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National Engineering Handbook

Stream Restoration Design

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Cover photo: Streams and rivers are as complex as they are beautiful. A combination of the principles and analytical tools used in the fields of engineering, landscape architecture, geology, hydraulics, hydrology, ecology, and fluvial geomorphology are necessary to properly analyze and design stream and riverine projects.

Preface

The management of streams is a continuing balance between what people want and what plants and animals need. In an ideal world, a stream can satisfy both—in reality, the balance is ephemeral, at best, as streams evolve and humans continue to imprint their desires on the adjoining or upland landscape. Intervention is often needed when the balance becomes so skewed that the function of streams for either people or nature is at risk.

Just as one would consult a doctor regarding an illness affecting the body's function, one should consult a hydraulic engineer, stream ecologist, geomorphologist, aquatic biologist, or other riparian specialist for the diagnosis or treatment of a stream disorder or problem. An inappropriate or poorly designed restoration project can worsen or broaden the disorder. Site-specific designs based on sound, scientific experience are needed to properly select the size, orientation, and location of stream restoration techniques. Effective designs also need to include appropriate management techniques that remove sources of disturbance, allow the design elements to function well together, and enhance the stream's ability for ecological regeneration.

In planning and designing solutions to some stream problems, simply modifying adjacent land and riparian management practices may be all that is needed to improve degraded stream conditions. Streams are integrators of all upland problems, so some stream conditions are symptomatic of mismanagement of their surrounding watershed(s). In these cases, solutions may lie not only in restoring the stream directly, but in changing land uses and management practices throughout the entire watershed.

In a response to heightened environmental sensitivity, softer approaches are increasingly preferred by permitting agencies and the public. Green or natural engineering is making a strong foothold in the restoration of streams. One green technique, streambank soil bioengineering, has been used for centuries, historically with rock, wood, and native vegetation and now including developed plant materials and geosynthetics. Several large soil bioengineering projects were installed on United States streams (and rivers) in the 1930s, but these labor-intensive methods fell from favor largely until the 1960s. Many of the 1960s projects were not designed and constructed for habitat and landscape enhancement but primarily for structural controls. Przedwojski, Blazejewski, and Pilarczyk (1995) noted that the "application of living materials in civil engineering, including river training, is not as well managed as … earth and concrete structures." In the late 1980s to the present, stream restoration practitioners began to fully embrace green engineering and how-to guides and a one-size-fits-all design approach proliferated. New products and materials emerged, such as geosynthetics, specialized planting equipment, as well as selection and release of improved plant species for riparian areas. Engineers, hydrologists, and biologists also recognized the importance of including other disciplines such as fluvial geomorphologists to achieve comprehensive restoration goals.

Though there has clearly been impressive and needed movement toward green stream restoration, a paucity of supporting design research, engineering principles and scholarship exists. Robinson (2002) found that natural stream techniques had not been proven to the degree that conventional riprap has been, and, thus, often appeared more risky to landowners, permitters, and designers.

The state-of-the-art is still developing, as well as the supporting science and technology. This handbook marks a beginning. It contains tools and guidance to support stream restoration activities—specifically tools to use in designing restoration solutions. The focus of this handbook is on the how-to. It provides the user with specific tools to perform analyses and designs. This handbook presents engineering and ecological assessment and design tools that are applicable to a wide range of stream restoration work. The information contained herein represents both green techniques and structural approaches.

Please note that this handbook makes no endorsement of one particular approach over another and is not intended as a requirement document for purposes of funding or permitting. The guidance provided can be used to design and implement some of the techniques used in stream restorations. It is anticipated that as new methods are validated, they will be added to this guidance document or a supporting Web site.

Acknowledgments

Numerous people have provided source information, as well as expert reviews and comments. Their contributions are acknowledged and very much appreciated. The experience that they have helped document in this handbook will promote the science and art of stream restoration design.

Steering team

Carolyn Adams, director, U.S. Department of Agriculture, Natural Resources Conservation Service, East National Technology Support Center, Greensboro, NC

Jerry Bernard, national geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

Charlie Galgowski, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Tolland, CT

Howard Hankin, national aquatic ecologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

Bruce Newton, director, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Lamont Robbins, co-director, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX (retired)

David Thackeray, national civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, Washington, DC

Technical editors

Jerry M. Bernard, national geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

Jon Fripp, stream mechanics engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Kerry Robinson, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, East National Technology Support Center, Greensboro, NC

Publications staff

Lynn Owens, editor, U.S. Department of Agriculture, Natural Resources Conservation Service, National Cartographic and Geospatial Center, Technical Publications Team, Fort Worth, TX

Wendy Pierce, illustrator, U.S. Department of Agriculture, Natural Resources Conservation Service, National Cartographic and Geospatial Center, Technical Publications Team, Fort Worth, TX

Suzi Self, editorial assistant, U.S. Department of Agriculture, Natural Resources Conservation Service, National Cartographic and Geospatial Center, Technical Publications Team, Fort Worth, TX

Contributing authors

Wade Anderson, design engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

William Armstrong, senior director of development and marketing, BWR Corporation, Bartlesville, OK

Robert Armstrong, senior project manager, Huitt-Zollars, Inc., Dallas, TX

Peggy Bailey, civil engineer, Tetra Tech, Inc., Breckenridge, CO

Phil Balch, stream restoration specialist, The Watershed Institute, Topeka, KS

Laurie Barnes, environmental generalist, Salix Applied Earthcare, Redding, CA

Frank W. Beaver, assistant professor, University of North Dakota, Department of Geology and Geological Engineering, Grand Forks, ND

Jerry Bernard, national geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

David Biedenharn, research hydraulic engineer, U.S. Army Corps of Engineers, Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS (retired)

Todd Bobowick, biologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Torrington, CT

Ruth Book, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL

Kathryn Boyer, fisheries biologist, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Larry Brannaka, assistant professor, University of New Hampshire, Civil Engineering Department, Durham, NH

Diane Brittle, U.S. Geological Survey, Earth Science Information Center, Reston, VA

Rosanna Brown, landscape architect, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Ghislan Brunet, technical director, Maccaferri, Soil Bioengineering and Ecological Systems, MD

Dave Burgdorf, plant materials specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, East Lansing, MI

Janine Castro, geomorphologist, U.S. Fish and Wildlife Service, Portland, OR

Dave Cline, civil engineer, Tetra Tech, Inc., Seattle, WA

Dennis Clute, construction engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Tracey Cohen, landscape designer, The Bioengineering Group, Inc., Salem, MA

Mark F. Colosimo, senior engineering advisor, Department of State, International Joint Commission, Washington, DC

John B. Conroy, U.S. Geological Survey, Rolla, MO

Ron Copeland, research hydraulic engineer, Mobile Boundary Hydraulics, Vicksburg, MS

Frank Cousins, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, East Lansing, MI

Bradley Cutler, Golden Hills Resource Conservation and Development, Oakland, IA

Kaila Dettman, watershed hydrologist, Salix Applied Earthcare, Redding, CA

Ben Doerge, geotechnical civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Martin Doyle, University of North Carolina, Department of Geography, Chapel Hill, NC

Brock Emmert, geomorphologist, The Watershed Institute, Topeka, KS

Lawrence Fragomeli, structural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Katherine Fontaine, civil engineer, Burgess & Niple, Columbus Ohio

Jon Fripp, stream mechanics civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Bill Fullerton, civil engineer, Tetra Tech, Inc., Lafayette, CA

Tony G. Funderburk, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Central National Technology Support Center, Fort Worth, TX

Charles Galgowski, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Tolland, CT

Thom Garday, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Water Management Center, Little Rock, AR

Fred Gasper, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, East Lansing, MI

Larry Goertz, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX (retired)

Wendi Goldsmith, geologist and soil scientist, The Bioengineering Group, Inc., Salem, MA

Shane Green, area range/riparian specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Salt Lake City, UT

William Hansen, hydrologist, U.S. Department of Agriculture, Forest Service, Francis Marion and Sumter National Forests, Columbia, SC

Roberto "Bobby" Hernandez, community planner, U.S. Envioronmental Protection Agency, Water Quality Protection Division, Region 6, Dallas, TX

Jim Henderson, environmental planner, U.S. Army Corps of Engineers, Research and Development Center, Environmental Laboratory, Vicksburg, MS

Chris Hoag, wetland plant ecologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Interagency Riparian/Wetland Plant Development Project, Plant Materials Center, Aberdeen, ID

Doug Holy, national invasive species specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

Mark Johnston, project manager, BWR Corporation, Oklahoma City, OK

Meg Jonas, research hydraulic engineer, U.S. Army Corps of Engineers, Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS

Nancy Kennedy, flood plain administrator, City of Edmond, OK

Alica Ketchem, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Richmond, VA

Mary King, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Altoona, WI

Wayne Kinney, streambank specialist, Midwest Streams Inc., Edwardsville, IL

Dennis Law, soil scientist, U.S. Department of Agriculture, Forest Service, Francis Marion and Sumter National Forests, Columbia, SC

Ming-Han Li, assistant professor, Department of Landscape Architecture and Urban Planning, Texas A&M University, College Station, TX

Morris Lobrecht, design engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Merri Martz, fisheries biologist, Tetra Tech, Inc., Portland, OR

Kenneth W. Mayben, area civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Weatherford, TX

Dinah McComas, civil engineering technician, U.S. Army Corps of Engineers, Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, MS

Richard B. McComas, civil engineer, Starkville, MS

Danny McCook, geotechnical engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

John McCullah, watershed geologist, Salix Applied Earthcare, Redding, CA

Dan Mecklenburg, ecological engineer, Ohio Department of Natural Resources, Division of Soil and Water Conservation, Columbus, OH

Chris Miller, plant materials specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Somerset, NJ

David Moore, hydraulic engineer, Burgess & Niple, Inc., Columbus, OH

Daniel Moore, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

L. Jean O'Neil, ecologist, U.S. Army Corps of Engineers, Research and Development Center, Environmental Laboratory, Vicksburg, MS (retired)

Michael A. Pace, cartographer, U.S. Geological Survey, Rolla, MO

Paul Pedone, geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Portland, OR

Erick Powell, engineer, Brockway Engineering, Twin Falls, ID

David J. Putnam, biologist, U.S. Fish and Wildlife Service, State College, PA

Dick Quinn, hydraulic engineer, U.S. Fish and Wildlife Service, Newton, MA

Ray Riley, water resources planning specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Water Management Center, Little Rock, AR (retired)

Kerry Robinson, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, East National Technology Support Center, Greensboro, NC

Dave Rosgen, hydrologist, Wildland Hydrology, Fort Collins, CO

David Rush, environmental projects coordinator, Red River Regional Council, Grafton, ND

Leland Saele, design engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX (retired)

Robert Sampson, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Boise, ID

Lanka Santha, civil engineer and CEO, RoLanka International, Inc., Stockbridge, GA

Patti Sexton, civil engineer, Tetra Tech, Inc., Irvine, CA

Don Shanklin, construction engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX (retired)

Douglas Shields, Jr., research hydraulic engineer, U.S. Department of Agriculture, Agriculture Research Service, National Sedimentation Laboratory, Oxford, MS

Darlene Siegel, fisheries biologist, Tetra Tech, Inc., Portland, OR

Andrew Simon, research geologist, U.S. Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory, Oxford, MS

Robert Snieckus, national landscape architect, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

W. Barry Southerland, fluvial geomorphologist, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Christopher Spaur, ecologist, U.S. Army Corps of Engineers, Baltimore, MD

James Stautzenberger, contract specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, South Central Region, Ft Worth, TX (retired)

Lyle Steffen, geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE (retired)

Mitchell Strain, civil engineer, Burgess & Niple, Columbus, OH

James Stribling, biologist, aquatic ecologist, Tetra Tech., Inc., Owings Mills, MD

Donald Stover, engineering equipment operator, U.S. Fish and Wildlife Service, Erie National Wildlife Refuge, Guys Mills, PA

John Thomas, project director, Hungry Canyons Alliance, Oakland, IA

Lyn Townsend, forest ecologist, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Stanley W. Trimble, professor, University of California at Los Angeles, Geography Department, Los Angeles, CA

Ronald Tuttle, national landscape architect, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC (retired)

William A. Wallace, structural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

David Walowsky, civil engineering technician, U.S. Department of Agriculture, Natural Resources Conservation Service, La Fayette, NY

Andrew Ward, professor, The Ohio State University, Department of Food, Agricultural, and Biological Engineering, Columbus, OH

Jason Warne, graduate research assistant, University of North Dakota, Department of Geology and Geological Engineering, Grand Forks, ND

Chester Watson, professor, Colorado State University, Fort Collins, CO

Sean Welch, state hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Portland, OR

Kurt Welke, fisheries manager, Wisconsin Department of Natural Resources, Madison, WI

Monica Wolters, biologist, U.S. Army Corps of Engineers, Research and Development Center, Environmental Laboratory, Vicksburg, MS

Alan Wood, state project engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Harrisburg, PA

Donald Woodward, national hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC (retired)

William Worobec, project director, Big Bear Creek Restoration Project, Dunwoody-Big Bear Hunting and Fishing Club, Williamsport, PA

Ken Worster, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Scott Wright, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Tangent, OR

Steven Yochum, hydrologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Lakewood, CO

Reviewers

Wade Anderson, design engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Clif Baumer, environmental engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Columbia, MO

Tim Beechie, stream ecologist, National Oeanic and Atmospheric Association, Northwest Fisheries Science Center, Seattle, WA

Jerry Bernard, national geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

Kathryn Boyer, fisheries giologist, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Kelsi S. Bracmort, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

Art Brate, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Columbus, OH (retired)

Rosanna Brown, landscape architect, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Dave Burgdorf, plant material specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, East Lansing, MI

Janine Castro, geomorphologist, U.S. Fish and Wildlife Service, Portland, OR

Beth E. Clarizia, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Indianapolis, IN

Ron Copeland, research hydraulic engineer, Mobile Boundary Hydraulics, Vicksburg, MS

Dale Darris, conservation agronomist/Corvallis PMC, U.S. Department of Agriculture, Natural Resources Conservation Service, Corvalis, OR

Dave Dishman, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Portland, OR

Ben Doerge, design engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Eric Fleming, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Salt Lake City, UT

Darcie Frantila, scientific technical editor, Wildland Hydrology, Fort Collins, CO

Jon Fripp, stream mechanics civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

William Fullerton, hydraulic engineer, P.E., Tetra Tech, Inc., Lafayette, CA

Tony G. Funderburk, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Central National Technology Support Center, Fort Worth, TX

Charlie Galgowski, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Tolland, CT

Marie Garsjo, geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Larry Goertz, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX (retired)

Craig Goodwin, geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Lincoln, NE

Johnny J. Green, director, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Shane Green, state range management specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Salt Lake City, UT

Angela Greene, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Canaan Valley Institute, Davis, WV

Kale Gullett, fisheries biologist, U.S. Department of Agriculture, Natural Resources Conservation Service, East National Technology Support Center, Greensboro, NC

Howard Hankin, national aquatic ecologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC

William Hansen, hydrologist, U.S. Department of Agriculture, Forest Service, Francis Marion and Sumter National Forests, Columbia, SC

Presley Hatcher, chief, Permits Section, U.S. Army Corps of Engineers, Regulatory Branch, Fort Worth, TX

Roberto "Bobby" Hernandez, community planner, U.S. Environmental Protection Agency, Region 6, Water Quality Protection Division, Dallas, TX

Chris Hoag, wetland plant ecologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Interagency Riparian/Wetland Plant Development Project, Plant Materials Center, Aberdeen, ID

Sonia Maassel Jacobsen, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, St. Paul, MN

Robert Joy, plant materials specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, HI

Harold L. Klaege, state conservationist, U.S. Department of Agriculture, Natural Resources Conservation Service, Salinas, KS

John Leif, manager, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, East Lansing, MI

Barb Lensch, geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Madison, WI

Ming-Han Li, assistant professor, Texas A&M University, Department of Landscape Architecture and Urban Planning, College Station, TX

Morris Lobrecht, design engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Sharla B. Lovern, agricultural engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Stillwater, OK

Edwin Mas, tropical technology specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Mayagüez, PR

Danny McCook, geotechnical engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Peter D. McKone, wildlife biologist, director of Environmental Services, Dunaway Associates, Fort Worth, TX

Chris Miller, plant materials specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Somerset, NJ

Daniel Moore, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Carlos Morganti, plant material/grazing land specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Mayagüez, PR

Scott Mueller, assistant state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Madison, WI

George Pess, stream ecologist, National Oeanic and Atmospheric Association, Northwest Fisheries Science Center, Seattle, WA

Frank Reckendorf, fluvial geomorphologist, Reckendorf and Associates, Salem, OR

Dean M. Renner, stream mechanics engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Olympia, WA

Kerry Robinson, hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, East National Technology Support Center, Greensboro, NC

Phil Roni, watershed program manager, National Oeanic and Atmospheric Association, Northwest Fisheries Science Center, Seattle, WA

Dave Rosgen, hydrologist, Wildland Hydrology, Fort Collins, CO

Kae Rosgen, Wildland Hydrology, Fort Collins, CO

Glenn Sakamoto, manager, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, Honolulu, HI

Rob Sampson, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Boise, ID

Roy Schiff, Yale University, Ph.D. candidate

Mark Schuller, fisheries biologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Spokane, WA (retired)

Patti Sexton, civil engineer, P.E., Tetra Tech, Inc., CA

Louise O. Slate, civil engineer, project manager, H.W. Lochner, Inc., Raleigh, NC

Marty Soffran, agricultural engineer, SCC Streambank Protection Technical Liaison, U.S. Department of Agriculture, Natural Resources Conservation Service, Salina, KS

Robbin B. Sotir, soil bioengineer, Robbin B. Sotir and Associates, Inc., Marietta, GA

W. Barry Southerland, fluvial geomorphologist, U.S. Department of Agriculture, Natural Resources Conservation Service, West National Technology Support Center, Portland, OR

Chris Spaur, ecologist, U.S. Army Corps of Engineers, Baltimore, MD

Allan Stahl, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Annapolis, MD

Paul Starkey, civil engineering technician, U.S. Department of Agriculture, Natural Resources Conservation Service, Buffalo, WY

James Stautzenberger, contract specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Ft Worth, TX (retired)

Ashley Steel, quantitative ecologist, National Oeanic and Atmospheric Association, Northwest Fisheries Science Center, Seattle, WA

Tony Stevenson, state conservation engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Little Rock, AR

Darrel M. Temple, research hydraulic engineer, U.S. Departement of Agriculture, Agriculture Research Service, Stillwater, OK (retired)

Larry Tennity, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Dover, DE

John Thomas, project director, Hungry Canyons Alliance, Oakland, IA

Hans O. Tiefel, professor, Religion and Ethics, College of William and Mary, Williamsburg, VA (retired)

Ron Tuttle, national landscape architect, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC (retired)

Brandon Viers, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Columbia, MO

Andrew Ward, professor, Ohio State University, Department of Food, Agriculture, and Biological Engineering, Columbus, OH

Sean Welch, state hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Portland, OR

Robin White, geologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Albuquerque, NM

Peter Wilcock, professor, Johns Hopkins University, Department of Geography and Environmental Engineering, Baltimore, MD

Alan D. Wood, state project engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Harrisburg, PA

Donald Woodward, national hydraulic engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC (retired)

Ken Worster, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, National Design, Construction, and Soil Mechanics Center, Fort Worth, TX

Scott Wright, civil engineer, U.S. Department of Agriculture, Natural Resources Conservation Service, Tangent, OR

Steven Yochum, hydrologist, U.S. Department of Agriculture, Natural Resources Conservation Service, Lakewood, CO

Executive Summary

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has worked with private landowners since the 1930s to implement conservation plans that address their farm or ranch natural resource needs. Those plans often include voluntary measures to address problems associated with streams and, increasingly, to enhance habitat functions important to aquatic species of concern. In short, the agency works with the public in managing streams to meet their ecological needs and the needs of people who work and live nearby. NRCS technical assistance is based on science-based solutions that result in installed projects that range from relatively simple streambank protection to more complex plans covering watershed-scale stream and riparian restoration efforts involving multiple partners and agencies. There is a recognized need for the agency's technical guidance documents to be consistent, accurate, available, and current with stream-related innovations and improvements.

In 1998, an NRCS-led effort resulted in 15 Federal agencies producing the document entitled "Stream Corridor Restoration: Principles, Processes, and Practices" (NEH 653). Diverse groups of users, both nationally and internationally, are using this interagency document to plan stream corridor restoration projects. However, this document stopped short of providing specific design guidance tools that are required as the NRCS increasingly becomes involved in stream restoration projects that cover the full range of treatments, from natural to management to structural. These stream restoration projects require designs that can best be developed from a balance of skills in both engineering and ecology. This extensive document was assembled to ensure NRCS specialists and field personnel have the best design tools available.

The primary emphasis of this handbook is on how-to techniques; theory is only briefly discussed. Concise outlines, tables, and formulas are presented. While primarily an NRCS effort, stream and aquatic ecology experts from a variety of Federal, state, and local agencies, as well as private consultants and universities, contributed to the content.

Much of the information herein is not new; it is compiled from a rich system of existing guides used to treat or restore streams. Many of these legacy guides, however, consist of narrowly focused technologies primarily for engineered solutions, constructed earth channels, or bank armor, and do not fully integrate ecological, biological, or geomorphic criteria. NRCS developed guidance in the late 1980s and early 1990s for soil bioengineering practices, but these documents are dated and do not provide a system-based or holistic approach to analysis and design. Other information written and published by others, both inside and outside NRCS, provides guidance for balancing ecological goals with appropriate combinations of management and engineering designs. Guidance, tools, and procedures contained in this design handbook are those currently available for use—no additional research or development was specifically fostered for this effort. As appropriate, information was updated, reformatted, and edited to fit within the handbook's structure.

This handbook does not prescribe specific design procedures, nor does it assume that all stream restorations or rehabilitations will require structural treatments. Successful and sustainable stream work requires a thorough, contextual understanding of dynamic physical, chemical, and biological processes; risks and limitations; and range of applications for appropriate tools. It also involves weighing the wide array of management and intervention options that can be used to attain the desired and achievable condition. The overall stream restoration planning process should result in clear and obtainable goals, which should be implemented through appropriate designs. The best-designed treatment cannot make up for rushed, cookie-cut, or poorly defined plans.

In summary, this assembly of tools will help designers achieve a balance of management and engineering techniques. It does this by providing NRCS and other stream practitioners with principles and methods to restore functions in ways that enhance the natural abilities of streams and stream corridors to self-repair and adjust to variations in sediment and water loads without substantially compromising the needs and goals of the adjacent landowners.

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Terminology

This section provides a ready reference for some of the words and phrases used in the field of stream restoration design to the section or sections of the handbook where it is most thoroughly addressed. Other institutional and legal definitions exist for these terms, and many other definitions may exist in published sources. The definitions provided here are in the context of the scope and content of this handbook.

Term	Definition	Reference
Adaptive management	An approach to management that addresses changing site and project conditions, as well as taking into affect new knowledge; a management approach that incorporates monitoring of project outcomes and uses the monitoring results to make revisions and refinements to ongoing management and operations actions.	Ch. 16
Adfluvial fish	Species that hatch in rivers or streams, migrate to lakes as juveniles to grow, and return to rivers or streams to spawn.	TS 14N
Aggradation	Long-term sediment deposition occurs on the bed of a channel; opposite is degradation or bed erosion.	Ch. 13
Alaska Steeppass Fishway	See Denil Fishway.	TS 14N
Alignment	Planform of a channel.	Ch. 12
Allowable shear stress design method	A threshold channel design technique whereby channel dimensions are selected so that the average applied grain bed shear stress is less than the allowable shear stress for the boundary material.	Ch. 8
Allowable velocity	The greatest mean velocity that will not cause the channel boundary to erode.	Ch. 8
Allowable velocity design method	A threshold channel design technique whereby channel dimensions are selected so that the applied velocity during design conditions is less than the limiting velocity of the channel boundary.	Ch. 8
Alluvial channel	Streams and channels that have bed and banks formed of material transported by the stream under present flow conditions. There is an exchange of material between the inflowing sediment load and the bed and banks of an alluvial channel.	Ch. 7
Alluvial channel design	A design approach whereby a channel configuration is selected so that it is in balance with the inflowing sediment and water discharges.	Ch. 9
Amphidromous fish	Species that move between fresh and salt water during some part of their life cycle, but not for breeding.	TS 14N
Anadromous fish	Species that incubate and hatch in freshwater, migrate to saltwater as juveniles to grow, and return to freshwater as adults to spawn.	TS 14N

Analogy design method	A design approach that is based on the premise that conditions in a reference reach with similar characteristics and watershed conditions can be copied or adapted to the project reach.	Ch. 7 Ch. 9
Analytical design method	The use of bed resistance and sediment transport equations to calculate channel design variables.	Ch. 7
Anastomosed channels	Multiple-thread streams. The multiple channels tend to be narrow and deep because their banks are typically cohesive sediments; often found on alluvial fans.	Ch. 1
Anthroprogenic constraints	Constraints on a stream or river that are caused by human activities or constructed projects.	Ch. 2
Annual duration gage analysis	The analysis of the recorded peak flow values that have occurred for each year in the duration of interest; typically used for the estimate of flows with return intervals in excess of 2 years.	Ch. 5
Annual flood	The highest peak discharge that can be expected to occur on average in a given year.	Ch. 5
Areal sediment sampling	See Surface sediment sampling.	TS 13A
Arid	An area which generally has insufficient rainfall to support conventional agriculture without supplemental irrigation.	TS 14I
Armor layer	A streambed containing at least some sediment that is too large to be transported by the hydraulic flow conditions, finer particles are selectively removed, leaving a layer of coarser materials.	Ch. 7, TS 13A
Armor layer (sampling)	Technique used to sample the upper layer of coarse surface layer material.	TS 13A
Articulating concrete block (ACB)	A matrix of interconnected concrete block units installed to provide an erosion resistant revetment for streams and rivers.	TS 14L
Attenuation	The subsidence or flattening of a floodwave as it moves down the channel.	Ch. 6
Avulsions	Occur when bank erosion and longitudinal adjustment occur at a large scale and is typically characterized by rapid changes in channel planform.	Ch. 1
Barb	See Stream barb.	
Baseflow	See Low flow.	
Band-aid solution	Treatment techniques used to address small, local issues.	Ch. 14
Bank zone	The area above the toe zone, located between the average water level and the bankfull discharge elevation.	Ch. 4, TS 14I

Bankfull depth	The distance from the deepest part of the channel to the bankfull elevation line, typically measured across a straight section (riffle) of a channel.	Ch. 3
Bankfull discharge	Used as a surrogate for channel-forming discharge, defined, in part, by the visual identification of morphological bankfull indices.	Ch. 5
Bankfull indices	Field indicators of bankfull discharge.	CH. 5, TS 5
Bankfull width	The width of channel at bankfull elevation.	CH. 3
Bankline migration	The adjustment of planform in natural meandering channels.	Ch. 12
Bat	A flying mammal (*Chiroptera*). TS13D	Ch. 3
Bed control structure	A type of grade control structure that is designed to provide a hard point in the streambed that is capable of resisting the erosive forces of the stream.	TS 14G
Bed zone	The bottom of the channel.	Ch. 4, TS 14I
Bedding layer	See Filter layer.	TS 14K
Bedform scour	Vertical channel bed movement that results from the troughs between crests of the bedforms.	TS 14B
Bedrock	A solid rock on the face or beneath the Earth's surface.	Ch. 3
Bend scour	Bed erosion along the outside of a river or stream bend.	TS 14B
Bendway weirs	A flow-changing bank stabilization technique used to protect and stabilize stream and river banks. Flows are directed over the weir perpendicular to the angle of the weir.	TS 14H
Biota	The plants and animals of a region.	Ch. 1
Braided streams	Multiple-thread streams formed in response to erodible banks, high bed-material sediment load, and rapid and frequent variations in stream discharge. The multiple channels of braided streams tend to be shallow and wide.	Ch. 1
Branch packing	A soil bioengineering technique used to fill localized slumps and gullies. It involves the use of alternating layers of live cuttings and soil.	TS 14I
Bridge pier scour	Erosion of a streambed around the piers of bridges.	TS 14B
Brush layering	A soil bioengineering technique that provides protection against surface erosion and shallow-seated slope failure. It involves the use of alternating layers of live cuttings and soil.	TS 14I

Brush mattress	A streambank soil bioengineering technique that includes a layer of live cuttings placed flat against the sloped face of the bank.	TS 14I
Brush revetments	A soil bioengineering technique used to stabilize streambanks. Brush and tree revetments are nonsprouting shrubs or trees installed along the toe of the streambank to provide bank erosion protection and to capture sediments.	TS 14I
Brush spur	A long, box-like structure of brush that extends from within the bank into the streambed. They function very similarly to stone stream barbs.	TSs 14I, 14J
Brush trench	A soil bioengineering technique that is a row of live cuttings that is inserted into a trench along the top of an eroding streambank, parallel to the stream. The live cuttings form a fence that filters runoff and reduces the likelihood of rilling.	TS 14I
Brush wattle fence	See Wattle.	
Bulk sediment sampling	See Volumetric sediment sampling.	TS 13A
Burst swimming speed	Refers to the highest swimming speeds of a fish; generally lasts less than 20 seconds and ends in extreme fatigue.	TS 14N
Catadromous fish	Species that hatch in saltwater, migrate to freshwater as juveniles to grow, and return to saltwater to spawn.	TS 14N
Catchment	See Drainage area.	
Celerity	The speed that a floodwave moves down the channel.	Ch. 6
Channel alignment design	Techniques used to establish a stable channel planform.	Ch. 12
Channel classification	See Classification.	
Channel evolution	Systematic changes of a stream channel to a perturbation.	Ch. 3
Channel evolution model (CEM)	A model that illustrates the stages through which a stream progresses when subjected to destabilizing influences.	Ch. 3
Channel evolution model classification	A classification system that provides a predictable sequence of change in a disturbed channel system.	Ch. 3
Channel-forming discharge	Concept based on the idea that for a given alluvial stream, there exists a single discharge that, given enough time, would produce the width, depth, and slope equivalent to those produced by the natural flow in the stream. This discharge, therefore, dominates channel form and process.	Ch. 5
Channel slope	The average slope of the longitudinal thalweg profile.	Ch. 1
Channel stage classification	A stream classification system based on the channel evolution model.	Ch. 3
Channel stages	See Channel evolution model.	

Channel storage	Water that is temporarily stored in a natural or constructed channel while en route to an outlet.	Ch. 5
Channelization	The alteration of an existing river or stream for a specific physical, biologic, or aesthetic purpose.	Ch. 1
Check dam	A small dam constructed to slow stream velocity and/or prevent degradation.	TS 14P
Classification	The categorization of a stream reach into a specific class based on factors and measurements such as dominant mode of sediment transport, entrenchment ratio, and sinuosity. Streams can also be classified by their biota, habitat conditions, baseflow levels, and direct measures of water quality.	Ch. 3
Clear water scour	Occurs when there is insignificant transport of bed-material sediment from the upstream into the contracted section.	TS 14B
Coefficient of determination	Usually expressed as R^2, this commonly used measure of the goodness of fit is a dimensionless ratio of the explained variation in the dependent variable over the total variation of the dependent variable.	Ch. 5 Ch. 9
Coir fascine	A soil bioengineering technique used to stabilize streambanks. A manufactured product consisting of coconut husk fibers bound together in a cylindrical bundle held by natural or synthetic netting.	TS 14I
Compaction	The process of densifying soil so that air is expelled and the pore space is reduced.	TS 14I
Conditional letter of map amendment (CLOMA)	Provides Federal Emergency Management Agency's comment on whether a proposed project would be excluded from the Special Flood Hazard Area.	Ch. 17
Conditional letter of map revision (CLOMR)	Provides for a review of whether a proposed project within the Special Flood Hazard Area meets the minimum flood plain management criteria of the National Flood Insurance Program.	Ch. 17
Confidence limits	Provide a measure of the uncertainty or spread in an estimate. In hydrologic gage analysis, they are a measure of the uncertainty of the discharge at a selected exceedance probability.	Ch. 5
Confluence	The point where two streams or rivers merge. If they are of approximate equal size, this point may be called a fork.	Ch. 2
Conservation management unit (CMU)	An area having similar land use and treatment needs and management plan.	Ch. 4
Constraints	Limitations on the physical or biologic behavior and characteristics of a stream.	Ch. 2
Constructed channel	A ditch or reconstructed natural channel.	Ch. 2

Construction inspector	The person responsible for the day-to-day quality control inspection required to ensure that the work is installed according to the design, industry standards, and contract requirements.	Ch. 15
Contour fascines	See Fascines.	
Contract types	The many methods used to direct and pay for the installation of stream restoration or stabilization. The contract types vary primarily by administrative burden, construction oversight, and incentive for the contractor to control cost.	Ch. 15
Contracting officer (CO)	The person responsible for administering the contract including ensuring that the proper type of contract is being used and funds are spent according to regulations.	Ch. 15
Contracting officer's representative (COR)	The person responsible to the state engineer and the contracting officer to see that the work is carried out as designed and in accordance with the contract requirements.	Ch. 15
Contraction scour	Erosion of a streambed that occurs when the flow cross section is reduced by natural features, such as stone outcrops, ice jams, or debris accumulations, or by constructed features such as bridge abutments.	TS 14B
Conveyance	A measure of the flow-carrying capacity of a cross section.	Ch. 6
Cost reimbursement contract	A contract type whereby the contractor is paid for identified costs that are defined as reimbursable. See Contract types.	Ch. 15
Crib wall	A soil bioengineering technique used to stabilize streambanks. The crib is a hollow, box-like structure of interlocking logs or timbers. The structure is filled with rock, soil, and live cuttings or rooted plants.	TS 14K
Crimping and seeding	A soil bioengineering surface roughening treatment that secures straw to the surface. It is a temporary surface treatment that protects and promotes the establishment of permanent grasses and vegetation.	TS 14I
Critical shear stress	The shear stress at the initiation of particle motion.	Ch. 8
Cross-section area	See Flow area.	
Cross vane structure	A structure that provides grade control and a pool for fish habitat.	Ch. 11, TS 14G
Crumb test	A common field test for dispersive clays.	TS 14A
Darting speed	See Burst swimming speed.	
Dead stout stakes	Diagonally cut 2- by 4-inch lumber used to secure soil bioengineering practices.	TS 14I
Deflector	A structure that forms a physical barrier to protect the bank, and forces the flow to change direction either by direct impact or deflection.	TS 14H

Degradation	Long-term sediment removal occurring through increased erosion from the channel bed.	Ch. 13
Denil fishway	A rectangular channel fitted with a series of symmetrical, closely spaced baffles that redirect flowing water and allow fish to swim around or over a barrier.	TS 14N
Denil ladder	See Denil fishway.	
Depth	The distance between the channel bottom and the water surface.	Ch. 6
Design flows	Stream restoration design should consider a variety of flow conditions. These flows should be considered from both an ecological, as well as a physical, perspective.	Ch. 5
Design layout	The physical location of design elements in a stream restoration project; the most common methods used to locate features on a drawing include referencing to a baseline or centerline, creating a grid, or using a global positioning system (GPS).	Ch. 15
Design storm	A prescribed precipitation distribution and associated recurrence interval.	Ch. 5
Dimensionless shear stress	The ratio of the critical shear stress and the product of the grain diameter and the submerged specific weight of the particle, also referred to as the Shields parameter.	Ch. 8
Discharge	The rate of flow, often expressed in cubic feet per second, or ft^3/s.	Ch. 5
Disturbances	Changes to the physical or ecologic condition that are outside of the normal range of natural variations. Disturbances can be natural or anthropogenic.	Ch. 1
Ditch	A long, relatively narrow, constructed channel.	Ch. 10
Do Nothing option	See Future without action alternative.	
Dominant channel processes	Dominant channel processes are the forces at work in the watershed, which cause and limit channel change.	Ch. 13
Dominant discharge	See Channel-forming discharge.	
Dormant post planting	A soil bioengineering technique involving the use of large dormant stems, branches, or trunks of live woody plant material, that are planted for bank erosion control and creation of riparian vegetation.	TS 14I
Drag	The fluid force component acting on a sediment particle, which is parallel to the mean flow.	TS 14J
Drainage area	The area from which surface rainfall runoff is contributed to a specific point.	Ch. 5

Drained soil conditions	This is not a description of the water level in the soils, but rather a description of the pore pressure condition in the soil when it is loaded. A drained condition implies that either no significant pore pressures are generated from the applied load or that the load is applied so slowly that the pressure dissipates during the slowly applied loading. See Undrained soil conditions.	TS 14A
Duration	The length of time that water flows at a given discharge or a given depth.	Ch. 6
Effective discharge	The mean of the arithmetic discharge increment that transports the largest fraction of the annual sediment load over a period of years; often used as a surrogate for channel-forming discharge.	Ch. 5
Embankment bench	A technique used to stabilize steep banks with little or no disturbance at the top of the slope and minimal disturbance to the streambed. A gravel bench is constructed along the toe and protected with riprap.	TS 14K
Endangered Species Act (ESA)	A 1973 Act of Congress instructing Federal agencies to carry out programs to conserve endangered and threatened species and to conserve the ecosystems on which these species depend.	Ch. 17
Energy	A property of a body or physical system which enables it to move against a force. It is the amount of work required to move a mass through a distance.	Ch. 6
Engineer	The person responsible for the technical requirements of project installation and represents the owner.	Ch. 15
Entrenchment	The extent of vertical containment of a channel relative to its adjacent flood plain.	Ch. 3
Entrenchment ratio	The flood-prone width divided by the bankfull width.	Ch. 3
Ephemeral stream	A stream or reach of a stream that flows only in direct response to precipitation, and whose channel is above the water table at all times. The term may be arbitrarily restricted to a stream that does not flow continuously during periods of as much as a month.	Ch. 7
Ephemeroptera, Plecoptera, and Trichoptera Index (EPT)	A biologic assessment technique that is used to assess land use and water quality within a watershed. It uses benthic macroinvertebrates, such as stoneflies, mayflies, and caddis flies as indicators.	Ch. 3
Equilibrium bed slope	The slope at which the sediment transport capacity of the reach is in balance with the sediment transported into it.	Ch. 13, TS 14B
Equipment rental contracts	A contract type used in instances where a fixed-price construction contract would be impractical because of the nature of the work and when it would not be feasible to prepare detailed drawings and specifications. It requires substantial construction oversight. See Contract types.	Ch. 15

Equilibrium slope	The slope of a channel at which the sediment transport capacity of the reach is in balance with the sediment transported into it.	Ch. 13, TS 14G
Erosion	The wearing away of soil by running water, wind, or ice.	Ch. 1
Erosion control blankets (ECB)	A temporary protective blanket laid on top of bare soil vulnerable to erosion; commonly made of mulch, wood fiber, or synthetics.	TSs 14D, 14I
Erosion control fabric	See Erosion control blankets.	TSs 14D, 14I
Erosion stop wattle fence	See Wattle.	
Excavated bench	A technique used to stabilize steep banks with little or no disturbance at the top of the slope and minimal disturbance to the streambed. It involves shaping the upper half or more of the high bank to allow the formation of a bench to stabilize the toe of the slope.	TS 14K
Extremal hypothesis	A hypothesis that assumes a channel will adjust its geometry so that the time rate of energy expenditure is minimized.	Ch. 9
Facet	A distinct morphological segment of a longitudinal profile; riffle, pool, run, or glide (tail-out).	TS 3E
Fascine	A soil bioengineering technique used to provide stabilization to the toe of streambanks. A long bundle of live cuttings bound together into a rope or sausage-like bundles.	TS 14I
Federal Acquisition Regulations (FAR)	Regulations that govern Federal contracts.	Ch. 15
Filter layer	A layer that prevents the smaller grained particles from being lost through the interstitial spaces of the riprap material, while allowing seepage from the banks to pass. This layer typically consists of a geosynthetic layer or sand, gravel, or quarry spalls.	TS 14K
First-order stream	An unbranched tributary.	Ch. 3
Fish ladders	The broad category of techniques used to provide migrating fish with upstream passage around or through fish passage barriers.	TS 14N
Fish screens	The broad category of devices used to preclude adult and juvenile fish from entering flow diversion structures, pump intakes, diversion channels, pipes, or penstocks.	TS 14N
Fishways	See Fish ladders.	
Fixed-price contract	In most cases, considered to be the preferable type of construction contract. However, it requires an accurate cost estimate and construction details. See Contract types.	Ch. 15

Flood	A general term given to a relatively high flow measured in height or discharge quantity.	Ch. 5
Flood frequency	The anticipated period in years before a given flood will reoccur.	Ch. 5
Flood insurance rate map (FIRM)	The official map of a community on which the Federal Emergency Management Agency has delineated both the special hazard areas and the risk premium zones applicable to the community.	Ch. 17
Flood plain maps	Maps developed by the National Flood Insurance Program to reduce damages and loss of life caused by floods. The basis for flood management, regulation, and insurance requirements by identifying areas subject to flooding are provided.	Ch. 17
Flood-prone width	The width of the active flood plain at the flood plain elevation (twice the maximum bankfull depth); composed of the active channel (bankfull width) and left and right flood plain (flood-prone) widths.	Ch. 3
Floodway	The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation by more than designated height.	Ch. 17
Flow area	The area of the cross section between ground and water surface.	Ch. 6
Flow-changing devices	A broad category of structures which can be used to divert flows away from eroding banks.	TS 14H
Flow depth	See Depth.	
Flow duration	The percentage of time that a flow level is equaled or exceeded in a stream or river, typically represented with a flow-duration curve.	Ch. 5
Flow-frequency analysis	A consistent, statistical method for denoting the probability of occurrence of flows at a specific point in a stream system.	Ch. 5
Fluvial	Streams and rivers, in geography and Earth science, it is used to refer to all topics related to flowing water.	Ch. 1
Fluvial fish	Species that live in the flowing waters of rivers or streams, but migrate between rivers and tributaries for breeding, feeding, or sheltering.	TS 14N
Fluvial geomorphology	The study of the origin and evolution of landforms shaped by river processes.	Ch. 1
Force account agreements	Used when the sponsor performs the work using its own equipment and personnel.	Ch. 15

Formal contract	Under the Federal Acquisition Regulations as of 2005, formal contracts must be used for projects with a value greater than $100,000.	Ch. 15
Friction factor (*f*)	The roughness coefficient in the Darcy-Weisbach velocity equation.	Ch. 6
Froude number	A dimensionless ratio, relating inertial forces to gravitational forces, and representing the effect of gravity on the state of flow in a stream.	Ch. 6
Future without Action alternative	The option that involves allowing the site to progress without a project. The resources, both physical and ecological, that may be lost by not implementing the project are assessed as part of this alternative.	Chs. 2, 14
Gabion	A rock-filled wire mesh basket used to stabilize streambanks and slopes.	TS 14K
Gabion grade control	Grade control structures built with rock-filled wire mesh baskets.	TS 14G
Gage analysis	The use of statistical techniques to estimate probable frequency of flow events from recorded stream or river gage records.	Ch. 5
General permits	Issued Nationwide or regionally for categories of activities that are either similar in nature and cause only minimal individual and cumulative adverse impacts.	Ch. 17
General scour	Streambed erosion affecting the entire channel cross section.	TS 14B
Geocell	A product composed of polyethylene strips, connected by a series of offset, full-depth welds to form a three-dimensional honeycomb system.	TS 14D
Geogrid	A geosynthetic formed by a regular network of integrally connected elements with apertures greater than a quarter inch to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to function primarily as reinforcement.	TS 14D
Geologic assessment	The review of both the surface and subsurface features of geology and their possible impacts on a stream or river.	Ch. 3
Geomorphic analog	The use of a stable stream reach as a template for restoration design.	Ch. 2
Geomorphic goals	Goals or objectives based on concepts of landscape position, landforms, and ongoing processes that change them.	Ch. 2
Geomorphology	The study of the origin and evolution of landforms.	Ch. 1
Geonet	A geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids and gases.	TS 14D

Geosynthetic	A planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as part of a manmade project structure, or system.	TS 14D
Geotechnical analysis	The evaluation of the forces involved in bank instability problems including gravity acting on the soils in the slope, the internal resistance of soils in the slope, and the seepage forces in the soils in the bank.	TS 14A
Geotextile	A permeable geosynthetic comprised solely of textiles.	TS 14D
Glide	The downstream end of pools, just upstream of the next riffle, where the channel slope becomes adverse as the deeper section is intercepted by the tailing off point bar.	Ch. 11
Goals	The overall desired outcome, such as restore channel to pre-flood conditions.	Chs. 2, 16
Grade control	See Grade stabilization techniques.	
Grade stabilization techniques	Techniques used to stop channel degradation, typically accomplished by the construction of inchannel structures.	TS 14G
Grain Reynolds number	The ratio of the product of shear velocity and grain diameter to kinematic viscosity.	Ch. 8
Grass-lined channel design method	A threshold channel design technique used where climate and soils can support permanent vegetation, and baseflow does not exist. The approach is similar to the allowable velocity channel design method.	Ch. 8
Gravelometer	Device used to assist with the measurement of particles sampled as part of a pebble count.	TS 13A
Ground water	Water in a saturated zone or stratum beneath the land surface.	Ch. 1
Grout	See Grouted riprap.	
Grouted riprap	A riprap bed where the voids have been filled with concrete; often used where the required stone size cannot be obtained or at sites where a significant and damaging debris load is expected.	TSs 14K, 14G
Gully/gullies	Entrenched channels extending into areas with previously undefined or weakly defined channel conditions.	TS 14P
Gully plug	A small earthen dam constructed at one or more locations along the gully.	TS 14P
Habitat	A specific environment in which a particular plant or animal lives.	Ch. 1
Hybrid design methods	The use of a combination of analytical, as well as analogy and hydraulic geometry design methods, to calculate design variables.	Ch. 7

Hydraulic control structure	A type of grade control structure designed to reduce the energy slope along the degradational zone to the degree that the stream can no longer scour the bed.	TS 14G
Hydraulic depth	The ratio of the cross-section area of flow to the free surface or top width.	Ch. 6
Hydraulic geometry design method	Design approach based on the concept that a river system tends to develop in a predictable way, producing an approximate equilibrium between the channel and the inflowing water and sediment.	Chs. 7, 9
Hydraulic radius	The ratio of the cross-sectional area of flow to the wetted perimeter or flow boundary.	Ch. 6
Hydrodrill	See Waterjet stinger.	
Hydrodrill stinger	See Waterjet stinger.	
Hydro-physiographic area	A drainage basin where the combination of the mean annual precipitation, lithology, and land use produces similar discharge for a given drainage basin.	Ch. 3
Incentive contracts	A contract type that links the contractor's profit to performance by establishing reasonable and attainable targets that are clearly communicated to the contractor. See Contract types.	Ch. 15
Incipient motion design	See Threshold channel design.	
Index of Biotic Integrity (IBI)	A biological assessment technique that uses fish surveys to assess human effects on a stream and its watershed.	Ch. 3
Individual permit	A type of permit that involves the evaluation of a specific project.	Ch. 17
Infiltration	The downward movement of water into the surface of soil.	Ch. 1
Informal contract	Under the Federal Acquisition Regulations as of 2005, informal contracts and contracting procedures can be used for projects with a value of $100,000 or less. Informal contracts are those put in place using simplified acquisition procedures.	Ch. 15
Intermittent stream	A stream that flows only at certain times of the year when it receives water from springs or from some surface source such as melting snow in mountainous areas. The term may be arbitrarily restricted to a stream that flows continuously during periods of at least 1 month; also may be a stream that does not flow continuously, as when water losses from evaporation or seepage exceed the available streamflow.	Ch. 7
Irrigation ditch	A long, narrow constructed channel used to convey irrigation water from its source to place of use.	Ch. 1

Jetties	A flow-changing technique used to stabilize and protect stream and river banks. Fence-like structures extending from the bank and into the stream.	TS 14H
J-hook	A rock structure used to provide bank stabilization.	Ch. 11, TS 14G
Joint planting	A streambank soil bioengineering technique that includes cuttings of live woody plant material inserted in the voids of riprap, and into the ground below the rock.	TSs 14I, 14K
Jumping height	The maximum height obtained by a specific species and age of fish. Older and larger fish have greater maximum jumping heights, although some species have no jumping abilities at any age.	TS 14N
Labor-hour contracts	A variation of the time-and-materials contract, differing only in that materials are not supplied by the contractor. See Contract types.	Ch. 15
Lane's relationship	A qualitative conceptual model, also known as a stream balance used as an aid to visually assess stream responses to changes in flow, slope, and sediment load.	Ch. 13
Lane's tractive force design method	See Allowable shear stress design method.	
Large woody materials (LWM)	Habitat and bank stabilization provided until woody riparian vegetation and stable bank slopes can be established. Trees, branches, and rootwads are considered large woody materials. Also called large woody debris.	TS 14J
Letter contracts	Written preliminary contractual instruments that authorize the contractor to begin work immediately.	Ch. 15
Letter of map amendment (LOMA)	An amendment to the currently effective Federal Emergency Management Agency map establishing that a property is not located in a Special Flood Hazard Area.	Ch. 17
Letter of map revision (LOMR)	An official amendment to the currently effective Federal Emergency Management Agency map.	Ch. 17
Letter of permission (LOP)	A type of permit issued through an abbreviated processing procedure.	Ch. 17
Lift	The fluid force component on sediment particles perpendicular to the mean flow direction.	TS 14C
Live bed conditions	May be assumed at a site if the mean velocity upstream exceeds the critical velocity for the beginning of motion for the median size of bed material available for transport.	TS 14B

Live brush sills	A soil bioengineering technique that involves rows of live cuttings inserted into an excavated trench. This treatment is intended to promote sediment deposition and can function as erosion stops.	TS 14I
Live pole cuttings	A soil bioengineering technique that involves the use of dormant stems, branches or trunks of live woody plant material inserted into the ground that are planted for bank erosion control and creation of riparian vegetation.	TS 14I
Live post planting	See Dormant post planting.	
Live siltation	See Live brush sills.	
Live stakes	See Live pole cuttings.	
Local scour	Erosion of the streambed immediately adjacent to some obstruction to flow.	TS 14B
Log crib	See Crib wall.	
Log-Pearson type III distribution	The most commonly used frequency distribution for peak flows in the United States. It applies to nearly all series of natural floods; commonly used for stream gage analysis.	Ch. 5
Longitudinal peak stone toe (LPST)	A type of bank protection involving the placement of a windrow of stone in a peak ridge along the toe of an eroding bank.	TS 14K
Loose rock grade control structure	A simple type of a grade control structure consisting of placing natural stone or other nonerodible elements across the channel to form a hard point.	TS 14G
Low flow	A general term that refers to the average low flows in a stream. It is typically due to soil moisture and ground water. Critical habitat conditions often occur during low flows.	Ch. 5
Low-flow channel	A portion of a channel that conveys low or baseflows.	Ch. 10
LUNKERS	Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids—a technique providing both streambank stability and edge cover aquatic habitat.	TS 14O
Maintenance	Actions taken to ensure that the stream restoration project performs as designed and attaining project objectives.	Ch. 16
Manning's *n*	An empirical factor in Manning's equation which accounts for frictional resistance of the flow boundary.	Ch. 6
Meander	Deviation of the stream direction from the shortest possible path down a stream valley.	Ch. 12
Meander geometry	The five parameters commonly used in the description of meander patterns, including wavelength, radius of curvature, arc length, amplitude, and beltwidth.	Ch. 12

Meander length	The product of the meander wavelength and the valley slope divided by the channel slope.	Ch. 12
Meander ratio	The length of the stream divided by the length of the valley.	Ch. 12
Mobile boundary stability	The rate at which sediment enters the channel reach from upstream equal to the capacity of the reach to transport sediment of the same composition on downstream.	Ch. 7
Model (1–D)	One-dimensional models only consider forces that occur in one direction (usually the streamwise). Velocity and other stream properties may vary upstream and downstream, but not from bank to bank and not from the bed to the water surface.	Chs. 1, 5
Model (2–D)	Models are usually depth-averaged. They simulate variation in the horizontal plane, but assume no variation in the vertical.	Chs. 1, 5
Model–conceptual	Describes the objects and relationships either with words or diagrams.	Ch. 1
Model–empirical	Contains any empirical relationship, one based on data. An empirical model is based, at least in part, on observed data, rather than a thorough understanding of the underlying physical principles.	Ch. 1
Model–lumped	Describes processes on a scale larger than a point, while a distributed model describes all processes at a point, then integrates processes over space and time to produce a total system response.	Ch. 1
Model–mathematical	Formal mathematical models representing objects and interactions quantitatively with equations.	Ch. 1
Model–parametric	Has parameters that must be estimated in some fashion.	Ch. 1
Model–physical	Three-dimensional representations, usually at some relevant scale.	Ch. 1
Model–steady	Predict conditions that occur for a given set of boundary conditions. For example, a flow model might predict the water surface elevation, given a fixed channel geometry and a constant flow.	Ch. 1
Model–stochastic	Outputs are predictable only in a statistical sense. Repeated use of a given set of model inputs produces outputs that are not the same, but follow certain statistical patterns.	Ch. 1
Model–unsteady	Predicted variations that occur with time, such as during the passage of a storm hydrograph, by dividing such an event into a series of steady-state time steps. Complex, unsteady models have feedback loops that allow channel boundaries or other key variables to respond to inputs and change between time steps.	Chs. 1, 5
Momentum	The mass of a body times its velocity.	Ch. 6

Monitoring	The process of measuring or assessing specific physical, chemical, and/or biological parameters of a project.	Ch. 16
Montgomery and Buffington classification	A classification system based on defining channel processes. It is a geomorphic process-based system.	Ch. 3
Muddying-in	The practice of pouring a slurry mix of water and soil into the hole around the cutting stem of a plant to achieve good soil to stem contact.	TS 14I
National Environmental Policy Act (NEPA)	The Federal law establishing a national policy for the environment and requires specific actions by Federal agencies.	Ch. 17
National Flood Insurance Program (NFIP)	A program administered by the Federal Emergency Management Agency providing for flood insurance, flood plain hazard mapping, and flood plain management.	Ch. 17
Nationwide General Permit (NWP)	A type of general permit issued nationally by the U.S. Army Corps of Engineers for specific dredge or fill activities.	Ch. 17
National Pollutant Discharge Elimination System (NPDES)	A provision of the Clean water Act regulating point discharges into waters of the United States.	Ch. 17
Natural channel	A river, stream, creek, or swale that has existed long enough and without significant alteration to establish a dynamically stable route.	Ch. 2
Navigable waters	Defined for U.S. Army Corps of Engineers regulatory purposes as those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce.	Ch. 17
Newbury riffle	A type of constructed loose rock grade control structure.	TS 14G
No Action alternative	See Future without action alternative.	
NRCS Conservation Practice Standards	Guidance provided for applying conservation technology and set the minimum criteria for acceptable application of the technology. State variations on these standards may be more restrictive.	Ch. 4
NRCS contract specialist	The person who assists the administrative officer in contract matters for contracts and agreements.	Ch. 15
NRCS Planning Process	Steps used to develop an appropriate plan for natural resource protection or improvement.	Chs. 2, 4
NRCS State Conservation Practice Standards	Each state determines which NRCS National Conservation Practice Standards are applicable in their state. States add the technical detail needed to effectively use the standards at the field office level, and issue them as state conservation practice standards. Minimum criteria may be more restrictive than the national standards.	Ch. 4

Objectives	The detailed, focused outputs or outcomes that achieve the project goals.	Chs. 2, 16
Open channel flow	Flow where one surface is open to the atmosphere.	Ch. 6
Ordinary high water	The limit of U.S. Army Corps of Engineers jurisdiction in nontidal waters of the United States, in the absence of adjacent wetlands; defined as that line on the shore established by the fluctuations of water and indicated by physical characteristics.	Ch. 17
Outliers	Data points that depart significantly from the trend of the remaining data.	Ch. 5
Owner	The person responsible for contracting for construction. For NRCS Federal contracts, NRCS is considered the owner during construction.	Ch. 15
Partial duration gage analysis	The analysis of the recorded peak flow values above a preselected base value that have occurred for each year in the duration of interest; typically used for the estimate of flows with return intervals less than 2 years.	Ch. 5
Pattern	Plan view of a stream reach.	Chs. 3, 12
Pebble count	Technique used to sample the surface layer of sediments in gravel-bed streams.	TS 13A
Perennial stream	A stream that flows continuously. Streams flowing continuously throughout the year and are generally lower than the water table in the region adjoining the stream.	Ch. 7
Performance of work agreement	An agreement that requires that the value of work to be performed by the sponsoring local organization be determined by negotiation between the sponsoring local organization and NRCS and be included in the project agreement. NRCS must estimate the cost of the work to establish the maximum value of work before signing the agreement.	Ch. 15
Pile foundations	Used to transfer foundation forces through relatively weak soil to stronger strata to minimize settlement. The most likely applications for pile foundations in stream restoration and stabilization projects are as support for bank stabilization structures (retaining wall) and as anchors for large woody material.	TS 14F
Pin deflectors	Variations of the permeable jetty, generally used in streams where only a small reduction in velocity is needed. Generally wood pilings are used for their construction.	TS 14H
Piston aerial sampler	Device used to facilitate underwater aerial sediment sampling of fine material.	TS 13A
Plan	A sequence of logical steps followed to reach a goal or objective.	Ch. 2

Planform	Horizontal alignment of a channel; view is perpendicular to the Earth's surface.	Ch. 12
Point bar	A depositional area formed on the inside bank of a meander that sometimes remains bare of vegetation due to the frequent recurrence of the bankfull discharge.	Ch. 12
Pool	The area in a natural channel deeper and somewhat narrower than the average channel section.	Ch. 12
Practice standards	See NRCS Conservation Practice Standards.	
Pressure head	The potential energy of water, usually the result of its mass and the Earth's gravitational pull.	Ch. 6
Programmatic General Permit (PGP)	A type of general permit issued to avoid unnecessary duplication of regulatory control exercised by another Federal, state, or local agency.	Ch. 17
Project agreements	Any agreement(s) entered into by NRCS and sponsors, in which detailed working arrangements are established for the installation of cost-shared measures.	Ch. 15
Pump intake fish screens	See Fish screens.	
Quality assurance (QA)	Tasks or procedures undertaken to ensure that procedures are adhered to that will assure that the work will meet the minimum requirements. Quality assurance activities vary in accordance with the complexity and hazard class of the stream restoration project.	Ch. 15
Quality assurance plan (QAP)	Identifies the individuals with the expertise to perform various QA tasks, outline the frequency and timing of testing, estimate the contract completion date, and be co-approved by all responsible supervisors.	Ch. 15
Quality control (QC)	Tasks or procedures undertaken to ensure that the work installed meets the minimum requirements of the contract.	Ch. 15
R^2	The coefficient of determination. This commonly used measure of the goodness of fit is a dimensionless ratio of the explained variation in the dependent variable over the total variation of the independent variable.	Chs. 5, 9
Reach	A length of stream or river having some defined uniform characteristics.	Ch. 1
Reclamation	A series of activities intended to change the biophysical capacity of an ecosystem. The resulting ecosystem is different from the ecosystem existing prior to recovery. The term has implied the process of adapting wild or natural resources to serve a utilitarian human purpose, such as the conversion of riparian or wetland ecosystems to agricultural, industrial, or urban uses.	Ch. 1

Reconnaissance	A preliminary investigation not involving detailed investigation and relying heavily on existing data and observations.	Ch. 3
Redirective structure	A flow-changing bank stabilization technique. Designed to be placed in the stream, minimize direct impact, and rely more on the characteristics of fluid mechanics to modify the streamflow direction.	TS 14H
Reference reach design method	An alluvial channel design approach whereby channel dimensions are selected from a similar stable channel.	Chs. 2, 9
Regime design method	An alluvial channel design approach whereby channel dimensions are selected with the aid of empirically derived equations.	Ch. 9
Regional curves	A tool frequently associated with the Rosgen geomorphic channel design approach, but also applicable to other design methods. It involves bankfull dimensions correlated to drainage area. See Hydraulic geometry design.	Ch. 11, TS 5
Regional general permits (RGPs)	A type of general permit issued regionally.	Ch. 17
Regression equations (gage analysis)	Used to transfer flood characteristics from gaged to ungaged sites through use of watershed and climatic characteristics as predictor variables.	Ch. 5
Regulated stream systems	Streams or rivers that are cleared of wood, dammed, channelized, leveed or constrained by other types of hard structures.	Ch. 1
Rehabilitation	Making the land useful again after a disturbance. It involves the recovery of ecosystem functions and processes in a degraded habitat.	Chs. 1, 2
Resource management systems (RMS)	Sets of approved conservation practices.	Chs. 2, 4
Restoration	The reestablishment of the structure and function of ecosystems. Ecological restoration is the process of returning an ecosystem as closely as possible to predisturbance conditions and functions.	Ch. 1
Retard	A flow-changing bank stabilization technique. A retard structure increases flow resistance by increasing drag, thereby slowing the velocity in the vicinity of the structure. These structures are more porous with a high percentage of open area.	TS 14H
Reynolds number	A dimensionless ratio, relating the effect of viscosity to inertia, used to determine (index) whether fluid flow is laminar or turbulent.	Ch. 6
Riffle	The area in a natural channel that is wider and shallower than the average channel section.	Ch. 12
Riffle pool spacing	The distance between the riffles and the pools in a channel.	Ch. 12

Rigid boundary stability	Attained when the interaction between flow and the material forming the channel boundary is such that the soil boundary effectively resists the erosive efforts of the flow.	Ch. 8
Rigid drop grade control structure	A complex type of grade control structure that is used for large drops. These structures are frequently constructed of concrete or a combination of sheet pile and concrete.	TS 14G
Riparian zones	The areas between aquatic and upland habitats.	Ch. 1
Riprap	Large stone used to provide immediate and permanent stream and river bank protection.	TS 14K
Riprap sizing	See Stone sizing.	
Risk	The exposure of life, property, and/or the environment to loss or harm.	Chs. 2, 5
Risk analysis	The assessment of the consequences of specific action or inaction to life, property, and/or the environment.	Ch. 2
River	A large natural waterway confined within a bed and banks. In the context of this handbook, the term stream is often used interchangeably with river.	Ch. 1
River classification	See Classification.	Ch. 3
Rolled erosion control products	Consist of both erosion control blankets used for temporary erosion protection and turf reinforcement mats for more permanent erosion protection.	TS 14D
Rootwad revetments	Use of locally available logs and root fans to add physical habitat to streams in the form of coarse woody debris and deep scour pockets.	TS 14I
Rosgen classification	A stream classification system based on measurements of existing morphology.	Ch. 3
Rosgen geomorphic channel design method	A hybrid channel design approach that incorporates geomorphic measurements, hydraulic geometry and some analytical calculations.	Ch. 11
Rosgen stream type	See Rosgen classification.	
Rotary drum fish screens	See Fish screens.	
Run	The steepest section and shortest longitudinally, starting at the downstream end of a riffle as the channel enters the next pool.	Ch. 11
Salmonid	Family of fish which includes the salmons, trouts and chars. All of the species breed in freshwater, are migratory, and spend part of their life cycle in the ocean.	TS 14N
Scour	Downward vertical erosion in a channel bed.	TS 14B

Seasonal stream	An intermittent stream that flows only during a certain climatic season, such as a winterbourne. A stream or segments of a stream that normally goes dry during a year of normal rainfall. Seasonal streams often receive water from springs and/or long-continued water supply from melting snow or other sources.	Ch. 7
Sediment budget analysis	A quantitative sediment impact assessment of channel stability using the magnitude and frequency of all sediment-transporting flows done by comparing the mean annual sediment load for the project channel with that of the supply reach.	Ch. 13, TS 13B
Sediment competence	The ability to move the largest particle made available to the channel.	Ch. 11
Sediment continuity analysis	The volume of sediment deposited in or eroded from a reach during a given period of time is computed as the difference between the volumes of sediment entering and leaving the reach.	Ch. 13
Sediment impact assessment	An evaluation of a designed channel's ability to transport the inflowing water and sediment load, without excessive sediment deposition or scouring on the channel bed.	Ch. 13
Sediment rating curve	Correlates sediment flow to discharge for a stream reach or section.	Ch. 13
Sediment rating curve analysis	Sediment impact assessment technique used to assess the sediment transport characteristics of an existing or proposed stream project. This approach uses sediment rating curves to compare the sediment transport capacity of the supply reach to the existing and proposed project reach conditions.	Ch. 13
Sediment sampling	Technique used to quantify sediment in streams and rivers.	TS 13A
Shear	The pull of water on the wetted area in the direction of flow, and measured in units of force/area.	Ch. 9
Shear stress (average)	The product of the energy slope, hydraulic radius, and unit weight of water. Spatial and temporal variation may result in a higher or lower point value for shear stress.	Ch. 8
Sheet pile	Flat panels of steel, concrete, vinyl, synthetic fiber, reinforced polymer, or wood. Typical applications include toe walls, flanking and undermining protection, grade stabilization structures, slope stabilization, and earth retaining walls.	TS 14R
Shields diagram	Classic method for determining critical shear stress.	Ch. 8
Shields parameter	See Dimensionless shear stress.	
Sinuosity	The channel centerline length divided by the length of the valley centerline.	Chs. 3, 12
Slope stability	See Geotechnical analysis.	

Soil anchor	Technique used to anchor woody material to the streambed or bank to resist fluvial forces.	TS 14E
Soil bioengineering	The use of live and dead plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment.	TS 14I
Soil cement grade control	Structures constructed with a mix of Portland Cement and onsite soils.	TS 14G
Specific energy	The energy per unit weight of water at a given cross section with respect to the channel bottom.	Ch. 6
Specific force	The horizontal force of flowing water per unit weight of water.	Ch. 6
Spur dikes	Short dikes that extend out perpendicular from the bank into the channel along a reach of eroded bank.	TS 14H
Stability	A channel is considered stable (or in dynamic equilibrium) when the prevailing flow and sediment regimes do not lead to long-term aggradation or degradation.	Ch. 13
Stakeholders	Individuals or groups who fund a project or are affected by the project.	Ch. 2
Standard individual permit (SP)	A type of permit issued for activities that have more than minimal adverse impacts to waters of the United States. The evaluation of each permit application involves more thorough review of the potential effects of the proposed activity.	Ch. 17
State administrative officer (SAO)	The person responsible for all administrative matters for contracts and most agreements.	Ch. 15
State conservation engineer (SCE)	The person responsible for the design and ultimately responsible for ensuring proper construction of projects in a given state.	Ch. 15
Steady state models	Predict conditions that occur for a given set of boundary conditions.	Ch. 1
Stinger	Metal rod used to facilitate planting live cuttings into rock riprap.	TS 14I
Stone sizing	Technique used to determine the minimum size stone to resist stream velocity.	TS 14
Stream	A small natural waterway with a detectable current. Defined within a bed or banks. In the context of this handbook, the term stream is often used interchangeably with river.	Ch. 1
Streambank	The sides of a stream or river.	Ch. 2
Stream barbs	A flow-changing bank stabilization technique that are low dikes or sill-like structures that extend from the bank towards the stream in an upstream direction. As flow passes over the sill of the stream barb, it discharges normal to the face of the weir.	TS 14H

Streambed	The bottom of a stream or river.	Ch. 1
Stream classification	See Classification.	
Stream corridor	Includes the stream and extends in cross section from the channel's bankfull level towards the upland (perpendicular to the direction of streamflow) to a point on the landscape where channel-related surface and/or soil moisture no longer influence the plant community.	Ch. 1
Stream corridor restoration	One or more conservation practices used to overcome resource impairments and reach identified purposes.	Ch. 1
Stream order classification	A stream classification system based upon the degree of channel branching. An nth order stream is formed by the intersection of two or more (n-1) order streams.	Ch. 3
Stream power	The product of shear stress and mean velocity. A measure of the available energy a stream has for moving sediment, rock, woody, or other debris.	Chs. 6, 11
Stream setbacks	A width required to allow a stream to self-adjust its meander pattern.	TS 14S
Surface sediment sampling	Techniques used to characterize the surface of a gravel bed.	TS 13A
Sustained swimming speed	Refers to the low swimming speeds of a fish species. In general, it can be maintained for extended time periods with little to no fatigue.	TS 14N
S_e or $S_{Y,X}$	The standard error of estimate, typically expressed as S_e or $S_{Y,X}$. This is a measure of the quality of a regression equation and is the root mean square of the estimates. It is a measure of the scatter about the regression line of the independent variable.	Ch. 5
Thalweg	The deepest portion of the channel, sometimes referred to as the low-flow channel.	Ch. 1
Threshold channel	A channel in which channel boundary material has no significant movement during the design flow. The term threshold is used because the channel geometry is designed so that applied forces from the flow are below the threshold for movement of the boundary material.	Ch. 7
Threshold channel design	A design approach whereby a channel configuration is selected so that the stress applied during design conditions is below the allowable stress for the channel boundary.	Ch. 8
Timber crib	See Crib wall.	
Time-and-materials contract	Contract used to procure supplies or services on the basis of direct labor and materials costs. See Contract types.	Ch. 15
Toe zone	The portion of the bank between the average water level and the upper edge of the bottom of the channel.	Ch. 4, TS 14I

Top width	The width of a channel cross section at the water surface.	Ch. 6
Tractive power design method	A threshold channel design technique used in the assessment of channels in cemented and partially lithified (hardened) soils.	Ch. 8
Transfer methods (gage analysis)	Technique used to extrapolate peak discharges upstream or downstream from a stream gage or from gage data from a nearby stream with similar basin characteristics.	Ch. 5
Transition channel	A stream or river which may behave as an alluvial channel in one flow condition and as a threshold channel in another flow condition.	Ch. 7
Tree revetment	See Brush revetments.	
Tributary	A continuous perennial stream.	Ch. 1
Turf reinforcement mats (TRM)	Used to provide permanent erosion protection.	TS 14D
Two-stage channel design method	A hybrid channel design approach that incorporates a natural alluvial channel nested with a constructed flood plain bench.	Ch. 10
U.S. Army Corps of Engineers Regulatory Program	Program that evaluates permit applications for most construction activities that occur in the Nation's waters, including wetlands.	Ch. 17
U.S. Forest Service: Framework of Aquatic Ecological Units	An aquatic framework containing standard terms and classification criteria for aquatic systems and their linkages to terrestrial systems at all spatial scales.	Ch. 3
Uncertainty	The likelihood of a consequence occurring.	Ch. 2
Undrained soil conditions	This is not a description of the water level in the soils, but rather a description of the pore pressure condition in the soil when loaded. An undrained condition assumes pore pressures will develop due to a change in load. The assumption is that the pore pressures that develop are not known and thus must be implicitly considered in the methods used to test samples for this condition. See Drained soil conditions.	TS 14A
Uniform flow	Occurs when the gravitational forces that are pushing the flow along the channel are in balance with the frictional forces exerted by the wetted perimeter that are retarding the flow.	Ch. 6
Unsteady models	Predict variations that occur with time, such as during the passage of a storm hydrograph, by dividing such an event into a series of steady-state time steps.	Ch. 1
Valley slope	The maximum possible slope for the channel invert and is determined by the local topography, and a channel with a slope equal to the valley slope would be straight.	Ch. 9

Vanes	Flow-changing structures constructed in the stream designed to redirect flow by changing the rotational eddies normally associated with streamflow. They are used extensively as part of natural stream restoration efforts to improve instream habitat.	TS 14H
Vegetated gabion	A vegetated gabion incorporates topsoil into the void spaces of the gabion. Woody plantings and/or grass are planted into or through the structure.	TS 14K
Vegetated geogrid	See Vegetated reinforced soil slope.	
Vegetated reinforced soil slope (VRSS)	A soil bioengineering technique that is made up of layers of soil wrapped in synthetic geogrid or geotextile, with live cuttings or rooted plants installed between the wrapped soil layers.	TS 14I
Vegetated riprap	See Joint planting.	
Vegetated rock wall	A mixed-construction soil bioengineering streambank stabilization technique. The structural-mechanical and the vegetative elements work together to prevent surface erosion and shallow mass movement by stabilizing and protecting the toe of steep slopes.	TS 14M
Vegetated soil lifts	See Vegetated reinforced soil slope.	
Vegetated stone	Combining rock with soil bioengineering treatments can achieve benefits from both techniques.	TSs 14I, 14K
Velocity head	The kinetic energy of water.	Ch. 6
Vertical fixed plate fish screen	See Fish screens.	
Vertical traveling fish screen	See Fish screens.	
Visual geomorphic assessment	A qualitative assessment that includes judgment of current conditions, expected future conditions, and the river's anticipated response to the designed project.	Ch. 13
Volumetric sediment sampling	The techniques generally considered to be the standard sediment sampling procedure. It involves the removal of a predetermined volume of material that is large enough to be independent of the maximum particle size.	TS 13A
W-weir	Technique used to provide grade control on large rivers.	Ch. 11
Waterjet	See Waterjet stinger.	
Waterjet stinger	A device that uses high-pressure water to hydrodrill a hole in the ground to plant unrooted cuttings.	TS 14I
Watershed	A topographically bounded area of land that captures precipitation, filters and stores water, and regulates its release through a channel network into a lake, another watershed, or an estuary and the ocean.	Ch. 1

Wattle	A soil bioengineering technique made up of rows of live stakes or poles with live plant materials woven in a basket-like fashion. A wattle fence can be used to deter erosion in ditches or in small dry channel beds to resist the formation of rills and gullies.	TS 14I
Wetlands	Defined for U.S. Army Corps of Engineers regulatory purposes as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.	Ch. 17
Wetted perimeter	The length of cross-section boundary between water and ground.	Ch. 6
Width-to-depth ratio	The bankfull width divided by the mean bankfull depth (dimensionless.	Ch. 3
Wolman pebble count	See Pebble count.	
Wolman walk	See Pebble count.	
Woody debris	See Large woody materials.	
Work	Force applied over a distance.	Ch. 6

Chapter Summaries

The NRCS Stream Restoration Design Handbook (NEH654) presents a variety of engineering and ecological assessment and design tools. This handbook is not meant to be read linearly as a book; it is a set of tools and approaches that can be applied to stream restoration designs. The terms river or stream may be used in this handbook, but the terms do not denote a statutory size or watershed drainage area limitation or requirement. Any work performed on rivers and streams is under the purview of all applicable Federal, state, tribal, and local guidelines.

Chapter 1 Introduction: Ecological and Physical Considerations for Stream Projects

The NRCS Stream Restoration Design Handbook provides guidance for teams of engineers, biologists, geomorphologists, hydrologists, landowners, and resource managers who are planning and designing stream restorations. Goals may include controlling floods or sediment sources, improving stormwater drainage, stabilizing banks, improving fish habitat, or restoring the ecological functions and processes of a stream and its flood plain. Many approaches and techniques can be used to reach these goals, but a good understanding of the living and nonliving components of the stream ecosystem, its watershed, how they interact and affect each other, and the timeframes over which stream processes occur will improve the probability of desirable outcomes. Chapter 1 presents a brief overview of current knowledge regarding stream ecosystem processes and functions important to consider when designing stream improvements. For a more comprehensive treatment of these processes, readers may wish to review one of several excellent references, including Stream Corridor Restoration: Principles, Processes, and Practices, developed by the Federal Interagency Stream Restoration Working Group.

Chapter 2 Goals, Objectives, and Risk

Chapter 2 addresses the development of goals and objectives and the assessment of risk from an ecological, as well as a life and property perspective. Identification of stream problems and their causes is a critical step in the overall planning process. Understanding the true nature of stream problems is challenging because of the dynamic nature of streams, their seasonal changes, responses to disturbances, and their ability to recover. Recognizing the current condition of a stream, comparing it to historical conditions, and projecting its future conditions are challenging; nonetheless, the conditions to be documented determine goals and objectives met through the outcomes of the plan. Risk and risk assessment is introduced in this chapter and also described throughout this handbook.

Chapter 3 Site Assessment and Investigation

Chapter 3 describes procedures for assessing watershed and site conditions. Stream corridor inventory and assessment techniques are identified and compared. Information is provided on stream stability, as well as geological and biological assessments. A description of the uses, advantages, and disadvantages of various geomorphic stream classification systems is also provided. This chapter addresses fluvial processes and broader geologic issues related to ecological function, as well as stream design and behavior.

Chapter 4 Stream Restoration Design Process

Conservationists are frequently faced with conditions along and in streams that are characterized as problems because certain functions are not being provided or simply that the overall character of the stream system has changed. It may be that the system is damaged and needs to be repaired or that a shift in perception of stream functions and values has occurred, spurring some sort of action to be taken.

Often, solutions to identified stream problems are suggested at the time that they are identified, such as: “The streambank is sloughing in. We need to put rock riprap on it.” It could be that the problem merits that response. It could also be that the nature of the bank erosion problem is more complex and may be related to a general instability of the stream system. This chapter describes design approach that is applicable to the variety of potential treatment alternatives that are employed.

Chapter 5 Stream Hydrology

Stream restoration designs should consider a variety of flow conditions from both an ecological, as well as a physical perspective. A wide variety of sources and techniques for obtaining hydrologic data are available to the designer. Chapter 5 provides a description of the flows and their analysis that should be considered for assessment and design. The computation of frequency distributions is presented. Transfer equations, risk, and low flow methods are also addressed. This chapter also describes advantages and limitations of four general approaches for estimating channel-forming discharge or dominant discharge for stable channel design.

Chapter 6 Stream Hydraulics

Human intervention in the river environment, especially with projects intended to restore a riverine ecosystem to some healthier state, must take full consideration of streamflow, or stream hydraulics. Chapter 6 provides working professionals, both engineers and non-engineers, with practical information about hydraulic parameters and associated computations. It provides example calculations, as well as information about the role of hydraulic engineers in the project design process.

Chapter 7 Basic Principles of Channel Design

Channel design may involve the stabilization or realignment of an existing stream, or it may involve the creation of an entirely new channel. A wide variety of sources and techniques for designing stable channels are available to the designer. These techniques may focus on open channel design work ranging from natural stream restoration to primarily structural rehabilitations. The purpose of chapter 7 is to provide a framework to the designer to assess the use and application of several analysis and design techniques, which are presented in greater detail in subsequent chapters. Chapter 7 provides background that should be useful in the evaluation of the appropriateness of these techniques to address specific goals, constraints, and conditions. To provide a context for the different design techniques, a clear description of threshold and alluvial channels is presented. In addition, a general description of channel design variables and approaches is presented. These broad and occasionally overlapping categories of stream types and design approaches can be used to evaluate the appropriateness of the design techniques for a specific objective and site.

Chapter 8 Threshold Channel Design

Threshold channel design techniques are used for rigid boundary systems. In a threshold channel, movement of the channel boundary is minimal or nonexistent for stresses at or below the design condition. Therefore, the design approach for a threshold channel is to select a channel where the stress applied during design conditions is below the allowable stress of the channel boundary. There are a wide variety of sources and techniques for designing stable threshold channels that are available to the designer. Chapter 8 provides an overview and description of some of the most common threshold channel design techniques. Examples are provided to illustrate the methods.

Chapter 9 Alluvial Channel Design

Alluvial channel design techniques are generally used for movable boundary systems. In an alluvial channel, there is a continual exchange of channel boundary material with the flow. Therefore, the design of an alluvial channel requires an assessment of sediment continuity and channel performance for a range of flows. Many sources and techniques for designing stable alluvial channels are available to the designer. Chapter 9 provides an overview and description of some of the most common alluvial channel design techniques. The use and application of regime, analogy, hydraulic geometry, and analytical methods are presented and described. Examples are provided to illustrate the methods.

Chapter 10 Two-Stage Channel Design

Constructed channels are part of extensive portions of productive agricultural land in the United States. These channels provide important drainage and flood control functions. However, these agricultural channels are often constructed as traditional trapezoidal ditches using threshold design techniques. While this approach is suitable in some areas, channels of this design can require frequent and expensive maintenance in other parts of the country. This maintenance is often in the form of dredging and cleanout of deposited sediment. In addition, natural ecological functions can be lost. This chapter presents an alternative design to the conventional drainage channel, which seeks to mimic natural alluvial channel processes through the use of a two-stage channel design. This two-stage channel system incorporates benches that function as flood plains. However, these two-stage channels are not an exact copy of natural streams, as the width of the benches is often small due to the confining geometry of the constructed channel. This chapter outlines measurement and analysis procedures that can used to design two-stage channel systems that are more self-sustaining than conventional one-stage constructed channels.

Chapter 11 Rosgen Geomorphic Channel Design

Chapter 11 outlines a channel design technique based on the morphological and morphometric qualities of the Rosgen classification system. This approach has been implemented throughout numerous locations in the United States and is often referred to as the Rosgen design approach. The essence for this design approach is based on measured morphological relations associated with bankfull flow, geomorphic valley type, and geomorphic stream type. This channel design technique involves a combination of hydraulic geometry, analytical calculation, regionalized relationships, and analogy in a precise series of steps. While this technique may appear to be straightforward in its application, it actually requires a series of precise measurements and assessments.

Chapter 12 Channel Alignment and Variability Design

Natural channel design includes establishment of a stable planform and often the incorporation of variability within the channel. The designer of a channel is also often asked to provide an assessment of natural bankline migration, as well. The purpose of chapter 12 is to provide systematic hydraulic design methodologies that can be used in the performance of these tasks. A wide variety of sources and techniques for these assessments are available to the designer. An overview and description of some of the most common design techniques are described. Examples are provided to illustrate the methods.

Chapter 13 Sediment Impact Assessments

Sedimentation analysis is a key aspect of design since many projects fail due to excessive erosion or deposition. A sediment impact assessment is conducted to assess the effect that a full range of natural flows will have on possible significant aggradation or degradation within a project area. Chapter 13 provides a brief overview of several types of sediment impact assessments along with their rigor and level of uncertainty. The focus of this chapter is primarily on techniques that are appropriate for the analysis of alluvial channel, but threshold channels are also described. While there are variants in each of the presented techniques, and more information may be required to perform the assessments described, it is the intent of this chapter to provide the reader with an introduction to sediment impact assessments sufficient to select the appropriate approach for many circumstances. References are provided that outline specifics regarding the mentioned techniques.

It should also be supplemented that while this analysis of the sediment impact assessment is presented in the context of following the channel design, much of this analysis should also be done in the sediment assessment phase of the design process that precedes channel design. However, it is supplemented here as an important closure loop on any proposed design.

Chapter 14 Treatment Technique Design

Stream design and restoration often includes specific treatments on the riparian area, on the bank, or in the bed of a stream. Treatments can include techniques that provide ecological enhancement, as well as protection of these areas. This chapter provides an overview of some of the frequently used treatment techniques for bank protection, grade protection, and habitat enhancement, using a wide range of plant materials, rock, and other inert materials. In addition, analysis techniques that are needed for the successful design of these and other techniques are provided. Where information is available, the benefits, flexibility, risks, and costs of each technique are described from a physical, as well as an ecological perspective.

The list of techniques in this chapter should not be interpreted as an endorsement of any product that is mentioned, nor should it be inferred that one treatment or approach is superior to another. The approaches listed are not exhaustive. Other techniques, as well as variations of each of the ones described, exist and may be appropriate and applicable for use in restoration designs. This chapter provides techniques which often focus on the treatment of local problems, but these techniques and other design elements are often used to provide a holistic approach in larger or more complex restoration projects.

Chapter 15 Project Implementation

Chapter 15 addresses general project implementation issues with an emphasis on NRCS programs, requirements, and guidance. The four phases involved in project implementation are planning, design, contracts and agreements, and installation. This chapter describes how each phase is interrelated, how each phase requires knowledge of the limitations or restrictions of the other phases, and provides a general overview of project implementation.

Chapter 16 Maintenance and Monitoring

Maintenance and monitoring are actions intended to ensure the objectives of the stream restoration project are met over time. Continued performance of the project features and stream system health are dependent on appropriate maintenance and monitoring of the system. Chapter 16 provides an overview of key issues in the development of monitoring and maintenance plans. Incorporation of adaptive management as a component of operations is included as a possible approach to maintenance and operation of the project.

Chapter 17 Permitting Overview

Stream design and restoration design activities are subject to various local, state, and Federal regulatory programs. Most of these regulations are aimed at protecting natural resources and the integrity of the Nation's water resources. Chapter 17 provides a brief overview of the regulatory authorities and programs that may be applicable to stream design work. The focus is providing an awareness-level understanding of this important issue and sources to obtain more and current information. The reader should not interpret the description provided in this chapter as the only source of regulatory requirements. Local, state, and Federal regulatory authorities should be consulted as part of the planning and design efforts.