LOW WATER STREAM CROSSING (LWSC)

General: A Low Water Stream Crossing (LWSC) is an engineered structure used to cross channels with periodically dry beds, or channels where the normal depth of flow is relatively low. Such improved stream crossings have less downstream sediment levels than unimproved stream crossings, and are therefore more environmentally "friendly" than unimproved crossings. An engineered LWSC, when properly constructed, will help maintain water quality and decrease maintenance expenditures. As such, the designer should consider use of constructed Low Water Stream Crossings (LWSC) to traverse streams on tank trails, and on other unimproved roads where a bridge is not practicable.

Background: Tank trails and other unimproved roads often must traverse small or large streams and creeks, where a bridge may not exist. Such an intersection of road and stream networks creates a location for greater sediment discharge, stream habitat fragmentation, and increased maintenance expenditures. The creek or stream bed does not necessarily need to have year round flowing water; rather, it may consist of a dry wash that has seasonal storm water runoff during storm events, with little or no standing water between storm events. In addition to erosion, such seasonally wet channels can be subject to extensive trail subsidence or large potholes, created as vehicles repeatedly traverse areas of moist soil.

Vehicles crossing a flowing stream erode the channel bottom (i.e. displace sediment from the channel bed) by mechanical action. Vehicles also erode the stream banks through mechanical action at the points where the vehicle enters and exits the water. In addition,

the bow wave created by a vehicle as it moves through the water will wash up the opposite bank, and erode the opposite bank at the point where the vehicle exits the water. Because the wave radiates outward, it will erode the opposite bank not only at the exit point, but also some distance both up and downstream of the crossing site. The bow wave carries sediment back into the stream as it recedes from the shoreline. Finally, there is often substantial erosion on the approach sections of tank trail during storm events, with sediment laden stormwater runoff from the trail directly into the stream at the crossing site. The overall effect of vehicle traffic at an unimproved LWSC site is erosion of the stream bottom and banks at the crossing, and loss of vegetation along the banks near the intersection of stream and trail. This results in reduced water quality by increasing sediment and turbidity loads. Increased sediment loads smother bed dwelling organisms through sediment deposition, and can reduce aquatic plant population due to reduced sunlight penetrating turbid waters.

The environmental impacts discussed in the preceding paragraph can be mitigated by an engineered LWSC. If an unimproved earthen LWSC site already exists on a tank trail, then the designer should consider improving or "hardening " it using a variety of materials, such as geosynthetics, stone base, riprap, an articulated roadbed system (cable concrete), and adapted embankment vegetation. If the channel bottom at a crossing site was hardened previously with stone, then the designer should assess the LWSC and determine if additional protection is required for the entry and exit points on the banks at the crossing site. If a new trail is being constructed and a crossing site does not yet exist, then in addition to constructing a hardened LWSC, the designer should attempt to properly site the new LWSC. Design and construction of a LWSC is very site dependent. Topography, soil type, and stream and stream channel characteristics will vary from site to site, and must all be considered by the designer.

Hydrologic Analysis. The first step when building a new engineered LWSC is to locate the proposed crossing site, and to perform a hydrologic analysis of the proposed site. This analysis is necessary so that designers can get an idea of flow conditions at the site under a variety of conditions, and determine if the site is suitable for a LWSC. They will need to determine if the stream at a proposed location is perennial, intermittent, or ephemeral. A perennial stream has flow for most of the year in a well defined channel. An intermittent stream can be defined as one where continuous flow generally occurs only during the "wet" or rainy season. An ephemeral stream generally has flow only for short periods after extreme storms, and the channel may not be well defined. Designers will need to assess the size of the drainage area serving the proposed LWSC site, so that they can get an idea of flow conditions (such as stream depth and flow velocity) at the proposed site under normal conditions and during storm events. It will be necessary to determine the typical "normal" depth-of-flow and flow velocity, and the depth-of-flow and flow velocities associated with peak flow during storm events (including a 25 year storm) at the LWSC. These considerations are important since a poorly sited LWSC may require lots of maintenance, or may have to be closed to vehicle traffic more frequently due to high flow conditions. Designers must also consider existing channel geometry (width, depth, side slope, and channel bed slope). The results of the hydrologic analysis should be used to make a determination if the proposed site is a good one at which to

locate a LWSC. If the site is not a good, then it may be necessary to move the LWSC to another location.

Equation 1 is a combination of Manning's Equation and the Continuity Equation; it can be used to estimate depth-of-flow (H) in feet at a proposed LWSC site under a variety of conditions (i.e. typical and during design storm events). This information can be used to give an indication as to how often a LWSC site may have to be closed to vehicle traffic due to high flow conditions. The equation assumes that the LWSC is constructed with minimal disturbance to the channel and that the channel is essentially rectangular. The value of H is determined by trial and error for the channel, given Q, w, S, and n.

1. $$Q = \frac{1.486(wH)^{5/3}}{n(w+2H)^{2/3}}\sqrt{S}$$

Where Q = Design Discharge (ft^3/s) from the Hydrologic Analysis

n = Manning Roughness coefficient

S = Channel slope (ft/ft)

W = Channel width (ft)

H = depth of flow (ft) associated with Q

For very wide channels where $w/H \geq 10$, Equation (1) can be simplified to

2. $$H = \left(\frac{nQ}{1.486wS^{1/2}}\right)^{3/5}$$

Flow velocities in the channel under a variety of conditions can be calculated using Manning's Equation, as flows:

3. $$v = \frac{1.46}{n}R^{2/3}S^{1/2}$$

Where v = Velocity of stream flow (ft/s)

n = Manning's roughness coefficient

R = hydraulic radius (ft)

S = Channel Slope (ft/ft)

The designer must also determine if the channel is stable at the proposed LWSC site. If a channel modification must be made, then the designer should analyze stream tolerance to change. Any channel modifications should be as close as possible to the existing channel alignment and cross section geometry. In general, designers should avoid or minimize any channel modifications. If extensive channel modifications are necessary to construct a LWSC, or if modifications will have an adverse impact on the environment, then it may be better to move the LWSC to another location. The elevation of the completed LWSC should be the same as the original existing stream bed elevation to allow free stream flow and movement of aquatic life. The best design is one that meets the goals of the designer while at the same time having a minimal impact on the stream.

LWSC Design and Construction Guidelines

In general, to construct an engineered LWSC, the trail approaches into and out of the crossing, and the channel bed should be hardened with gravel, large rock, or concrete. Some design options are outlined below.

LWSC constructed with Rock Rip-Rap and Gravel:

a. Approaches on each side of the LWSC should be cut where necessary so as not to exceed a maximum grade of 12 percent. The approach road should be a minimum of 5.0 meters (16.3 ft) in width and should extend to either side of the crossing along the tank trail for a minimum of 25 meters (82 ft)

b. If necessary, dewater the LWSC site within the limits of construction. Excavate the bottom of the channel crossing to a depth of 1.2 meters (3.9 ft) or until a rock ledge or hard clay pan is encountered. The minimum width of the excavation should be 6.1 meters (20 ft). The length of the excavation should equal the width of the channel plus 3 meters (10 ft) on either side with excavation depth tapering to 0.5 meters (1.5 ft) for the remaining approach distance

c. Upon completion of excavation, high strength non-woven geotextile fabric shall be laid in a manner to cover the surface of the excavated area in the channel bed. The excavated area should be filled in 0.5 meter lifts and compacted with 46–61 cm (18–24 in) rock rip rap until the original stream bed elevation is reached.

d. A layer of medium weight geotextile fabric shall be laid on the surface of the graded approaches. The excavated area should be filled with a 30 cm layer of 20-30 cm (8-12 inch) rock and compacted. Once the rock bed has been constructed and compacted, then a 30 cm layer of 3–5 in rock shall be placed on the base to fill voids in the larger rock, and also act as a wearing surface.

e. This layer of 3-5 inch rocks is incorporated into the crossing to fill voids in the larger rock.

f. To provide drainage for the approaches, V-shaped ditches should be constructed on both sides of the trail at the entry and exit points to the crossing. The side slopes of the V-ditches should not be less than 3:1. If the approach grades are greater than 5 percent, a layer of riprap should be applied to the drainage ditch and properly sized to accommodate the velocity and volume of runoff flow. Designers should consider constructing water bars or diversions to divert runoff into riparian areas before it reaches the crossing site.

g. The roadbed section and materials used in its construction constitute the transition between the crossing and the tank trail. The approach road should be stabilized with non-erodible materials.

h. All bare areas of soil should be covered in rock or planted with native riparian vegetation. See Civil Details in the Appendix of this document.

LWSC constructed with Articulated Cable Concrete:

The channel bed and approaches at a LWSC site can be hardened with articulated cable concrete (see Figure 1) using the following general construction procedure. This design option is suitable for all LWSC channels (perennial, intermittent, or ephemeral).

a. If necessary, dewater the LWSC site within the limits of construction. Excavate the bottom of the channel crossing to a depth of 1.0 meters (3 ft) or until a rock ledge or hard clay pan is encountered. The minimum width of the excavation should be 6.1 meters (20 ft). The length of the excavation should equal the width of the channel plus 3 meters (10 ft) on either side with excavation depth tapering to 0.5 meters (1.5 ft) for the remaining approach distance.

b. Approaches on each side should be cut where necessary so as not to exceed a maximum grade of 2 percent. The approach road should be a minimum of 5.0 meters (16.3 ft) in width and should extend to either side of the crossing along the tank trail for a minimum of 25 meters (82 ft).

c. Upon completion of excavation, non-woven geotextile fabric should be laid in a manner to cover the surface of the excavated area. The excavated area should be filled to a depth of approximately 0.45 meters (18 in.) with 15 cm (6 in.) of rock riprap and compacted. A second layer of 5 to 7 cm (2 to 3 in.) of rock will then be placed to a depth of 0.3 meters (12 in.) with compaction occurring every 0.15 meters (6 in.).

d. Once the rock road bed has been constructed and compacted, then articulated concrete mats with geotextile backing should be placed on the aggregate base. The cable concrete should have an overall width of 4.9 meters (16

ft). The articulated concrete mat sections should be toed in at an angle on the upstream and downstream edges.

e. A layer of 19-mm (3/4 in.) aggregate should be placed on the articulating concrete mats to fill the voids between the concrete blocks.

f. To provide drainage for the approaches, V-ditches should be constructed on both sides of the trail at the entry and exit points to the crossing. The side slopes of the V-ditches should not be less than three to one. If the approach grades are greater than 5 percent, a layer of riprap should be applied to the drainage ditch and properly sized to accommodate the velocity and volume of runoff flow. Designers should consider constructing water bars or diversions to divert runoff into riparian areas before it reached the crossing site.

g. The roadbed section and materials used in its construction constitute the transition between the crossing and the tank trail. The approach road should be stabilized with non-erodible materials. The designer should consider stabilizing the approaches to the LWSC with non-erodible material as follows. The tank trail should be excavated to a depth of approximately 1 ½ feet in the approach areas where cable concrete is not being installed. Upon completion of excavation, non-woven geotextile fabric should be laid in a manner to cover the surface of the excavated area. The excavated area should then be backfilled to a depth of approximately 1 foot with stone and compacted. A 6-inch layer of aggregate stone should then be placed on the stone base layer and compacted.

h. All bare areas of soil should be covered in rock or planted with native riparian vegetation. See Civil Details in the Appendix of this document.

Figure 1. LWSC Constructed of Cable Concrete

LWSC constructed with Cellular Confinement System:

Another design option for intermittent or ephemeral streams with low flow is a LWSC constructed using a geoweb cellular confinement system that is backfilled with stone (see Figure 1). The channel bed and approaches should be excavated to a depth of at least 1 foot (12 inches). Upon completion of excavation, the subgrade should be compacted, and a non-woven geotextile fabric laid in a manner to cover the surface of the excavated area, and toed in. A geoweb system should then be installed and anchored on the geotextile fabric. The geoweb and excavated area should then be backfilled with stone to the top of the geocells. An additional layer of aggregate stone should then be placed on top of the geocell stabilized stone base layer until flush with the channel bottom, and compacted. See Civil Details in the Appendix.

Figure 2. LWSC Constructed with a Geoweb Cellular Confinement System

Guidelines for Hardening Approach Sections of Trail Using Cable Concrete:

If a LWSC site has already been hardened previously with stone, then it may only be necessary to stabilize the approach roads and banks (both upstream and downstream). The following procedure can be considered by the designer.

a. If necessary, perform local dewatering of the channel in the area where the channel and banks need to be improved. The bottom of the channel should then be excavated to a depth of approximately 1-meter. The excavation should extend about 10 feet from the stream bank towards the center of the channel. The channel should be excavated in this manner on both sides. The center of the channel will not be excavated since the bottom has already been previously hardened with stone.

b. The approach trail or road should be a minimum of 5.0 meters (16.3 ft) in width and extend to either side of the crossing along the trail for a minimum of 25 meters (82 ft).

c. Upon completion of excavation, non-woven geotextile fabric will be laid in a manner to cover the surface of the excavated area. The excavated area will be filled to a depth of approximately 12 in. with stone and compacted.

d. Once the rock road bed has been constructed and compacted, then articulated concrete mats with geotextile backing should be placed on the aggregate base. The mats should have an overall width of 4.9 meters (16 ft). The articulated concrete mat sections should be toed in at a 45 degree angle into the stream bed (Detail C, app C).

f. A layer of 19-mm (3/4-in.) aggregate should be placed on the articulating concrete mats to fill the voids between the concrete blocks.

g. To provide drainage for the approaches, V-ditches should be constructed on both sides of the tank trail at the ingress and the egress points to the crossing. The side slopes of the V-ditches should not be less than 3:1. If the approach grades are greater than 5 percent, then a layer of riprap should be applied to the drainage ditch and properly sized to accommodate the velocity and volume of runoff flow. If possible, designers should consider constructing water bars or diversions to divert runoff into riparian areas.

h. The stream bank at the entry and exit points should be stabilized with rock riprap. See Civil Details in the Appendix of this document.

Traffic Controls and Signage. Traffic advisory signs to warn drivers about the LWSC should be placed on the approach trails to the LWSC site. If possible, there should also be a turnaround location for vehicles. An advisory speed limit sign with the recommended crossing speed should also be placed on approach trails to the site. There will be periods of high flow in the channel when a LWSC cannot be safely used. Traffic controls must be developed by the installation, and implemented at the LWSC site to advise vehicle drivers if the LWSC can be safely used. Representative signage is included in the civil details in the Appendix.

Other Considerations. Construction of a LWSC should be performed during periods of low flow in the channel, and not during periods of fish spawning or migration. Designers should include hydrologists and biologists during the planning phases of construction. Periodic inspections and maintenance should be performed at LWSC sites, particularly after storm events. Stream channels and banks should be restored when the LWSC is abandoned or is no longer in use.

References.

Sample, L., Steichen, J., Kelley, J., *Water Quality Impacts From Low Water Fords On Military Training Lands*, Journal of the American Water Resources Association, August 1998.