the rail-and gabion structure supporting the downstream side of a concrete-encased sewer line. Scour action is now able to progress upstream, which is the stated objective of the City Engineer. The sewer line is scheduled for replacement this winter by a steel free span pipe a few inches higher and a few feet downstream.

Photo Notes: River deepened about 6 feet in 5 years primarily due to the removal of check dams and other artificial grade controls by the City. The gabion structure collapsed due to undercutting. Bed scouring continuing. Structure reported as severely damaged in 1975.

Photo 8. 23 November 1976

In 1977 the concrete jacket was replaced by steel span. One center pier is mentioned in the inspection notes, though 1978 photos show two. The second pier may have been added or the earlier report may be in error.

Fig. 6's apparent recovery in the mid-1970's probably reflects an error in a relative observation. No inspection notes suggest that the scour reversed.

Sewer Line Crossing 7

Inspection Report, 14 March 1978
The sewer main crossing, formerly jacketed in concrete at invert grade, was replaced in 1977 by a steel pipe free span with one center post. The pipe is at the original grade but the Santa Fe River has scoured to a level 4 or 5 feet beneath it. This pipe is likely to be swept away in event of a trash-laden major flood.

The piers may have been insufficiently deep for an ultimate scour condition. The exposed sewer line impeded flood flow.

1980's

The piers provided inexpensive short term reprise for a municipal infrastructure problem. General degradation of the channel reach, however, necessitated a more-enduring resolution.

Photo 9. 15 March 1982

Inspection Report, 15 March 1982
The scoured channel now is a full eight feet beneath the sewer line spanning the Santa Fe River, constituting a deepening by 4 feet in the past 4 years.
Photo Note: Fully 8 foot clearance under sewer.

Sewer Line Crossing 8

Photo 10. 19 May 1983

Inspection Report, 19 May 1983
Photo Note: There seems to be some cutting in channel.

Inspection Report, 24 April 1984. The clearance beneath the sewer pipe span now is a full eleven feet. In 1975 the Santa Fe River was flowing over the sewer line (then encased in concrete).

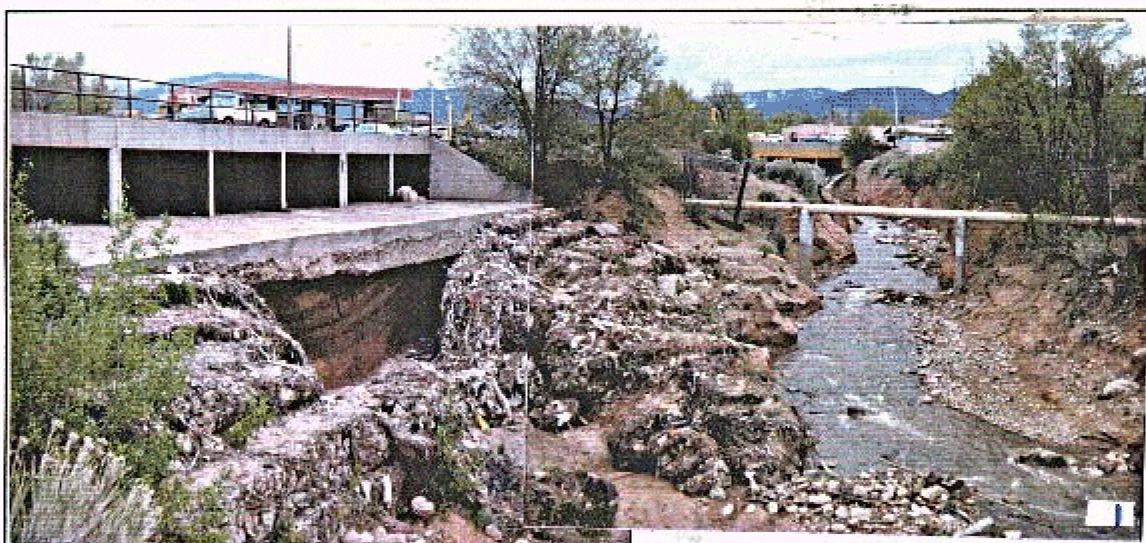


Photo 11. 25 April 1985

Sewer Line Crossing 9

Inspection Report, 25 April 1985
Photo Note: River grade was 12 feet higher in 1970. Flowed over sewer pipe.

Photo 12. 8 March 1988

Photo 13. 22 January 1989

Sewer Line Crossing 10

1990's

Degradation continued to the point where St. Francis Drive was endangered.

Photo 14. May 1991

Photo 15. May 1991

Sewer Line Crossing 11

Photo 16. May 1991

Photo 17. May 1991

Sewer Line Crossing 12

Photo 18. May 1991

Photo 19. May 1991

Sewer Line Crossing 13

Photo 20. May 1991

Photo 21. May 1991

The reach from St. Francis Drive to the Arroyo Mascaras confluence was lined in 1992 in conjunction with New Mexico State Highway and Transportation Department work. Channel improvements included gabions and rock mattresses, concrete drop structures, and extensive grouting. The sewer line piers were removed, allowing the pipe to freely span the channel.

Design drawings are attached to illustrate the engineering complexity of improvements. The concrete drop structure toe extends 2 feet below the downstream riprap. This cover is of concern, given the river's bleak history of stationary bottom gabions. H-Piles, 6 feet o/c, may bear the structural load, but will do nothing to inhibit undercutting, should the gabions fail.

The drawings specify grouting the channel bottom only. As-built, the sidewalls are grouted as well, reducing any hope the structure ever had for attractiveness.

Photo 22. 14 August 1992

Inspection Report, 25 September 1992
Site V has been replaced by the City with 3 large drop structures and wire wrapped rock streambank lining.

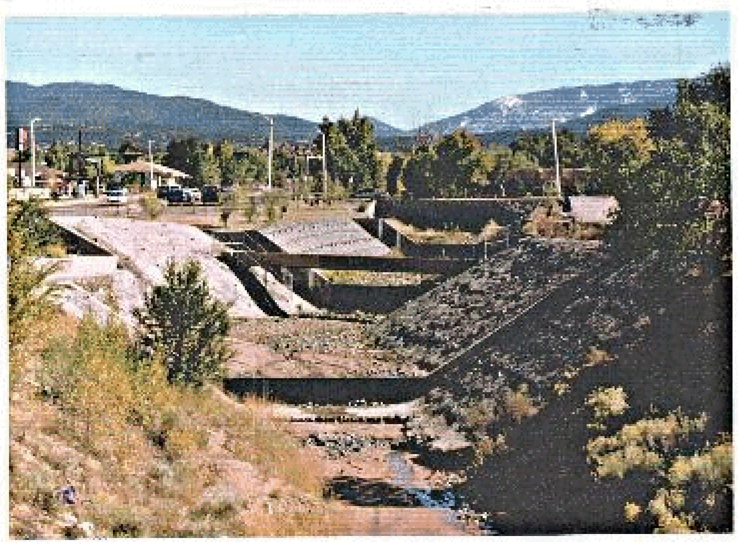


Photo 23. August 1994

Sewer Line Crossing 15

Photo 24. 30 July 95

Photo 25. 26 June 1997

Sewer Line Crossing 16

Photo 26. 26 June 1997

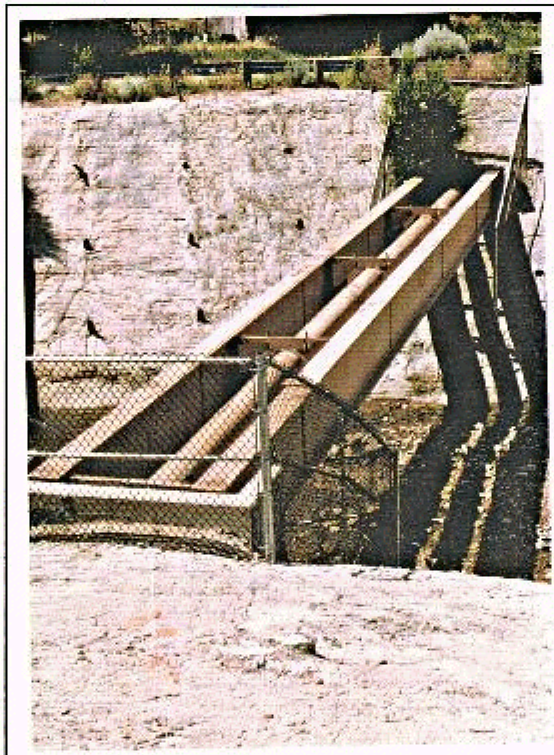


Photo 27. 26 June 1997

FEMA mapping indicates that the pipe is below the 100-year water surface. Flood flow overtops St. Francis Drive and reenters the channel in this reach. The sewer line is but a minuscule aspect of Santa Fe's vulnerability to probable flood events. I-beams bracketing the sewer line may shield the line from debris impact.

The 1992 improvements are unaesthetic by Santa Fe standards. A mural on a grouted sideslope does not compensate for the blight. The structure, in prime view from St. Francis Drive, serves as rallying point for opponents of channel lining elsewhere. The Corps is perceptually incriminated by a non-Corps design.

Sewer Line Crossing 17

Future

The 1992 improvements appear to be structurally sound. Nothing else has lasted five years in that location. As the river lacks an encompassing sediment assessment, however, there is no assurance as to the long-term adequacy of the work.

Flooding may destroy much of Santa Fe's riverine improvements. Many Santa Fe River structures are sized for less than the 100-year event. By virtue of its rock tonnage, the 1992 work will likely be among the last to leave. Catastrophe aside, however, vulnerability remains from the same persistent erosion that conquered Phase I.

Active scour, evidenced by minor headcutting, is apparent downstream of the 1992 improvements. Downstream grade control structures are under attack. Another cycle of general scour may occur. To preclude another episode of headcutting (as opposed to battling a hole at the toe of the 1992 project) additional downstream protection may someday be required.

Recommendations

1. Monitor the downstream reach. Corps inspection responsibility seems vague, given the abandonment of the Corps' Phase I and II structures, but some agency needs to be persistent.
2. Determine the long-term sediment tendencies. Again, this is not necessarily a Corps task. Multiple agencies should be involved.
3. Review the 1992 design in light of long-term tendencies. Remedy deficiencies, particularly any associated with the toe.

Sheet1

	Inspection Date	Stabilization Structures	Local Deposition	Vegetation	Drains and Rundowns	General Scour	Misc.
Project	**Emergency Flood Control Work, Mascaras Arroyo**						
Contract	DA-29-005 CIVENG-59-9						
Final Inspection	1959						
Note:	Near old City Baseball Park. Project folder not provided. Reference from 70-0001 folder.						
Project	**Santa Fe Emergency Flood Control Project, Phase I**						
Contract	DACW47-70-C-0001						
Final Inspection	2-Apr-70						
Project	**Santa Fe Emergency Flood Control Project, Phase II**						
Contract	DACW47-71-C-0011						
Final Inspection	17-Mar-71						
Note:	As these three projects are similar in location, design and function, inspections are combined. Most comments refer to particular sites.						
	18-Sep-70	Sand washing through	Sand in steel culvert.	Weeds.			
	18-Mar-71	Sand washing through	Sand in CBC	Bed overgrowth.			Power pole anchors in channel.
	17-Sep-71	Sand washing through	Sand in CBC	Bed overgrowth.			Power pole anchors in channel.
	19-Jan-72	59-9 "once again" very good condition. 70-0001 and 71-0011 Excellent	Many toe protection and invert control structures wholly buried.			Modest flood in 71. 1 ft. scour in lower part of project.	
	20-Mar-72	Sand washing through	Sand in CBC	Some bed overgrowth.			Power pole anchors catching debris
	30-Jul-74	Wall sections excellent. Undercut units should adjust.	Many toes buried.	Cluttered, but not problem.		Long, high stages of 1973. Pronounced scour.	

Page 1

Sheet1

	Inspection Date	Stabilization Structures	Local Deposition	Vegetation	Drains and Rundowns	General Scour	Misc.
	30-Apr-75	As built along Mascaras. Undercut at confluence, but not shifted or ruptured. Failing at sewer line.		Tree limbs thrown in channel. 15 ft. elms in mud bank.		Continued below Mascaras. 3 or 4 ft. scour beneath sewer. Otherwise unchanged.	
	23-Nov-76	One broken basket upstream. Box culvert apron undercut and collapse. Total failure at sewer line.		Trees in mud bank.		Continued below Mascaras.	
	14-Mar-78	Some broken baskets. Three unit sill collapsed beyond repair.	Many toes buried.	Tree thicket to be cleared.		Light 77 runoff. Stable upper reaches. Gradual continued scour in lower reach. 4 or 5 ft. scour beneath sewer.	Failing unit deflecting flow into masonry wall.
	15-Mar-82	Gabion hole filled with concrete. Upstream ends vulnerable to scour. Collapsed sill holding together.		Elms form a channel wall. 4 in. elms growing through gabions anchor and protect.		Long 79 and 80 runoffs. 1-3 ft. upstream scour, 8 ft. scour beneath sewer.	Pothole under wall induced by failed old grade control structure.
	19-May-83	Upstream ends vulnerable to scour. Collapsed sill holding together.		Continued clearing.		1 ft. additional scour.	
	19-Jun-84	Wire near end of life. Upstream ends vulnerable to scour. Collapsed sill provides no protection.		5 in. elms through gabions.		11 ft. beneath sewer.	
	25-Apr-85	Beyond repair. Undercut apron. Rotted.	Many toes covered.	5-10 in. trees form channel wall. Clean bed.		High flows. Stable.	

Page 2

Sheet1

	Inspection Date	Stabilization Structures	Local Deposition	Vegetation	Drains and Rundowns	General Scour	Misc.
	8-Mar-88	6-7 ft. cut beneath culvert. Exposed rebar. Broken wires.		Tree walls. Beneficial vegetation in gabions. Excellent tree cleaning.			
	12-Sep-90	Deteriorating gabions will be undercut.		Tree walls. Beneficial vegetation in gabions. Excellent tree cleaning.			
	25-Sep-92	Undercut gabions and concrete. Settled and broken baskets. Replacement at St. Francis.	One site completely buried.		Gabion backfill washed out.		
	2-Jan-96	Once-buried basket wire severely damaged or rusted where now exposed. Failed wall. Undercutting. Damaged or destroyed grade control structures.			Slumped or bulged wall due to local inflows at random locations.	2 ft. since the 70's above S. Francis. Minor undercutting along upper reach walls.	

Page 3

Sheet1

	Inspection Date	Stabilization Structures	Local Deposition	Vegetation	Drains and Rundowns	General Scour	Misc.
Project	**Flood Protection of Capshaw Junior High School**						
Contract	DACW47-79-C-0064						
Final Inspection	5-Sep-79						
	22-Mar-82	Wall at 1:3, not 1:2. Less resistance to failure.	Plugged RCP outlet.	Sparse, but good grass		Downstream headcut heading for project.	
	19-May-83						
Project	**Streambank Protection on Alameda Street**						
Contract	DACW47-91-C-0007						
Final Inspection	25-Jul-91						
	2-Feb-96	Broken baskets and missing rocks. Undercut apron not settling. Erosion at sides.		Woody growth in gabions	Cracked and undercut.		
Project	**Emergency Bank Protection, County Road 62 Bridge**						
Contract	DACW47-94-C-0024						
Final Inspection	27-Jan-95						

Page 4

U.S. Army Corps of Engineers
ALBUQUERQUE DISTRICT
NON-FEDERAL LEVEE MAINTENANCE
LEVEE INSPECTION

ASSURANCE NO.	APPLICANT City of Santa Fe	DATE OF INSPECTION
LENGTH 5 miles (approx)	LEVEE Santa Fe River (Channel)	8 March 1988

	Rating A	Rating M	Rating U	Remarks
Inspector/Inspection Team				
A. Levee Embankment				None
1. Levee Depressions				
2. Levee Surface Erosion				
3. Slope Stability				
4. Animals Burrows				
5. Levee Growth				
6. Encroachments				
B. Channel/Floodway				None
1. Riprap/Revetment Protection				
a. Riverward Levee Slope				
b. Toe				
c. Channel Bank				
2. Channel/Floodway capacity				
C. Structures		X		Gabions along toe of wall, many locations.
1. Movement of Concrete				
a. Floodwalls		X		Gabions wires have rusted through, in some locations
b. Headwalls				
c. Aprons				
2. Concrete Surfaces				None
3. Structural Foundations		X		(see gabions, above)
4. Culverts				None
a. No breaks, holes e.g.				
b. Negligible Debris				
5. Gates				None
Other Inspection Data Check Items: Levee, Drainage Structures, Floodwall, Closure Structures, Channels and Floodway, Relief Wells, Piezometers and Road Surfacing				
Total: A, M or U		X		

ADDITIONAL REMARKS:

Signature: Frank Collins

An inappropriate inspection form

COUNTY ROAD 62 BRIDGE AT THE SANTA FE RIVER, BANK PROTECTION PROJECT
SANTA FE COUNTY, NEW MEXICO

ANNUAL INSPECTION AND REPORT CHECKLIST

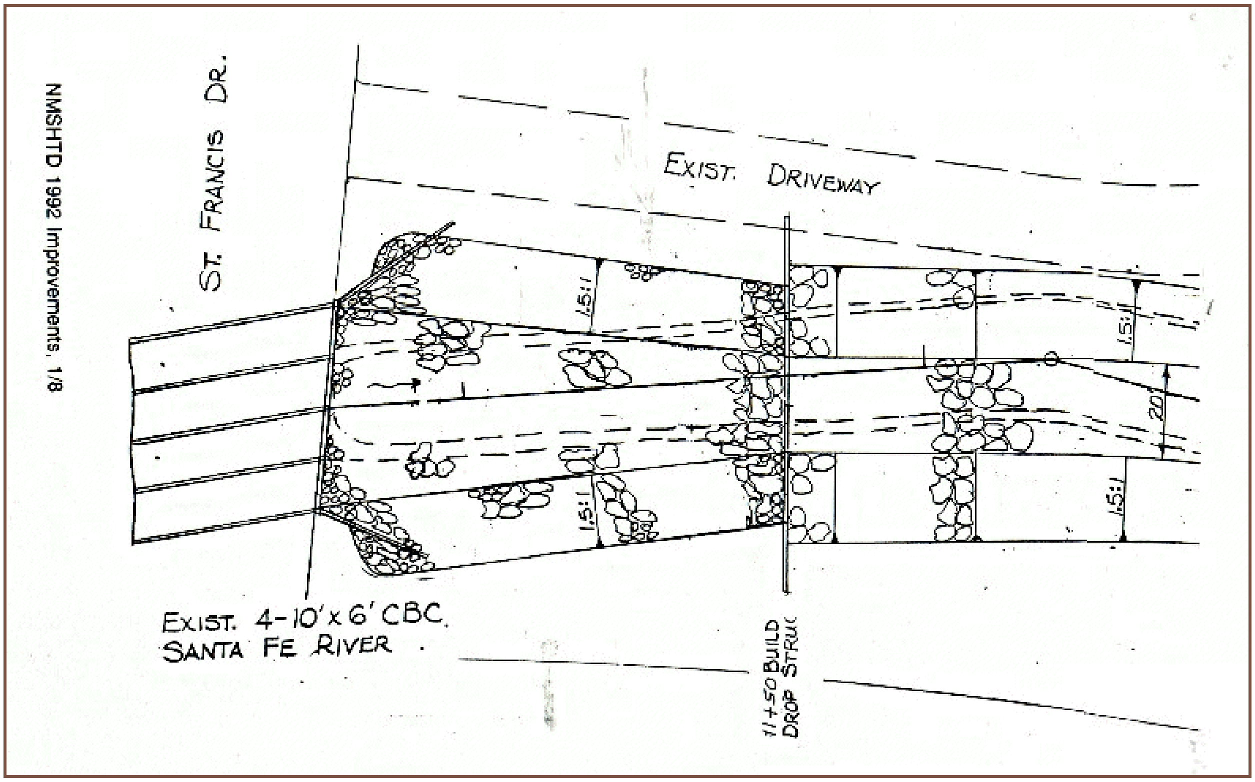
Inspected by:____________________

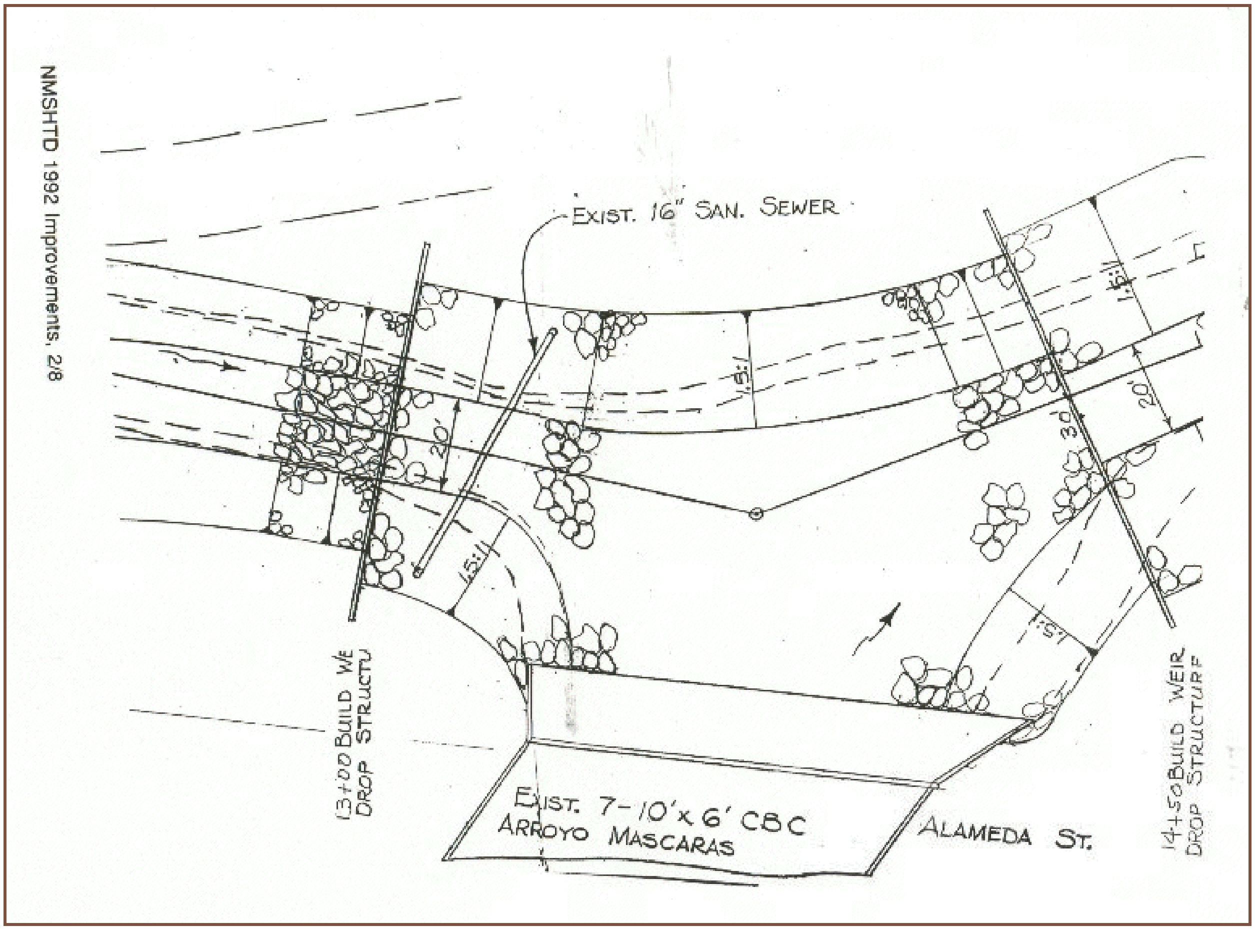
Title:____________________

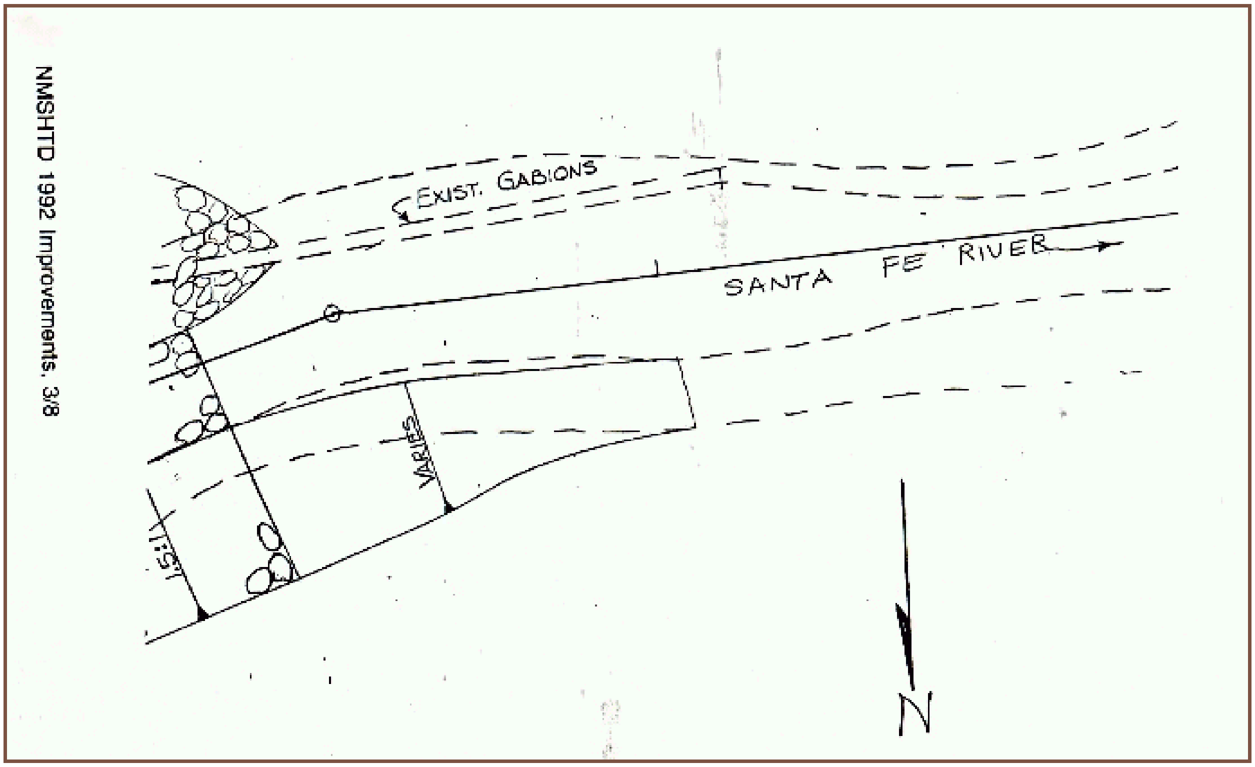
Date:____________________

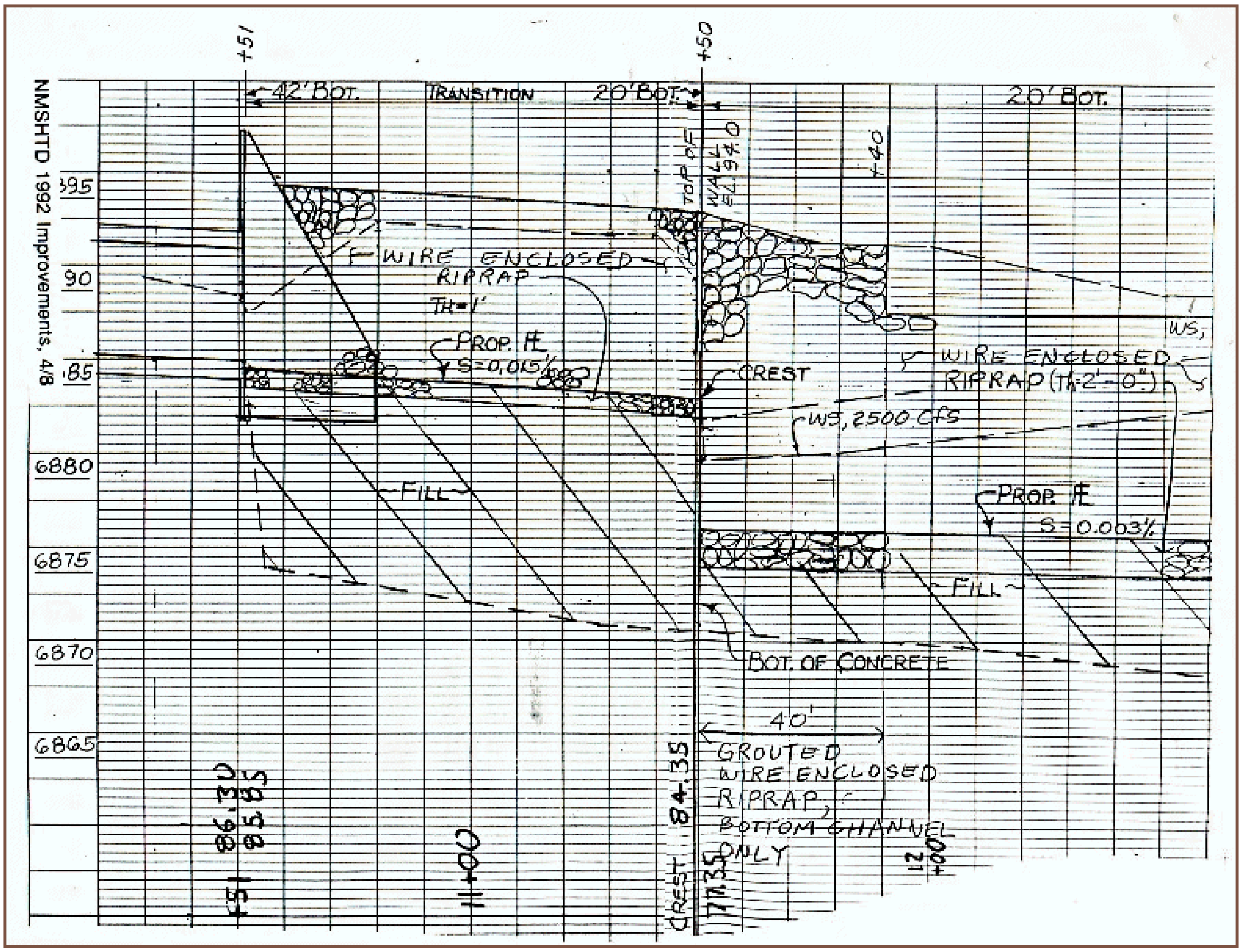
Item No.	Description	Condition	Recommended Maintenance
1.	Wire Wrapped Riprap Blanket		
2.	Gabion Drop Structure Concrete and Exposed wire		
3.	Concrete Capping		
4.	Debris		
5.	End protection for flanking		
6.	Settlement		
7.	Wire condition (general)		
8.	Encroachments		
9.	Scour or undermining		

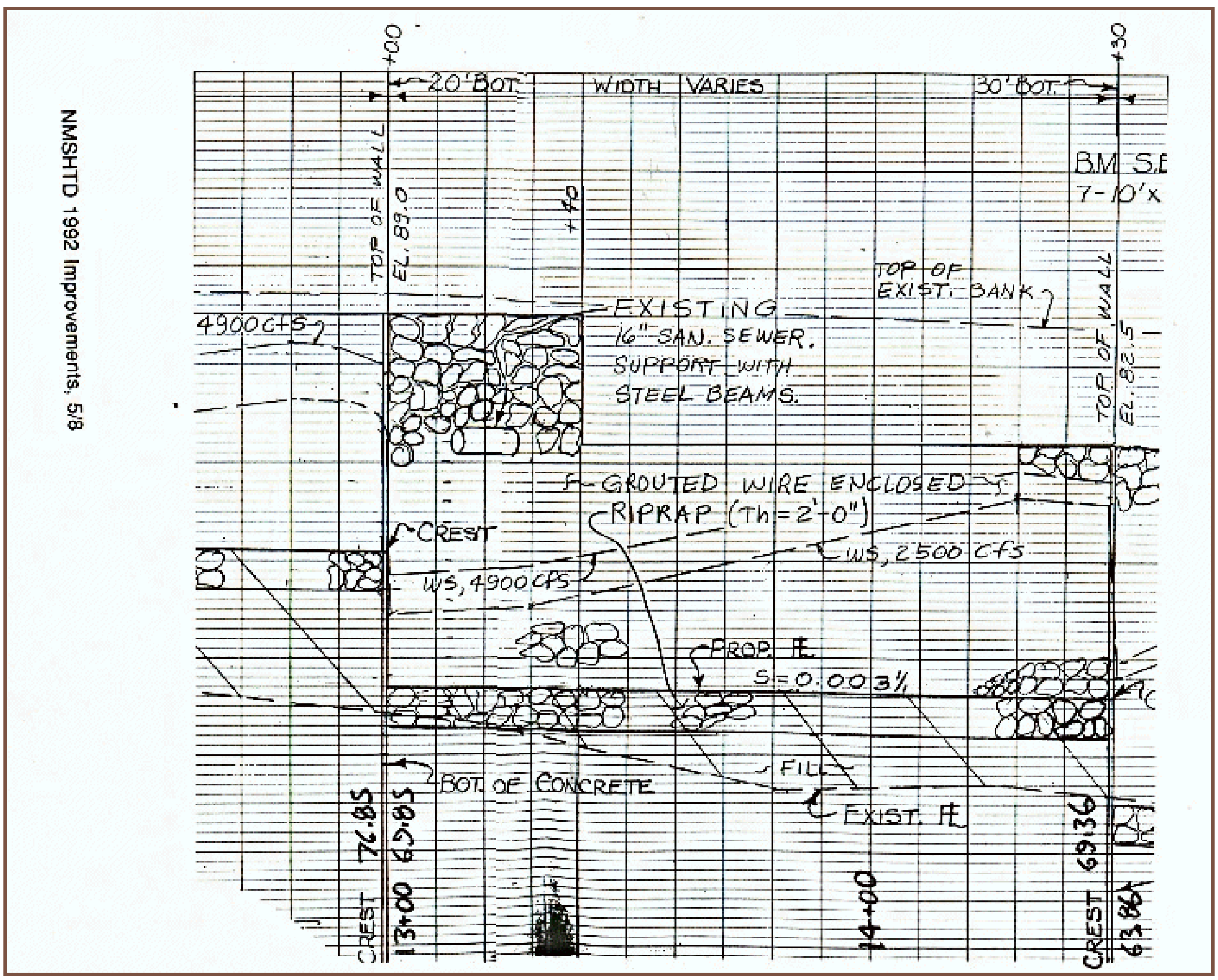
An improved inspection form

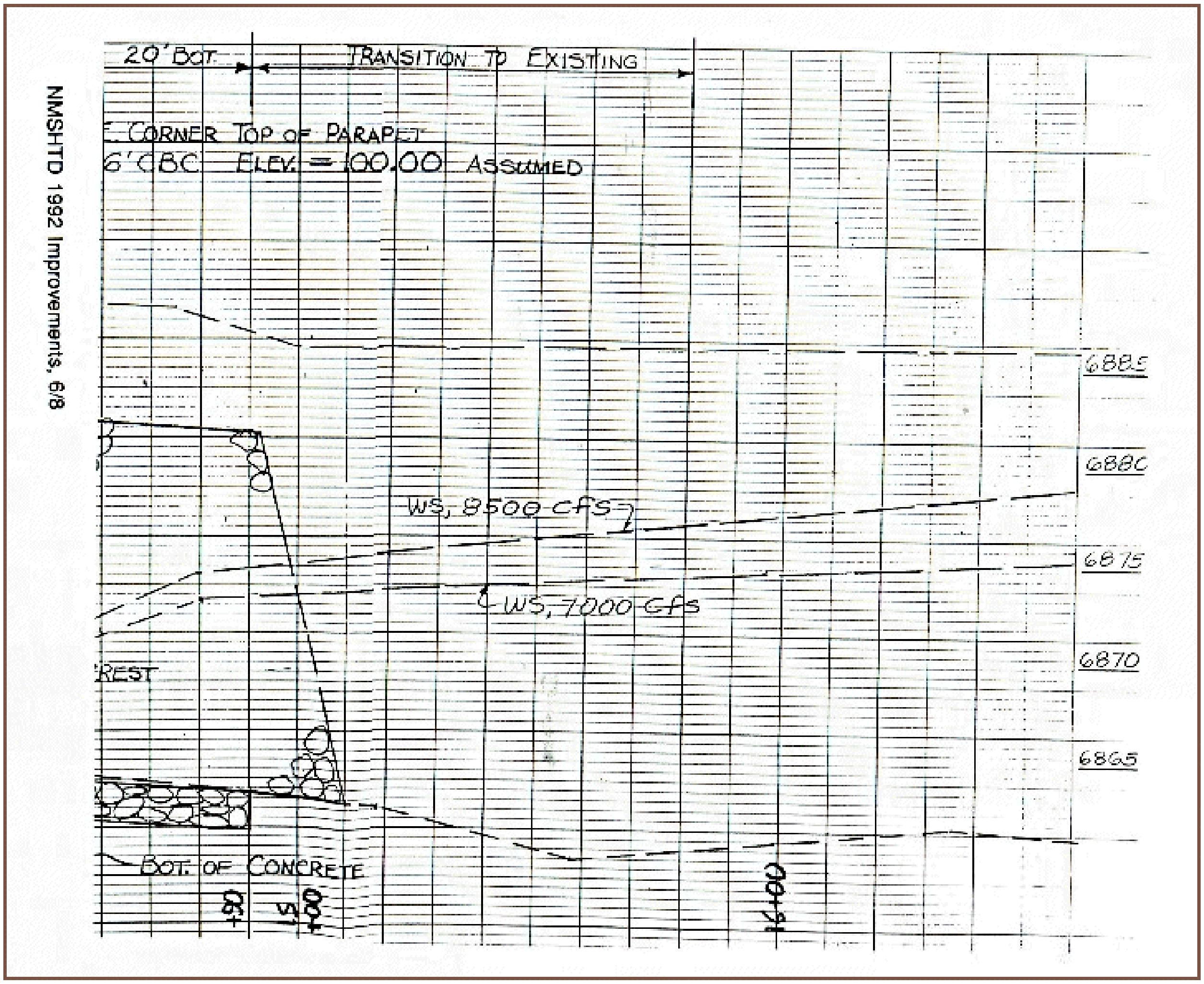

NMSHTD 1992 Improvements, 1/8
ST. FRANCIS DR.
EXIST. DRIVEWAY
1.5:1
1.5:1
1.5:1
1.5:1
20'
EXIST. 4-10'x6' CBC
SANTA FE RIVER
11+50 BUILD DROP STRUC

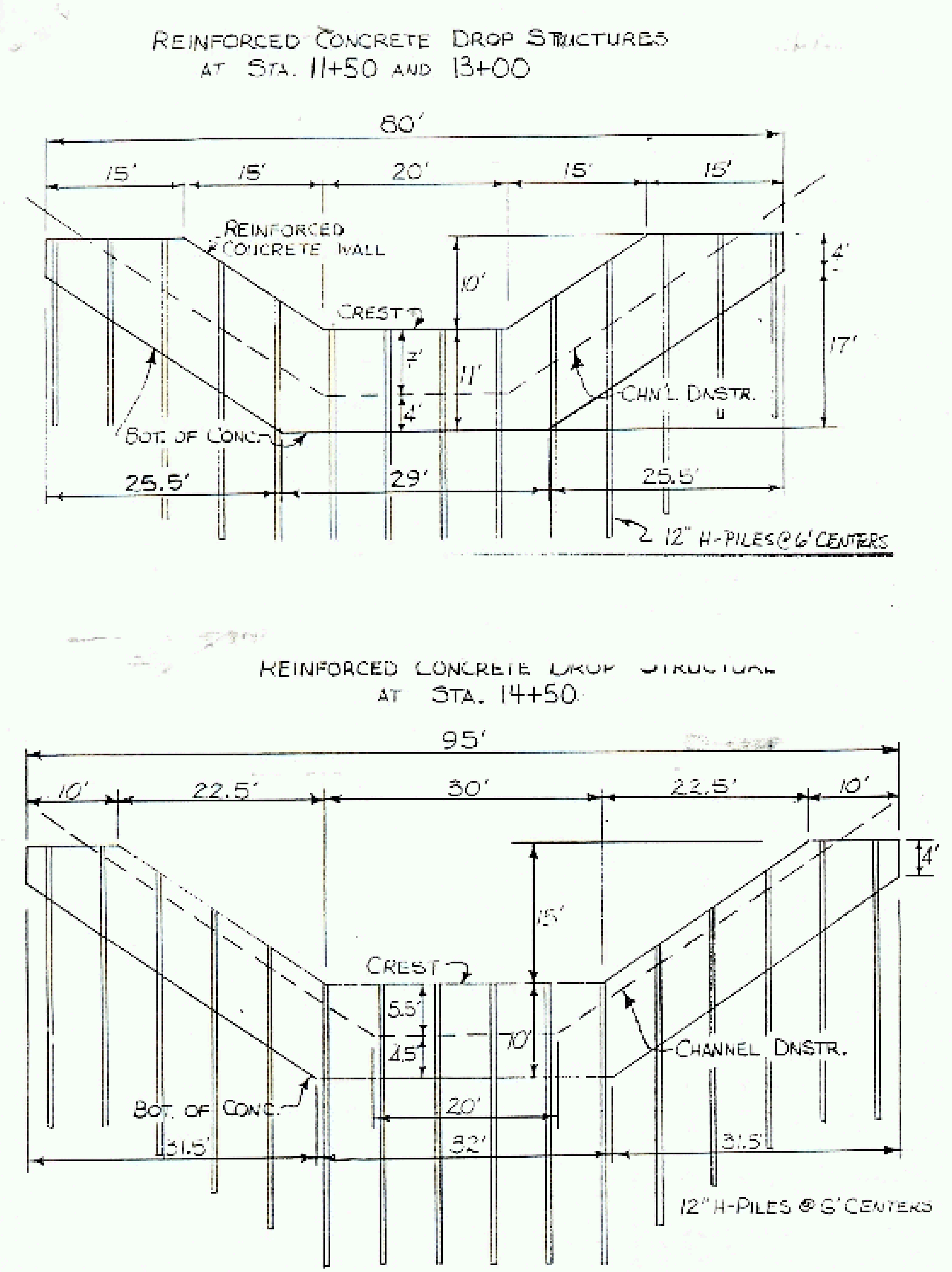

NMSHTD 1992 Improvements, 2/8
EXIST. 16" SAN. SEWER
1.5:1
20'
30'
13+00 BUILD WE
DROP STRUCTU
14+50 BUILD WEIR
DROP STRUCTURE
EXIST. 7-10'x 6' CBC
ARROYO MASCARAS
ALAMEDA ST.


NMSHTD 1992 Improvements. 3/8
EXIST. GABIONS
SANTA FE RIVER
VARIES
1.5:1
N

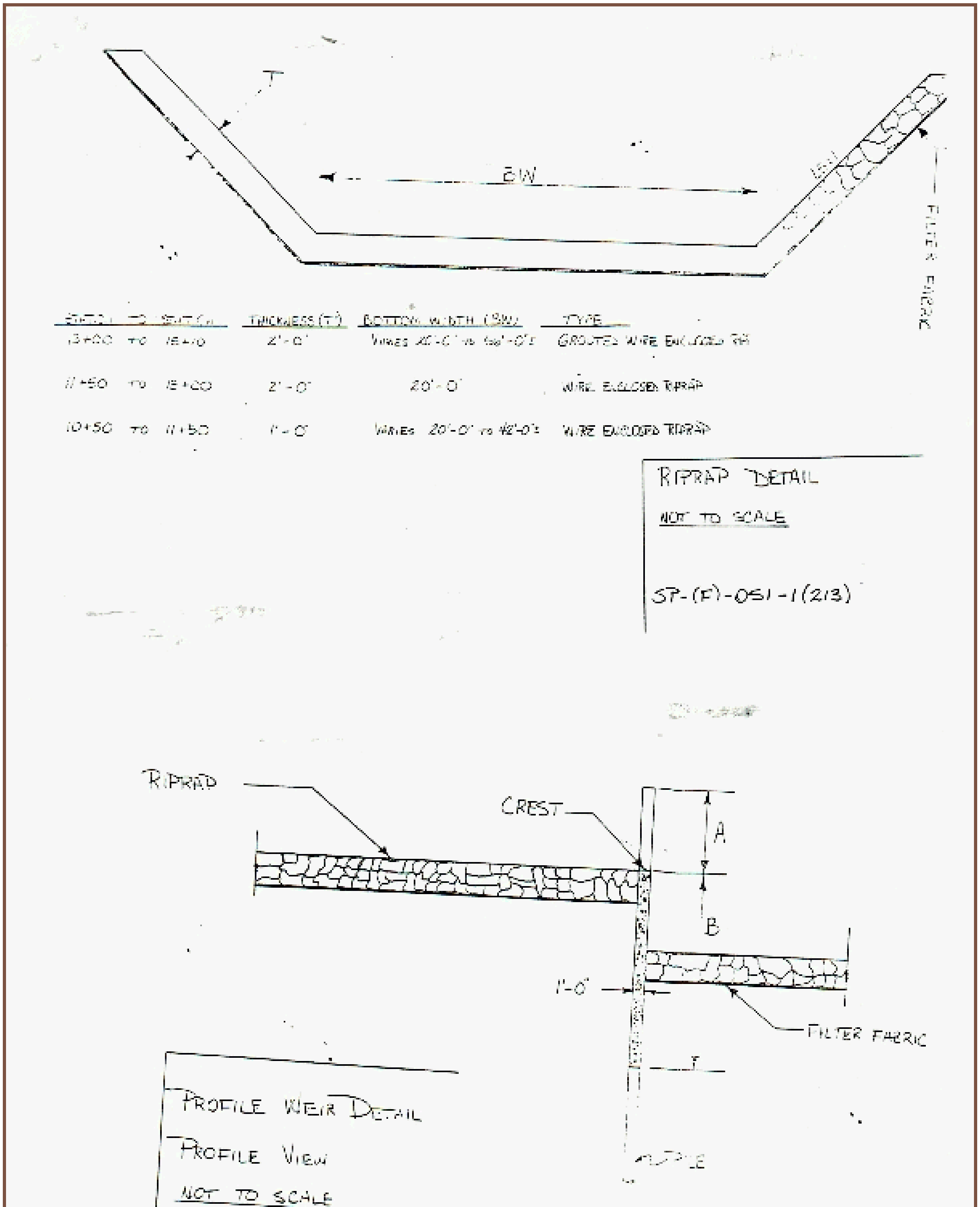

NMSHTD 1992 Improvements, 4/8
42' BOT.
TRANSITION
20' BOT.
20' BOT.
TOP OF WALL
WIRE ENCLOSED RIPRAP
TH=1'
PROP. ℄
S=0.015%
CREST
WIRE ENCLOSED RIPRAP (TH=2'-0")
WS, 2500 CFS
FILL
PROP. ℄
S=0.003%
FILL
BOT. OF CONCRETE
40'
GROUTED WIRE ENCLOSED RIPRAP, BOTTOM CHANNEL ONLY
6880
6875
6870
6865
11+00
CREST


NMSHTD 1992 Improvements, 5/8
20' BOT.
WIDTH VARIES
30' BOT.
+00
+30
+40
TOP OF WALL
EL. 89.0
BM S.E
7-10'x
TOP OF EXIST. BANK
TOP OF WALL
EL. 83.5
4900 cfs
EXISTING 16" SAN. SEWER. SUPPORT WITH STEEL BEAMS.
GROUTED WIRE ENCLOSED RIPRAP (Th = 2'-0")
CREST
WS, 2500 cfs
WS, 4900 cfs
PROP. ℄
S = 0.003%
FILL
BOT. OF CONCRETE
EXIST. ℄
CREST 76.85
13+00 65.85
14+00
CREST 69.36
63.86


NMSHTD 1992 Improvements, 6/8
20' BOT.
TRANSITION TO EXISTING
CORNER TOP OF PARAPET
6' CBC ELEV. = 100.00 ASSUMED
6885
6880
WS, 8500 CFS
6875
WS, 7000 CFS
6870
REST
6865
BOT. OF CONCRETE
16+00



NMSHTD 1992 Improvements, 7/8



NMSHTD 1992 Improvements, 8/8

+++++++++++++++ **The End** ++++++++++++++

Any questions, please contact info@pdhnow.com

QUIZ for Floodwater Lessons Learned: Channel Stabilization in Santa Fe, NM

1. Santa Fe, New Mexico is the oldest (1607) state capital in the United States. During its history, many structures have been placed in the Santa Fe River. Some of these structures functioned as grade controls, causing the river to aggrade (store sediment). This led to a decrease in flood channel capacity. Some housing developments along the Santa Fe River were in the 100-year floodplain. Removal of many grade control structures increased channel capacity enough to increase channel capacity to hold the 100-year flood. This removed many housing developments from the 100-year flood plain.

a. True

b. False

2. After the grade control structures were removed, considerable channel erosion was observed.

a. True

b. False

3. Gabion walls should have a layback of

a. 6-inches

b. 12-inches

c. 18-inches

d. 24-inches

e. 30-inches

4. Sidewalls seldom fail when the toe is undercut.

a. True

b. False

5. In order to prevent channel wall toe undercutting

a. The base of the wall must be hardened with reinforced concrete

b. No special technique is required

c. The toe must extend below the scour line during a flood

6. When a gabion or rock mattress is undercut

a. The rock is safely supported by the wire

b. The wire is ruptured by the rock, but the rock remains in the mattress

c. The mattress slumps on the ground and still protects the bank

d. The wire ruptures and rocks exit the structure

7. High stream velocities can damage rock basket sidewalls by pulling rock from the baskets.

a. True

b. False

8. End erosion of sidewalls

a. Can be prevented by using a slightly thicker sidewall

b. Is not usually a problem in arid climates

c. Can be prevented by installing end-wall tiebacks

d. “b” and “c”

e. Dumping loose rock at the ends of the sidewall

9. Pushing up rock from the stream to protect an eroded sidewall toe

a. Is a great idea

b. Will fail in large floods because “If the river brought it down, the river will take it away.”

c. I a cheap alternative that may give some protection against small floods

d. “a” and “b”

e. ”b” and “c”

10. The City of Santa Fe intentionally removed grade control structures to increase channel capacity. These structures include culverts replaced by bridges, sills constructed before the 1960s, and rock barriers, which may date from the 1950s.

a. True

b. False

11. Grade control structures left in place in a now aggressively degrading stream

a. Will continue doing their job of grade stabilization

b. Will likely need reinforcement

c. Can easily be reinforced by shoveling some dirt and rock from the channel to fill in any holes immediately below the structure

12. A wide channel crossing is less likely than a narrow one to induce scour

a. False because there is little difference in channel velocities

b. True because the wide channel will have lower water velocities than a narrow crossing

13. Gabions placed below eroding culvert worked we to control erosion

a. True

b. False

14. Channel erosion can

a. Increase channel capacity

b. Expose bridge piers

c. Expose iron bars in reinforced concrete

d. Erode public confidence

e. All of the above

15. The bottom of a drop structure

a. Must rest firmly on the existing channel bottom

b. Be hardened

c. Be placed below the design flood scour line

d. Be made of reinforced concrete

e. “a” and “d”

16. Where general scour is absent vegetation may be used to protect channel sidewalls.

a. True

b. False

17. Shrubs and saplings rooted in gabion basket sidewalls

a. Will eventually compromise the structure

b. Will help anchor the sidewalls during flooding

c. Will grow too big and break the wire causing rock to spill out

d. Needs to be removed

e. “a”, “c”, and “d”

18. Several-inch diameter trees used to hold gabion sidewalls up

a. Can grow too big and damage the baskets

b. Are a good economic practice in many areas

19. Several-inch trees in a city channel

a. Are an eco-friendly multi-use opportunity

b. Should be encouraged to provide rustic scenery in urban environments

c. Are potentially very dangerous if enough trash forms a temporary dam and diverts water out of the channel during a large flood

d. Should be removed during annual maintenance

e. “c” and “d”

20. Tree trunks and roots can hold up gabion walls and anchor foundations until the trees die.

a. True

b. False