West Virginia
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RESILIENTLY BRIDGING THE GAP

PRIVATE WATER CROSSINGS
WV VOAD BRIDGE REPLACEMENT GUIDELINES

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1. INTRODUCTION

Southern West Virginia residents experienced three separate flooding events from storms on April 3, April 8 and July 10 of 2015. Many residences were damaged and over 300 private water crossings were reported damaged or completely destroyed due to powerful floodwaters and heavy floating debris. In Lincoln County alone, where the pilot project was performed, over 80 residences experienced bridge or culvert destruction. Without aid, many of these families may never have the ability to safely access their houses.

Members at the monthly WV VOAD meeting in Charleston, WV on August 18, 2015 requested the development of a guideline for the design and construction of private bridge replacement for bridges that were destroyed by the flooding. The WV VOAD Bridge Committee was formed as a result to oversee this effort. This guideline was developed with the input of local, state, and federal agencies and advisors. The participants of the WV VOAD Bridge Committee, Bridge Committee Partners and Bridge Committee Advisors are listed in the appendices.

2. PROJECT OWNERSHIP AND REGULATORY CONDITIONS

2.1 The bridges to be replaced are all on private land and privately owned by individuals.

2.2 The County Floodplain/Building Permits Manger and WV VOAD shall coordinate and monitor progress of required permits to ensure that all permits are filed with the respective agencies. The county floodplain/building permit shall be the first permit issued so as to ensure all applicable local and FEMA floodplain requirements are met before filing the remaining permits. The required permits are listed below, in no particular order of precedence:

1. US Army Corps of Engineers (USACOE) Nationwide Permits:
   - NWP 3 Maintenance
   - NWP 13 Bank Stabilization
   - NWP 14 Linear Transportation Projects (Bridges)
2. WV Division of Natural Resources (WVDNR)- Endangered Species
3. WV Division of Natural Resources (WVDNR)- Land and Streams
4. WV Department of Highways (WVDOH) – Encroachment Permit (Driveway Permit)
5. WV State Historic Preservation Office (WVSHPO) review
6. County Building Permit

2.3 It appears that most of the bridges to be replaced are located in FEMA Zone A (Approximated Zones) or FEMA Zone X (outside the 100 year flood zone) flood zones. Most of the bridges are also from top of bank to top of bank, such that the structures are completely outside the waterway and therefore do not require USACOE permits.

3. LIABILITY

3.1 The Property Owner shall assume all liability for the bridge. A Hold Harmless Agreement to this effect, drafted by WV VOAD Legal Aid, shall be signed by the Property Owner before the commencement of any work.

3.2 The Hold Harmless Agreement shall hold harmless the Agency or Entity performing or assisting the construction of the bridge, WV VOAD, Local County Commissions and their employees, and any sub-contractors hired to do specialty work for the job.

3.3 The Home and Property Owner shall be given and shall sign a document spelling out the maintenance requirements for the bridge. This document shall include spelling out the weight capacity limitations and responsibilities to make public notice of those weight limitations.

4. PROJECT CONTEXT

The majority of the destroyed private bridges were situated in a manner that created obstructions to the stream channel. The bridge superstructures were either below the flood water elevation and were therefore overtopped and/or the abutments were built protruding into the stream channel, restricting its natural width.

Bridge superstructures should ideally be reconstructed above the flood water elevation. For many of the sites this document addresses however, it is topographically impractical to achieve this since the bridge location itself is below the flood water elevation. In some cases the abutments of the bridges are directly adjacent to the highway right-of-way (generally 15ft from the center of the road in the project area) and ramping up to a higher elevation is not possible.

Economic resources in this area are severely limited. The poor state of construction of most of the bridges attests to the fact that the owners had limited economic means for design and construction. State and federal assistance is either unavailable or very limited for private bridges. A State of Emergency was declared for the storm events described in the introduction. Individual Assistance was requested for each event but denied by FEMA. As an economically depressed area, the private landowners have very limited economic means to assist in the reconstruction.

5. PROJECT INTENT

Due to their location, it is inevitable that bridges in this area will be overtopped by flood waters caused by severe storms within their expected lifetimes. As such, they will be subject to destructive forces. It is important to note that the proposed bridge replacement designs are not guaranteed to withstand these severe storms since that would make their construction cost prohibitive. The intent of the bridge replacement program is to provide structures that are as resilient as possible given the limited economic resources available.

Resiliency is aimed for by utilizing the following design principles:

1. Design shall seek to avoid impeding the natural flow of the water. New abutments shall be located outside of the stream channel so as to minimize interference with the natural stream bed and to maintain the overall integrity of the waterway. Several of the existing damaged bridges have piers located in the stream bed that appear to be stable and in good condition. In these cases, the piers may be reutilized if they are stabilized or reinforced where necessary.
2. Bridge superstructure elevations shall be established with as much clearance above the floodwater elevation as possible. This, in conjunction with installing abutments outside of the stream channel, will generally result in longer bridge spans than the bridges that are being replaced.
3. Design of bridge abutments shall be to minimize the likelihood that they shall be undermined or damaged by erosion and scour.
4. Bank stabilization shall be provided with riprap and/or gabions so as to minimize erosion and scouring.

6. CODE AND DESIGN CRITERIA

All of the bridges to be replaced are privately owned. Due to this, design and construction is not required to conform to The American Association of State Highway and Transportation Officials (AASHTO) or Federal Highway Administration (FHWA) specifications. Building to AASHTO specifications would be cost prohibitive. Bridges also do not fall under the International Residential Code (IRC) for private dwellings. Instead, structural design criteria were developed to meet the loading conditions of vehicle sizes expected to cross the private bridges while still keeping the construction economically feasible. These guidelines were developed utilizing information from the following sources:

The International Residential Code (IRC) 2012
FEMA P-778 Private Water Crossings, June 2009

Private Water Crossing #2 DR-4219-WV
AASHTO "Guide Specifications for Design of Pedestrian Bridges"
AASHTO "Standard Specifications for Highway Bridges" 17th Edition

7. TECHNICAL AND COST CONSIDERATIONS

Due to the limited economic resources and anticipated construction by individuals and not-for- profit agencies who may have limited technical experience in bridge building, the following shall be considered in the design of the bridge:

1. The bridge construction shall be as economical as feasible.
2. Construction techniques shall be as simple as feasible so as to minimize skilled construction supervision needs.
3. Semi-skilled volunteer-friendly construction methods shall be maximized.
4. Heavy and expensive construction equipment shall be minimized.
5. Design details shall aim to minimize the need for bridge maintenance.

8. DESIGN LOADS

The following design loads are intended for bridges that will carry pedestrians and a low volume of private passenger vehicles and heavy duty pickups, but are not designed or intended to carry typical highway traffic.

8.1 Pedestrian Live Loading

40 pounds per square foot (psf) on bridge walking area.

Commentary: The AASHTO "Guide Specifications for Design of Pedestrian Bridges" specifies a uniform pedestrian loading of 90psf. It is unlikely that a private bridge will be subjected to this loading. The IRC2012 specifies 40psf live load for residential areas.

8.2 Vehicle Size and Weight Class

7.5 ton vehicle loading. One vehicle maximum capacity. A single vehicle shall be placed to produce the maximum load effects. The vehicle live load shall not be placed in combination with the pedestrian live load.

Commentary: The weights of the vehicles most likely to cross these private bridges are listed as follows:

- Small pickup or minivan ≈ 6,000 pounds
- Heavy duty pickup ≈ 12,000 pounds
- Rescue vehicle (i.e. ambulance) ≈ 13,000 pounds
- Moderate sized machinery (e.g. small backhoe) ≈ 15,000 pounds

Discussion with the Duval Fire Department concluded that in most cases, the bridges need not be designed for fire trucks (H20 loading category) since they stay on the main road and will not access private driveways due to unknown conditions. Designing for the H5 loading category (capacity of 5 tons, or 10,000 pounds) is not sufficient, but designing for the next loading category up (H10, which has a capacity of 10 tons, or 20,000 pounds) is not necessary and cost prohibitive. As such, a 7.5 ton (15,000 pound) loading capacity was chosen.

8.3 Wind Loading

50 pounds per square foot (psf) applied to the projected vertical area of the bridge.

Commentary: As per AASHTO "Guide Specifications for Design of Pedestrian Bridges". In general, this wind load is less than the anticipated transverse water loading.

8.4 Transverse Water Loading

For many of the bridges it is highly probable that the flood waters will overtop the superstructure, subjecting it to pressure from the flowing water and resulting drift buildup. To account for this the bridges shall be designed to withstand a transverse pressure of 280psf applied to the superstructure in a uniform distribution. This corresponds to a stream velocity of 10mph and a drift buildup against a square-edged superstructure.

Commentary: As per AASHTO Standard Specifications for Highway Bridges 3.18.1.1

8.5 Uplift Loading

Provision shall be made for adequate attachment of the superstructure to the substructure.

Commentary: As per AASHTO Standard Specifications for Highway Bridges 3.17.1

8.6 Curb Loading

250 pounds per linear foot of curb, applied at the top of the curb.

Commentary: This is one-half of the loading given in AASHTO "Standard Specifications for Highway Bridges" 3.14.2.1. Due to the location of the bridges at driveway entrances, maximum speeds of 15mph are expected, resulting in greatly reduced impact loads.

9. DESIGN DETAILS

9.1 Deflection

Allowable live load deflection shall not exceed either of the following:

1. Allowable live load deflection shall not exceed l/360, where l is the length of the bridge span for pedestrian loading and H5 (5 ton) loading.
2. Allowable live load deflection shall not exceed l/240 for a vehicle weighing 7.5 tons.

Commentary: The AASHTO “Standard Specifications for Highway Bridges” 10.6.2 states that spans preferably should be designed so that the live load deflection shall not exceed l/800. The deflection limits specified in the AASHTO specification are not mandatory, only recommended criteria that are up to the judgment of the engineer. The AASHTO “Guide Specifications for Design of Pedestrian Bridges” specifies a deflection limit of l/500 for pedestrian load. Since the deflection criterion is what in many cases controls the size and therefore the cost of the beams, allowing a more liberal deflection criterion results in significant cost savings. The IRC specifies an allowable live load deflection not to exceed l/360 for floor beams and not to exceed l/240 for “all other structural members”.

9.2 Vibrations

Vibration analysis shall not be considered. Due to the location of the bridges at driveway entrances, maximum speeds of 15mph are expected, limiting excessive vibrations.

9.3 Bridge Deck Width

The total clear width of the bridge deck shall be 10 feet.

Commentary: AASHTO “Guide Specifications for Design of Pedestrian Bridges” 1.2.1.2 specifies a clear deck width of 6 feet to 10 feet for a H5 Truck and a clear deck width over 10 feet for an H10 Truck. Increasing the deck width increases cost.

9.4 Curbs

A bridge curb shall be installed. The height of the bridge curb above the roadway shall be not less than 8 inches and preferably not more than 10 inches.

Commentary: Curb height complies with AASHTO “Standard Specifications for Highway Bridges” 2.2.5

9.5 Signage

A marker guide post will be installed at each of the four corners of the bridge superstructure. One of the posts facing the highway will include the maximum vehicle loading limitation.

9.6 Bridge Approach Ramp

The approach ramps to the bridge shall be surfaced with compacted crusher run material.

10. BRIDGE PLANS

Plans shall be developed for each bridge site for permitting and construction purposes. Each plan will include the following:

1. Cover Page with site location map
2. Bridge Elevation
3. Superstructure
4. Decking
5. Abutments
6. Specifications
7. Material Estimate

11. APPENDICES

A.1 WV VOAD BRIDGE COMMITTEE MEMBER LIST
A.2 BRIDGE COMMITTEE PARTNERS
A.3 BRIDGE COMMITTEE ADVISORS

B.1 BRIDGE TYPES
B.2 ABUTMENT TYPES
B.3 DECK TYPES
B.4 EXAMPLE SET OF PLANS

A.1: WV VOAD BRIDGE COMMITTEE MEMBER LIST

Jenny Gannaway: WV VOAD
Jim Ditzler: United Church of Christ
Barbara Chalfaut: Presbytery of WV
Jack Cobb: American Baptist Men
Byron Boggs: Southern Baptist Men
Dale Peercy (NVOAD): Lutheran Disaster Response
Jeff Allen: Council of Churches
Jason Yancey (NVOAD): Operation Hope
MDS personnel: Kevin King, Larry Stoner and Rodney Burkholder
Johann Zimmermann, PE

A.2: BRIDGE COMMITTEE PARTNERS

Michelle Breeland: FEMA
Marlyn Lynch: WV-DHSEM State IA Officer
Kevin Sneed: State Flood Plain Manager
County Flood Plain and Building Permits Managers:
- Rick Helton - Lincoln County
- Amanda Starr - Mingo County
- Greg Lay - Boone County
- Ray Perry - Logan County
- Randy Fry - Wayne County
- Annette Taylor - Nicholas County
- Dan Riley - McDowell County

Duval Fire Department: Wendy Beaver

A.3: BRIDGE COMMITTEE ADVISORS

Jimmy Wriston: WVDOT PE, Engineering Advisor
Randy Campbell: United States Army Corp of Engineers (USACE)

B.1: BRIDGE TYPES

Numerous types of structures are available for bridging the water ways. Each location lends itself to different options at different costs and levels of complexity. The range of options includes the following:

1. Culverts: These shall only be used for crossing drainage ditches and small waterways due to their potential to restrict the stream flow.
2. Low water crossings: These shall be avoided due to impassable conditions during inclement weather.
3. Poured-in-place concrete: These will in general be too expensive.
4. Precast concrete bridges: These will in general be too expensive.
5. Prestressed concrete plank: These may be an economic alternative for shorter spans, but are not available in the project region.
6. Steel truss: These may be the only option for larger spans, but their cost is beyond the economic constraints of this project.
7. Laminated timber superstructures: These may be economically and technically suitable in some situations.
8. Steel beam: From field observations of existing bridges that have withstood flooding in the project region, this option most economically meets the design criteria for most sites.

For this project, a bridge with a steel beam superstructure is the most economically and technically viable option. Typical bridge plans for these are given in the appendix.

B.2: ABUTMENT TYPES

Abutments shall be located outside the stream channel, if possible, so that they do not impede the flow of the stream. They shall be protected against erosion and scour. .

Along with deck failures, failure of footings that were not supported on bedrock was observed to be the main cause of past bridge failures. Severe erosion results during flooding events due to unstable soils and siltation of stream beds. Without extensive erosion protection, culverts are due to failure as well. After the experience of constructing several bridges, it has been decided that all footings for the new bridges of this project shall rest on micropiles driven to resistance, which is usually bedrock. This bedrock can usually be encountered within 4 to 15 feet below the stream bed. It was found that 4”diameter steel micropiles could be successfully vibrated through river jack with the weight of a backhoe bucket to the depth of about 4 feet. Below that depth, a driver attachment on a 1500 pound breaker hammer can be used as an economical pile driver.

The micropiles support a concrete footing. To avoid dewatering costs, excavation for the footing is kept at or above the water table. This footing supports one of the following:

A. The footing may be installed at an elevation so that the deck beams rest directly on the pile cap.
B. The footing is installed at the water level and a reinforced masonry abutment wall is built up to the elevation needed for the installation of the deck beams. A reinforced concrete wall may also be used, but may be more expensive due to labor costs and concrete pumping equipment needed to pump concrete across the stream.
C. The option of a concrete pier built on the footing was experimented with (instead of a wall), with either a steel or concrete crossbeam on top to support the deck beams. A steel beam is to be avoided though if it will be in ground contact underneath the bridge, resulting in corrosion. A reinforced concrete beam was found to be too labor and time intensive. Thus this option is not being used anymore.

Grade beam footings built on top of gabion walls may be used where a retaining wall structure is needed and where gabions are needed anyway for erosion control structures.

Large concrete abutments with footings in structurally sound soils well below the scour line or on bedrock and with wing walls to redirect water flow, typical of highway bridges, would be ideal but are beyond the economic constraints of this project.

The “Typical Bridge Plans” in the appendix show option A and B above and a grade beam on a gabion wall.

B.3: DECK TYPES

Cast-in-place concrete, laminated pressure-treated lumber, and locally sourced white oak planking were considered as viable options for the bridge decking. All were economically feasible.

Due to the limited amount of time volunteer groups have for installing the bridges, the forming, pouring, and removing of forms required for a cast-in-place concrete deck is difficult to schedule. As such, this option was deemed impractical.

Pressure-treated decks made of nail-laminated 2x4's (vertically oriented) are easily installed by volunteers. Field observations of this type of bridge deck in the project area have shown that they will last 20 to 30 years. The bridges already constructed using this guideline documents have used this decking option exclusively with great success.

White oak decking is durable and is frequently used for private bridges in this area. Although it has yet to be used on any of the bridges already constructed using this guideline document, it remains a viable option.

B.4: TYPICAL BRIDGE PLANS

1. Cover Page
2. Bridge Elevation
3. Superstructure
4. Decking
5. Abutments
6. Specifications
7. Material Estimate