

U.S. Department
of Agriculture

Forest Service

National Technology
and Development
Program

0625 1808—SDTDC

2500—Watershed, Soil
& Air Management
7700—Transportation
Management

October 2006



Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations



Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations



Kim Clarkin, Hydrologist
San Dimas Technology and Development Center

Gordon Keller, Geotechnical Engineer
Plumas National Forest

Terry Warhol, Civil Engineer
Umatilla National Forest

Suzan Hixson, Hydrologist
Prescott National Forest

October 2006

Information contained in this document has been developed for the guidance of employees of the U.S. Department of Agriculture (USDA) Forest Service, its contractors, and cooperating Federal and State agencies. The USDA Forest Service assumes no responsibility for the interpretation or use of this information by other than its own employees. The use of trade, firm, or corporation names is for the information and convenience of the reader. Such use does not constitute an official evaluation, conclusion, recommendation, endorsement, or approval of any product or service to the exclusion of others that may be suitable.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Table of Contents

Foreword□	ix
Acknowledgments	xi
1 Introduction		
1.1	What are low-water crossings?.....	1—1
1.2	Potential benefits of low-water crossings.....	1—7
2 Planning: The big picture		
2.1	Evaluate the whole road.....	2—1
2.2	Evaluate the crossing site in its watershed context.....	2—2
3 Selecting the best structure for the site		
3.1	Is a low-water crossing appropriate?.....	3—3
3.2	What type of low-water crossing best fits the site?.....	3—7
4 Design elements, considerations and tools		
4.1	Overview of key engineering design elements.....	4—2
4.2	Structure-site compatibility and crossing location.....	4—9
4.2.1	Structure site compatibility.....	4—9
4.2.2	Crossing Location.....	4—14
4.3	Fish and aquatic organism passage.....	4—15
4.4	Roadway and site geometry.....	4—19
4.4.1	Channel Geometry.....	4—19
4.4.2	Roadway Design Geometry.....	4—20
4.5	Site hydrology.....	4—20
4.6	Hydraulic design.....	4—25
4.7	Scour, bank protection, and preventing channel changes.....	4—32
4.7.1	Scour.....	4—35
4.7.2	Rock Riprap for Channel and Bank Protection.....	4—39
4.7.3	Vegetation, Other channel and Streambank protection measures.....	4—46
4.8	Structural design of the driving surface.....	4—50
4.9	Safety.....	4—52
4.9.1	Traffic safety.....	4—52
4.9.2	Recreation safety.....	4—55
4.10	Materials selection.....	4—56

Low-Water Crossings

4.11	Best management practices for erosion control and water quality protection.....	4—58
4.11.1	Maintaining water quality.....	4—58
4.11.2	Erosion control.....	4—61
4.11.3	Best management practices.....	4—62
5	Low-water crossing types: pros, cons, idiosyncrasies, and anecdotes	
5.1	At-grade rock fords.....	5—1
5.2	Concrete slab fords	5—3
5.3	Precast concrete planks.....	5—5
5.4	Cable concrete blocks.....	5—6
5.5	Geocell fords.....	5—8
5.6	Porous, large rockfill fords	5—10
5.7	Gabion and Jersey barrier sill fords.....	5—12
5.8	Vented fords with small single or multiple culverts	5—14
5.9	Vented ford with concrete box culverts.....	5—16
5.10	Vented fords with large open-bottom arch culverts.....	5—18
5.11	Low-water bridges.....	5—19
6	Summary	6—1
7	References	7—1
8	Glossary	8—1

Appendixes

A—	Case studies (Included on CD inside back cover)	
1—	Red Clover Rock Ford.....	A—5
2—	Twenty-mile Creek Rock Fords	A—11
3—	Nurse Creek Rock Fill Ford	A—21
4—	Forest Road 732 Jersey Barrier Fords.....	A—29
5—	Willow Creek Concrete Plank Ford	A—37
6—	Fitzpatrick Creek Cable Concrete Block Mat Ford.....	A—45
7—	Woodrock Guard Station GEOWEB Ford	A—57
8—	Agua Fria River Concrete Slab Ford.....	A—67
9—	Mesman Slotted Concrete Slab Ford.....	A—77
10—	Black Canyon Concrete Plank Ford	A—89
11—	Babcock Crossing Vented Ford	A—93
12—	Grubbs Concrete Slab Vented Ford.....	A—103

Table of Contents

13—North Fork Consumnes River Tributaries Box Culvert Vented Fords	A—111
14—Rocky Creek Vented Box Culvert Ford.....	A—119
15—Moonlight Crossing Concrete Box Vented Ford	A—133
16—Sibley Creek Vented Ford	A—145
17—Stony River Treated Timber Box Culverts.....	A—157
18—French Creek Embedded Concrete Box Vented Ford.....	A—163
19—Mill Creek Embedded Box Culvert Vented Ford	A—173
20—Deep Creek Low-Water Bridge.....	A—185
21—Capps Low-Water Bridge.....	A—195
B—Site investigation form	B—1
C—Rosgen Channel types	C—1
D—Low-water crossing effects on water quality	D—1

Foreword

Low-water crossings are road-stream crossing structures designed to be overtopped by high flows or by debris- or ice-laden flows. They can be desirable alternatives to culverts and bridges on very low-volume roads and trails, and they can offer substantial environmental advantages in some stream environments. They are useful, for example, where streamflow is highly variable and large amounts of woody debris pose a risk to crossing structures. This publication reviews both the advantages and disadvantages of different low-water crossing structures in various stream environments and illustrates situations in which low-water crossings may be the optimal choice of crossing structure. The publication aims to provide multidisciplinary teams planning and designing road-stream crossing structures with answers to questions about where and how to best use overtoppable crossing structures.

The publication's four objectives are as follows:

- (1) To address how low-water crossing structures affect stream functions and stability in various environments.
- (2) To provide guidance for selecting low-water crossing structures that minimize disruption of channel processes and habitats.
- (3) To summarize basic design parameters and requirements.
- (4) To examine a wide range of field examples that illustrate the performance, problems, and advantages of different types of low-water crossings.

This publication is unique because it specifically deals with providing for aquatic organism passage and minimizing damage to channel stability and habitats. It focuses on the geomorphic and road management conditions that favor using low-water crossings as a means of minimizing negative effects to structures, stream channels, and aquatic habitats. It provides guidance on locating, selecting, and designing low-water crossings to fit the channel so they are less likely to obstruct stream functions, damage the aquatic system, and sustain structural damage during floods.

Meeting road management objectives while fulfilling site-specific biological and geomorphic goals requires a true interdisciplinary approach in which a biologist, and hydrologist, or geomorphologist work with the design engineer. Biologists and hydrologists do not usually have backgrounds in structural requirements for roads, traffic safety, road alignment issues, and the like. Engineers are not generally familiar with the swimming abilities and passage needs of fish or with fluvial geomorphology or sediment transport issues. A successful structure must

Low-Water Crossings

integrate the engineering requirements with hydrologic and biological factors. No one person or discipline has all this knowledge and range of experience. Many crossings that later failed were built by individuals who either had limited knowledge about these structures or did not consider all the relevant factors. Thus an interdisciplinary planning and design approach is critical to the overall success of a low-water crossing structure.

The publication is organized into five chapters.

Chapter 1 defines and introduces the various types of low-water crossings and explains in general terms where and when they can be useful.

Chapter 2 addresses key questions necessary for evaluating roads and sites in the larger context of the watershed and transportation system. This evaluation is critical in successfully launching a crossing replacement or construction project.

Chapter 3 describes the process of selecting the best structure for a site. For example, if the structure should be a low-water crossing, then what type of low-water crossing should be used? What considerations go into these decisions?

Chapter 4 brings together the basic tools and procedures for engineering design of low-water crossings, and shows how applying these tools and procedures can achieve various objectives.

Chapter 5 summarizes the authors' observations and recommendations about the benefits and risks of 11 types of low-water crossings.

Appendix A contains 21 case studies, some with plans and drawings from the actual construction contracts. Appendix A also lists the names of forest staff employees and others who provided the information and sometimes the photos for each case study. In addition, several case studies include information on similar structures in other locations.

Appendix B contains the Hydraulic Structure-Site Examination Form. Purpose and uses of the form are described in Chapter 4, section 4.2.

The authors trust this publication will help managers recognize—and develop designs for—sites where low-water crossings are likely to benefit the aquatic system. The publication also serves as a useful warning about unintended detrimental effects that low-water crossings can have on streams and aquatic species.

Acknowledgments

Many people in the U.S. Department of Agriculture (USDA) Forest Service regions and on forests contributed substantial time, expertise, and energy to this publication. Those listed as contacts for individual case studies provided information for one or more case studies and reviewed them for accuracy. We are very grateful for their information and insights.

We are particularly grateful to the following individuals who contributed information and advice:

Barton Clinton, Research Ecologist, USDA, Forest Service, Coweeta Hydrologic Laboratory, Otto, NC

Bill Crane, Civil Engineer, USDA, Forest Service, San Dimas Technology and Development Center, San Dimas, CA

Douglas E. Eberhardt, Chief, Clean Water Act Standards and Permits Office, San Francisco, CA

Nelson Hernandez, Deputy Regional Engineer, USDA, Forest Service, Pacific Southwest Region, Vallejo, CA

Richard Jones, Geotechnical and Bridge Engineer (retired), USDA, Forest Service, Southern Region, Atlanta, GA

Mike McCorison, Air Quality Program Manager, USDA, Forest Service, Pacific Southwest Region, Vallejo, CA

Jason Robertson, Wild & Scenic Rivers, Bureau of Land Management, Washington, DC

Larry Schmidt, Director, Streams Systems Technology Center, USDA, Forest Service, Fort Collins, CO

Kerry G. Scott, Project Engineer, Missouri Department of Conservation, Columbia, MO

Richard Standage, Fishery Biologist, USDA, Forest Service, Ouachita National Forest, AR



Special recognition to the USDOT FHWA Coordinated Federal Lands Highway Technology Implementation Program for their technical and financial contributions.

Low-Water Crossings

Finally, the following USDA Forest Service reviewers helped us improve the publication by offering thoughtful comments and critiques: Glenn Todd Allison, Rosanna Barkawi, Greg Bevenger, Merv Eriksson, Mike Furniss, Dave Gloss, Les Gonyer, Robert Gubernick, Nelson Hernandez, Roy Jemison, Russ Lafayette, Greg Napper, John Potyondy, Terry Savery, Bruce Simms, Richard Standage, Julianne Thompson, and Ray Zubick.

Paul Karr drew most of the graphics for the publication.