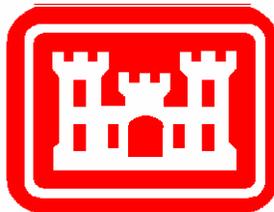


PUBLIC WORKS TECHNICAL BULLETIN 200-3-41
30 SEPTEMBER 2006

**LESSONS LEARNED: STREAMBANK
STABILIZATION ON ARMY TRAINING LANDS**



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PWTB 200-3-41
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DEPARTMENT OF THE ARMY
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No. 200-3-41

Facilities Engineering
Environmental

LESSONS LEARNED: STREAMBANK STABILIZATION
ON ARMY TRAINING LANDS

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) transmits practical information on methods, materials, and structures for erosion control, specifically on streambank stabilization. Military installations can use biological or soft engineering methods in conjunction with Best Management Practices (BMP) for a comprehensive erosion control program. It is designed for use by natural resource managers, land managers, and trainers for streambank stabilization on training lands. The emphasis is on relaying lessons learned from a field demonstration thereby helping such individuals select methods suitable for current conditions and to avoid pitfalls associated with the use of inappropriate methods.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through URL:

c. http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army facilities within the United States containing training lands with streams.

3. References.

a. Army Regulation (AR) 200-3, Environmental Quality, Natural Resources-Land, Forest and Wildlife Management, 28 February 1995, as modified 20 March 2000.

b. Other references are listed in Appendix D.

4. Discussion.

a. AR 200-3, implemented in 1995, requires that installations be good stewards of land resources by controlling sources of erosion to prevent damage from facilities to the land, water resources, and equipment. Hydrologic erosion is associated with multiple laws and regulations (Clean Air Act, Clean Water Act, etc.), which all affect how Army training lands are managed.

b. Due to the nature and intensity of military training activities, many Army training lands and roads are severely degraded and in need of repair. Degraded landscapes jeopardize realistic and effective training as well as troop safety. As a result of these concerns, it is imperative to mitigate and rehabilitate critical areas of Army training lands. Actively eroding streambanks are an environmental and compliance issue for many Army installations. High sediment loads contributed from adjacent trails, crossings, and unstable streambanks can negatively impact stream quality, wildlife habitat, and troop safety. High sediment loads can cause: downstream degradation, undermining of critical habitat, impacts to aquatic species, failure of structures, loss of training time, and potential regulatory actions (i.e., Notices of Violation).

c. One solution to help decrease sedimentation is the rehabilitation and stabilization of streambanks and corridors on installation lands. Without repair, further streambank degradation will continue interfering with tank trails, installation water quality, wildlife and threatened/endangered species (TES) habitat, and training realism. The objectives of this work were to (a) identify types of stabilization techniques currently available that would be suitable for military activities, (b) provide information to help start restoration techniques for land managers, and (c) conduct a demonstration of several stabilization methods on a military installation.

d. This PWTB provides information based on the above objectives along with lessons learned from a field demonstration at Camp Atterbury. This PWTB will help land managers ensure

long-term sustainability of Army training lands, structures, and resources.

e. Appendix A provides a simplified definition of streambank erosion processes, impacts, and the importance of streambank stabilization on military lands.

f. Appendix B gives background information on biological and soft erosion control technologies that were proposed and evaluated for the demonstration project. It also describes methods and issues that are associated with erosion control and streambank stabilization on military lands. "Soft" is defined as design where noncontiguous biological and nonbiological materials are used to stabilize an area.

g. Appendix C presents lessons learned from a streambank stabilization demonstration at Camp Atterbury, IN. Included in Appendix C are the steps that were taken for initial survey, design development, permitting, and post-construction evaluation.

h. Appendix D includes a short list of Army regulations, acts, and other laws that apply to erosion and land management on military installations. The final section of Appendix D includes references cited in the other appendices.

5. Points of Contact. HQUSACE is the proponent for this document. The POC at HQUSACE is Malcolm E. McLeod, CEMP-II, 202-761-0632, or e-mail: malcolm.e.mcleod@usace.army.mil. Questions and/or comments regarding this subject should be directed to the technical POC:

U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory
ATTN: CEERD-CN-E (Heidi R. Howard)
2902 Newmark Drive
Champaign, IL 61822-1072
Tel.: (800) 872-2375 ext. 5865
FAX: (217) 373-7266
e-mail: heidi.r.howard@erdc.usace.army.mil

FOR THE COMMANDER:



M.K. MILES, P.E.
Acting Chief, Engineering and Construction
Directorate of Civil Works

Appendix A: Erosion and Military Land Issues

Prepared by:

Heidi R. Howard	ERDC/CERL
Niels G. Svendsen	ERDC/CERL
Michael L. Hargrave	ERDC/CERL
Daniel R. Gambill	University of Illinois
Lucas K. Erhart	University of Illinois
William R. Ochsner	Camp Atterbury, Indiana
Bradley D. Schneck	Camp Atterbury, Indiana
Karstin M. Carmany	Camp Atterbury, Indiana

Proponent:

Malcolm E. McLeod	HQ USACE
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Definitions and Causes of Erosion

Erosion is the translocation or removal of soil particles and aggregates via water, wind, frost, ice and/or extreme sun/heat action (Gray and Sotir 1996, p 19). Primary factors affecting erosion are the climate, topography, and soil texture along with land cover and past and present land use (Gray and Sotir 1996, p 19; Schwab et al. 1955, p 92). Water erosion is generally caused by raindrop impact and the associated surface runoff (Figure A1). Energy for particle detachment and associated transport of the particles is derived from raindrops striking the soil surface and from the runoff across the soil surface (Agassi 1996, p 239).

The two types of water erosion are natural and accelerated. Accelerated erosion results from disturbances within the natural system, generally caused by humans and their influences. Accelerated erosion can be subdivided into three categories – sheet, rill, and gully – and can include stream channel erosion, which is soil removal from stream banks and/or sediment scour along the channel bottom. This form of erosion should be considered separately from the rainfall-associated types of erosion listed above (Gray and Sotir 1996, p 28).



Figure A1. Raindrop impact on soil surface (source: USDA).

Fluvial systems, overland stream systems, can be very dynamic and are impacted by a wide variety of both hydrologic and geomorphic variables. Generally, streams are separated into two geomorphic groups: alluvial or bedrock. Alluvial streams are formed within alluvial deposits and are generally active or dynamic; whereas, bedrock streams are channels with flows more or less controlled by the strength and resistance of the bedrock material (Gordon et al. 1992, p 88).

The dynamic nature of these systems makes it difficult to conform streams to man's wishes. Human impacts disturb the balance of stream systems. Often, negatively altering flow will impact natural resources both up and downstream. Stream erosion does occur naturally, but the influence of human activities can drastically increase erosion and alter the hydrology of an area. In general, stream channel erosion results from the removal of soil from streambanks and/or scour resulting from sediment transport along the channel bottom (Gray and Sotir 1996, p 28).

Several processes impacting streambank and channel integrity were identified by Keown et al. and include:

- Mass Wasting: Slumping or sliding that is caused by the undercutting, steepening, or impeded drainage during flood recession
- Flow Erosion: Tractive stress imposed by flowing water
- Piping: Seepage erosion as a result of bank drainage
- Wave Erosion: Pumping action, pore pressure fluctuations, and washing/wave action
- Freeze / Thaw Degradation: Solifluction, volume instability, and impeded drainage.

Other processes resulting from the actual geomorphology of an area also play into stream erosion. These processes have been identified by Keown et al. as:

- Widening: Channel enlargement caused by increased stream flow and/or sediment discharges.
- Deepening: Scouring of the channel bottom caused by increased flows and or changes in slope.
- Sinuosity Change: Bank loss that occurs during and upon a change in planform or stream meander configuration. Bank loss is usually accompanied by accretion somewhere else along the affected reach.
- Piping: Piping can be thought of as erosion resulting from the movement and/or seepage of groundwater. As with overland flow, the movement of groundwater can pick up particles of soil and transport these particles out of the soil to carve out craters, shoots, or pipes that will exit through the streambank. Over time, concentrated flow will result and form a system of pipes or flow lines that allow an increased flow from areas that have lower resistance. This process is common in alluvial systems and many times mass movement of a streambank will occur as a result (Figure A2).



Figure A2. Combination of piping and undercutting (Atterbury).

Why Erosion and Streambank Stabilization Are Important

First, success of the Army's training mission depends on resources required to fight and win effectively. This innately implies that conservation of soil and water quality is an essential component of training. Military lands need to be maintained in settings that provide realistic and challenging opportunities to practice individual and battle-focused tasks and missions. In order to improve the ability of military lands to sustain training, streams need to be protected from further degradation.

Second, many streams across an installation have a road, trail, low-water crossing, or bridge associated with them. As such, it is also common for these man-made objects to be placed in less than optimal locations for that stream system, causing increased erosion in and around the bridge or sediment accumulation (aggregation) within a low-water crossing. This has a direct impact on maintenance dollars and labor.

Finally, Army Regulation (AR)-200-3 mandates that installations be good stewards of the land. Impacts to a stream system that result in streambank degradation or failure can also negatively impact critical habitat for threatened and endangered species (TES). Riparian ways or corridors are commonly associated with species for which land must be managed. The loss of even one roosting tree due to undercutting on a streambank can be cause for concern when managing for a TES. Elevated temperatures, salinity, sediments, etc can also result from erosion and the degradation of riparian and in-stream conditions.

Generally, the first step in erosion control and land management is to ensure vegetation establishment and growth. Most water in a stream is runoff from both above and below ground. As such, the presence of vegetation dramatically impacts and affects the stability of the streambanks and resistance to erosional processes. All slopes are impacted or subjected to soil erosion and mass wasting (Gray 1996, p 106).

Increases in erosion will result in a directional increase in sediments of the impacted watershed. Suspended and depositional sediments have negative effects on primary producers, invertebrates, benthic invertebrates, vertebrates, and associated habitats (Waters 1995; Henly et al. 2000). This process will result in different physical and chemical properties, changing the suitability for plant and animal species composition.

PWTB 200-3-41
30 September 2006

Movement of most anything (e.g., cattle, humans, vehicles) across a landscape can cause erosion. Human activities and land use can significantly speed up or slow down natural erosion. Humans modify soil formation processes by altering chemical and physical soil properties such as bulk density, infiltration rates, and productivity (Toy et al. 2002). Army training activities and associated structures can degrade natural resources much like other activities such as logging, construction, or farming negatively influence erosion, but on a unique scale. Effective land conservation begins with conserving the soil's quality and productivity. The U.S. Department of Agriculture (USDA) Soil Conservation Service has estimated that, with effective and dense vegetative covering, soil losses due to rainfall erosion can be decreased a hundredfold. Fiener and Auerswald (2003a and b) found that surface runoff and sediment delivery from a grassed waterway were reduced by 82 percent over an 8-year period.

PWTB 200-3-41
30 September 2006

Appendix B: Methods and Technologies for Stabilization

Evaluation and Survey of a Stream System

A comprehensive survey is the first step to successful stabilization. A survey is necessary to determine the best approach, if any, to take to help stabilize a streambank and prevent further degradation of the stream system. Most state Departments of Water Quality, Natural Resources, etc. will provide assistance in both the evaluation process, technology selection, and 404/401 permitting for stream rehabilitation and stabilizations on your land.

Typical permitting and designing questions include:

- Is the stream perennial, intermittent, or ephemeral?
- Do you have an alluvial or bedrock stream?
- Is the channel stable, degraded, aggradated, or a combination?
- Is the stream natural or channelized?
- What is the channel shape?
- What is the streambank shape?
- What is the bed material of the stream?
- What is the stream order?
- What is the size of the watershed?
- What is the stream flow (measured or assumed)?
- Why is there a need for stabilization (structure protection, critical habitat, water quality, etc)?
- What is the size (length or area) of the area needing rehabilitation?
- All sites are characterized by their drainage; a system will revert to its natural flow or course, and this must be kept in mind when rehabilitating a site.
 - Incorporate the natural water flow within the design to help retain and maintain the natural drainage pattern.
 - Maintain or restore the natural hydrology of the area.
 - Channeling of a natural system will fail; keep within the natural meandering widths of your system.
 - Always retain the original streambed elevation when and where possible.
- What TES, state-listed, or Species of Concern are located within the stream or riparian area?
- If using a biotechnical method, plan for the construction accordingly.

30 September 2006

- Refer to your local nursery, Natural Resource and Conservation Service, Department of Natural Resources manual, etc for appropriate species selection, species requirements, etc.
- Determine if the conditions of the rehabilitation site are appropriate for the selected vegetation:
 - sunlight
 - slope aspect
 - soil moisture
 - recovery and establishment time.
- Collect species during dormant periods, keeping in mind male/female ratios.
- Plant species when optimal.
- If conditions are unfavorable, plan for supplemental irrigation.
- Minimize disturbance when implementing your design.
- Do not remove trees, roots, or other forms of vegetation unless absolutely necessary.
- Obtain site data: ground survey, topographical maps, aerial photographs, and soil survey.
- Develop an erosion and sediment control plan for during and after construction.
 - Use sediment basins, barriers, or traps (straw bales, mulch, silt fencing, coconut coirs, etc) during and after construction to help keep sediment onsite.
 - Maintain temporary vegetative coverage when and where possible.
 - Develop control plan for post-construction that establishes acceptable percentage for vegetation coverage and/or germination.
- Will the stabilization be done in-house or with contract?
- When will repairs/maintenance need to be made?
- What Federal, state, or local permits will be required for this project? Know local, state, and Federal regulations for permitting.
 - Engage associated groups and properly budget time for permitting.
 - Obtain legal documents for project:
 - 404 Permits
 - 401 Permits
 - State Erosion/Sediment Control Permit
 - NEPA 106 Permit
- Who will submit your permit and what costs are associated with obtaining a permit?
- Develop backup plans for failure or damage of the system.

- Develop post-restoration maintenance and monitoring plans.
- Document design, permits, and surveys along with before and after site rehabilitation photographs or measurements.
- How will success be measured? Set goal for success.
- What types of post-rehabilitation monitoring will take place?

Depending on the requirements for your state 401/404 permitting agency, and/or Section 106 permit/notification, a complete survey that includes cross-sectional analysis and flows may be required. This survey should be done anyway to help determine which stabilization method you will use. Numerous published resources are available that provide methods for surveying, evaluating, and determining the most optimal stabilization methods for your site conditions.

Coordination with your Post Environmental Department and assigned regulatory offices is imperative to ensure a successful permit application. Most state agencies have "pre-application coordination meetings" where all involved agencies and stakeholders meet to discuss the project. This early involvement can help reduce the time it takes for a permit to be granted. Acquiring permits taked anywhere from 30 days to 6 months – plan accordingly.

Demonstration Considerations

A wide assortment of technologies was evaluated for the field demonstration portion of this project. Factored in were cost, compatibility with training, longevity, ecological benefits, suitability for site conditions and easy implementation with in-house labor and resources. Living building materials for the protection of structures and crops, and for slope stabilization, have been used for centuries (Norton et al. 2002). Studies have shown that erosion, slope stabilization, and sedimentation can be controlled with quick and cost-effective soil biotechnical and bioengineering methods when combined with the correct physical control materials (Toy et al. 2001; Abramson et al. 2001; Gray and Sotir 1996; Agassi 1996; Koerner 1998). In recent years, many land managers have reverted to these simple technologies for protection and erosion control. This PWTB concentrates mostly on bioengineering techniques, but also considers a few harder technologies due to site conditions.

Technologies that were evaluated included combinations of the following: revegetating, live staking and bundling, fiber coir logs, erosion control blankets, soil lifts, composted erosion

control socks, riprap, cabled-concrete^(TM) gabion mattresses, and gabion baskets. These technologies and methods were determined to be easily implemented, familiar to most land managers, and cost data can be easily obtained. (See Figures B1, B2, B4, B6, B8, B9, B11, and B12.)

Vegetation: Special care was taken in the selection of the vegetation for the site. Care in the selection of vegetation species is necessary to ensure that the species selected are compatible to an installation's ecosystem, slopes, and training activities. Locally adapted native species are generally the best for revegetating an area. Using planning tools such as VegSPEC can help with the selection of both native and adapted species that will be compatible to an installation's region and successful for riparian and stream corridor systems.

Soil Lifts: Due to site soil texture and the time of year that construction started, soil lifts were not used. Soil lifts require a more loamy soil texture than that present at Camp Atterbury. Well established vegetation including stakes and bundles, would have been needed and contracting constraints meant the project was started in July 2005 during extremely dry conditions.

Live Staking: Live staking and bundling was strongly considered and selected due to the natural occurrence of *Salix sp.* along the selected stream corridor. An entire bunker full of cuttings was collected and kept in water, in anticipation that they would be used. Unfortunately, contracting and weather caused significant delays requiring postponement of all staking and bundling until February 2006. (See Figures B3 through B5.)

It is critical to note that, for successful restoration of an area, it is necessary to set up a restoration project that is both self-sustaining and has a healthy genetic diversity. When using asexual propagation, both sexual and genetic diversity are critical to produce a healthy plant community (Dreesen 2003; Landis et al. 2003). When using a nonrooted cutting for either bundling or staking, consideration for the sex of the donor plant is necessary. Genetic diversification is more at issue when cuttings are taken back to create nursery stock, as nursery stocks tend to be clones of one individual and unisex. Therefore, it is in the best interest of the restoration effort to collect cuttings from several locations and identify the cutting's sex at the time of harvest.



Figure B1. Soldiers harvesting *Salix ssp.* for use in wattles.

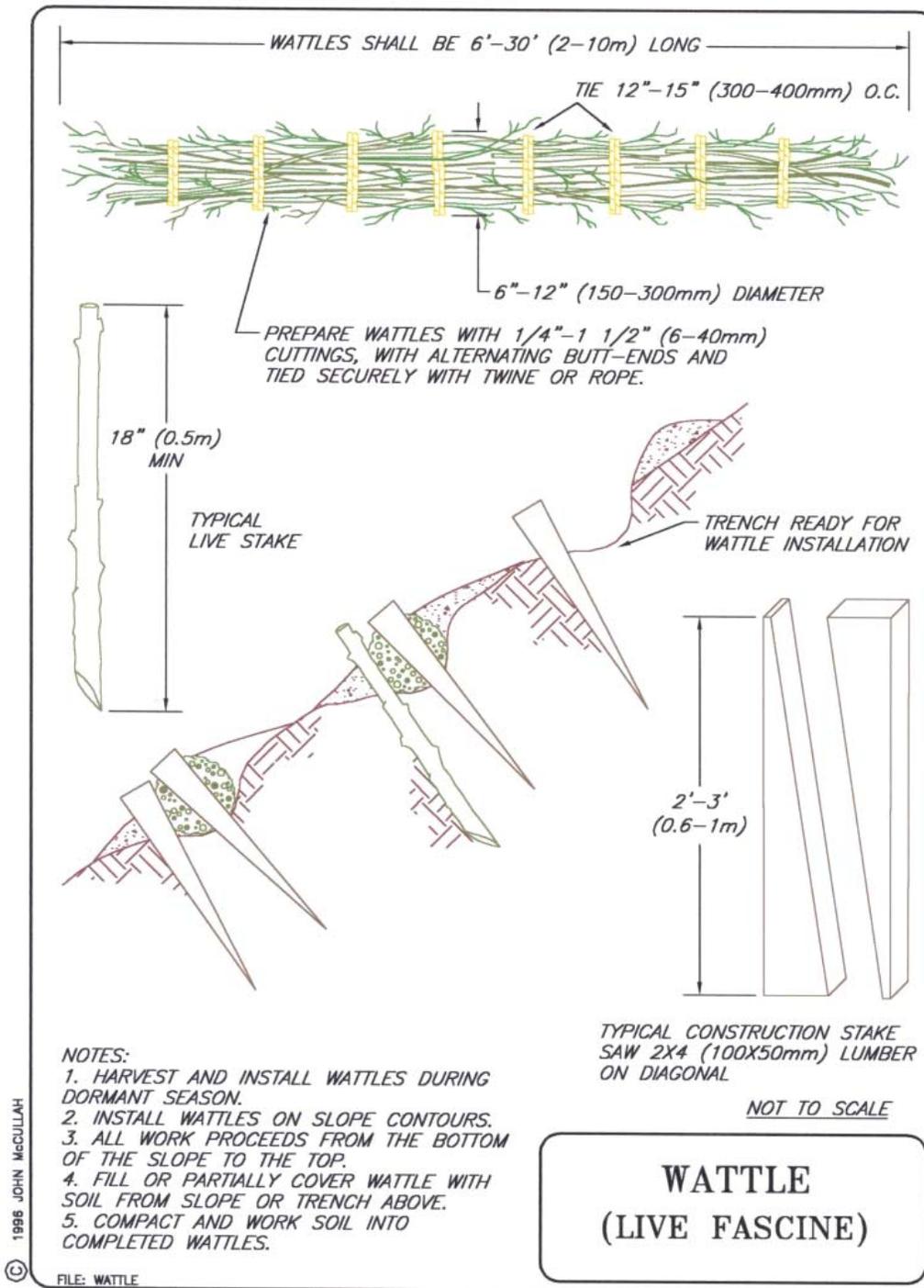


Figure B2. Illustrative diagram of a wattle (BioDRAW®).



Figure B3. Live staking in combination with bundles/wattles at Fort Leonard Wood, MO (J. Proffitt, Fort L. Wood).

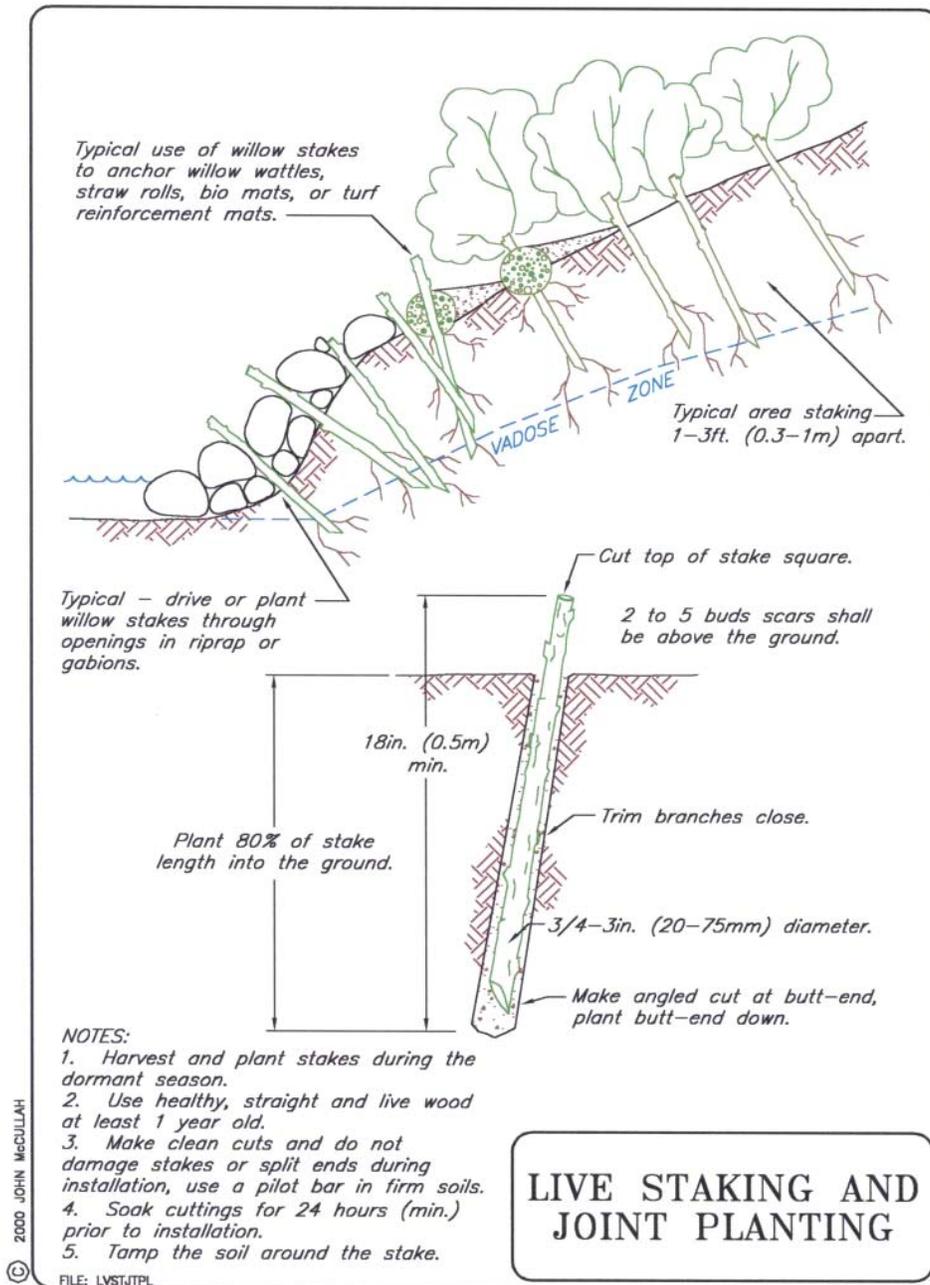


Figure B4. Illustrative diagram of proper live staking and joint planting (BioDRAW®).



Figure B5. Live staking on a hill slope, done during dormancy (BioDRAW®).

Fiber Coir Logs: Fiber logs have been developed to reduce overland flow along a slope. They also have been used for toe stabilization along streambanks, helping to both provide energy absorption and habitat for wetland species. Shredded coconut coir was bundled together with jute. It is common for some companies to offer the logs with native plants or seeds incorporated into the "biologs" for many wetland remediation efforts (Figure B7). To obtain such materials, it is necessary to go with a local company that can modify or construct the roll, log, or coir with species appropriate for the ecosystem and slopes. On one area, a vegetated biolog was used at the toe of a bank, which allows the root systems to establish before the log breaks down, creating a foothold for the toe of the slope.

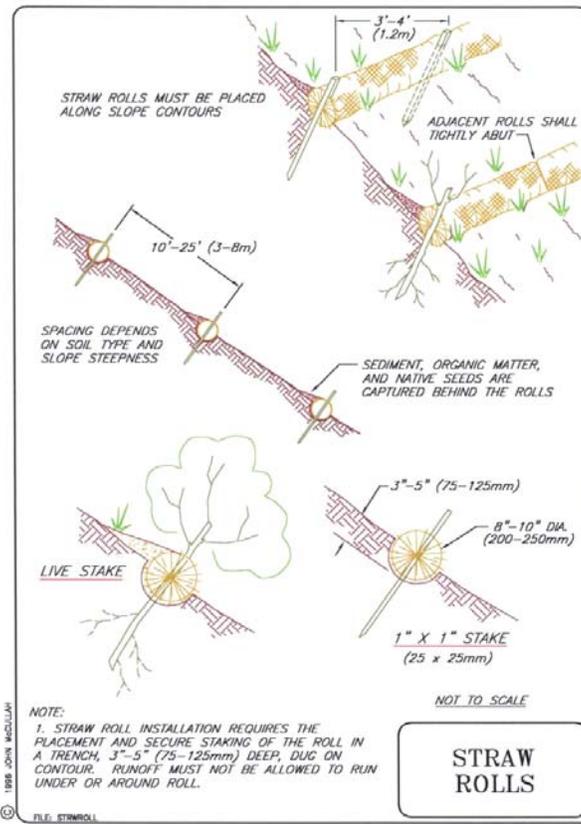


Figure B6. Diagram showing proper installment of fiber log, roll, or coir (BioDRAW®).



Figure B7. Vegetated biologs.

Riprap: Riprap is coarse cobbles of rock placed to protect a channel bank or to promote infiltration above a drain. Riprap is often stabilized with wire mesh or vegetation. Vegetated riprap uses vegetation root systems as the structural strength to help bind and stabilize the riprap on the sites that are vulnerable to erosion (Figure B8). Riprap was utilized in gabions, gabion mattresses, and at the toe of one slope stabilized with an erosion control blanket.

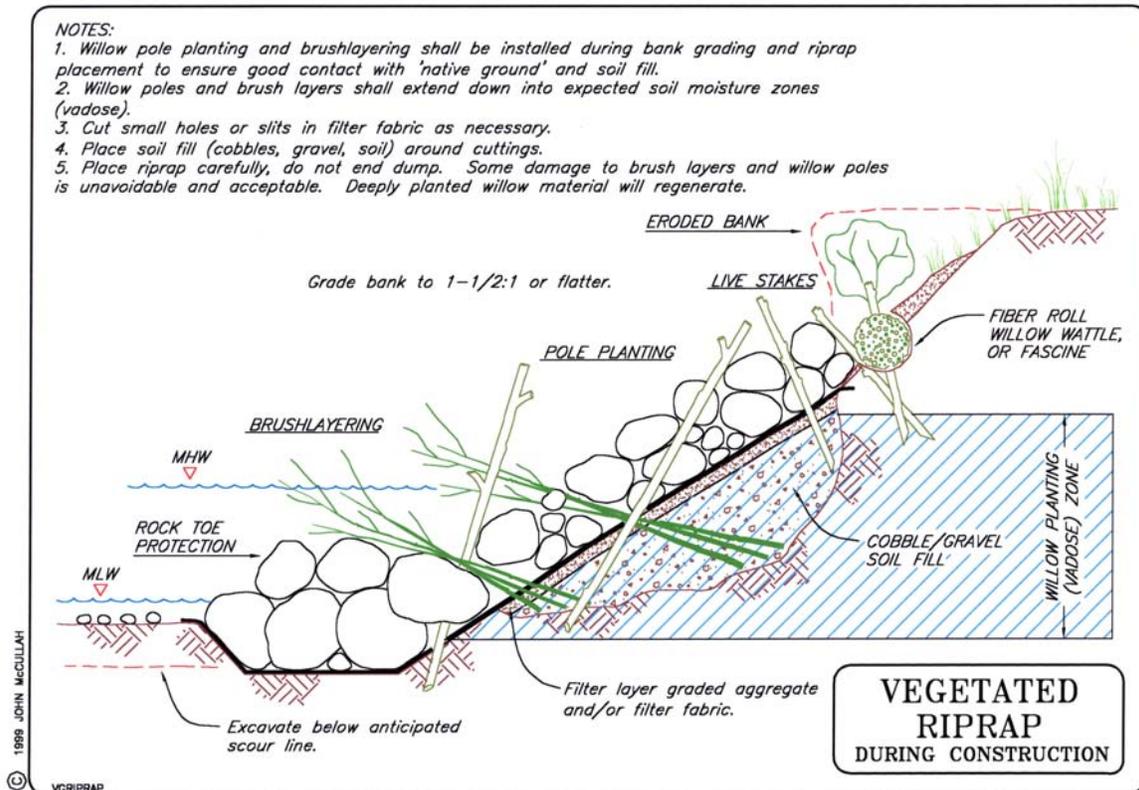


Figure B8. Vegetated riprap diagram (BioDRAW®).

Composted Mulch Socks: Mulching is the application of organic material to the soil surface to protect it from raindrop impact and overland flow. Mulch absorbs the erosive impact of rainfall and reduces the overland flow velocity, significantly reducing soil loss from a site. New technologies are available using composted mulch in conjunction with soil and seed that help stabilize an area. Geotextile/polynetting "socks" ranging in size from 6 to 24 inches in diameter are filled on-site with a compost/soil/seed mixture and can be built one on top of the other to stabilize an area. The socked organic mulches provide a nutrient-rich seedbed leading to quick vegetation establishment and coverage of an area (Figure B9).



Figure B9. Compost filled sock system helps increase infiltration while providing channel stability (source: Filtrexx).

Erosion Control Blankets: Erosion control blankets are permanent or biodegradable mats designed to protect steep slopes that are susceptible to erosion (Figure B10). Woven fibers (e.g., plastic [geocomposites], jute, coconut) are used to reinforce, protect, and stabilize surfaces until vegetation is established. Blankets can include seeds and fertilizer to promote vegetation establishment on the slope (Figure B11). Blankets are not to be confused with geotextiles (i.e., filter fabrics). Made of polymers, geotextiles act as a barrier and filtering system since they can transmit water within the plane of their structure (Koerner 1998). A wide range of blankets is available for most purposes. A combination of biodegradable blankets that were utilized alone for normal slope protection were chosen for this project but also were used within "green gabions" and "green gabion mattresses" as a liner to help retain the soil and seed that were mixed in with the riprap.



Figure B10. Improper choice and installation of an erosion control blanket along a streambank resulted in failure.



Figure B11. Demonstration of two different blankets, biodegradable jute and synthetic polymer.

Gabions: Gabions are baskets or mattresses of wire filled with riprap or stone and used as structural reinforcement on steep slopes or in stream channels (Figures B12 and B13). They can be either vegetated or unvegetated. Gabions are practical for many uses but are most effective in the stabilization of a large slope or in cases of high energy flow. Buried or toed-in gabions are a common stabilizer in areas where build-up is needed. Gabion systems are a relatively inexpensive, reliable, and well-researched technique. They are long lasting but, if they are planted with woody vegetation, their lifespan can increase. They are used most often in slope stabilization, large overland flow drop structures, and riverbank stabilization projects. Consult with a gabion provider to determine if coated wire is recommended for site conditions (e.g., low-pH water or soils, or debris field interactions). For this project, a combination of gabions, regular and "green," were used. In February 2006 some areas will be live-staked.



Figure B12. Gabions were used to develop this drop structure (source: USDA).



Figure B13. Gabions incorporating soil, erosion control blanket and seed.

Appendix C: Lessons Learned, Camp Atterbury Field Demonstration

Each installation has its own challenges to meet ranging from mitigating erosion problems to implementing an effect project at a reasonable cost. This appendix describes steps taken in the Camp Atterbury stabilization demonstration:

- Coordinate with all stakeholders
- General guidelines
- Field demonstration
- Summary.

Coordinate With All Stakeholders

First and foremost, coordinate with all personnel responsible for permitting processes on the installation; include all the expertise necessary to ensure a success. For example, a soil scientist, environmental engineers, a hydrologist, and biologists were consulted for the Camp Atterbury project.

General Guidelines

To have a successful project, keep the following in mind:

- (1) Follow Best Management Practices (BMPs).
- (2) Follow the permit process for any given project (e.g., 404).
- (3) Enlist the help of specialists to include:
 - a. Engineer and biologist for design specifications, survey, etc.
 - b. Hydrologist to determine watershed loads, stream flows, and geomorphology.
 - c. TES Group, Directorate of Public Works (DPW), Environmental, Cultural Resources for permitting process, impacts, etc.
- (4) Have a solid design and backup for any project implemented.
- (5) Make sure the selected materials are available locally and in adequate supply, and are staged for ease of use.
- (6) Implement a post-construction monitoring program to ensure success of the project.
- (7) Assume long-term maintenance will be required.

Field Demonstration

Camp Atterbury Joint Maneuver Training Center near Edinburgh, IN was chosen as the demonstration site for several reasons: (1) they were the installation host for the 2005 Integrated Training Area Management (ITAM) Workshop, (2) they had experienced degradation of several streambanks over the last few years and expressed concern that bridges might become impacted with further erosion, and (3) proximity to the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory in Champaign, IL.

Camp Atterbury is approximately 35 miles southwest of Indianapolis, IN. Several studies by Risch (2004), Svendsen (2005), and Robinson (2004) found that Atterbury's streams were not significant contributors to stream degradation, but there has been concern with the installation's streambanks, streams, and riparian areas. The soils are highly erodible, mostly alluvial, and constitute a wide range of aeolian loess, glacial till, and bedrock composite. They have a complex stream system that transects the installation.

The demonstration site was chosen by Camp Atterbury Engineering DPW. The site was located on Mauxferry Road and Nineveh Creek. An under-constructed bridge had accumulated a large amount of woody debris over the years resulting in scour at the northwest and northeast abutments (Figures C1-C8). A series of techniques were used to help determine suitable stabilization methods for use by in-house labor on other sites (Figures C9-C13). Post-construction photographs (Figures C14-C19) illustrate vegetation establishment and settlement 1 month after construction was completed.



Figure C1. Demonstration site preconstruction, upstream side, northwest corner.



Figure C2. Demonstration site preconstruction, downstream side, northeast corner.



Figure C3. Demonstration site preconstruction, downstream side, northeast corner.



Figure C4. Demonstration site preconstruction, upstream side, southwest corner.



Figure C5. Demonstration site preconstruction, downstream side, southeast corner.



Figure C6. Demonstration site preconstruction, downstream side, northeast corner.



Figure C7. Demonstration site preconstruction, upstream side, southwest corner.



Figure C8. Demonstration site preconstruction, upstream side, northwest corner.



Figure C9. Demonstration site during construction, southwest. A cabled-concrete™ access ramp was installed along with a Filtrex™ compost-sock system.



Figures C10 and C11. Demonstration site during construction, northwest. A combination of gabion baskets and gabion mattresses with a riprap toe was installed. Slopes were kept to 2:1, and the gabion mattresses were inoculated with soil and native seeds and overlaid with an erosion control blanket. The top of the streambank was treated with a straw-filled polynet erosion control blanket while a jute blanket was used within the mattresses.



Figure C12. Demonstration site during construction, looking upstream to northwest corner. This view illustrates incorporation of erosion control blankets.



Figure C13. Demonstration site during construction, looking from top of bridge downstream at northeast corner. This view illustrates incorporation of erosion control blankets within gabion baskets and the riprap shelf/toe that was installed to help rebuild the bank.



Figure C14. Demonstration site 1 month post-construction, looking at upstream southwest corner (see Figure C9).



Figure C15. Demonstration site 1 month post-construction, looking downstream from southwest corner. East of the access ramp, filtrex™ overlaid the socks with an erosion control netting (LockDown Netting™).



Figure C16. Demonstration site 1 month post-construction, looking at downstream southeast corner. A series of toes were installed along this bank; far west had a fiber-coir biolog with native wetland species, then a section with only a fiber-coir log, followed by a section with minimal riprap, and the final section had only the erosion control blanket.



Figure C17. Demonstration site 1 month post-construction; upstream northwest corner.



Figure C18. Demonstration site 1 month post-construction; looking at northwest corner.



Figure C19. Demonstration site 1 month post-construction; view from bridge downstream at northeast corner.

Summary

Lessons were learned from this demonstration. During the permitting process, back-to-back flooding events occurred changing the cross-sections of the selected site. Due to the flooding across Indiana, the permitting agencies were overwhelmed with high-priority cases, and permits took a bit longer than normal. Weather, delayed contracting, and late starts all impacted the project.

Post-construction impacts have also been experienced. Unusually dry conditions and high temperatures during the fall made establishment of vegetation difficult. It was learned the hard way that posting signs to "keep-off" may have been helpful after a Pyrotechnics Unit decided to light up on the level surface above the gabions, effectively burning all the erosion control blankets on the northeast side.

PWTB 200-3-41

30 September 2006

Currently, ongoing in-stream monitoring is taking place and live-staked *Salix sp.* will be added during the month of February 2006 at the toes of the gabion baskets and a portion of the gabion mattresses. The entire site will be re-seeded with native species again in March or April 2006 to help ensure successful establishment of vegetation.

Appendix D: Resources

General

Ecosystem Management and Restoration Information System (EMRIS) is a website tool developed by ERDC Environmental Laboratory that provides up-to-date and easy-to-use information for retrieval on a wide-range of ecosystem management and restoration.

<http://el.erdcl.usace.army.mil/emrrp/emris>

Erosion Control - a magazine website

<http://www.forester.net/ec.html>

International Erosion Control Association - This organization provide a comprehensive listing of available resources for erosion control.

www.ieca.org

Land and Water: The magazine of natural resource management and restoration -

<http://www.landandwater.com/>

USDA's Natural Resources Conservation Services -

<http://www.nrcs.usda.gov>

USDA's Agricultural Research Services -

<http://www.ars.usda.gov/research/programs.htm>

Emergency Stabilization Treatments

<http://fire.r9.fws.gov/ifcc/Esr/Handbook/default.htm>

Web-based Resources for Planning

VegSpec is a web-based decision-making tool for the development of site-specific revegetation efforts. It uses soil, plant, and climate data to select plant species that are site-specific, practical, and appropriate for a variety of applications including restoration, erosion control, etc. *VegSpec* can be accessed at the below website.

<http://aec.army.mil/usaec/technology/conservation07.html>

Statements of Work (SOW) - The U.S. Fish and Wildlife Service has developed a practical SOW for general biological engineering. The SOW includes general contractor guidance for construction of riprap, cribs, gabions, etc, and estimation sheets for the land manager. This resource could prove useful for a land manager to use in the development of an SOW for outsourcing and contracting land rehabilitation work on their installation.

<http://www.fs.usda.gov/r9/about/docs/fs-road/250.pdf>

Recommended Books on Soil Bioengineering and Erosion

- a. Abramson L.W., T.S. Lee, S. Sharma, and G.M. Boyce. 2001. *Slope Stability and Stabilization Methods*. John Wiley & Sons, Indianapolis, IN, pp 513-582.
- b. Agassi, Menachem. 1996. *Soil Erosion, Conservation, and Rehabilitation*. Marcel Dekker, Inc., New York.
- c. Charman, P.E.V., and B.W. Murphy. 1991. *Soils Their Properties and Management*, 2nd ed. Oxford University Press.
- d. Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. *Stream Hydrology: An Introduction for Ecologists*. John Wiley & Sons, New York, NY.
- e. Gray, D.H., and R. Sotir. 1996. *Biotechnical and Soil Bioengineering Slope Stabilization*. John Wiley & Sons, New York, NY.
- f. Haigh, Martin J. 2000. *Reclaimed Land: Erosion Control, Soils and Ecology*. A.A. Balkema Publishers, Brookfield, VT, pp 93-129.
- g. Koerner, R.M. 1998. *Designing with Geosynthetics*, 4th ed. Prentice Hall Publishers, Upper Saddle River, NJ.
- h. Lal, R. 1994. *Soil Erosion Research Methods*, 2nd ed. St. Lucie Press, Delray Beach, FL. Soil and Water Conservation Society, Ankeny, IA.
- i. Schwab, G.O., D.D. Fangmeier, W.J. Elliot, and R.K. Frevert. 1955. *Soil and Water Conservation Engineering*, 4th ed. John Wiley and Sons, Inc., New York, NY.

PWTB 200-3-41
30 September 2006

j. Toy, Terrence J., George R. Foster, Kenneth G. Renard. 2002. Soil Erosion: Process, Prediction, Measurement, and Control. John Wiley and Sons, Inc., New York.

k. USDA, Soil Conservation Service. 1992. Chapter 18: Soil Bioengineering for Upland Slope Protection and Erosion Reduction. Part 650, 210-EFH, Engineering Field Handbook.

l. Wittler, R.J., S.D. Keeney, D.R. Eby, and D.L. LaGrone. 1997. "Building Banks on Muddy Creek with Barbs," Management of Landscapes Disturbed by Channel Incision: Stabilization-Rehabilitation-Restoration, pp 549-554.

Land Management and Erosion Control Laws and Regulations

NEPA 1969: <http://ceq.eh.doe.gov/nepa/regs/nepa/nepaeqia.htm>

Clean Water Act 1972: <http://www.epa.gov>

Soil and Water Conservation Act 1977:
<http://ipl.unm.edu/cwl/fedbook/soilwate.html>

Clean Air Act 1990: <http://www.epa.gov>

Sikes Act: <https://www.denix.osd.mil/denix/Public/ES-Programs/Conservation/Laws/sikes.html>

Army Regulation (AR) 200-3, Natural Resources – Land, Forest and Wildlife Management:
http://www.usapa.army.mil/pdffiles/r200_3.pdf

AR 200-4, Cultural Resources Management:
<http://www.gordon.army.mil/dpw/enrmo/ar200-4.html> prescribes Army policies, procedures, and responsibilities for meeting cultural resources compliance and management requirements. AR 200-4's scope includes the National Historic Preservation Act (NHPA); American Indian Religious Freedom Act (AIRFA) and Executive Order 13007; Native American Graves Protection and Repatriation Act (NAGPRA), Archaeological Resources Protection Act (ARPA), 36 CFR 79; and other requirements and policies affecting cultural resources management. The National Historic Preservation Act of 1966 as amended (Public Law 89-665; 16 U.S.C. 470 et seq.) requires Federal agencies to take into account the effect of their undertakings on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places.

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PWTB 200-3-41
30 September 2006

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