PUBLIC WORKS TECHNICAL BULLETIN 200-1-115
15 DECEMBER 2011

LOW-WATER CROSSINGS — LESSONS LEARNED

Public Works Technical Bulletins are published by the U.S. Army Corps of Engineers. They are intended to provide information on specific topics in areas of Facilities Engineering and Public Works. They are not intended to establish new Department of Army policy.

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
441 G Street NW
Washington, DC 20314-1000

CECW-CE

Public Works Technical Bulletin 15 December 2011

No. 200-1-115

FACILITIES ENGINEERING
ENVIRONMENTAL

LOW-WATER CROSSINGS — LESSONS LEARNED

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) transmits information about the success of different designs of low-water crossings (LWCs) on military installations. Proper LWC design and construction techniques can maximize accessibility to rangelands or can minimize construction and repair costs and environmental degradation.

b. All PWTBs are available electronically at the National Institute of Building Sciences' Whole Building Design Guide webpage, which is accessible through this link:

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

2. Applicability. This PWTB applies to all U.S. Army facilities containing training lands with streams. This information is intended to be used by land managers and installation Directorate of Public Works (DPW) personnel.

3. References.

a. Army Regulation (AR) 200-1, "Environmental Quality, Environmental Protection and Enhancement," Headquarters, Department of the Army, Washington, DC, 13 December 2007.

4. Discussion.

a. AR 200-1, as revised in December 2007, contains policy for environmental protection and enhancement, implementation of pollution prevention, conservation of natural resources, sustainable practices, compliance with environmental laws, and restoration of previously damaged or contaminated sites.

b. This PWTB reports a comprehensive review of the current state of LWCs on Army and National Guard installations. A questionnaire was sent to installation Integrated Training Area Management (ITAM) Coordinators and Land Rehabilitation Area Management (LRAM) Coordinators. Results were used to determine where potential issues may result from LWCs.

c. Lessons learned from the installation surveys illustrated that in general, a cookie-cutter approach was taken by most installations. However, installations that utilized a systematic approach to hydrology, parent material, and LWC function had much higher success rates.

d. Additionally, a comprehensive review of the current knowledge on LWC was conducted to help with the assessment of the current state of LWC use on military installations.

e. Appendix A gives background information on LWCs. The various types of LWCs are detailed along with the stream conditions that impact the specific design of an LWC. Environmental factors such as erosion and ecosystem management are also discussed.

f. Appendix B explains where LWCs can be used and why they are important to the military.

g. Appendix C presents the lessons learned about LWCs that have been used on military installations. Design considerations, different erosion control measures, and the good and bad aspects of the crossings are also included.

h. Appendix D provides a copy of the questionnaire used and summarizes responses from installations.

i. Appendix E lists the references cited in Appendices A–D.

5. Points of Contact (POCs).

a. Headquarters, U.S. Army Corps of Engineers (HQUSACE) is the proponent for this document. The POC at HQUSACE is Mr.

Malcolm E. McLeod, CEMP-CEP, 202-761-5696, or e-mail: Malcolm.E.Mcleod@usace.army.mil.

b. Questions and/or comments regarding this subject should be directed to the technical POC:

U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
ATTN: CEERD-CN-N (Heidi R. Howard)
2902 Newmark Drive
Champaign, IL 61822-1076
Tel. (217) 373-5865
FAX: (217) 373-7266
E-mail: Heidi.R.Howard@usace.army.mil

FOR THE COMMANDER:

For JAMES C. DALTON, P.E., SES
Chief, Engineering and
Construction Division
Directorate of Civil Works

APPENDIX A

BACKGROUND AND CROSSING TYPES

Acknowledgements

The major contributors to and authors of this study are:

- Heidi Howard and Niels Svendsen
  US Army Engineer Research and Development Center–Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL.

- Jacklyn Holmes
  Massachusetts Institute of Technology (MIT), Cambridge, MA

- Jude Holscher
  University of Illinois at Urbana-Champaign (UIUC), Urbana, IL.

Background

Land-use impacts from vehicle and troop movements have been extensively studied at military installations. Yet, little research has been undertaken to examine the effects these movements have on the longevity and sustainability of low-water crossings (LWCs) and their impacts on the stream network (Malinga 2007). In the past, the presence of LWC structures within or over a stream on military training areas was dictated solely by the need for vehicular access and ease of this access to certain regions of the installation to accomplish a training objective. Thus, heavier equipment such as tanks and trucks would generally cross at a fordable location first as dictated by their vehicle characteristics to break down the stream channel banks and make it more accessible to smaller vehicles. Over time, the more heavily used LWCs received infrequent maintenance in some locations, thus making them more usable for multiple activities. Frequently, the location and number of these stream crossings within a stream segment varied depending on the type of military training conducted within that area. Many training areas with streams passing through them had a high number of one-time crossing locations and a lower number of moderately improved multiple-pass crossing locations. With such an approach, stream instability and impact on stream quality can be high, since there is little consideration for the impact of vehicles on streams.

At present, the approach to LWC site selection and design has changed considerably, especially within the past ten years. This change is due, in part, to the availability of a variety of new technologies that simplifies LWC installation, which has heavily influenced the building of “unvented” fords. Emerging technologies for streambed stabilization (various geotechnical treatments) are being evaluated for their effectiveness and applicability in military training areas. As information is collected over time, new approaches are being adopted to improve LWC design, installation, and maintenance (Malinga et al. 2007; Sample et al. 1998). Furthermore, site location and stability play an increasingly important role in the impact of LWCs on the streamwater ecosystem. The LWC design process must consider upland soil and water influx, as the control of soil erosion is critical to maintaining healthy streams, decreasing land maintenance requirements, improving installation environmental sustainability, and protecting the habitat of threatened and endangered species.

Movement throughout the military installations is paramount but must be balanced to offset erosion and habitat impact. Because of the varying size and weight of military vehicles, the site for a crossing design must consider a particular area’s specific uses. Once an accurate picture of the LWC traffic is determined, the various types of LWCs can be considered.

This project looks at what LWCs are, where they are used, why they are important to the military, and the lessons learned about the different kinds of crossings. Lessons learned from the installation surveys illustrated that in general, a cookie-cutter approach was taken by most installations. However, installations that utilized a systematic approach to hydrology, parent material, and LWC function had much higher success rates. This information is intended to be used by land managers and installation DPW engineers to help choose the correct crossing during the design process. Project information was obtained through interviews with officials involved in building and maintaining LWCs at military installations.

Types of Low-Water Crossings

LWCs within military training areas are present in any location where unimproved roads and trails intersect the stream network and stream size is small enough to permit the use of such a fording structure. Maneuver areas, tank trails, and range course roads are all examples where LWCs are suitable (Svendsen et al. 2006). Proper LWC design and construction techniques can maximize stream stability, stream ecosystem health, and structure longevity.

The many different LWC designs divide into three main groups:

1. Unvented (ford)
2. Vented (using a pipe or culvert)
3. Low-water bridges (bridge capable of handling overtopping water flow)

Unvented

Unvented fords are usually selected on ephemeral streams (streams with temporary flow during or after a precipitation event) or streams with shallow flows that are safe to drive though. The fords can be either at or above-grade of the stream bed. At grade is typically chosen if any concern about wildlife or erosion exists. Figure A-1 shows an unvented cable-concrete ford that is at grade.

Figure A-1. This completed articulated concrete crossing is an example of an unvented ford (photo by Chris Collins, Fort Campbell, KY).

Vented

Vented crossings keep the vehicles out of the water most of the year as long as the flows are low. The number and size of culverts depends on the geometry of the stream and the flow characteristics. The crossings are designed to be low and overtop in extreme storms (Figure A-2). It is less likely that a vented ford will be used on military training lands due to its life-cycle cost. However, the road network that accesses these areas may have vented fords at locations crossing large or frequent streamflow where traffic volume, vehicle type, and personnel safety require them.

Figure A-2. Vented low-water crossing (photo by Joe Proffitt, Fort Leonard Wood, MO).

Low-Water Bridge

Low-water bridges are the final type of LWC. Low-water bridges are very similar to other bridges except they are built lower (Figure A-3). Similar to the vented crossings, the water level can rise above the driving surface. These structures typically have a bridge deck and footings if the stream is wide enough.

Figure A-3. Low-water bridge (photo courtesy of U.S. Fish and Wildlife Service, MO).

The vented portion of the LWC should be designed so that the vented ratio (the amount of water flowing constantly at stream bed grade) is comprised of natural material; this design is desirable if there is a concern for wildlife passage.

The road network is significantly connected to the stream network in a hydrological sense, and the greater the road/trail density, the greater the connection. Jones et al. (2000) examined the effects of road network interactions with stream networks at the landscape scale and illustrated how the road networks affect flood/debris flow and modify disturbance patch dynamics or fragmentation dynamics in mountain landscapes. They found that the intersection of the road/stream alters the starting and stopping points of debris flow and changes the balance between the intensity of flood peaks and the stream network’s resistance to change. Essentially, this finding indicates that regardless of how well selected a low-water ford might be, it will always affect the stream channel regime because changes in stream channel geometry will disrupt any state of equilibrium that might have existed prior to the location being used as a crossing. A common problem found on many military training area low-water ford sites is the reuse of previously poorly selected sites. Many are located in areas of high stream instability or disrupt the connectivity of stream ecosystem habitats; historically, no planning would have gone into site selection. Additionally, due to financial constraints, low-water ford installation practices may be sub-standard, compromising an already unstable location in the stream reach.

LWC construction and installation begins with the understanding that each site is unique and there is no “standard” design to achieve the military needs and ecological function. The design must correspond to a careful analysis of the loads expected over the crossing and the stream characteristics on a watershed scale at the crossing location.

APPENDIX B

USE AND IMPORTANCE OF LOW-WATER CROSSINGS

Where to Use an LWC

Unimproved LWCs or “low-water fords” are most frequently found on ephemeral and low-flowing streams with rock, gravel, or sand stream bottoms. As heavy vehicles (tanks, trucks) ford these streams, they can contribute greatly to area streambank erosion and area soil erosion due to excessive vegetation loss and soil disturbance (Howard et al. 2006). Additionally, because these vehicles can access locations typically unsuited to LWCs, it is also common for these fords to occur in sub-optimal locations within the stream system. In turn, this causes increased upland erosion and flow routing through the approach roads, sediment accumulation (aggregation) at the ingress/ egress (entrance/exit), dam formation upstream along with backwater ponding, and downstream scour (Malinga et al. 2007).

Hardened or unvented LWCs have a stable driving surface of rock, concrete, asphalt concrete blocks, concrete planks, gabions, geocells, or a combination of materials. On some structures, a small channel is included at the structure’s low point to pass low flows or aquatic animals (Clarkin et al. 2006). These structures are more common on frequently used trails and roads and can accommodate smaller vehicles. The structures are most frequently built on streambank gradients of 3:1 or less and streams with continuous flow that have ingress and egress points located at or above bankfull flow. In general, these LWC locations have been selected because the road/stream interaction has proven to be relatively stable (i.e., consistent crossing and low crossing maintenance). In almost all instances, these hardened sites were at one time non-hardened until use patterns or other needs necessitated an upgrade to a more stable crossing.

Unvented LWCs are favored for several reasons: cost, ease of installation, low channel maintenance requirements, and stream habitat preservation for threatened and endangered species. Additionally, unvented fords are useful in naturally unstable channels such as alluvial fans and braided systems or channels with a high variability of flow (Clarkin et al. 2006). An unvented LWC is more economical than a bridge for use on low-traffic roads. They can also be used if an existing bridge is not designed to hold extreme vehicle loads (Figure B-1).

Figure B-1. Low-water crossing situated next to bridge. (Photo by Scot Serafin, Fort Knox)

Why LWCs Are Important

Issues stemming from unimproved LWCs (erosion, aggregation, ponding) can disrupt stream equilibrium and cause water quality problems. Beyond environmental costs, this presents both monetary and mission impact: stream instability influences water quality, stream ecosystem health, and reduces training area carrying capacity (the ability of an area to be fully utilized for its designated purpose). By improving the crossing, both the military maneuvers and the ecosystem can function more successfully.

The safety of those using the crossing is also critical. Markers are essential to show the edge of the above-grade crossing if the road is not well defined (Figure B-2). Without markers, it can be difficult to know where the edge is when the water level rises.

Figure B-2. Markers along edge of LWC with depth marks (photo by Scot Serafin, Fort Knox, KY).

Depth gages are also required for safety (Figure B-3). Lighter vehicles are still subject to the forces of the stream’s flow and drivers must make an informed judgment to determine if it is safe to cross.

Figure B-3. High-water depth gauge (photo by Joe Proffitt, Fort Leonard Wood, MO).

APPENDIX C

LESSONS LEARNED

Key Design Criteria/Considerations

The following questions, when taken as a whole, should be considered during the planning and initial design of a low-water stream crossing to evaluate a low-water ford in its watershed context (Clarkin et al. 2006).

1. Is the crossing located on or near unstable landforms, and is it located in a depositional area? Is the stream geometry suitable for the proposed design?
2. What type of stream bottom or substrate is present? What is the geology of the substrate—rock, gravel, or sand? Streams primarily composed of silt or clay substrates are generally unsuited for unimproved LWC.
3. Is the channel stable at a watershed scale and what changes upstream/downstream might occur if development occurs?
4. What types of flows are expected from the watershed? Base flows/Peak flows? Crossing should not alter the hydrology of the stream.
5. What hydrologic changes are likely to occur, and how will this affect the streamflow regime?
6. What aquatic biota are present within the watershed and what are their needs?
7. What are the constraints (private lands, threatened and endangered species, sediment or total maximum daily load (TMDL) requirements, archeological sites)?
8. If there is a current crossing, how is it affecting the stream (deposition, aggradation, streambank erosion)? For a proposed crossing, will the soil type require extending the approaches to prevent sediment transport?
9. Is the site in an active flood plain or is the channel entrenched?
10. Is the channel locally stable?
11. What is the maximum expected load for the crossing? (An overdesigned crossing may cause greater disruptions than necessary; the failure of an under-designed crossing may also cause disruptions.)
12. What are the maintenance requirements of the design?
13. What are the benefits and drawbacks of a design type?

These questions and their answers will help the planners and designer determine if the site is an appropriate location for the LWC. If a crossing already exists at the site and the decision to have a low-water ford is not appropriate, then military land managers should consider removing the crossing or restricting its use.

Erosion control measures must also be determined based on what will work for each site. These are the most common measures taken when installing an LWC:

- Geoweb/geotextile- These materials can be used quite effectively to improve crossings. Unfortunately, these materials can also be problematic if they are not correctly installed and maintained. Without enough rock or concrete on top of the geotextile, it can be washed out and cause the crossing to fail. If the material becomes exposed, it can also be hooked by traffic and cause problems.

- Contouring- This measure is key when installing a crossing that will last. Contouring the land and area around the crossing can help the stream accept the crossing. This makes the crossing seem more natural and will have a better chance of natural vegetation establishment.

- Vegetation is very important to controlling erosion and keeping the stream as a natural habitat.

Common Issues with LWCs

Natural low-water unvented ford crossings can be used in some cases where the stream bed is solid and traffic is rare. This option is the most inexpensive, but not necessarily the safest or most environmentally friendly for the stream if the traffic load surpasses the load the crossing is capable of handling. These crossing may cause the surface of the stream bed to break down and result in erosion and sediment transport downstream (Figure C-1).

Hardening the ford can be a good option. Depending on the soil type, work may also need to be done to reduce scouring on the approaches and the downstream edge of the crossing.

Narrowing the flow across the ford is not good for the environment because when the flow is narrowed, the flow velocity is increased. Increasing the velocity of the flow will increase erosion. The crossing in Figure C-2 has two problems. The flow is narrowed when it crosses the cement, and the downstream edge is scouring from the water dropping off the LWC.

Figure C-1. Crossing before improvement showing blown culvert, erosion, and scouring of an improperly sited and designed crossing (photo by Joe Proffitt, Fort Leonard Wood, MO).

Figure C-2. Narrowed stream where scouring is occurring (photo by Art Hazebrook, Fort Hunter Liggett, CA).

Scouring (Figure C-3) can be very dangerous. In higher flows, the edge cannot be seen. It could be disastrous if there is a large drop and a vehicle gets off the crossing. Riprap can be added to reduce this effect.

Along with scouring on approaches, ruts from traffic and gullies can be formed from water running into the stream from the approach. Proper water diversions are a possible way to lessen this unwanted consequence (Figure C-4).

Figure C-3. Scouring has occurred on downstream edge of crossing (photo by Chris Collins, Fort Campbell, KY).

Figure C-4. LWC installation with rip rap used in ditches to prevent erosion (photo by Johnny Markham, Fort Benning, GA).

Installation Land Managers and ITAM Coordinators at Tier 1 and 2 ITAM installations were interviewed and asked to give what they felt were the pros and cons for each type of crossing they had at their installations. Many of the answers were similar. The sections below summarize the most common answers.

Unvented Crossings - General

Unvented crossing designs are simple and effective given the right stream and load requirements. The surface hydrology can be kept very natural, and the permit process for this crossing is the easiest.

Unvented crossings can potentially have problems with the aprons being insufficient in length. Vehicle tires will also get wet and any soil on the vehicle may wash off into the stream. They also can require a larger upfront cost than a simple vented crossing due to the need for excavation and potential concrete pads. More detail on the issues of specific hardening methods for unvented LWCs is given below.

Unvented - Articulated Concrete

Articulated concrete crossings are a very common unvented LWC. They tend to need little maintenance, and the articulated concrete can be hauled into areas where a cement truck cannot go.

Crossing location is paramount in the success of an articulated concrete crossing. Conditions must ensure that they can be anchored well to the stream bed (Figure C-5). Additionally, they must also be watched for scouring. Presence of these sorts of issues may point to a crossing that was installed in an unsuitable part of the stream.

Some maintenance is required for these crossings. Rock may need to be added if the stream is removing the concrete from the driving surface. It may also need to be cleaned out if sediment starts to collect on the crossing.

Figure C-5. Articulated concrete was not sufficiently anchored (photo by Chris Collins, Fort Campbell, KY).

Unvented - Cement Slab

Cement slab crossings (Figure C-6) offer a smooth driving surface and last longer than an articulated block crossing. However, the cement slab affects the stream flow and downstream sides of the crossing and can create scour on the stream bed. If the scour or other force contributes to the failure of the crossing,

Figure C-6. Cement slab LWC (photo by Joe Proffitt, Fort Leonard Wood, MO) .

they are quite costly to repair seeing that cement trucks may be unable to access LWCs in remote parts of the rangeland. Scouring may need to be addressed with rip rap on the downstream edge to disperse the stream's energy. Sediment deposition on the road surface may also be an issue and removal may be necessary.

Unvented - Interlocking Blocks

Interlocking blocks are relatively inexpensive and provide a low-impact solution for an LWC that will carry the heaviest military vehicles. Installation of the blocks is faster than heavier, solid cement interventions, taking a day on average. Upon completion, the interlocking block crossings appear to mesh well with the surrounding landscape aesthetics (Figure C-7).

Figure C-7. Interlocking blocks on approaches (photo by Scot Serafin, Fort Knox, KY).

Data collection is still needed to understand the interlocking block's resilience under tank traffic. With frequent hummer traffic, weak spots may appear in the crossing. In heavy storm events, the weak spots may be further undermined or the crossing may even fail.

The maintenance for the interlocking block entails adding gravel for a smoother driving surface. Other rock may be added for scour protection.

Unvented – Rock-Hardened Crossing

Using rock to harden a stream crossing can be less expensive than concrete, and the use of natural materials works well with the hydrology of the streambed. However, rock-hardened crossings tend not to last as long as the cement crossings and are dependent on certain soils. Rock will continually need to be added to keep the crossing in good shape. The gravel used to smooth the road surface tends to wash away.

Unvented – Geo Containment System Crossing

The Geo Containment system does not alter surface or subsurface hydrology. It requires little maintenance and uses vegetation for erosion prevention. The system is used only in very low flows, with low tire pressures (psi), and low-traffic crossings.

Even though this system does not require much maintenance once vegetation has been established, it may need soil added incrementally until the vegetation can act as a stabilizer.

Vented Crossing – General

With a vented crossing, vehicle tires stay dry when flows have not overtopped the crossing, keeping soils from the vehicles from entering the stream. Because the approaches do not go into the stream, there is less worry about erosion down them. The smaller vented crossings can be inexpensive as well.

On the con side, heavy military vehicles can crush any exposed ends of the culverts. Culverts can also cause the stream to lose its natural hydrological properties and can clog from debris (Figure C-8) flowing down the stream or from beaver activities. In high flows, the crossing can become a restriction impeding access, become a safety issue to personnel, or result in an increase in erosion and sediment loads.

Figure C-8. Large, plugged culverts (photo by Jerry Paruzinski, Fort Hood, TX) .

Since vehicles tend to damage the edges of the vented crossings or road maintenance crews may intentionally crimp the culverts shut to reduce potential for clogging or further vehicle damage, maintenance on culverts is required. Routine maintenance involves the removal of sediments, clogs, and debris. Additional maintenance is needed to keep culvert ends as open and “un-crimped” as possible to help reduce the potential for restricted flow.

Low-Water Bridge

A low-water bridge is an effective way to keep the steam bed more natural than a culvert will, while still keeping tires dry and the soil from washing off the vehicles.

Low-water bridges are still susceptible to clogging and they can be more expensive to design and build. As with the vented crossings, the low-water bridge will require maintenance to remove any debris, and erosion will need to be monitored and repaired.

Summary

It has been mentioned throughout that low-water fords have historically been selected on the basis of military training needs rather than stream ecosystem health and erosion control/sediment movement. In fact, the military is dealing with a legacy of poorly selected low-water ford sites across the United States and only recently has begun to evaluate the maintenance costs and environmental damage at these locations. Within the past ten years, the consideration and selection of appropriate designs for these sensitive areas has become more commonplace (Malinga et al. 2007; Svendsen 2005; Howard 2002; Sample et al. 1998). At that time, new technologies and materials were becoming available in the market to facilitate easy low-water ford installation. Unfortunately, early designs failed to consider and stress the importance of site selection, soil type, and topography, and stream ecosystem preservation. Svendsen (2006) stressed that improving streambank stabilization techniques and improving low-water ford substrate materials would enhance LWC longevity and reduce nearby erosion. However, these improvements failed to address upland water, sediment, and debris input at the low-water ford approaches. Malinga (2007) analyzed a number of low-water fords and assessed their stability using Rosgen’s geomorphological classification. They found that, over time, there will be a need to constantly modify LWCs relative to the level of stream instability at the site. This finding further stresses the importance of selecting optimal site locations for stability. Clarkin et al. (2006) analyzed hundreds of low-water fords on U.S. Forest Service lands and examined the suitability of various LWC structures for fish passage and overall stream system health. They found this design criterion to be critical. By minimizing stream impacts to the biotic system, one was essentially minimizing erosion and sediment inputs, stream hydrology changes, and geomorphological instability.

Management of military lands will always include a tradeoff between what is good for the environment and what is necessary for military training. Even so, it is important to note that historically military training area preservation has progressed in a positive direction over time. Of all federal lands, Army installations have the greatest density per acre of threatened and endangered species. While this is an accomplishment, it is also an ongoing challenge. To maintain this success will require greater effort, particularly in regard to stream ecosystem health.

APPENDIX D

QUESTIONNAIRE AND RESPONSES

Personnel at the following installations responded to a questionnaire written by Heidi Howard, U.S. Army Engineer Research and Development Center, Champaign, IL. Questions related to low-water crossings on the lands that these individuals manage or use for training exercises. The respondents provided information about the installation and maintenance of LWCs at their installations. They also provided comments on budget allocations for LWCs and other information regarding the performance of the LWC with respect to environmental factors such as erosion, stream health, and animal interactions. A sample of the questionnaire is included below:

Questions to ask about low-water crossings:

Does your installation have any low-water crossings?

What types are in place? [vented (using pipes or culverts), unvented, low-water bridge, or weir]

Any special design considerations (wildlife considerations)?

Approximately how many?

What stream types have the crossings?

- o Perennial - Water flows in well-defined channel at least 90% of the time.
- o Intermittent - Flow generally occurs only during the wet season. (50% of the time or less)
- o Ephemeral - Flow occurs for short time after extreme storms; channel is not well defined.

What kind of usage do the crossings see [loads/quantity]

- o Low-water bridge
- o Vented
- o Unvented

How did you decide their location?

Based on stream characteristics or because of troop movements?

Did you use any geotextile in the construction of the crossings?

Woven or interlock?

Why?

Did that change how the crossing was built?

What is the slope for the approach? --

Is there a standard, or what is a common range?

Are the approaches hardened? If so, how? (Y / N)

What materials are the stream bed driving surfaces made of?

- Vented:
- Unvented:

Unvented: at grade or above grade of the stream bed?

(At / Above)

Vented: typical size of the passage?

Has improving the crossings with geotextile or rock hardening helped with erosion and stability?

- Do you have equipment that measures this erosion?

Does water flow into the stream from the approaches? (Y / N)

Does the water flow from the approaches require more maintenance (cause gullies)? (Y / N)

Approximately how many times a year do you fix this erosion?

- o Vented:
- o Unvented:

What is the typical 'life expectancy' for a crossing?

- o Unvented:
- o Vented:
- o Low water Bridge:

Have any of the crossings failed?

- o Unvented:
- o Vented:
- o Low-water Bridge:

After failure, were the crossings rebuilt in the same place or moved?

Do you have any photos of the crossings we could see? (Y / N)

Downstream, upstream, from both approaches

Any photos of a crossing after failure?

Is it possible to get a Map or GIS of the crossing area [approx 300 yards on either side of the crossing]?

(If not, UTM coordinates?)

What are the pros and cons for each type at your installation?

Vented:

Pros-

Cons-

Unvented:

Pros-

Cons-

Low water bridges:

Pros-

Cons-

Is there any cost data for installation and/or maintenance? (Including materials and labor)

Vented-

Unvented-

Low-water bridge-

Is there anything else I should know about your low-water crossings?

Could I e-mail you once I get my notes typed up to make sure that the info is correct and send you any other questions I may have? (Y / N)

***

Respondents are listed by their installation. Their responses have been collected into general categories.

1. FT. BRAGG, NC

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented Vented	12	Tank	Geoweb No perf.	4-5%	At	Yes	Low	Yes

Unvented - Keeps stream natural but installation is more labor intensive, soils require hardened approaches.

Vented – Approaches are stable, but ends get crushed, more maintenance for flushing.

Controlled burns can damage plastic venting.

2. FT. LEWIS, WA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	11	Striker Humvee	Woven	Not steep	Above	Yes	Low	No

Unvented - Simple and cost effective, easy to put in, permits easy to obtain, some aprons not long enough.

3. FT. HOOD, TX

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	437	5 ton Hummers future: tanks	Honeycomb	Min:20-20-20	At	Yes rock and concrete	Gully plug req. for tanks 4500 over area	yes

Vented: Works well on small areas and some tank crossings, but maintenance costs escalate especially with crushed edges.

Unvented: Drainage is good and maintenance is easier, but the hardened shoulders can be an issue and contribute to maintenance costs.

Cost data: Varies on size; $25,000 – $250,000

4. FT. BENNING, GA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	7	Varies	Woven	Varies	at	Yes	Low	No

Unvented - Very little maintenance, saves money in long run, a little more expense in short run.

5. FT. DRUM, NY (Powerpoint)

6. FT. CAMPBELL, KY

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented Cable / Slab	17 - 21	Trucks	Woven	Not steep	at	Yes stable before	Low - none	Yes, shot rock

Unvented crossings are cheap and low impact, but there are issues of undercutting.

$15,000 installed (labor and material)

7. FT. CARSON, CO

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	29 +	Tank	Woven	4:1	2ft above	Yes	n/a - none	Yes, part.

8. USARHAW, HI - PTA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	20 +	Striker	Geoweb at approach	3-4%	at	Yes,seed openings	Low - none	n/a

Cable concrete is better in the long run. Cheaper and quicker to build once made. 200 mats were constructed but the 8x16 forms had to be shipped from main land and the installation needed concrete trucks contracted to pour. PTA also used on very steep slopes.

9. FT. RILEY, KS

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented Vented	87	Tracked	Woven	n/a	At	Yes	Low – Medium contouring for water	Yes

Unvented crossings work very well with no depositions. It works well with stream bed. However, placements are not the best on some. The stream is trying to correct itself and deposition is occurring. Unvented crossing cost roughly $20,000-26,000.

10. FT. LEONARD WOOD, MO

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented Vented Lowbridge	1 20 3	Tanks (all)	Woven - unvented	Varies, gradual	At	Yes, no wallows	Low - road grading, water diversion	Yes, truck error

Vented crossing requires cleaning or replacement of culverts that get blown out in a storm. Still preferred on installation.

Unvented crossings have higher initial costs but lower maintenance.

11. FT. PICKETT, VA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented Vented	10	n/a 20+ cross/wk	Woven - abundant	< 10%	Vented - 10+in culvert	Low-none	Low - road grading, water diversion	no

Vented crossing allows for traffic out of water, but it does impact invertebrate life and native animals.

Unvented crossings cost less with a more natural stream bed (concrete results in less sediment in creek). The water crossings are not preferred for some vehicles.

12. FT. SILL, OK

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented (rip rap) Vented	20 +	Tank	Woven-by recommend	3:1 max.	At	n/a	Low - road grading, water diversion	no

Vented: Heavy vehicle pinch shut

Unvented: Fixed erosion eliminates sedimentation and improves safety, but high material cost.

Material cost: $26-27 per ton for riprap delivered.

13. FT. KNOX, KY

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	5	Tank	none	Quite steep, gradual	At	Yes, plugs on sandbars	Some 5-6 years	Yes,

Vented: Anything can pass. Level from bank to bank. Water level can change a lot. Maintenance to keep from plugging – not wildlife friendly

Unvented: Interlocking block - $. Works well with landscape. Passable. Quick to install (day). Looks nicer. Only humvee traffic. May not hold tanks. Little bit of maintenance. Weak spot exposed in heavy storm. Plan to use cable concrete in future.

14. FT. RUCKER, AL

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Vented	1	Humvee	woven	3%	At	n/a	clogging	n/a,

Vented crossings are quite effective at handling weight, however shelling/fire damage is and costly difficult to repair.

15. FT. HUNTER LIGGETT,CA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Vented	1	Tank	woven	3-5%	At	yes	100-500 year events high	yes

Concrete is long lasting, but costly repairs and high maintenance are drawbacks.

Cable concrete can be placed in areas that cement truck cannot access, but will not last if not anchored well.

16. USACE ALASKA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	4	Strikers	Non-woven	10:1	At	Some	Some. Glacial outwash issues	yes

Unvented crossing helps manage erosion, and the surface is more consistent than native stream bed. It can be maintained using a bulldozer. Installation methods are expensive compared to the amount of improvement.

17. FT. BLISS, TX

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	30	Tracks	Woven	3%	At	Yes. minor	High. Silt scour	Yes

Unvented crossings are quick and easy. Native materials can be used, but they require lots of maintenance.

18. CAMP GRAYLING, MI

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Vented 4-24″ dia	4	Heavy, varies	Woven	n/a	n/a	Yes w/ correct install	Best 25 years Worst 10 years	Yes

Vented: Honeycomb works well if designed well. Proper design from start will help it last. If it is set too high, don’t last as long. Problem 19 years ago.

19. FT. BLANDING, FL

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Vented Unvented	200 50+	6 Wheel 80,000lb max	Woven	n/a	At unvented Vented 36-60″	Yes. Esp. for sand	High. Gullies on approach	Yes

Vented: Culverts cheaper, but restricted in high flow

Unvented: Easier to permit. Not much maintenance, but will not hold up as well on traffic associated with logging practices.

20. FT. STEWART, GA

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	88	Tank	Woven	n/a	At	Yes.	n/a	No

Unvented: Little maintenance. It utilizes surface and subsurface hydrology.

21. FT. DRUM, NY

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	1	Tank	Woven	< 5%	At	Some	Low	No.

Unvented: No maintenance. Pioneer species have returned. Only downside is the tires getting wet.

22. CAMP SHELBY, MS

Type	#	Vehicle Max.	Geotext	Slope Avg.	Grade	Erosion Control	Maintenance	Fail
Unvented	10+	Tank	none	Max 10%	At	Yes. Water bar used	Low	No.

APPENDIX E

REFERENCES

Clarkin, K., G. Keller, T. Warhol, and S. Hixson. 2006. Low-water crossings: geomorphic, biological, and engineering design considerations. U.S. Department of Agriculture, Forest Service (October).

Howard, H.R. 2002. Innovative Uses of Recycled Tank Tracks for Erosion Control. PWTB 200-1-16. Retrieved 18 Dec 2009 from http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_16.pdf

Howard, H.R., N.G. Svendsen, M.L. Hargrave, D.R. Gambill, L.K. Erhart, W.R. Ochsner, B.D. Schneck, and K.M. Carmany. 2006. Lessons Learned: Streambank Stabilization on Army Training Lands. PWTB 200-3-41. Washington, DC: U.S. Army Corp of Engineers. Retrieved 7 Dec 2009 from http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_3_41.pdf

Jones, J.A., F.J. Swanson, B.C. Wemple and K.U. Snyder. 2000. Effects of roads on hydrology, geomorphology and disturbance patches in stream networks. *Conservation Biology* 14(1):76-85.

Malinga, G.A. 2007. Analyzing the effects of low water fords on stream stability at Fort Riley, Kansas. M.S. Thesis. Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, Kansas.

Malinga, G.A., J. Steichen, T. Keane, S.L. Hutchinson, and P.H. Woodford. 2007. Assessing impact of low water fords on stream stability, Fort Riley, KS. Paper 072138, 2007 ASAE International Meeting, American Society of Agricultural and Biological Engineers. St. Joseph, Michigan.

Sample, L.J., J. Steichen, and J.R. Kelly, Jr. 1998. Water quality impacts from low water fords on military training lands. Journal of the American Water Resources Association. August 1998, 34(4):939-949.

Svendsen, N.G., P.K. Kalita, D.L. Gebhart, and M.L. Denight. 2006. Defilade, stationary target and moving target embankment, low water crossing, and course road designs for soil loss prevention. ERDC/CERL TR-06-31. Champaign, IL: U.S. Army Engineer Research and Development Center.