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Engineering Technical Information System

Engineer of the Year

Left to right: Sterling Wilcox, Tom Pettigrew, and E. Walter LeFevre.

On February 22, 1990, Tom A. Pettigrew, Jr., Transportation System Management Engineer, Region 3, and his wife were brought to Washington. The purpose of this visit was to award Tom a plaque honoring him as the 1990 Forest Service Engineer of the Year.

This plaque was presented by Sterling Wilcox, Director of Engineering, and E. Walter LeFevre, President of the National Society of Professional Engineers (NSPE), at their National Conference in Crystal City (Arlington), Virginia.

The engineering achievements that earned Tom a cash award from the Regional Engineers and this plaque were a result of having:

(1) Provided leadership, nationally and locally, in the area of transportation management, which improved service to the public and the management of the Nation's natural resources.

(2) Coordinated the Forest Service Scenic Byways initiative in the Southwestern Region—an effort to heighten public awareness and enjoyment of the beauty of the National Forests. Developed operating procedures with cooperating States and assisted in developing nominations. His leadership has resulted in 8 of the first 50 approved Scenic Byways coming from that Region.

(3) Coauthored two successful systematic processes—Integrated Stand Management (ISM) and Integrated Resource Management (IRM)—and trained Federal, State, and private parties on both processes. ISM is a timber sale preparation process designed to ensure proper resource coordination and timely completion of timber sale planning. IRM is designed to ensure efficient implementation of Forest Plans by improving the ability to integrate all resource activities during the planning and design of all projects. IRM is now Regional policy.

(4) To meet resource objectives and public needs contained in National Forest Land and Resource Management Plans, is leading a major program to inventory, map, and decide on the management of every road, trail, trailhead, and off-road vehicle area in the Southwestern Region.

Awards for the 1989 *Engineering Field Notes* Articles

The selection of the top three *Engineering Field Notes* articles for 1989 has been made by our readers. You had several excellent articles to choose from, and now the votes have been tallied, and we are pleased to announce the winners.

Article	*Author*
Forest Sign Plan Using CAD/DBMS	Chuck Ritter Deschutes National Forest Region 6 Paul Flanagan Deschutes National Forest Region 6 Bill Renison Deschutes National Forest Region 6
Evaluation of the NAVCORE-1 Global Positioning System	Anthony Jasumback Missoula Technology and Development Center Washington Office
Increasing Productivity by Preparing Road Plans with CADD	Tom Strassmaier Mt. Hood National Forest Region 6 (previously of National Forests in Mississippi, Region 8) Jeff Orr National Forests in Mississippi Region 8

Congratulations! We would also like to thank everyone that sent in an article to be printed in *Engineering Field Notes.* Your time and effort are appreciated by others in the field. According to comments received, *Engineering Field Notes* articles are saving the Forest Service time and resources.

We also would like to extend our appreciation to everyone who took the time to fill out a rating sheet and to send it in. We apologize for the short turnaround time and are very grateful for your input. We hope *Engineering Field Notes* will continue to be a valuable resource to personnel in the field, but this is not possible without your help. So, write an *Engineering Field Notes* article and make a contribution to the organization, and possibly make a contribution to your checkbook at the same time.

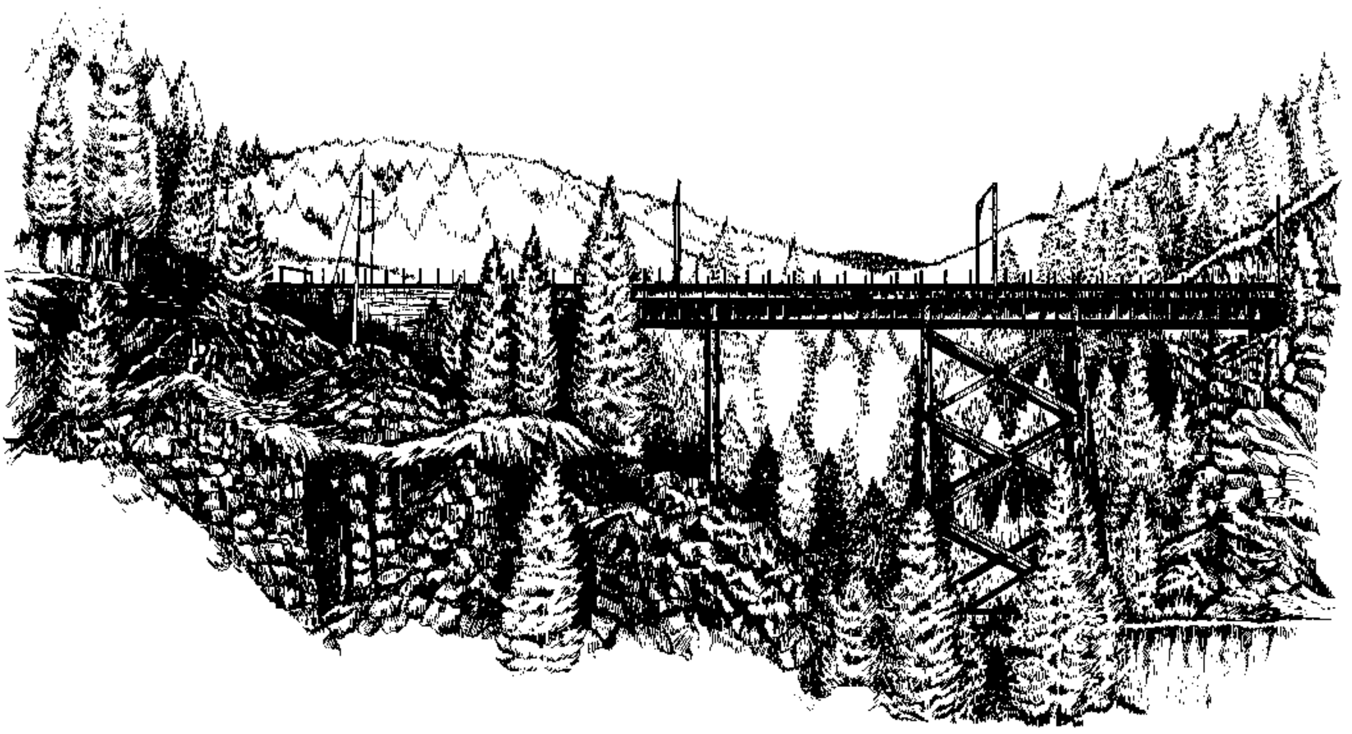
Turnkey Conversion of Railroad Trestles to Highway Access Bridges

Jim Penzkover
South Zone Engineer
Idaho Panhandle National Forests, Region 1

Larry Shepherd
Forest Construction Representative
Idaho Panhandle National Forests, Region 1

Introduction

The "turnkey" reconstruction of two 77-year-old railroad bridges to accommodate vehicular traffic required diverse survey, design, and reconstruction expertise. The bridge trestles rise over 100 feet from the river bottom and are 516 and 237 feet long. These trestles were two of several acquired in 1980 after the bankrupt Milwaukee Railroad abandoned trackage from eastern Montana to Tacoma, Washington. The Idaho Panhandle National Forests



acquired the 23.4 miles of the railroad from Taft, Montana, to Avery, Idaho, as a result of a 1985 congressional bill approving the purchase of the abandoned railroad right-of-way. This segment, constructed in the early 1900's, was the most expensive section of railroad constructed in the United States at that time. The 23.4-mile segment includes 3.3 miles of tunnels (one nearly 2 miles long) and 0.9 mile of trestle-type bridges.

Background

In 1987, the Idaho Panhandle initiated a cooperator agreement with Shoshone County to reconstruct 9 miles of railroad grade north of Avery. This 9-mile segment replaces 10 miles of winding substandard county road that follows the wandering North Fork of the St. Joe River on the opposite side of the canyon. The agreement between the two agencies provided for a cooperative effort to bring this segment of the railroad grade up to a county road standard. Shoshone County had the responsibility to modify the six tunnels, upgrade drainage, and provide minor realignment and aggregate base surfacing on the railroad grade. The Forest Service accepted the responsibility for reconstruction of the two railroad trestles with the installation of a new deck and guardrail system in compliance with AASHTO standards for normal highway loading.

The Forest Service had sketchy, 77-year-old drawings of the existing trestles and very little assurance that site dimensions and conditions matched the drawings. Regional Bridge Engineers and Idaho Panhandle Engineers evaluated the structures and investigated options for completing the survey, design, and reconstruction work. An *Engineering Field Notes* article outlined a Region 2 "turnkey" road project (March-April 1987, "Buffalo Pass Turnkey"), and the option of contracting the bridge reconstruction as a "turnkey" project was investigated.

A "turnkey" project is one in which the contractor surveys; designs; provides detailed drawings and special project specifications; furnishes all material, labor, and quality control; and constructs the project to conform with the design drawings approved by the owner. The "turnkey" method of contracting fit this project well.

The Competition in Contracting Act (CICA) permitting competitive negotiations was implemented in January 1985. A contract solicitation for a "turnkey" bridge reconstruction project was prepared and was the first such construction contract for Region 1.

Solicitation for Bids

Copies of the original 1909 drawings were included in the solicitation for technical and business proposals. The solicitation specifications outlined AASHTO standards and design features required for an HS 25-44 loading. The solicitation required each offeror to submit a technical and a business proposal, each part separate and complete to ensure independent evaluation. There was to be no mention of price in the technical proposal.

Offerors were directed to address in their technical proposal, in descending order of importance, the following topics for evaluation by a Board of Contract Awards:

(1) The names and specific qualifications and credentials of key personnel (contractor, designer, project superintendent, supplier, and quality control engineer) and their experience with this type of project.

(2) A description of the technical approach to the project, including design concept and a detailed sketch of proposed construction methods, quality control measures, safety measures, work schedule, and project superintendent's involvement.

(3) A résumé of the firm that indicates its ability to undertake the project, including number of years in business, experience in design and construction of concrete bridges, and a list of the work currently being performed, such as the contract value, point of contact, estimated completion date, and status of each project.

(4) A list of contracts for similar work with the Forest Service or other agencies completed within the past 5 years, including point of contact for each project.

(5) A statement of the firm's knowledge of local construction conditions, access, travel, crew accommodations, and so on.

Offerors were notified that the Government would award a firm fixed-price contract to the responsible offeror (1) whose proposal was technically acceptable and (2) whose technical proposal-cost relationship was most advantageous to the Government.

Evaluation of Proposals

Seven contractors from the Pacific Northwest responded to the solicitation. Two of the proposals included only a business proposal and not a technical proposal and were rejected as nonresponsive bids. The remaining five proposals were determined to be in the competitive range and were evaluated according to the criteria listed in the solicitation notice. Technical and business proposals were evaluated by a Board of Contract Awards, composed of the following individuals:

Technical Proposal:
- Jim Penzkover (Zone Engineer)
- Duane Yager (Structural Engineer, Regional Office Bridge Section)
- Larry Shepherd (Project Contracting Officer's Representative)

Business Proposal:
- Don Kramer (Project Contracting Officer)
- Jack Sundt (Regional Office Contracting Officer)
- Carol Anderson (Regional Office Contracting Officer)

Table 1.—Ranking of technical proposals by Board of Contract Awards based on evaluation criteria.

Bid proposals	*Technical proposal (ranking)*	*Business proposal (price)*
Offer #1	* 1st	$591,640
Offer #2	* 1st	$492,378
Deb-Wall Steel Erectors, Inc.	3rd	$406,187 (Award)
Offer #4	4th	$377,236
Offer #5	5th	$387,123
Engineering Estimate		$399,143

*The top two technical proposals were ranked to be equal.

An evaluation system for ranking the technical proposals was formulated by the Board of Contract Awards. The evaluation system was based on the evaluation criteria rated by priority of importance as outlined in the solicitation request for proposal.

After ranking was completed (see table 1), the top two technical proposals were found to have the two highest business proposals (48 percent and 23 percent above the Engineer's estimate). The third-ranked technical proposal was found to be less than 2 percent above the Engineering estimate. After negotiations with all five offerors for further clarifications and best and final offers, Deb-Wall Steel Erectors, Inc., of Clinton, Montana, was awarded the contract.

The two lowest priced business proposals (3 percent and 5 percent under the Engineer's estimate) were rated significantly lower than the Deb-Wall Steel Erector's technical proposal. Because of the unique design in the technical proposal submitted by Deb-Wall Steel Erectors and some deficiencies in the two lowest ranked proposals, the Board of Contract Awards was able to justify awarding the contract to the third lowest bidder.

Design

The design was created by the contractor's design engineer, Muth Consulting Engineers, Missoula, Montana. The bridge deck was designed for precast laterally prestressed, transversely reinforced deck panels, longitudinally post tensioned in place. Deck panels were designed with a "tongue and groove" match cast face between abutting panels. The epoxy-coated match cast tongue and groove panels, posttensioned into place, reduce the amount of transverse reinforcing distribution steel required by distributing the loading from panel to panel (see figure 1).

A typical deck panel, weighing approximately 27,000 pounds, measured 10 feet, 6 inches by 18 feet, 3 ½ inches and averaged 12 inches thick. The Squaw Creek Bridge included 49 deck panels, and the Big Dick Creek Bridge required 24. The Big Dick Creek Bridge alignment is on a horizontal curve,

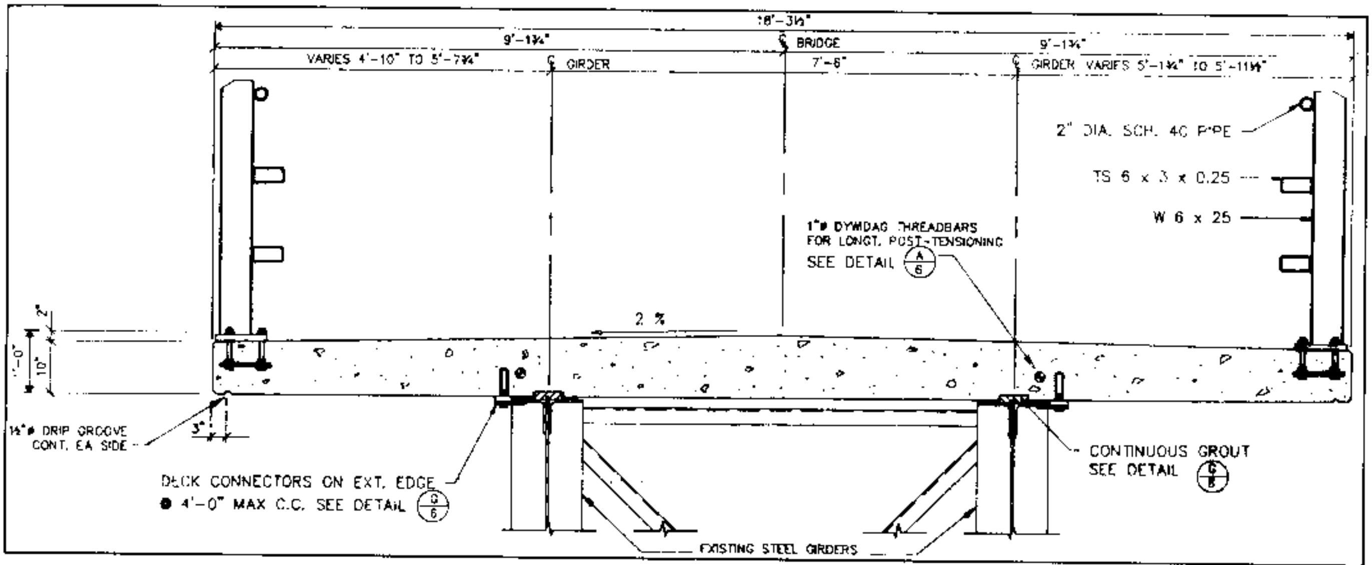


Figure 1.—Typical section of laterally prestressed, transversely reinforced deck slab to be longitudinally post-tentioned in place.

which necessitated that every panel have a slightly different dimension to fit the steel girders set on tangent sections.

Construction

As shown in figure 2, the original structure had concrete ballast boxes containing ballast aggregate, railroad ties, and rails. The rails and ties previously had been removed by a salvage company. There were a total of 192 ballast boxes, weighing in excess of 9,000 pounds each, that had to be removed before the new bridge deck and guardrail system were installed. The ballast aggregate alone weighed as much as loaded logging trucks parked bumper to bumper the full length of the bridge. The old ballast boxes were used to construct a conservatively designed, low-cost retaining wall adjacent to the Squaw Creek Bridge (see figures 3 and 4).

The laterally prestressed, transversely reinforced deck panels were precast in Spokane, Washington, by Central Prestress and transported 130 miles to the project site.

The match cast deck panels were placed on epoxy-coated, elastomeric bearing pads attached to the steel girder flanges. New deck panels were placed in sequence with their match cast faces and posttensioned in place with longitudinal Dywidag bars to the prescribed stress level (see figures 5, 6, and 7).

Matched tongue and groove faces were coated with Rescon 606 epoxy prior to posttensioning in place. After posttensioning of three or four panels at a time, a splicer coupler was attached to the Dywidag bars and the next series of panels were posttensioned together. Deck-to-girder clips were used to attach concrete deck panels to the steel girder flanges. After posttensioning, the Dywidag tendons and longitudinal flange keyways were filled with non-shrink grout.

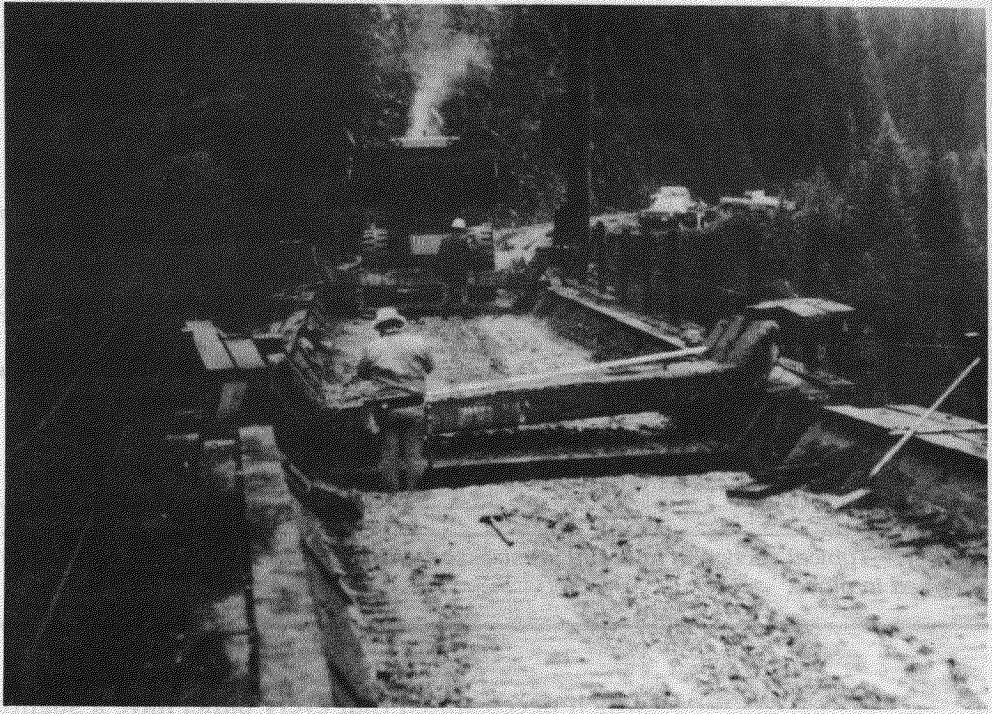


Figure 2.—Concrete ballast boxes were lifted during surveying operations to allow survey and design of new concrete deck panels to fit the existing steel bridge girders.

This process continued until reaching an expansion-contraction joint. The deck panels longitudinally posttensioned in place with Dywidag bars will perform as a continuous concrete unit between expansion-contraction joints to provide a durable and smooth riding surface. Spans between expansion-contraction joints ran up to 160 feet in length. The product used for joint material, determined by the span and resulting joint dimension, was either Evasote or Watson-Bowman/ACME expansion joint material.

Final Construction Costs

Costs for the completed.project, including survey, design, materials, construction, and quality control, totaled $477,350 for 753 lineal feet of 15-foot-wide (Squaw Creek Bridge) and 16-foot-wide (Big Dick Creek Bridge) bridge deck. This price included approach and bridge deck guardrail systems (figure 8), approach pavement, repair of concrete abutment, and construction of 1,900 square feet (face) of retaining wall. See the plan and profile for the Big Dick Creek Bridge in figure 9.

During design and construction, the contractor submitted two Value Engineering Change Proposals (VECP's) that were reviewed and accepted by the Forest Service. These were the first VECP's approved in Region 1 and allowed the contractor and Government to share cost savings.

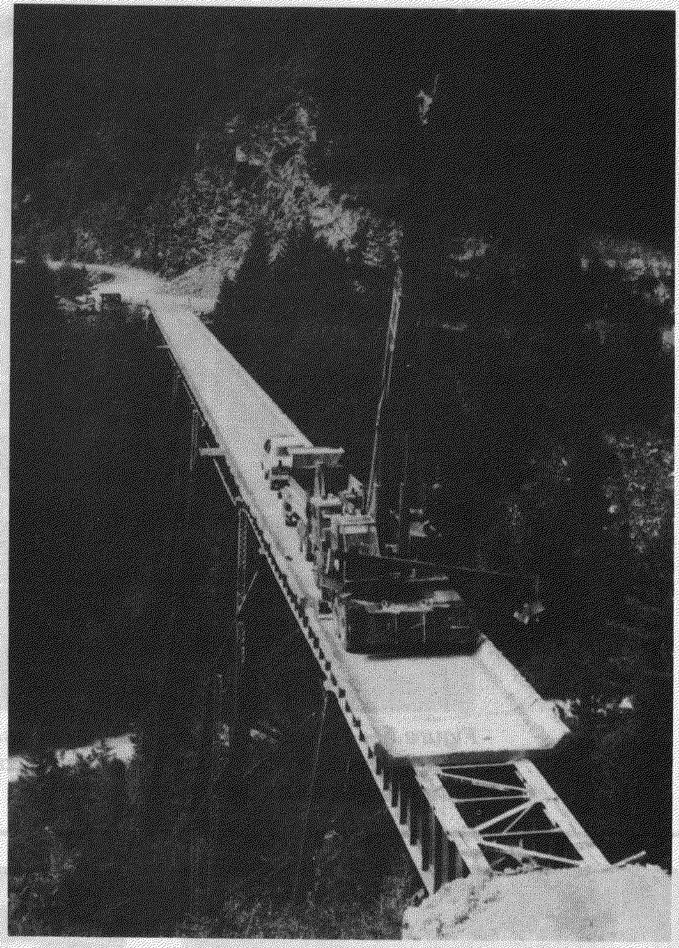


Figure 3.—Removal of the existing concrete ballast boxes from the Squaw Creek Bridge. Ballast boxes were used to construct a retainng wall.

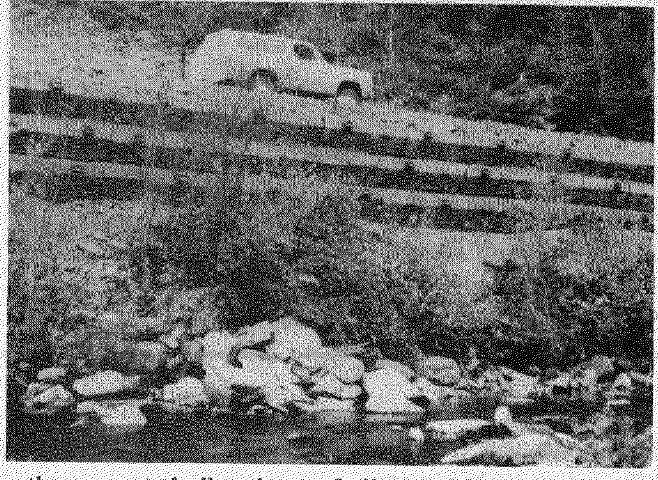


Figure 4.—Construction of the three-tiered retaining wall using the concrete ballast boxes (left) and the completed wall (right).

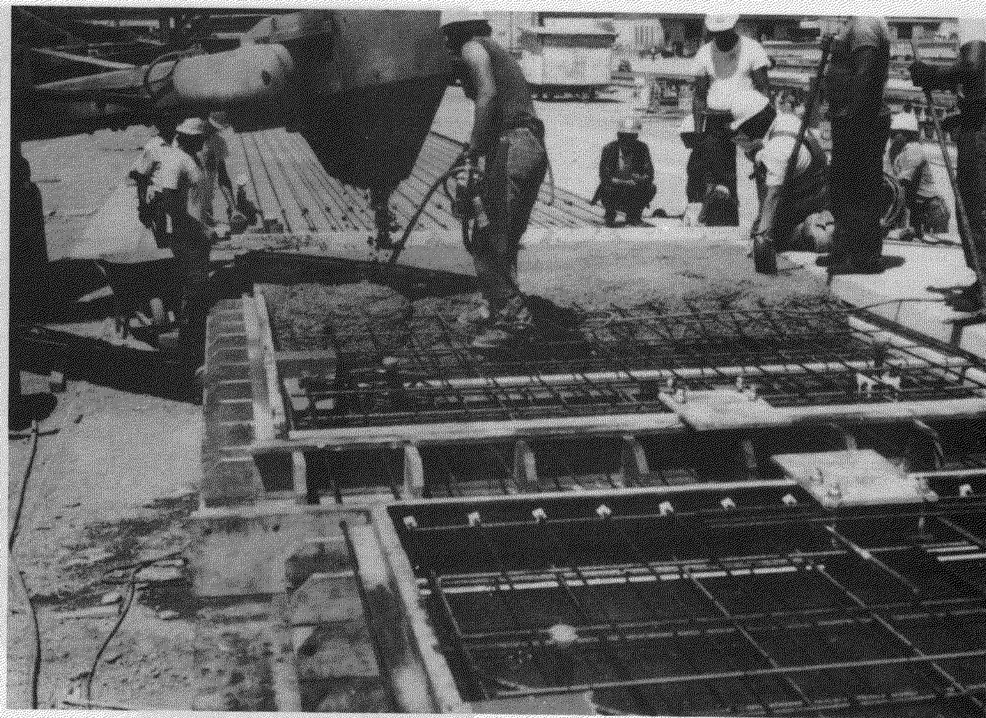


Figure 5.—Precasting of laterally prestressed and transversely reinforced deck panels. "Tongue and groove" faces were match cast to adjacent panels to ensure uniform fit during posttensioning.

Figure 6.—Placement of the deck panels on Big Dick Creek Bridge.

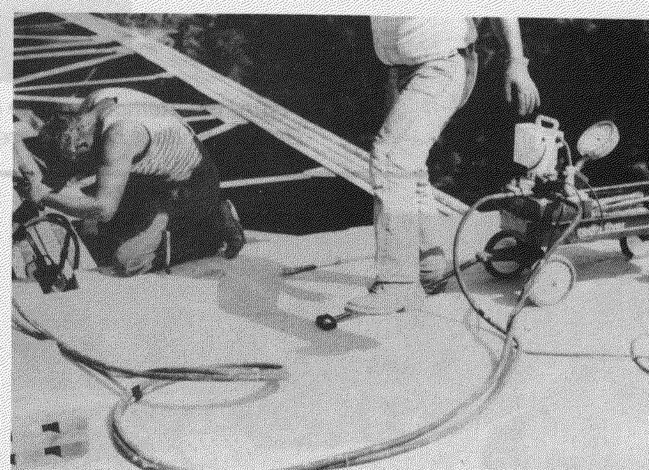


Figure 7.—Posttensioning of longitudinal Dwywidag bars.

Advantages of "Turnkey" Projects

The following are advantages of the "turnkey" construction concept:

(1) Allows for optimum staffing during the "peaks" and "valleys" in work load.

(2) Presents a reasonable solution to an emergency job—one that must be completed in a short period.

Figure 8.—Structural tube guardrail system being aligned on the Squaw Creek Bridge structure.

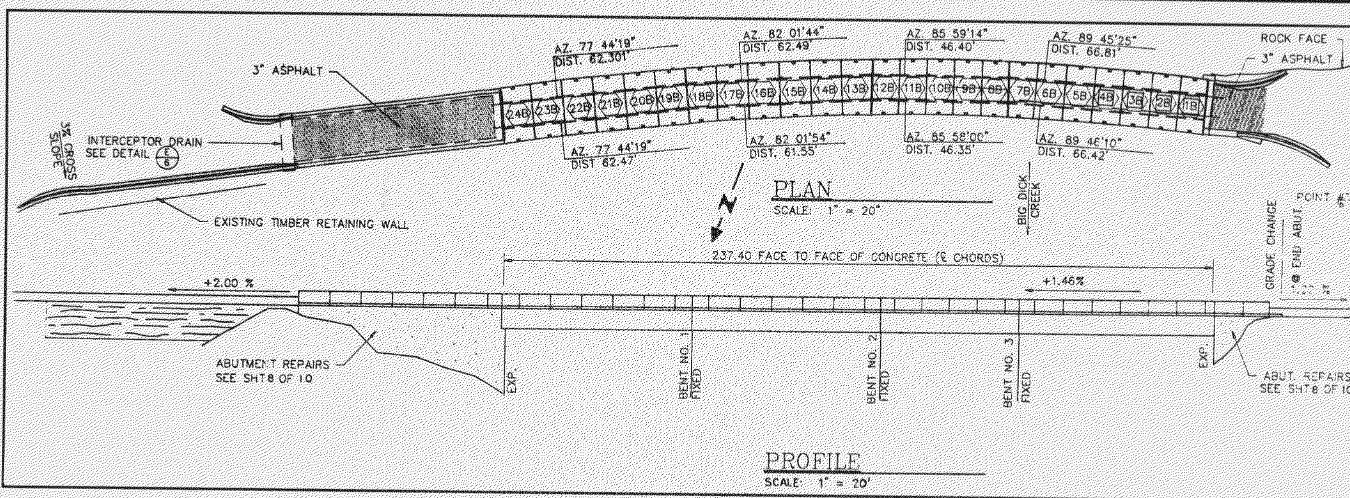


Figure 9.—Big Dick Creek Bridge (plan and profile).

(3) Provides contractors an opportunity to tailor the design to their available equipment and personnel. This may result in some cost savings in construction.

(4) Provides an opportunity to evaluate several technical design proposals.

(5) Transfers some of the liability from the Government to the contractor and its design engineer.

Conclusion

There are a number of Forest Service construction projects that lend themselves to the "turnkey" survey, design, and construction concept. We must not overlook this contracting option as a viable, cost-effective method of completing our project work.

For further information, contact Larry Shepherd at (208) 765-7408 or by DG: RO1FO4A, or Jim Penzkover at (208) 245-2531 (DG: RO1FO4DO4A).

Designed Natural-Appearing Cement Structures for Wet Area Enhancement

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Prescott National Forest, Region 3

Introduction

The Connell Mountain Wildlife Habitat Improvement Project was implemented in 1988 on the Chino Valley Ranger District of the Prescott National Forest. The Forest used a new application of shotcrete, an existing technique, to construct four instream sediment retention structures.

Objectives

The primary objective of the project was to enhance wildlife habitat of the project area by creating waters and developing areas capable of producing early spring forage. These habitat elements were determined to be limiting factors for Merriam's turkey, an important species in the area. The project also considered other indigenous species, such as elk, mule deer, and non-game species. Another objective was streambed restoration for the area, which contains many scoured and eroding water courses.

Method

The Chino Valley Ranger District has experience in developing waters and early spring forage through the placement of impermeable instream structures to create wet meadows. The District has now used masonry, poured concrete, and shotcrete structures to retain nutrient-rich sediments and water and to restore eroded streambeds and create wet meadows.

Site Selection

An ideal site for structure placement should include a narrow rock notch in competent bedrock on a low-gradient stream to minimize structure size and cost while maximizing the area affected. The site's accessibility also is an important consideration, as are precipitation levels and sufficient watershed size above the site to generate flows needed to charge the system. It is strongly recommended that a hydrologist be involved in the site selection phase of projects such as this one.

Development Technique

After selecting a suitable site, a cross-sectional survey of the rock notch and a profile of the upstream segment of the stream should be conducted. The cross section of the notch is necessary for determining design specifications. Some excavation also may be necessary. It is strongly suggested that an engineer with structural experience be involved in this aspect. The upstream profile will assist in determining the area to be affected by varying structure heights.

The above considerations are common to all the types of structures previously mentioned. The balance of this article primarily addresses the shotcrete application used in the Connell Mountain Wildlife Habitat Improvement Project, with some comparison to the other techniques mentioned.

Shotcrete

Shotcrete is a word used to describe both a material and a method. The material is concrete, mortar, or grout. The method is the application of this material by pneumatic pressure through a specially adapted hose. The concrete is literally shot into place against the form and around the reinforcing steel. The shotcrete process is commonly used in the construction of swimming pools and in the general construction industry for fireproofing steel members, installing floor and roof slabs, building walls, and covering brick, tile, or old concrete walls. The process also has been used in lining reservoirs.

The shotcrete process was suggested and selected as the technique to be used in the Connell Mountain Wildlife Habitat Improvement Project as a means of addressing esthetic concerns as well as lending itself to the use of a large volunteer work force that evolved in the development of this project.

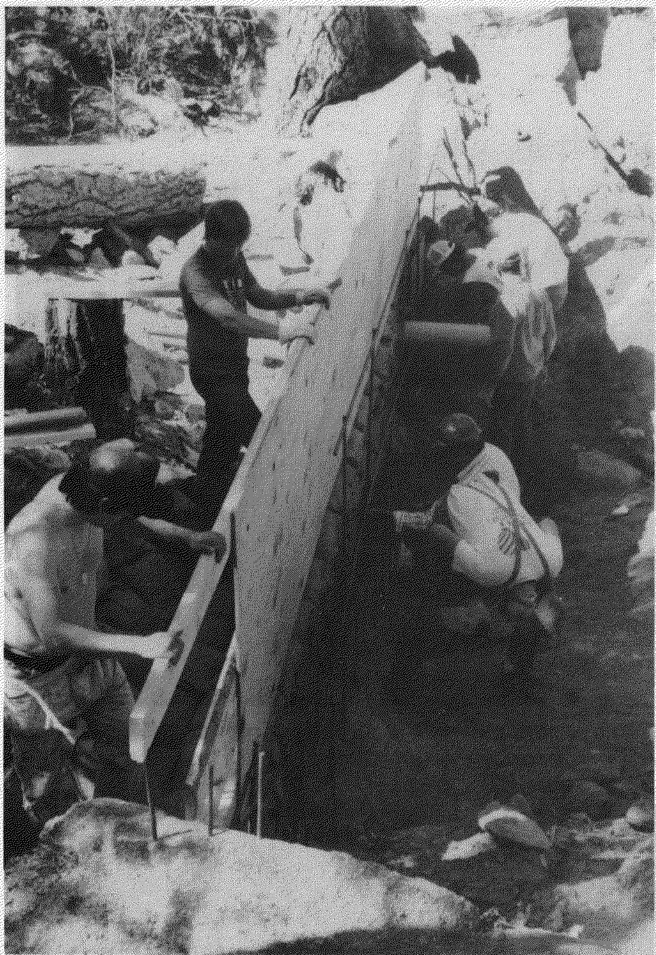
Project Development

After project approval and receipt of designs, the first step in the construction process involved the drilling and placement of 5⁄8-inch rebar into bedrock to pin the structure to bedrock. First, 5⁄8-inch holes were drilled with rock drills, and then 5⁄8-inch rebar was compression-driven into the holes to ensure a secure grip. The design specified a double row of pins 8 inches apart, with 16-inch spacing offset and 1 foot deep into the granitic bedrock. It was specified to have 12 inches of rebar extend above the surface to tie to the steel reinforcement matting of the structure.

The second step was to construct the backing against which the shotcrete was to be shot. The project chose a combination of sandbags and plywood backing. Sandbags were selected because of the onsite availability of sand and ease of placement into the irregular-shaped base. The sandbags were topped with braced 1⁄2-inch plywood panels because of the tendency of sandbags to topple at the heights desired. The plywood panels were easily constructed and fitted to the surface of the sandbags. Creativity in the choice of backing is quite feasible.

The third step involved the placement of the designed rebar mat tied to the bedrock pinning and suspended from the backing. Buttresses were designed into each structure to break the moment of the lateral forces and to prevent toppling. Four-inch pipes were placed in the base to allow drainage of the structures or to provide for offsite transport of water at a future date.

The next step was the actual shotcrete application of batch-dyed concrete against the backing. Standard concrete color tiles helped specify the type



Construction of the backing against which the shotcrete will be shot. Plywood has been braced on top of the wall of sandbags.

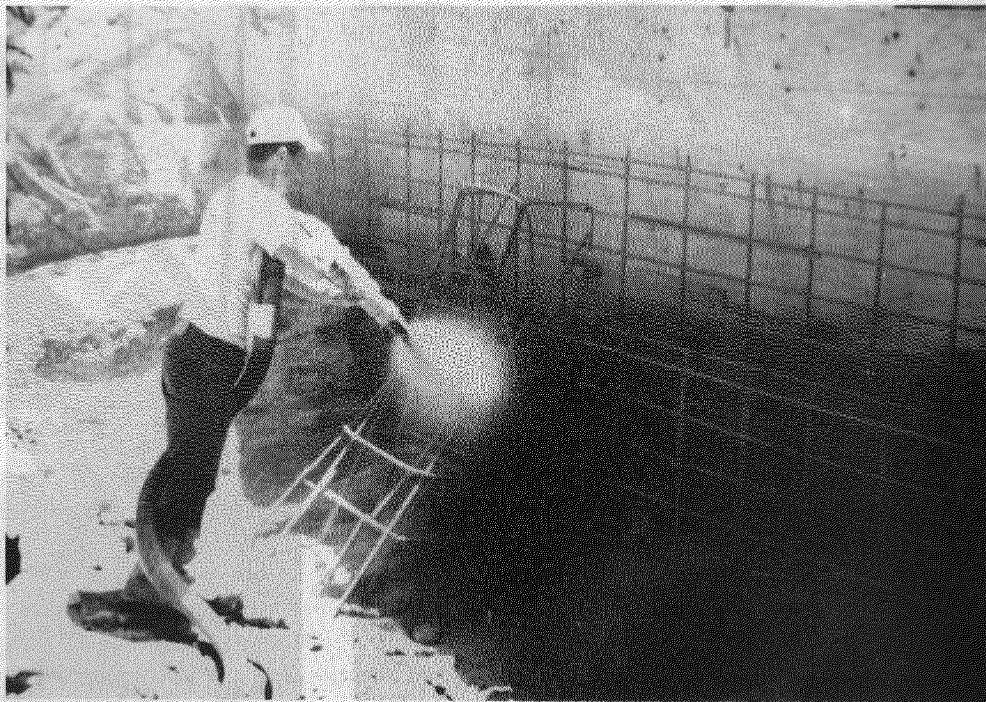
A rebar frame is being tied into place on the down-stream side of the framing.

and amount of dye used to match the surrounding rock. To create a natural-appearing structure, the structures were shot with varying degrees of irregularity. Because the shotcrete sets up rapidly, green and black dyes were splashed on immediately after application to simulate lichens and natural oxide stains. Trowels were used to scribe simulated fissures into the surface. Crushed mica from a nearby source also was thrown at the surface to simulate the sparkling crystals typical of natural granite. Artistry was present in these applications.

Finally, the forms were removed, the pipes were capped, and the sites were cleaned up.

Advantages & Disadvantages of Shotcrete

Besides the advantage of creating natural-appearing structures, shotcrete has a higher cure strength and faster cure rate than regular concrete. This is because of a lack of voids from the high-pressure application (150 psi) and the use of a much drier mix. A 2 ½-inch slump is characteristic of



The shotcrete is applied to the downstream side of the structure, covering the rebar framing. Butresses have been left temporarily through which stream flow can pass.

The structure is complete and blends in well with the natural surroundings.

shotcrete as compared with 7 or 8 inches for pumped concrete. This was demonstrated the day the last two structures were shot. Unexpected heavy rains occurred. Flows topped the structures shot the previous day. One structure was topped by floods 2 hours after it was shot without apparent adverse effects. The final structure was shot with an arch over a torrent of water and later plugged when the flows subsided. The luxury of interrupting the project until better conditions prevailed was not feasible as the concrete was en route. In essence, the shotcrete process saved the day. It is doubtful that poured structures could have withstood the conditions encountered.

The primary advantage of using the shotcrete process was the relative ease of forming the structures, allowing the use of a large volunteer work force.

A disadvantage of using the shotcrete process was the cost of services and equipment. This amounted to $3,000, or an average of $750 per structure. This cost was contributed in our project through the Challenge Cost-Share Program.

Another disadvantage was the use of additional concrete to create the irregular surface finish. We used a total of 53 yards of concrete in the four structures. A similar project in 1986 involving three comparably sized formed structures required only 28 yards. Forest Service costs were lower for the four shotcrete structures ($15,000) compared to three formed and poured structures ($16,000) because of the volunteer contribution of labor and materials, less forming materials (from forming only one side), faster forming, and lower cost of concrete, including the batch dye. The cost and amount of rebar were comparable between the two projects.

Environmental Benefits

Besides the benefit of enhancing wildlife values, these wet area enhancement structures increase the value of many resources. The Forest has used many instream structures in attempts to rehabilitate water courses, including earthen, gabion, wood, and metal structures. These structures have their place in Forest Service management efforts, but where suitable bedrock sites exist, concrete structures have two primary advantages—a long maintenance-free lifespan and the capability to retain water and sediment.

Upstream above the structures, nutrient-rich sediment is trapped, creating a sponge where water is retained. The wet sponge becomes densely vegetated with grasses, forbs, and other riparian plants. These areas green up early in the spring while much of the surrounding forest is dry and brown. This verdant growth is high in Vitamin A, a nutrient vital to wildlife, especially during their breeding and gestational periods of the reproductive cycle.

Areas downstream from the structures also benefit. The area below the structures will aggrade the streambed because of the reduction in the velocity of the water. In most cases, these structures will leak at the base or seep through fissures in the bedrock. The slow release of water promotes growth below the structure. Riparian species benefit from the extended duration of flows. Drain pipes are installed in the base of the structures to ensure that low-volume flow is maintained below the structure. This increases the availability of water for wildlife.

The structures also provide recreational opportunities. They provide pools for swimming until they silt in, and they offer the opportunities to picnic or camp near water—a valuable commodity in Arizona—and to observe wildlife, a popular pastime. The primary advantage of using shotcrete is that it allows the function to be esthetically pleasing.

Grazing Management Considerations

Range resources and management both benefit through the improved distribution of dependable waters. The Forest has only considered placing these structures in areas where there is effective grazing management. Placement in small pastures that can be intensively grazed for short periods outside the growing season has been shown to be effective. Seasonal use, again outside the growing period, should not have an adverse effect on meeting wildlife objectives. Yearlong rotational use may require exclusion fencing of the affected area to meet wildlife objectives; fencing would add to the cost. Offsite range benefits can be accommodated, however, by allowing the piping of water to a trough outside the fenced area.

Legal Considerations

Silt-retention structures are exempt from appropriative water rights laws. The Salt River Project, the holder of surface flow rights in the area, has been supportive of Prescott National Forest projects. If the structures were designed as water impoundments, surface-water rights would then be an issue.

Volunteer Considerations

Table 1 lists volunteer contributions to the Connell Mountain Wildlife Habitat Improvement Project.

There are two measures of the success of this volunteer-oriented project. The first is meeting the resource objectives. The other is the volunteers' perception of their involvement and contribution. One does not have a successful project without both types of success. This project was successful in accomplishing resource objectives and at the same time gave the volunteers a sense of contribution and accomplishment of important resource objectives.

A considerable amount of logistical planning, coordination, commitment to the above philosophy, and effort is required. The project was accomplished in one 2-day weekend and one 3-day weekend.

The partnership that evolved among the Forest Service, an off-road vehicle recreation group, a rancher, a wildlife conservation group, and several construction and service companies is unique and attests to the value of the project. The evolution of the partnership began with general solicitation for partners to achieve objectives of the National Recreation Strategy. Phil Auernheimer, President of the Arizona Desert Racing Association (ADRA), being familiar with similar past projects, volunteered his membership. Greg Bartzen, of Verde Valley Pools and also an ADRA member, volunteered to

Table 1.—Volunteer contributions to the Connell Mountain Wildlife Improvement Project.

Partner	*Contribution*	*Value*
Arizona Desert Racing Association (ADRA)	Skilled and unskilled labor, 252 man-days at $80/day average	$20,160
	Paid for structural engineer review	290
Greg Bartzen, Verde Valley Pools	Design and project engineering, 200 hours at $35/hour	7,000
Arizona Wildlife Federation	Shotcrete application (paid contractor)	3,000
Everett Construction	Rebar	250
CECO Concrete Equipment Company	Concrete pump	500
S.G. Steel Company	Rebar truck with operator	2,000
SW Tractor	Compressor	400
McDonald's	Cooler and drinks	50
Arizona Rebar	Rebar and labor	1,500
Cohills Building Specialties	Concrete dye	225
Aaron's Sanitation	Portajohns	100
ADRA membership	Transportation, food, and miscellaneous tools and equipment	2,000
Yolo Ranch	2 days of backhoe and operator	500
Total contribution		**37,975**
Forest Service matching funds		15,000
Total		**$52,975**

provide the survey, design, and engineering project supervision. The Arizona Wildlife Federation was contacted during the public involvement process and volunteered to contribute cash. ADRA solicited the other donations, except the Yolo Ranch, which was contacted by the District as one of the grazing permittees involved.

The Forest had planned to construct one poured concrete structure in 1988. The integration of the volunteers in the planning and the resultant suggestion of using the shotcrete technique and the level of support facilitated by the shotcrete process allowed the accomplishment of four structures.

While it should never be planned for or advocated, the adverse weather conditions encountered on this project actually added to the sense of reward involved in the project accomplishment. The harsh conditions were endured, and problems were overcome through undaunted will and effort. Everyone involved, including the contractors, simply refused to allow this project to fail.

New Revetment Design Controls Streambank Erosion

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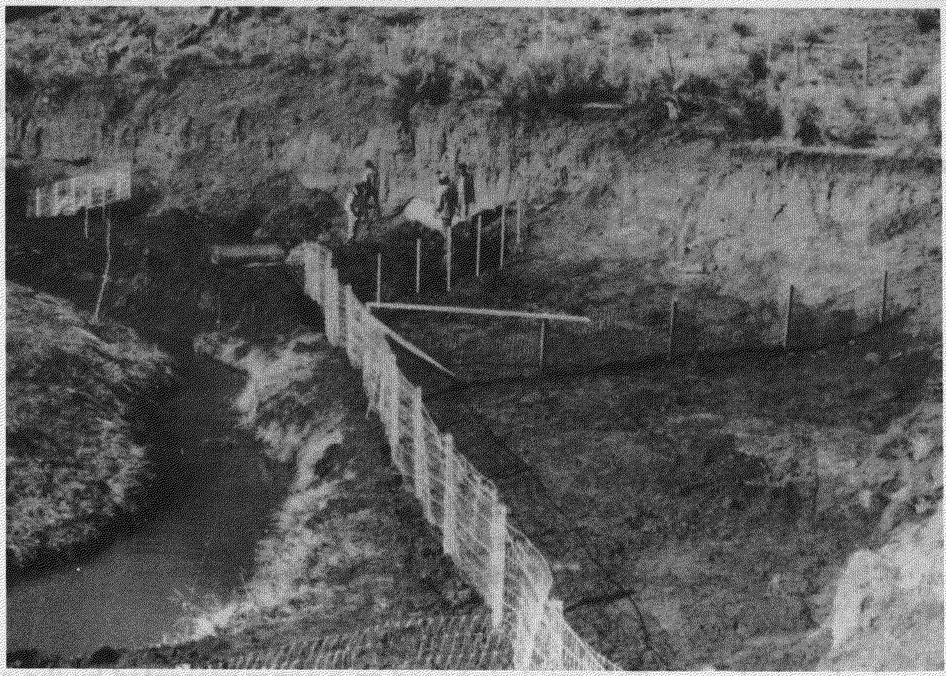
Acknowledgment

This article is based on a paper presented by the authors at the International Erosion Control Association Conference XX, February 15 to 18, 1989, Vancouver, British Columbia, Canada. A version of this article was published in the December 1989 issue of Public Works.

A watershed condition analysis of the Bluewater Creek watershed near Grants, New Mexico, showed that although most of the uplands were in at least satisfactory condition, stream channel meander cutting continued to provide excessive sediments to the fluvial system. An innovative revetment system eventually solved the problem.

The project site is located along the main channel of Bluewater Creek, one of two major streams contributing most of the flow into Bluewater Lake, a 2,350-acre impoundment in northwestern New Mexico. Located in the Zuni Mountains, the watershed contains 52,000 acres, 86 percent of which is managed by the Mt. Taylor Ranger District, Cibola National Forest, Southwestern Region. Average annual precipitation varies from 14 inches at Bluewater Lake to 24 inches at the highest elevation. Precipitation falls predominantly in the summer in short-duration, high-intensity thunderstorms.

The watershed strongly reflects its land use over the last 200 years. Hispanic and anglo settlement, accompanied by extensive grazing and lumbering, reduced ground cover, decreased water infiltration, increased runoff and surface erosion, and initiated channel degradation.(*1*) Timber harvest took place over most of the watershed between 1890 and 1940. Grazing of cattle and sheep continued, and fire scars on remaining trees and stumps testify to extensive wildfires. Since the Forest Service acquired the land in the early 1940's, better grazing and timber management have markedly improved the land.(*2*)



Construction view of revetment shows main baffle segment parallel to flow, one perpendicular baffle, and posts in place for a second.

A hydrologic function analysis was begun in 1984.(*3,4*) Results were summarized in 1987 by Hanes and LaFayette.(*5*) Generally speaking, most subwatersheds were in at least satisfactory condition. Improved land use had allowed most land surfaces to regain sufficient cover to arrest surface erosion and moderate most normal rainfall and snowmelt runoff.

Problems Remain

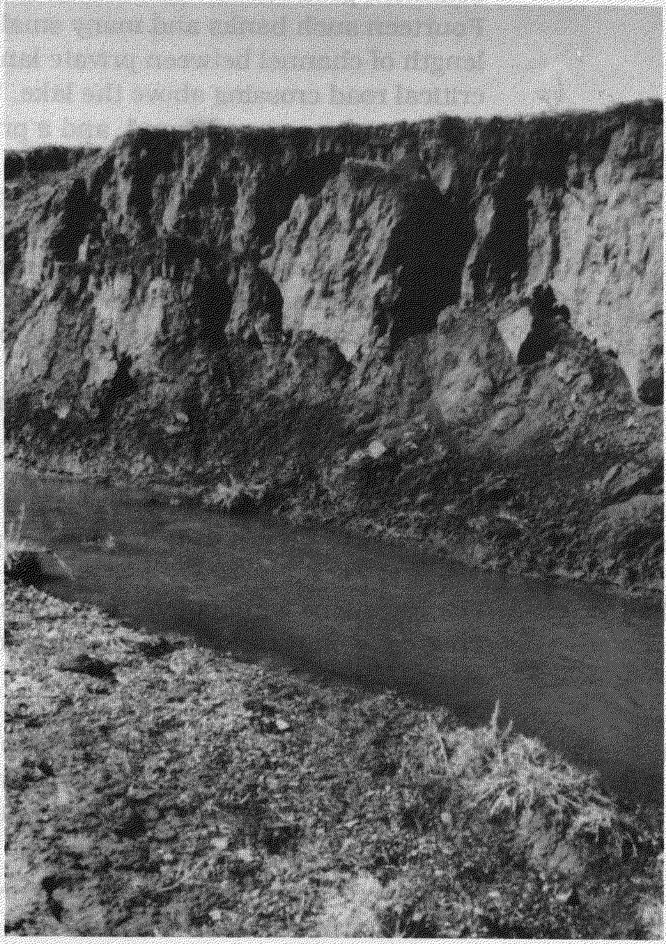
Problems persisted, however. Recovery of the drainage network has been slow. Headward gully erosion continues into broad meadows, lowering their water table, producing sediment, and decreasing productivity. Channel meandering causes very active streambank erosion, resulting in sedimentation of the stream and lake. Poorly located or unneeded roads channel water into drainages, as do livestock trails. Flood peaks remain unacceptably high while base flows remain small, limiting the extent of perennial streams in the watershed. Riparian vegetation remains far below potential, resulting in unstable streambanks, higher water temperatures, and low fish productivity.

Watershed study findings prompted a long-term program to improve hydrologic function and resultant benefits. Treatment goals include the following:

(1) Moderating flood peaks, prolonging base flows, and storing water within the soil mantle.

(2) Reducing sedimentation of the stream and lake.

(3) Increasing wildlife and fish productivity.



Bank slumping along the main stem of Bluewater Creek prior to the project.

(4) Boosting timber and forage productivity.

(5) Demonstrating watershed analysis and treatment methods.

(6) Preserving archeological resources.

Treatment methods include gully headout control, road closures and improved channel crossings, livestock management, increase in riparian vegetation, better timber management, control of channel base levels, increase in fish and wildlife management, and control of excessive streambank erosion. The remainder of this article addresses a way to achieve this last treatment method.

Streambank Erosion Control

Channel degradation and stream meandering had left several actively eroding streambanks along the main Bluewater Creek channel. Lateral water movement in the channel would undercut banks ranging from 10 to 20 feet high, causing a large prism of soil to fall directly into the active stream. Riparian vegetation was unable to become established on these banks, and sediment production was substantial, particularly during high runoff years. Fourteen such banks and many smaller ones were measured in a 4-mile length of channel between private lands to the center of the watershed and a critical road crossing above the lake. Ways to control this excessive stream-bank erosion were analyzed, and a preferred method chosen.

The method selected must stop streambank failures, thus limiting channel and lake sedimentation. It must work with the stream system rather than against it to preserve and promote maximum stream length and maintain channel gradient. The system should promote onsite sediment storage and development of riparian vegetation and overall ground cover.

Various streambank erosion control measures were evaluated for their advantages and disadvantages.

Livestock Control in Riparian Areas

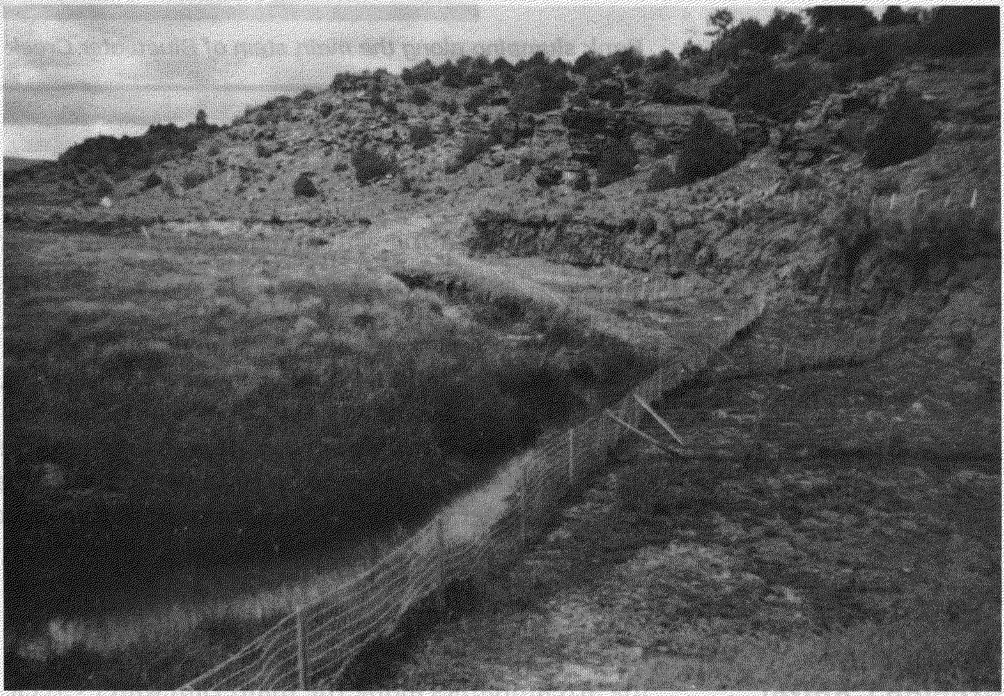
This would provide a cure only in the very long term. Water flowing along the base of high cut walls could continue to undermine vertical banks.

Riparian Planting

Planting alone without livestock control would be inexpensive but ineffective. Progress would require many years and may not control water at the base of existing cut banks.

Bank Shaping

Although shaping would reduce the prism of soil available to enter the stream as well as provide a site for plant growth, problems included where to dispose the cut slope soil and erosion of the exposed surface before plant



Excellent cover was established less than a year after revetment installation.

growth. It would not prevent water from running along raw banks or arrest meandering.

Gabions

Although effective in preventing bank erosion, problems include high cost, complex construction, and failure to promote sediment deposition onsite and riparian plant establishment.

Kellner Jacks or Tetrahedrons

These methods come close to meeting project goals because they follow stream contours and promote sediment deposition and riparian plant establishment. Negatives include relatively high cost, complex construction, and little esthetic appeal. Also, most jack systems are designed for larger stream systems.

Porous Fence Revetment

This alternative was chosen for several reasons. Fence materials allow water to pass through the system, thus reducing water velocity and promoting sediment deposition. Sediments provide a growth medium for riparian vegetation. Plant growth, particularly woody species, strengthen the total system while making it less visible to the public. The system largely preserves the meander length and gradient. Temporary livestock exclosure is needed to speed recovery, but controlled grazing can be resumed after several years.

Two stream meanders were chosen to apply the porous fence revetment system. Designated in an earlier examination of meanders as sites G and H, the two locations had a combined streambank length of 1,400 feet. Eroding meander scarps measured up to 18 feet vertically. Based on three USGS streamflow gauges around the Zuni Mountains, design flows for the 100- and 50-year recurrence interval floods were 1,420 cfs and 890 cfs, respectively, from the 39,000-acre watershed above the sites (figure 1).

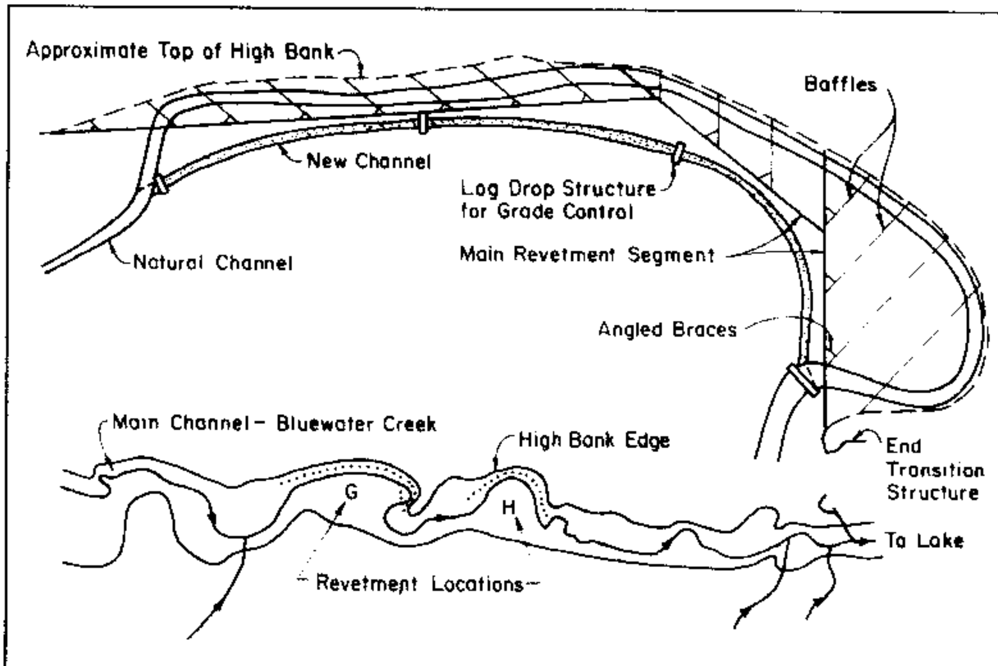


Figure 1.—Revetment locations on the creek and details of revetment G design.

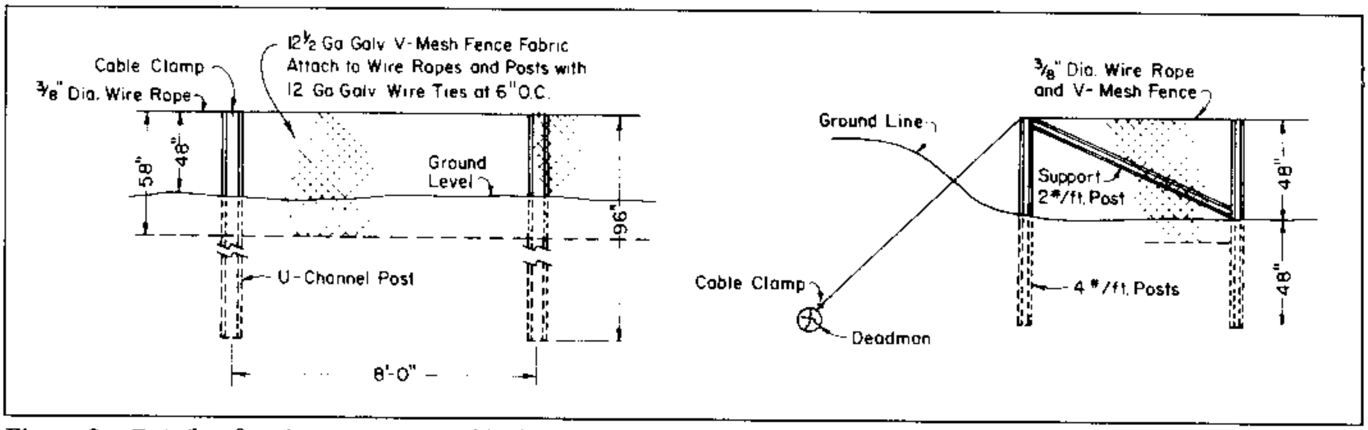


Figure 2.—Details of main revetment and baffle sections and the deadman and support assembly.

Soils are a deep alluvium, with the streambed entrenched into this material. Plants dominating high benches are rabbitbrush and snakeweed. Kentucky blue grass is found on lower terraces next to the stream course. Many old terraces and meander scars are evident, depicting a history of channel degradation and meandering. Before the arrival of European settlers, we theorize that Bluewater Creek flowed in a wide and shallow alluvial valley, growing significant riparian vegetation and providing home to numerous beaver and other wildlife.

Project Design & Materials

Materials are the key to this design. Other designs we had studied used posts of treated telephone pole, various diameter piping, old railroad rails, and similar materials.(*6*) All were difficult to handle and required drilling or other means to attach fencing materials. Fence materials typically were galvanized chain link fence or welded wire.

The design at Bluewater Creek uses predrilled, galvanized steel, U-channel sign posts commonly used to erect highway signs (figure 2). Posts can be bought in various lengths in 2-foot increments, in weights from 2 ½ to 4 pounds per foot. Two or more posts can be bolted together for added strength if desired. These posts are easy to handle and can be driven by hand or machine, and predrilling provides handy places to attach bolts, cable, and wire.

We chose fence material of 12 ½-gauge, galvanized, V-mesh woven wire. Horizontal strands are twisted double wire. Woven V-mesh verticals are wrapped around horizontals rather than welded—a stronger and more flexible system because spotwelds can break. Wire rope used for top support and deadmen are galvanized, as are all fasteners.

Each revetment section consists of several components. A new permanent channel is dug to keep water away from the eroding bank and to provide work space for construction and a site for sediment deposition and plant growth. The new channel must be maximized to maintain overall stream length and gradient.

The revetment consists of two elements: (1) one or more main segments aligned parallel to flow and (2) a series of baffles oriented perpendicular to flow, extending from the main segments back into the streambank. Main segments and baffles are faced with the fence material and attached so that water and debris will force the fence material against the posts. Galvanized wire rope extends along the top of the main segments, held at tension, and secured in the ground via deadmen made of post segments. Wire rope is similarly attached along the top of the baffle posts and secured in the banks. Fence material is secured to the posts and wire rope by 12-gauge, galvanized tie wire and galvanized U-bolts.

In this design, 8-foot posts were driven 4 feet into the ground, leaving 4 feet exposed. Posts for the main segments and baffles were on 8-foot centers. Fence material 58 inches high was used, with 10 inches being buried and the remaining 48 inches above ground. Burying was done to provide below-ground protection should the channel meander or widen against the revetment.

At several locations, 24-inch-diameter ponderosa pine logs were buried across the new channel, with the top edge of the log level with the stream bottom. This feature was designed to provide temporary grade control while the revetments became firmly established.

To enhance the revetments' effectiveness, several features were added to the project. All disturbed soil was seeded to promote ground cover and reduce erosion. Local willow cuttings were planted along banks of the new channel to provide bank strength and eventual shade. Cottonwood poles were planted to provide a future overstory component and seed source. Livestock grazing was eliminated for at least 5 years to give all vegetation a chance to become established, after which well managed grazing will be allowed.

Project Results

The revetments were installed by a contractor at sites G and H in the late fall of 1986. An above-average snowfall provided significant snowmelt runoff in the spring of 1987 before any vegetation could become established. The structures functioned flawlessly, however, capturing significant sediment deposits and small woody debris. The new channel widened considerably, but not enough to endanger the structures.

Vegetation growth in and around the structures did well during 1987, providing additional flow roughness to enhance sediment capture and provide ground and bank cover. Willow cuttings were planted on several occasions by various volunteer groups, and cottonwood poles also were put in place. The second winter saw little snow and little spring flow but significant summer thunderstorm runoff. Plant growth in and around the revetments was excellent. Willow plantings were partially successful. Most cottonwood poles lost their top vegetation but sprouted from the root collar in the summer of 1988.

Because improper installation and channel widening beyond expectations, several grade-control log structures were unsuccessful. Those logs, properly installed, continue to work well and remain submerged except during the lowest flows.

Project costs for materials, labor, and equipment totaled $27,700. With a bank length of 1,400 feet, the cost averaged $19.79 per foot of protected bank. As plant growth continues, maintenance costs should prove minimal, because each passing season provides additional root strength and bank cover.

The project designers feel confident that the project will continue to succeed. It has survived both high spring runoff and summer runoff events. Bank erosion is reduced, sediment deposition is occurring as planned, and plant growth is excellent. High-intensity storms in the summer of 1989 put the revetments to the test, and they did their job as designed.

Based on the success of these first two structures, the Forest Service has installed six additional revetment segments. Several design advances aided project success. The basic design is simple and easy to install, and it requires minimal equipment. Materials are readily available in various sizes and strengths to meet anticipated stream forces. It provides an integrated solution, combining revetment fencing, planting, seeding, and livestock management.

The designers feel several adjustments in design will make future projects more successful. Fences will be buried deeper, with only 1 ½ to 2 feet of fence exposed. This will be less obtrusive above ground, yet provide necessary control above and below the surface. The constructed channel will be further from the main revetment segments, providing additional insurance against undercutting. Grade-control logs may be eliminated because change in grade along the stream profile is minimal. Cottonwood cuttings will be grown in a nursery for 1 year before planting because rooted stock survive better than bare poles sunk to ground water level. Willows will be cut from local stock and planted as early as possible. These adjustments should strengthen the success of the initial design.

It is encouraging to note that local private landowners, previously skeptical of the Forest Service work along Bluewater Creek, are making inquiries about the project and considering similar work on their own adjacent lands.

References

1. Cooperrider, C.K., and B.A. Hendricks. 1937. Soil Erosion and Stream Flow on Range and Forest Lands of the Upper Rio Grande Watershed in Relation to Land Resources and Human Welfare. USDA Technical Bulletin No. 567.

2. USDA Forest Service. 1986. Preliminary Report—Hydrologic Function Analysis—Bluewater Creek Watershed, Mt. Taylor Ranger District, Cibola National Forest, Southwestern Region. Unpublished report. 47 p.

3. Maxwell, J.R., R.M. Solomon, L.J. Schmidt, R.A. LaFayette, and W.T. Hanes. 1985. Assessing Risks of Impaired Hydrologic Function. *Watershed Management in the Eighties.* New York: American Society of Civil Engineers. p. 163–173.

4. Hanes, W.T., R.M. Solomon, L.J. Schmidt, and R.A. LaFayette. 1986. Accelerated Erosion Risks vs. Watershed Condition. *Proceedings, Fourth Federal Interagency Sedimentation Conference,* Volume 2. Las Vegas, Nevada. 10 p.

5. Hanes, W.T., and R.A. LaFayette. 1987. Analyzing Watershed Condition: Symptoms vs. Causes. *Proceedings, Conference XVIII, International Erosion Control Association.* Reno, Nevada. p. 57–66.

6. State of California, Department of Public Works, Division of Highways. 1960. Bank and Shore Protection in California Highway Practice. Sacramento, California. 423 p.

Bridge End Fill Repair

Jim Johnson
Road Maintenance Engineer
Umpqua National Forest, Region 6

Editor's Introduction

About a year ago, the author was given the additional responsibility of bridge maintenance on the Forest's 132 bridges, along with his current responsibility of road maintenance. One of the first things he did was to take a field trip with Geotech Engineer Karel Broda to look at some bridge end fills needing repair. Gabions, or wire baskets, had worked quite well on a few of their bridges in the past, and their first inclination was to use the same method on these bridges. However, as they looked at the bridges and discussed it more fully, they decided to try something a little different. They are happy they did, because the new method has several distinct advantages over the old.

The Problem

The cantilever end of a bridge is designed to be flexible. It moves up and down with traffic loading and expands or contracts with temperature changes. This movement creates a void at the fill-bridge contact area that allows the support materials to leak out and cause the surfacing to fail.

An easy repair is to place a retaining wall in the fill at the bridge end. We chose Hilfiker wire mats because they are preformed, do not need additional forming, do not require special backfill, are easily handled, and are relatively inexpensive. (The cost for one 8-foot reinforcement mat, cap, backing mat, and ¼-inch screen was only about $60, including the hog ringer.)

The Solution

First determine how far down you need to go to intercept the slope line to provide support for the mat. Having the top end of the mat against the end of the bridge for 6 inches of vertical contact area is desirable (see figure 1). For one mat deep, have Hilfiker cut a 4-foot-long basket. If more assemblies are needed for vertical elevation, use the 8-foot standard length.

Excavate to the predetermined depth, compact the excavation floor, and start placing the mats, compacting as you go. Compaction is extremely important. If you do not plan on compacting to the degree needed, do not pave the road immediately; the aggregates should be paved as soon as possible.

Note: The sides of the wire mat assemblies are open. If the site requires enclosed sides, attach an additional wire mat sideways to the assembly.

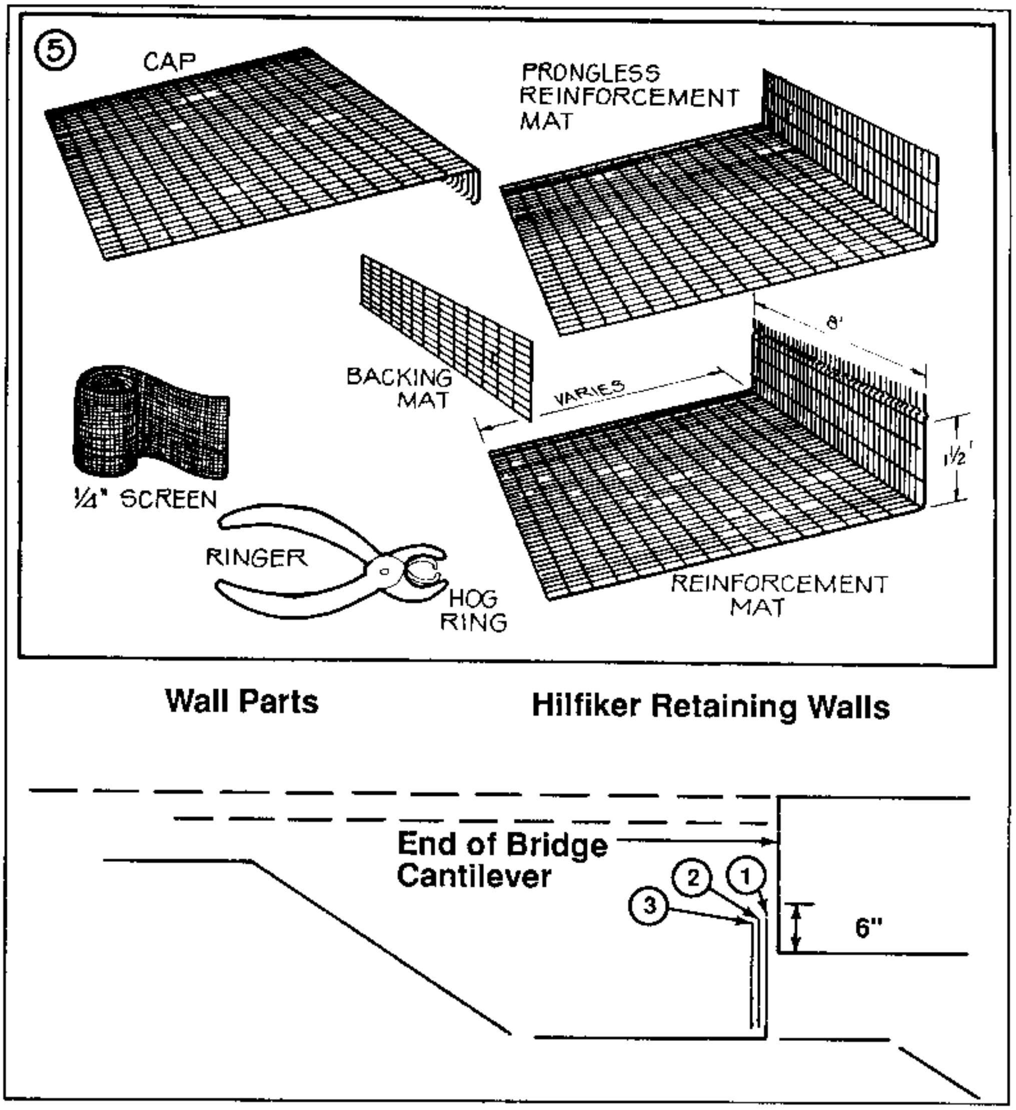


Figure 1.—Sketch of wall parts and Hilfiker retaining walls.

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