Project Final Report

for

A Grant Awarded Through the Section 319(h) Nonpoint Source Implementation Program Cooperative Agreement #C9994861-11

under the

Section 319(h) Kentucky Nonpoint Source Implementation Grant Workplan "Kentucky Stream Restoration Manual"

Kentucky Division of Water NPS 11-06
MOA PON2 129 1200002095 1

May 1, 2012 to December 31, 2016

Kentucky Stream Restoration Manual

UNIVERSITY OF LOUISVILLE.
STREAM INSTITUTE

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Funding for this project was provided in part by a grant from the US Environmental Protection Agency (USEPA) through the Kentucky Division of Water, Nonpoint Source Section, to the University of Louisville Research Foundation, Inc., as authorized by the Clean Water Act Amendments of 1987, §319(h) Nonpoint Source Implementation Grant #C9994861-11. Mention of trade names or commercial products, if any, does not constitute endorsement. This document was printed on recycled paper.

Acknowledgements

Arthur C. Parola, Jr., Ph.D., PE, Professor of Civil and Environmental Engineering at the University of Louisville and Director of the Stream Institute (ULSI), was the principal investigator. He developed and guided the development of project deliverables and led the Natural Channel Design Working Group (NCDWG) meetings.

Deven Carigan, Technical Advisor, Kentucky Nonpoint Source Pollution Control Program, Kentucky Division of Water, provided project oversight and reviewed this report.

Chandra Hansen, ULSI Research Technical Writer coordinated the activities of the Natural Channel Design Working Group and wrote and edited most of this final report.

Michael A. Croasdaile, PhD, Assistant Professor of Civil and Environmental Engineering at the University of Louisville, directed the collection and analysis of stream geomorphic data.

William S. Vesely, Clayton C. Mastin, and Jeong W. Park, ULSI Research Project Engineers, conducted fieldwork and data analysis.

We greatly appreciate the contributions of several NCDWG members and guests who shared their research or project expertise with the NCDWG:

Amy Braccia, Eastern Kentucky University
Mike Compton, Kentucky State Nature Preserves Commission
Eric Dawalt, Ridgewater, LLC
Mike Floyd, US Fish and Wildlife Service
Michelle Guidugli Cook, Eastern Kentucky University
Barbara Scott, Kentucky Division of Water

We also thank the 56 individuals who served as members of the Natural Channel Design Working Group:

Jessie Boles	KY Department of Fish and Wildlife Resources (KDFWR)
Rob Lewis	KY Department of Fish and Wildlife Resources (KDFWR)
Andrew Mowrey	KY Department of Fish and Wildlife Resources (KDFWR)
Bethany Mulhall	KY Department of Fish and Wildlife Resources (KDFWR)
Kristy Nowak	KY Department of Fish and Wildlife Resources (KDFWR)
Stephanie Petriello	KY Department of Fish and Wildlife Resources (KDFWR)
Dan Stoelb	KY Department of Fish and Wildlife Resources (KDFWR)
Matt Thomas	KY Department of Fish and Wildlife Resources (KDFWR)
Tom Van Arsdall	KY Department of Fish and Wildlife Resources (KDFWR)
Joseph Zimmerman	KY Department of Fish and Wildlife Resources (KDFWR)
Sarah Atherton	KY Division of Water (KDOW)
James Bicknell	KY Division of Water (KDOW)
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Keith Bowlin	KY Division of Water (KDOW)
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Jacob Culp	KY Division of Water (KDOW)
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Lisa Hicks	KY Division of Water (KDOW)
Emily Hogue	KY Division of Water (KDOW)
Adam Jackson	KY Division of Water (KDOW)
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Mark Martin	KY Division of Water (KDOW)
Aric Payne	KY Division of Water (KDOW)
Barbara Scott	KY Division of Water (KDOW)
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Jesse Robinson	University of Louisville Stream Institute (ULSI)
William S Vesely	University of Louisville Stream Institute (ULSI)
Jane E Archer	US Army Corps of Engineers (USACE)
Alan Goble	US Dept. of Agriculture, Natural Resources Conservation Service (NRCS)
Casey Shrader	US Dept. of Agriculture, Natural Resources Conservation Service (NRCS)
Michael A Floyd	US Fish and Wildlife Service (USFWS)
Jennifer Garland	US Fish and Wildlife Service (USFWS)
Jessi Miller	US Fish and Wildlife Service (USFWS)
Claudia Cotton	US Forest Service (USFS)
Andrew Christensen	US Forest Service (USFS)
Mike Jacobsen	US Forest Service (USFS)
Pamela J Martin	US Forest Service (USFS)
Jon Walker	US Forest Service (USFS)

The following 17 individuals attended meetings of the Natural Channel Design Working Group as guests:

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Executive Summary

Historic and contemporary land use and direct modification of streams have caused widespread degradation of stream habitat in the Commonwealth. As of 2010, the leading pollutant causing designated use nonsupport of Kentucky streams and rivers is sediment (sedimentation/siltation), and for 47.6% of streams listed as impaired in Kentucky, loss of aquatic habitat is named as the probable source of impairment (KDOW 2010). One method being used to remedy these degraded systems is stream restoration. Long-term, sustainable restoration of streams requires methods that tailor the design to the physiographic region, eco-region, and site-specific conditions of each stream. At present, however, most designs of Kentucky stream restorations are based on methods developed primarily in the western US for streams that have been impacted by land-use activities common to that region of the country and for streams in regions of relatively dry climates and high basin relief. Restoration design methods that address the specific land and stream characteristics and habitat degradation problems of Kentucky have not been well documented.

The goal of this project was to increase the likelihood that restoration projects will result in successfully functioning, self-sustaining streams and their associated wetlands. Two objectives were established to meet this goal: (1) develop a restoration manual for gravel-bed streams based on existing restoration design methods that address the specific land and stream characteristics and habitat degradation problems of Kentucky; and (2) continue to provide a forum for the Natural Channel Design Working Group (NCDWG) to exchange channel restoration assessment and design concepts and their applications to Kentucky streams. The NCDWG, to be composed of representatives from project partners (Kentucky Department of Fish and Wildlife Resources, KDOW, Kentucky Transportation Cabinet, Natural Resource Conservation Service, US Army Corps of Engineers, US Fish and Wildlife Service, and US Forest Service) would also serve as a multidisciplinary panel of reviewers to support the development of the manual.

The methods to be documented in the manual were to be those that have been developed and implemented by the University of Louisville Stream Institute (ULSI) to restore ecological functions of Kentucky gravel-bed streams and their associated wetlands. The following tasks were completed to develop the manual and coordinate the NCDWG: (1) a preliminary outline was developed; (2) mapping, surveys, photographs, and other supporting data were assembled or collected; (3) NCDWG meetings and/or field trips were held every two to three months to facilitate continued interagency communication and technology exchange and review and discussion of concepts relevant to the manual; (4) a draft of the manual was submitted to KDOW; (5) as an alternative to revising and completing the manual, a report on principles for restoration of stream-

wetland complexes was developed and distributed to KDOW and NCDWG for review and comment; (6) a design to address sediment and debris blockage problems on Obion Creek in western Kentucky was developed and submitted to KDOW; and (7) this final report evaluating the success of the project was submitted.

The long-term measure of success will be the level of improvement in the capacity of those who plan, implement, and/or regulate stream restorations to successfully identify and replace lost or degraded stream functions and values. Measures of success that could be obtained during the project period included the completion of a KDOW-approved Kentucky stream restoration manual, the number of NCDWG meetings held, and the number of partners contributing review.

As an alternative to revising and completing the manual, a report on principles for restoration of stream-wetland complexes was developed and distributed to KDOW and NCDWG for review and comment. Two project partners (US Fish and Wildlife Service and KDOW) reviewed and commented on the paper.

The NCDWG was extremely successful as a forum for the transfer of fundamental knowledge, procedures, and problems related to water resource conditions specific to Kentucky. The forum maintained consistently high interest and participation of state and federal agency professionals, and it became a resource on which agency personnel relied for efficient and effective acquisition and exchange of much-needed information and solutions. Twelve NCDWG meetings were held. Lectures and field trips facilitated the focused discussion of current stream stability and stream habitat problems and current restoration projects. This supported inter-agency exchange of knowledge of natural channel design and channel restoration assessment concepts and their applications to Kentucky streams. Interest and participation in the NCDWG remains high: an average of 13 members attended each meeting. ULSI continues to receive inquiries about joining the group.

Kentucky Stream Restoration Manual

By Arthur C. Parola, Jr., and Chandra Hansen

1. Introduction

1.1 BACKGROUND

Historic and contemporary land use and direct modification of streams have caused widespread degradation of stream habitat in the Commonwealth. As of 2010, the leading pollutant causing designated use nonsupport of Kentucky streams and rivers is sediment (sedimentation/siltation). Loss of aquatic habitat is named as the probable source of impairment for 47.6% of the streams listed as impaired in Kentucky (KDOW 2010). One method being used to remedy these degraded systems is stream restoration, broadly defined herein as activities undertaken to enhance, rehabilitate and/or re-create stream systems. Stream restoration activities constitute a substantial investment of financial resources. The in-lieu fee program administered by the Kentucky Department of Fish and Wildlife Resources (KDFWR) is currently the primary means of mitigating for adverse impacts to Kentucky streams and wetlands. From fiscal years 2002 through 2010, more than $70 million in fees were collected by the KDFWR in-lieu fee program (KDFWR 2010). During that same period, more than $47.6 million of those funds were spent on restoration/ enhancement of 57.2 mi of streams and creation/ restoration of 62 ac of wetlands. The average cost of those 54 projects was more than $880,000 (KDFWR 2010). These costs only partially account for the annual expenditures on stream and wetland restorations in Kentucky; they do not include on-site mitigation projects or restorations unrelated to mitigation, such as 319(h) demonstration projects, municipal projects, or Landowner Incentive Program efforts.

Given the amount of money being invested in stream restorations—and the reliance on them to further multiple watershed goals such as improving water quality; increasing or protecting habitat for rare, threatened, or endangered species; preserving biodiversity; and protecting adjacent landowners' property—the importance of ensuring the success of these efforts is considerable. Furthermore, as regulatory agencies come under increasing pressure to ensure that mitigation projects result in replacement of functions (e.g., USACE and USEPA 2010), the need is becoming more acute for assessment and design methods that address not just channel form but also stream and landscape ecological functions.

Long-term, sustainable, successful restoration of stream functions requires restoration design methods that are tailored to the physiographic region, eco-region, and site-specific conditions of each stream. The University of Louisville Stream Institute (ULSI)

has been developing and implementing design methods for restoring Kentucky streams and wetlands for the past 10 years. In these restorations, floodplains and stream channels were reconstructed to reestablish the historic surface and subsurface processes that would have occurred at the sites prior to human-imposed changes to the watershed's hillslopes, valleys, and stream channels. These self-sustaining restorations have the capacity to adjust to changes in the watershed. They are able to maintain grade control and stable habitat without being constrained to a fixed form that would be necessitated by structures commonly installed to direct flow through the channel.

While the restoration design methods developed by ULSI address the specific land and stream characteristics and habitat degradation problems of Kentucky, they have not been well documented, which severely limits the potential for them to be more widely used. Instead, most designs of Kentucky stream restorations continue to be based on methods developed primarily in the western US (Newbury and Gaboury 1994; Rosgen 1996), where past land-use activities, climate, and basin relief often bear little similarity to those of the eastern US, including Kentucky. Those methods also tend to rely on reference reaches, which are considered to represent target conditions but in fact tend to represent only partial recovery from a long history of direct and indirect impacts (Wohl and Merritts 2007). Stream restorations based on these methods are designed to stabilize streams and improve habitat; their emphasis is on the design of channel planform, pattern, and profile.

The restoration design approach that is currently the most widely implemented in Kentucky and the US is that developed by Rosgen (1996), whose methods emphasize reference reach characteristics and the bankfull channel form. Consideration of the specific regional characteristics, complexity, and dynamics of Kentucky stream systems tends to be limited both by the focus on design of the bankfull channel based on a reference reach and the limited availability of other practical methods. This in turn results in multiple design elements (e.g., groundwater and surface water hydrology) not being addressed or utilized that otherwise could improve stream ecological function and sustainability.

The design approach in most of these types of restorations focuses on bankfull flow and floodplain interaction, the design of the bankfull channel, transport of the largest bed material in the supplied load, and the use of structures for grade control and to improve habitat targeted for recreational fisheries. This often results in design of a high-stress channel to transport cobble, which creates bank stresses that eventually cause failure of the banks or the structures used to hold grade. Moreover, in several restorations where designs have relied on elevating the bed of the channel to reconnect it to the floodplain without considering groundwater interaction with the channel, the period of surface flow in the channel has been reduced, and in some cases base flow has been eliminated entirely. Where groundwater interaction is overlooked in the design, water quality and temperature may actually be degraded by the restoration if flow in the channel is reduced.

Members of the Natural Channel Design Working Group requested that a guide to restoring Kentucky streams be developed in 1999 (Margi Jones, KDOW, pers. comm.). Little guidance of that type, however, has been developed and made available. Without additional documentation regarding restoration design techniques that relate functions and the specific land and stream characteristics and habitat degradation problems of Kentucky, efforts to improve restoration practices in Kentucky are likely to be limited

and more difficult to implement than they would be if more complete guidance were available.

As the knowledge and techniques applied to watershed management continue to be refined, water resources managers and practitioners will benefit from opportunities to receive and exchange information about the application of those principles. Two means of facilitating that training and transfer of knowledge are the development of a restoration manual for Kentucky streams and the continued support of the Natural Channel Design Working Group (NCDWG). The stream restoration manual would strengthen the ability of state and federal agency personnel to determine how and where to best spend scarce resources in order to effectively address ecological impairments. An improved state of knowledge of restoration design principles also would facilitate the accurate identification of hydrologic impairments of stream systems and permit a more efficient application of best management practices (BMPs) to mitigate those problems. Likewise, planners and environmental practitioners would benefit from an increased awareness and understanding of the importance of incorporating hydrologic and hydraulic processes into design.

The second means of technology transfer, the NCDWG, was originally conceived as a forum for the transfer of fundamental knowledge, procedures, and problems related to water resource conditions specific to Kentucky. The forum has been extremely successful and continues to maintain consistently high interest and participation of state and federal agency professionals, who benefit from the opportunity the forum provides to link accepted and emerging theories with the conditions and problems they encounter in practice. The NCDWG has become a resource on which agency personnel rely for efficient and effective acquisition and exchange of much-needed information and solutions.

1.2 PROJECT PURPOSE AND SCOPE

The goal of this project was to increase the likelihood that restoration projects will result in successfully functioning, self-sustaining streams and their associated wetlands. Two objectives were established to meet this goal:

1. Develop a restoration manual for gravel-bed streams based on existing restoration design methods that address the specific land and stream characteristics and habitat degradation problems of Kentucky
2. Continue to provide a forum for the Natural Channel Design Working Group (NCDWG) to exchange channel restoration assessment and design concepts and their applications to Kentucky streams.

The methods to be documented in the manual were to be those that have been developed and implemented by the University of Louisville Stream Institute (ULSI) to restore ecological functions of Kentucky gravel-bed streams and their associated wetlands. The NCDWG, to be composed of representatives from project partners (Kentucky Department of Fish and Wildlife Resources, KDOW, Kentucky Transportation Cabinet, Natural Resource Conservation Service, US Army Corps of Engineers, US Fish and Wildlife Service, and US Forest Service) would also serve as a multidisciplinary panel of reviewers to support the development of the manual.

The following tasks were completed to develop the manual and coordinate the NCDWG:

1. A preliminary outline was developed.
2. Mapping, surveys, photographs, journal articles, and other supporting information were assembled or collected.
3. NCDWG meetings and/or field trips were held approximately every two to three months to facilitate continued interagency communication and technology exchange and review and discussion of concepts relevant to the manual.
4. A draft of the manual was submitted to KDOW.
5. As an alternative to revising and completing the manual, a report on principles for restoration of stream-wetland complexes was developed and distributed to KDOW and NCDWG for review and comment.
6. A design to address sediment and debris blockage problems on Obion Creek in western Kentucky was developed and submitted to KDOW.

This project led to the development and distribution of a report on principles for restoration of stream-wetland complexes to water resources practitioners and managers. This technology transfer will facilitate the effective use of stream restoration design to not only stabilize restored stream reaches but also restore stream and floodplain ecological functions. The project also continued the NCDWG, which provided the means to share the knowledge and perspectives about Kentucky stream morphology and ecology necessary for effective restoration.

2. Materials and Methods

2.1 MANUAL DEVELOPMENT

The methods to be documented in the manual were those that have been developed and implemented by ULSI to restore ecological functions of Kentucky gravel-bed streams and their associated wetlands. The activities completed for development of the manual are described below.

Preliminary Outline Development

A preliminary outline was developed and submitted to KDOW for approval. The outline consisted of six main sections: (1) introduction, (2) stream function and dynamics, (3) principles of design, (4) site assessment, (5) conceptual design process, and (6) detailed design process. These sections would include an introduction to design concepts; techniques for assessing sediment sources and loads and for identifying important geomorphic processes occurring on a watershed scale and their impact on stream stability, bank erosion, sediment supply, and stream habitat; development of conceptual design alternatives; techniques for completing detailed assessments (bed material load, site geotechnical characteristics, and groundwater and channel hydrology) and using them for design; introduction to the application of two-dimensional flow modeling to floodplain and channel design; and development of design alternatives and important components of a detailed design for a section of a stream and floodplain restoration.

Data Collection

Literature Review

A literature search was conducted for documents and books providing information relevant to the concepts and techniques to be discussed in the manual. Examples of relevant topics included geomorphic assessment procedures; physical stream impairments in Kentucky and the eastern US; principles of open channel flow; hydraulics and hydrology; sediment transport and mobility; the morphological development and significance of bankfull geomorphic conditions; bank stability and channel adjustment mechanisms; the association between stream morphology and ecological function; stream restoration techniques and methods; design procedures; and one- and two-dimensional modeling.

Remote and Field Data Collection

Mapping and other spatial data sets compiled by the Stream Institute were extensively reviewed to identify illustrative data and other content for the manual. These included topographic maps, contemporary and historic aerial photographs, land-use maps and descriptions, historic maps, soil maps, road maps, gauge data, or other similar information. Additional remote data and field data were collected to supplement existing data. Field reconnaissance activities included visual observations and more complex quantitative geomorphic assessments and data collection such as photo-documentation of channel and watershed features, assessment techniques, construction activities, and monitoring activities; measurements/surveys; and other similar information.

Development of Draft Manual

A rough draft of the manual was developed and submitted to KDOW for review. At the time the draft was submitted, KDOW was also notified that completion of the manual as proposed as a project output was not feasible. This conclusion was reached after multiple attempts to complete a full draft of the manual. In consultation with KDOW, an alternative set of project outputs was agreed upon and provided to KDOW:

1. All project products for which work had been invoiced, including the following:
   - Rough draft of the Kentucky stream restoration manual
   - Any associated research findings
   - Literature reviews
   - Field data
   - Photo-documentation
   - Maps and GIS layers
   - Natural Channel Design Working Group (NCDWG) meeting agendas, presentations, speaker notes
2. A report detailing fundamental principles of stream-wetland complex restoration.
3. A design effort that will help farmers and the Obion Creek Nature Preserve in Western Kentucky (see Section 3). Outputs included the following:
   - Grading plans for a sediment management area
   - 2-D hydrodynamic modeling output to show how this management area will affect flood flow direction

- Floodplain model that shows how the sediment management area would affect flood flows

4. A project final report and financial closeout report.

2.2 NCDWG COORDINATION

A listserv was established to facilitate email communication with and between NCDWG members. Dates for about five meetings per year were selected annually and announced via the listserv at the beginning of the year. Meeting agendas were established based on suggestions from the group members for field trips or lectures. Agendas were distributed to the listserv approximately one month before each meeting. A typical lecture meeting followed this agenda:

1. Presentation by team member with illustrative exercises
2. Discussion of presentation
3. Sharing of information about projects or restoration activities, manuals, books, or articles

3. Results and Discussion

3.1 MANUAL DEVELOPMENT

Although a final draft of the manual was not completed, work on its development led to several useful research findings that were incorporated into the principles report:

1. High sediment loads from upstream sources can significantly impact stream-wetland complexes. Efforts need to be made to reduce excessive loads from sources in the upstream watershed. Where site conditions permit, sediment splay areas should be created at the upstream end of restorations to store and attenuate pulses of high sediment loads that may enter the restoration.
2. Streams in forested watersheds such as White Pine Branch in the Daniel Boone National Forest are still impaired because of human activity that ceased more than four decades ago. The streams have incised to bedrock and drain their valley aquifers. The stream is dry for much of the year.
3. Most of the headwater streams in Kentucky, including those in forested watersheds, are incised or are incising as a direct or indirect consequence of channelization. Bedrock, boulder and cobble colluvium, boulder rubble, and man-made bed controls such as riprap and culvert inverts are the only forms of vertical controls that are persistent in these channels.
4. Channels that transport large gravel and cobble have bank shear stresses in channel bends that exceed the threshold stress for bank vegetation. If the goal of a restoration is to transport material that is larger than coarse gravel, then the banks in channel bends cannot be stabilized by vegetation alone.
5. Restorations should be designed with consideration of the effects of large storm events on the order of a 100-year peak flow. Vertical (profile) controls should be designed to withstand stresses produced by these large storm events.
6. The design of restored headwater channels that mobilize the largest particles in bars in the incised pre-restoration channel when flow is at “bankfull” results in channels

that are both laterally and vertically unstable. Coarse gravel and the boundary shear stress during large flow events (10-year recurrence interval or larger) will be much higher than those at bankfull, resulting in bank stresses higher than the vegetation thresholds, high sediment transport rates, and failure of all but the most robust vertical controls.

3.2 PRINCIPLES REPORT

The principles report produced as a substitute for the originally proposed manual describes design methods that incorporate not only in-channel habitat but also the surface and subsurface hydrology of the stream-floodplain system. A design conceptual model was developed from research of historical stream floodplain systems and sites where the authors have used this model to restore headwater streams in the eastern US. Although uncommon today, stream-wetland complexes may have been a common aquatic ecosystem prior to European settlement. Streams were part of an integrated surface and groundwater system with baseflow at or near the level of the wetland plant roots. Negligible amounts of gravel or fine sediment would have been transported. The restoration design is composed of four main parts: valley aquifer, baseflow channel, profile controls, and floodplain soils. The four components are designed based on eight principles drawn from the pre-settlement systems. These design methods have been successfully implemented in valleys with specific physical characteristics: a valley aquifer made up of coarse sediment over bedrock; negligible sediment supply; first- through third-order streams; and valley slopes of up to 10%. The design approach can work in many other situations but may require modification.

3.3 SEDIMENT MANAGEMENT DESIGN FOR OBION CREEK

ULSI completed a design effort that will help farmers and the Obion Creek Nature Preserve in Western Kentucky. Sediment and debris have blocked more than 2 miles of a channelized section of Obion Creek in eastern Hickman County, Kentucky. During high water flow events that occur several times per year, debris and sediment from the 120-square-mile watershed accumulate near the upstream end of the blockage. The blockage continues to extend upstream at a rate that has exceeded several hundred linear feet per year. As the blockage builds upstream, it causes several problems to adjacent farm land and to extensive wetlands. The water in the channel is ponded by the blockage, causing high groundwater and undrainable conditions in the adjacent farm fields. During each high flow event, sediment, debris and strong currents wash across the fields, leaving large trees, gravel and coarse sand deposits on top of productive silty loam soils. Channels form in the field where concentrated flow overtops the channel banks. Several hundred acres of productive farm lands are being affected at present. The gravel and coarse sand also spread onto the wetland soils of the downstream nature preserve, burying the natural silty wetland soils.

Past attempts to dredge the channel have resulted in rapid refilling of the channel with sediment and debris delivered from upstream. Unless the supply of sediment and debris is controlled, the channel will keep filling. A large portion of the sediment and debris could be captured and managed, however, to limit the growth of the blockage. The Obion Creek Watershed Conservancy District has proposed to construct an area to

divert and manage sediment and debris. The sediment and debris management area will be formed by excavating a 100−200-ft-wide strip of floodplain on private land near the current upstream end of the blockage. The area will be easily accessible for removal and hauling equipment to be used to maintain its storage capacity. To improve drainage, connections will be restored to old channels that were severed when Obion Creek was channelized. The old channels will be connected to the current main channel to reduce the groundwater level in adjacent farm fields. A similar restoration of old channels in the nature preserve downstream lowered the ponded water elevation by more than 3 feet. ULSI completed grading plans and flood flow analysis for the sediment management area.

3.4 NCDWG

NCDWG Participants

The NCDWG was originally established in 1999 as a multidisciplinary forum for interagency communication and technology exchange. Prior to this project, representatives to the NCDWG had been invited from state and federal agencies and institutions that conduct watershed assessments, design stream restorations, or regulate stream restoration projects within the Commonwealth. Those original invitees were selected based on an evaluation of their level of interest, their level of expertise, and the amount of time they could contribute to the working group. While some of those founding members still participate, many others have retired or relocated, and the personnel hired to replace them have been added to the group at the request of their supervisors.

New and continuing members who attended meetings during the project period represented one municipal agency, four state and four federal agencies, and one public higher education institution (Table 3.1). These individuals included biologists, botanists, water resources engineers, forest hydrologists, highway engineers, and bioengineers with varying levels of knowledge of and experience with the ecology and geomorphology of Kentucky streams. An additional 17 individuals attended various meetings as guests (see Acknowledgments).

Table 3.1 NCDWG Participants and Organizations

Agency/Organization Represented	No. Attendees
KY Department of Fish and Wildlife Resources (KDFWR)	10
KY Division of Water (KDOW)	21
KY State Nature Preserves Commission (KSNPC)	1
KY Transportation Cabinet, Division of Environmental Analysis (KYTC-DEA)	3
Lexington-Fayette Urban County Government (LFUCG)	2
University of Louisville Stream Institute (ULSI)	8
US Army Corps of Engineers (USACE)	1
USDA Natural Resources Conservation Service (NRCS)	2
USDA Forest Service (USFS)	5
US Fish and Wildlife Service (USFWS)	3
Total	**56**

NCDWG Meetings

The NCDWG met approximately bi-monthly (five times per year) from June 2013 through February 2015 at the Kentucky Department of Environmental Protection offices in Frankfort and at stream restoration sites. A total of 12 meetings were held; these included 5 lectures and field trips to 8 sites (Table 3.2). Attendance at each of the meetings varied between 5 and 22 participants, with an average of 13 participants, not including various invited guests.

A high priority of the group was the sharing and distribution of information on current stream stability and stream habitat problems and current restoration projects. Emphasis during each meeting was placed on developing a fundamental understanding of stream conditions within the Commonwealth; principles of open channel hydraulics; bank stability and channel adjustment mechanisms; data collection and interpretation procedures; and linking stream morphology and ecological function. These concepts were used as a foundation for understanding sediment mobility and transport; sediment sampling procedures and analysis; utilization of stream gage station data; advanced channel adjustment mechanisms; and additional data collection and interpretation procedures.

Table 3.2 NCDWG Field Trips and Lectures *Shading* indicates lectures; all others were field trips

	Meeting Date	Meeting Site	County	Site/Lecture Description
1	6/26/13	S. Fork Curry's Fork	Oldham	KDFWR in-lieu fee stream restoration mitigation site designed by ULSI.
2	8/28/13	Sinking Creek tribs	Laurel	KYTC stream restoration mitigation site designed by ULSI; water quality monitoring for a KDOW 319(h) watershed project. Laurel Branch crossing.
3	9/20/13	Slabcamp Creek	Rowan	KDFWR in-lieu fee stream restoration mitigation site designed by ULSI.
		White Pine Branch	Rowan	Amy Braccia's macroinvertebrate sampling in a restored section of Slabcamp and an unrestored section of White Pine in the DBNF.
4	11/6/13	Wilson Creek	Bullitt	ULSI's first stream and wetland restoration, completed in 2003 as a 319(h) demonstration project. Channel evolution and beaver.
5	*12/4/13*	*KDEP*		*Functional assessment and monitoring methods for stream restoration projects in Kentucky.*
6	7/31/14	S. Fork Curry's Fork	Oldham	KDFWR in-lieu fee stream restoration mitigation site designed by ULSI.
7	8/28/14	Kinniconick Creek	Lewis	Kinniconick sediment watershed plan for 319(h) project.
8	9/25/14	Clay's Mill	Fayette	Urban stream restoration in Lexington, KY.
		UT of S Elkhorn Cr	Fayette	Urban stream restoration designed by ULSI at Montessori Middle School of Kentucky, Lexington.
9	*10/30/14*	*KDEP*		*Stream restoration and ecological function patterns in fish assemblages 1.*
10	*12/4/14*	*KDEP*		*Stream restoration and ecological function patterns in fish assemblages 2.*
11	*1/30/15*	*KDEP*		*Stream restoration and macroinvertebrate assemblages.*
12	*2/26/15*	*KDEP*		*Stream restoration and vegetation. Rapid wetland assessment.*

At site visits, members were encouraged to present and discuss information from current restoration sites regarding stream physical impairment problems, construction issues, site evaluation and restoration methods and documents, and other topics relevant to the stream restoration manual. The group visited several stream restoration projects, allowing participants to see projects at various stages from construction to monitoring. The participants also had an opportunity to examine different methods of construction for different types of floodplains and channels. One of these sites was a ULSI stream restoration project on South Fork Curry's Fork in Oldham County, Kentucky, which had been visited in multiple NCDWG meetings prior to this project for field demonstrations of natural channel design concepts and techniques during many of its stages: conducting assessments, designing the restoration, and obtaining permits. The return visits to this site during the project period provided NCDWG participants with the opportunity to view the evolution of the site following completion of construction.

4. Conclusions

4.1 PROJECT MEASURES OF SUCCESS

Project success during the project period was to be measured according to four criteria:

1. Completion of KDOW-approved Kentucky stream restoration manual.
2. Number of partners contributing reviews: at least two project partners' reviews for each section of the manual.
3. Number of NCDWG meetings: at least nine during the project period.
4. The level of improvement in the capacity of those who plan, implement, and/or regulate stream restorations to successfully identify and replace lost or degraded stream functions and values. This criterion is to be a long-term measurement rather than being measured during the project period.

According to each of the above criteria, the project was a partial success. As an alternative to revising and completing the manual, a report on principles for restoration of stream-wetland complexes was developed and distributed to KDOW and NCDWG for review and comment. Two project partners (US Fish and Wildlife Service and KDOW) reviewed and commented on the paper.

Twelve NCDWG meetings were held. Lectures and field trips facilitated the focused discussion of current stream stability and stream habitat problems and current restoration projects. This supported inter-agency exchange of knowledge of natural channel design and channel restoration assessment concepts and their applications to Kentucky streams. Interest and participation in the NCDWG remains high: an average of 13 members attended each meeting. ULSI continues to receive inquiries about joining the group.

4.2 LESSONS LEARNED AND RECOMMENDATIONS

Kentucky Stream Restoration Manual

Geology, hydrology, and land-use history make each restoration site different. Although standardized restoration methods can be used in concept, they must be adapted to

address the specific valley bedrock and materials, constraints, and upstream supply of water, debris, and sediment of each site. A step-by-step guide for designing the restoration of any gravel-bed stream in Kentucky is, therefore, not possible for the current methods the UofL Stream Institute (ULSI) practices. The reason for this is that every site requires modification of the design approach depending on site constraints, construction contractors, financial limitations, permit requirements, project goals, and multiple other variables. The use of a fixed step-by-step design method that does not account for those variables will lead to restoration failures. A fixed set of instructions that could be used to anticipate and address every major contingency to ensure a robust design was simply not feasible at this time.

Although ULSI continually adapts design methods for each project, what remain unchanged are the fundamental principles that form the basis of the designs. An explanation of those principles would provide practitioners with a conceptual framework for developing appropriate methods for each restoration project. This is what was developed instead of the intended manual.

NCDWG

The NCDWG was conceived as a forum for the transfer of fundamental knowledge, procedures, and problems related to water resource conditions specific to Kentucky. The forum was extremely successful and maintained consistently high interest and participation of state and federal agency professionals. These personnel and their agencies benefitted from the opportunity the forum provided to link accepted and emerging theories with the conditions and problems they encounter in practice.

The NCDWG has become a resource on which agency personnel rely for efficient and effective acquisition and exchange of much-needed information and solutions. As the knowledge and techniques applied to watershed management continue to be refined, water resources managers and practitioners would benefit from opportunities to receive and exchange information about the application of those principles. The interest expressed by agency personnel and private consultants in expanding their knowledge and practice of sediment assessment and stream restoration strongly indicates the need for additional training opportunities, including continuation of the NCDWG. The continued support of the Natural Channel Design (NCD) working group would be an efficient means of facilitating the continued exchange and transfer of information about the knowledge and techniques applied to watershed management. Members have indicated that they would maintain their participation in the group if offered the opportunity.

References

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Appendix: Financial and Administrative Closeout

PROJECT OUTPUTS

Milestone	Expected Begin Date	Expected End Date	Actual Begin Date	Actual End Date
1. Submit all draft materials to the Cabinet for review and approval.	Duration	Duration	Mar 2013	Nov 2016
2. Submit quarterly invoices and project status reports, including expenditures from the KDFWR in-lieu fee project South Fork Curry's Fork.	Duration	Duration	Oct 2012	Nov 2016
3. Submit advanced written notice on all workshops, demonstrations, and/or field days to the Cabinet.	Duration	Duration	Mar 2013	Feb 2015
4. Upon request of KDOW, submit an annual report that will include any load reductions for KDFWR in-lieu fee project South Fork Curry's Fork and/or participate in the Cabinet-sponsored biennial NPS conference.	Duration	Duration	Jan 2014	Jan 2014
5. Draft preliminary outline of manual.	May 2012	Oct 2012	May 2012	Mar 2013
6. Submit preliminary outline of manual to KDOW for approval.	Nov 2012	Nov 2012	Mar 2013	Apr 2013
7. Conduct literature review.	Jun 2012	Nov 2015	Jun 2012	Aug 2016
8. Review/collect mapping and other supporting data.	Jun 2012	Nov 2015	Jun 2012	Aug 2016
9. Review/collect field data and photo-documentation.	Jun 2012	Nov 2015	Jun 2012	Aug 2016
10. Draft all sections of manual.	Dec 2012	Nov 2015	May 2013	Jul 2016
11. Conduct 5 NCDWG meetings per year: 3−4/yr to review and discuss draft manual sections, and 1−2/yr for field trips.	Jan 2013	May 2015	Jun 2013	Feb 2015
12. Distribute draft of principles report to NCDWG and KDOW.	Nov 2016	Nov 2016	Nov 2016	Nov 2016
13. Submit all project products for which work has been invoiced thus far, regardless of the state of development, by Nov. 18, 2016.	Nov 2016	Nov 2016	Nov 2016	Nov 2016
14. Incorporate comments from NCDWG and KDOW into a final draft principles report.	Nov 2016	Nov 2016	Nov 2016	Nov 2016
15. Submit revised principles report to KDOW by Nov. 30, 2016.	Nov 2016	Nov 2016	Nov 2016	Nov 2016
16. Complete a design effort for sediment and debris blockage issues on Obion Creek by Nov. 30, 2016.	Oct 2016	Nov 2016	Oct 2016	Nov 2016
17. Submit Obion grading plans, 2D hydrodynamic modeling output, and floodplain model by Nov. 30, 2016.	Nov 2016	Nov 2016	Nov 2016	Nov 2016
18. Submit project final report, financial closeout, and revised principles report to KDOW by Nov. 30, 2016.	Nov 2016	Nov 2016	Nov 2016	Nov 2016
19. Submit three hard copies and one electronic copy of the final report and one electronic copy of all deliverables produced by the project.	Dec 2016	Dec 2016	Dec 2016	Dec 2016

DETAILED BUDGET

Original Detailed Budget

Budget Categories	Section 319(h)	Non-Federal Match	Total
Personnel	$ 261,732	$ 0	**$ 261,732**
Supplies	8,130	0	**8,130**
Equipment	1,200	0	**1,200**
Travel	9,000	0	**9,000**
Contractual	15,500	0	**15,500**
Operating Costs	76,846	0	**76,846**
Other	0	248,272	**248,272**
Total	**$ 372,408**	**$ 248,272**	**$ 620,680**

Revised Detailed Budget

	Section	Non-Federal		Final Expenditures		
Budget Categories	**319(h)**	**Match**	**Total**	319(h)	**Match**	**Total**
Personnel	$ 270,285	$ 0	**$ 270,285**	$ 270,284.72	$ 0.00	**$ 270,284.72**
Supplies	3,216	0	**3,216**	3,215.89	0.00	**3,215.89**
Equipment	0	0	**0**	0.00	0.00	**0.00**
Travel	766	0	**766**	766.41	0.00	**766.41**
Contractual	0	0	**0**	0.00	0.00	**0.00**
Operating Costs	71,309	0	**71,309**	71,308.98	0.00	**71,308.98**
Other	0	230,384	**0**	0.00	230,384.00	**230,384.00**
Total	**$ 345,576**	**$ 230,384**	**$ 575,960**	**$ 345,576.00**	**$ 230,384.00**	**$ 575,960.00**

The budget was revised in October 2016 at KDOW's request. The University of Louisville Research Foundation (ULRF) was reimbursed $345,576. All dollars were spent; there were no excess project funds to reallocate.

SPECIAL GRANT CONDITIONS

Two grant conditions were applicable to this project and were met as follows:

Material Review Condition. An outline of the manual was reviewed and approved by KDOW prior to expending funds on first draft development.

Project Partners Condition. No federal funds were used as match. All project partners were contacted to obtain their commitment to participate prior to submitting an application. Letters of support were provided by all listed partners.