Temporary Bridges and Expedient Culverts

July 2022

Introduction

Work zone traffic management requires consideration of both normal conditions and potential emergencies. Adverse events such as severe storms and forest fires are becoming increasingly common in much of the United States, and some regions are prone to earthquakes, landslides, or other disasters. When such events occur at the same time a road or bridge is under construction, the safety and mobility impacts of a work zone can be magnified and access to communities can be cut off.

During adverse events, transportation facilities support first-responder access to stricken areas, evacuations, incident response, post-incident recovery, and traffic detours around disaster areas. Sometimes a route that was under construction before the adverse event cannot be reopened easily. In such cases, damaged alternative routes might require rapid repairs, or temporary access roads, all-terrain vehicle (ATV) trails, or pedestrian paths need to be built quickly. These facilities often require the installation of bridges or culverts at a time when it is difficult to bring in materials, equipment, or extra personnel.

This brochure provides an overview of the types of temporary bridges and culverts that can deployed quickly to meet this challenge, including bridges and culverts that can be assembled from locally available materials. As discussed in the *Expedient Roads and Trails Overview* brochure in this series, site-specific decisions require consideration of factors such as the degree of urgency, the type of traffic to be accommodated (e.g., pedestrians, ATVs, emergency vehicles), the distance to be spanned, and the available personnel, equipment, and materials.

Application Example

Eurobodalla is a shire (similar to a United States county) on Australia's Pacific coast. It covers more than 1,300 mi^2, mostly national parks and state forests, and is home to about 38,000 people. In December 2019, wildfires destroyed several timber bridges that provided access to rural communities and forest lands.

To restore access quickly, crews installed expedient roads bypassing the fire-damaged structures; one of these roads is shown in Figure 1. This allowed time for temporary bridges to be built on the old alignments, as shown in Figure 2. Later, with state and national financial assistance, permanent concrete bridges at higher elevations, such as those shown in Figure 3 and Figure 4, were installed to improve resilience to future fires and floods.

Eurobodalla Shire Council

Figure 1. Expedient road bypassing a fire-damaged timber bridge (note old pilings at left).

Eurobodalla Shire Council

Figure 2. Expedient road, with temporary bridge under construction.

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Figure 3. Temporary timber bridge facilitating construction of permanent bridge.

Eurobodalla Shire Council

Figure 4. Permanent bridge nearly completed; temporary bridge at left.

Temporary Fills and Low-Water Crossings

Temporary fills, such as that shown in Figure 5, are often the most expedient way to establish a temporary driving surface over a waterway. In some regions of the United States, they can serve as a stopgap during the dry season, buying time for the installation of bridges and culverts with hydraulic capacities sufficient to handle the stormwater flows expected in the wetter months of the year. Depending on the locally available materials, temporary fills are usually built from soil or gravel. If available, controlled low-strength material (CLSM), also referred to as concrete slurry or other terms, is sometimes an expeditious way to fill a low area.

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Figure 5. Temporary road bypassing a bridge washout.

At a low-water crossing (also called a ford), vehicles slowly drive through shallow water that flows across the road. Temporary low-water crossings, such as the one shown in Figure 6, are often an expeditious way for low-volume traffic to traverse waterways with limited or intermittent water flow. These crossings are usually designed to limit the water depth (during normal weather) to 6 in. or less, which can be traversed by most automobiles. If the water is deeper due to a major storm, a crossing might need to be closed to traffic or its use limited to vehicles designed for deeper wading. A separate brochure in this series describes low-water crossings in more detail.

U.S. Department of Agriculture, Forest Service

Figure 6. Temporary low-water crossing built from Jersey barriers and rock backfill in response to a wildfire.

Temporary Culverts

The use of temporary culverts such as that shown in Figure 7 can sometimes eliminate the need for a temporary bridge. If culvert pipe is not available due to the emergency, box culverts can be built by stacking bags filled with a sand-gravel mix to create abutments and then bridging the abutments with logs or timbers, as shown in Figure 8. This process is described in more detail in the *Bagged-Aggregate Construction for Traffic Management* brochure in this series.

© Massachusetts Department of Environmental Protection

Figure 7. Temporary culvert backfilled with gravel.

Japan International Cooperation Agency / https://www.youtube.com/watch?app=desktop&v=zcG7cdKXKxU

Figure 8. Hand construction of a box culvert using timbers and compacted bags of gravel.

Some temporary culverts require headwalls to stabilize embankments and reduce the risk of a washout. Often the headwalls can be built by stacking sandbags, gravel bags, or precast masonry units, as shown in Figure 9 and Figure 10. For greater durability, portland cement stucco can eventually be applied as a facing material to protect the bags from degradation by sunlight.

Eurobodalla Shire Council

Figure 9. Temporary culvert with sandbag headwalls, used to bypass a fire-damaged bridge.

Eurobodalla Shire Council

Figure 10. Temporary culvert with headwalls of large precast masonry units.

Temporary Pedestrian Bridges

The addition of one or more pedestrian bridges can often enhance emergency access to properties and add flexibility during incident response and recovery. Frequently these bridges are also suitable for light-weight wheeled traffic such as ATVs.

The complexity of a pedestrian bridge depends on the width of the required span. For very short spans (such as a narrow backhoe trench), a wooden pallet can serve as a simple and expedient bridge, as long as it is securely positioned and the walking surface has closely spaced boards or is overlaid with plywood. Suitable approaches should be provided, with ramps or fills for any grade changes.

Another quick way to allow pedestrians and light vehicles to cross a small trench is to stack several lengths of plastic water pipe in the trench, as shown in Figure 11 (Blinn et al. 1998). For walkability, the pipes can be covered with a few inches of soil or wood chips. Segments of plastic pipe tethered together with cables or seatbelt webbing can also be used for temporary walkways across ditches, as shown in Figure 12. As with trenches, these can be covered so that pedestrians do not have to walk directly on the pipes.

Blinn et al. 1998 / U.S. Department of Agriculture

Figure 11. PVC pipe bundle for temporary trench crossing.

Blinn et al. 1998 / U.S. Department of Agriculture

Figure 12. PVC pipe bundle crossing for a ditch or small waterway.

For somewhat longer spans, the most expeditious solution is often to fabricate a temporary pedestrian bridge from lumber, as shown in Figure 13. Larger boards such as the 4x4s shown in Figure 14 have been used to build bridges for ATVs and other light wheeled traffic.

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Figure 13. Temporary pedestrian bridge fabricated from lumber.

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Figure 14. Short-span timber bridge for pedestrians and ATVs.

Several vendors offer prefabricated short-span temporary pedestrian bridges, trench covers, and trench plates designed for pedestrian use. Aluminum wheelchair ramps such as that shown in Figure 15 are also well suited for use as short pedestrian bridges; some designs fold or roll up for portability, as shown in Figure 16. Warehouse dock plates and portable truck loading ramps can also be repurposed as short-span pedestrian bridges.

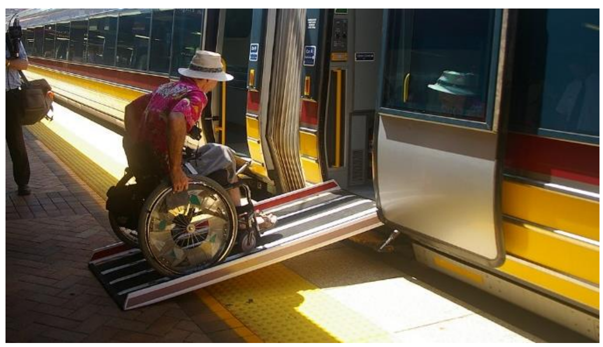

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Figure 15. Prefabricated aluminum wheelchair ramp.

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Figure 16. Roll-up portable wheelchair ramp.

Smooth steel street plates are intended mainly for vehicular use. Their surfaces can be slippery when wet, limiting pedestrian applications. In addition, street plate lifting lugs can be a pedestrian tripping hazard. Since the plates are usually about 1 in. thick, the edges can also be tripping hazards.

Commercial scaffolding systems such as that shown in Figure 17 offer flexibility for pedestrian bridges that require longer spans or 90° bends. Bailey bridges (described below under Temporary Bridges for Motor Vehicles) are frequently used for pedestrian applications requiring spans of 10 to 450 ft.

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Figure 17. Temporary pedestrian bridge assembled from scaffolding components.

Intermodal shipping containers can be repurposed as pedestrian walkways by cutting an opening in the front end, as shown in Figure 18. Surplus intermodal shipping containers are available in many areas and are often abundant near seaports and rail hubs. Nominal lengths are typically 20, 40, 45, 48, and 53 ft.

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Figure 18. Shipping container being repurposed as a temporary pedestrian bridge.

Long-span temporary pedestrian bridges are sometimes constructed on temporary pilings, as shown in Figure 19. Repurposing a barge as a floating pedestrian bridge, as shown in Figure 20, avoids the need for driving pilings into the river channel. Temporary pedestrian pontoon bridges such as that shown in Figure 21 are an expedient solution for long crossings over still or slowly moving water. Several companies offer prefabricated dock floats and floating boat docks that could be adapted for this application. There is also a prefabricated pedestrian pontoon bridge system developed by the Japan Ground Self-Defense Force (JGSDF) known as the JGSDF Light Footbridge, shown in Figure 22.

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Figure 19. Temporary pedestrian bridge for river crossing.

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Figure 20. Floating bridge for a temporary river crossing and its approach road.

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Figure 21. Temporary pedestrian pontoon bridge.

Rikujojieitai Boueisho / Japan Ground Self-Defense Force

Figure 22. JGSDF Light Footbridge, a prefabricated pedestrian pontoon bridge.

Temporary Bridges for Motor Vehicles

Like their pedestrian counterparts, temporary bridges used for motor vehicle traffic include a wide variety of designs. Several of the most prevalent types are described below.

Short-span temporary bridges. Wide steel beams are sometimes used for short spans that are low to the ground, as shown in Figure 23. Pre-stressed concrete panels have also been used in a similar manner.

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Figure 23. Short-span steel beam bridge.

Skidder bridges, also referred to as logging mats, laminated timber bridges, or other terms, are portable short-span bridges that are often built up from large timbers, as shown in Figure 24. In a typical design, each panel is 4 ft wide and 20 ft long and is comprised of 6 in. by 10 in. or 6 in. by 12 in. timbers, which are held together laterally by large screws and threaded rods (Vermont Agency of Natural Resources 2017). In most cases, two or more panels are placed side by side to provide the driving surface.

Vermont Agency of Natural Resources

Figure 24. Timber skidder bridge in a forestry application.

Prefabricated steel skidder bridges, also called bridge mats or panel bridges, are commercially available in various lengths and load capacities. An example is shown in Figure 25. Often these temporary bridges have tapered, ramp-like ends to simplify the transition to the adjoining surface and can be stacked for transport, as shown in Figure 26. The addition of forklift pockets and lifting rings could make skidder bridges even more versatile.

North Carolina Division of Forest Resources

Figure 25. Steel skidder bridge being placed with a grapple.

North Carolina Division of Forest Resources

Figure 26. Steel skidder bridges can be stacked for delivery to the sites where they are needed.

The log stringer bridge, an example of which is shown in Figure 27, is a traditional design that uses two or more logs as longitudinal beams. In rapid response situations in wooded areas, they can potentially be built with materials available at the site. To improve structural performance, the logs can be placed side by side and connected with cables (Blinn et al. 1998). Often a deck of small logs or wood planks running laterally is nailed or screwed to the log beams. Diagonal braces can be added for stability, and a layer of soil, gravel, or wood chips can be added to smooth the driving surface. If such a bridge is constructed from sawn timbers, it is usually called a sawn timber stringer bridge or timber beam bridge.

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Figure 27. Log stringer bridge.

Figure 28 shows the construction of a steel pipe bridge, which is conceptually similar to a log stringer bridge (personal communication with Jerry Downey, President, Savona Equipment, Ltd, 2021). The design uses large-diameter pipes welded side by side as beams and a gravel running surface installed over the pipes. Endplates tie the structure laterally and keep gravel out of the pipes. Longitudinal side plates or smaller pipes can be tack-welded on each side to retain the gravel. For lateral stability, cables or upper and lower tie bars connecting the pipes can be added every few feet, along with diagonal braces. Weep holes at the pipe bottoms limit moisture accumulation.

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Figure 28. Steel pipe bridge under construction.

Bailey bridge. Perhaps the most famous type of temporary bridge is the Bailey bridge, shown in Figure 29 to Figure 33. Developed for the British military in the early years of World War II, the design was soon adopted by other Allied forces and played a crucial role in numerous battles with its portability, rapid installation and removal, and ability to span up to 450 ft. The design has subsequently been used for many temporary civilian roadway and pedestrian bridges, such as the highway bridge shown in Figure 29. It is also used for semipermanent and permanent installations, especially in hard-to-reach areas. The patents for the Bailey bridge expired in the 1970s, making it a nonproprietary design that is produced by numerous companies worldwide.

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Figure 29. Bailey bridge used as a temporary highway bridge.

As shown in Figure 30, the Bailey bridge is a type of through truss comprised of interlocking 10 ft modules. Each component is small enough to be carried in most trucks and light enough to be carried by a few people. For example, the side panels are 5 ft high and 10 ft long and weigh less than 600 lb. This allows them to be lifted manually by groups of about 6 people without a crane. Lateral beams called transoms connect the trusses and support 10 ft steel stringers. Wood deck boards or other decking materials are placed across the stringers. Rollers in the supports allow the bridge to be launched incrementally from one side of a waterway or ravine, an essential feature for a military bridge. This design has also been adapted for use as a pontoon bridge, suspension bridge, and drawbridge (Russell and Thrall 2013).

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Figure 30. Bailey bridge display, illustrating the side panels, transoms, stringers, decking, and roller footings, with a launching nose visible at the far left.

To support heavier loads or longer spans, the side trusses can be doubled vertically and doubled or tripled horizontally, as shown in Figure 31 and Figure 32. Alternatively, a pedestrian walkway can be attached on the outer side of the truss. At some sites, support towers have been assembled from side panel sections rotated to vertical orientation, as shown in Figure 33.

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Figure 31. Bailey bridge with horizontally tripled and vertically doubled panels.

© Jaggery (Geograph) / West across Glangrwyney Bridge, Glangrwyney / CC BY-SA 2.0

Figure 32. Bailey bridge with horizontally and vertically doubled side panels; semipermanent application.

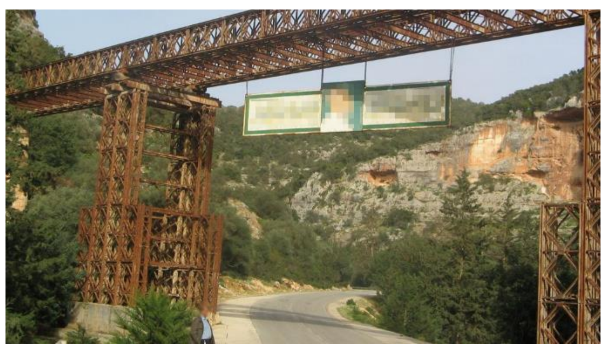

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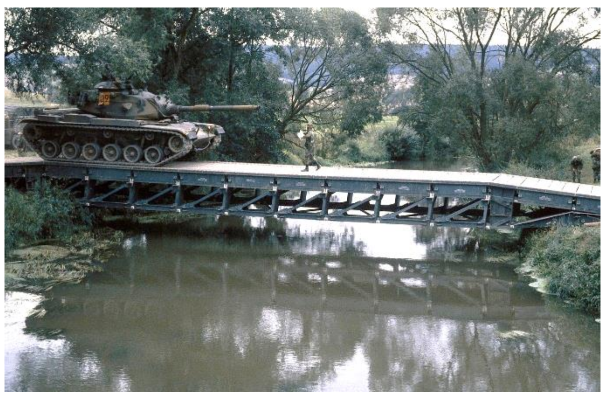
Figure 33. Bailey system side panels turned vertically and used as support towers.

Other modular panel bridges. Various rapid-assembly panel bridges are in commercial production (Structure Design and Rehabilitation, Inc. 2005). Many are derived from the Bailey bridge design. For example, the Mabey-Johnson Logistic Support Bridge (often simply called a Mabey bridge) is used in both civilian and military applications. An example of a Mabey bridge under construction is shown in Figure 34. It looks similar to a Bailey bridge but has larger panels that are designed to support heavier loads. Transportation agencies in New York State, among other jurisdictions, have used them extensively in temporary applications (Mabey Bridge & Shore, Inc. 2008).

U.S. Army / Flickr

Figure 34. Assembling a Mabey bridge.

There are also several types of portable modular girder bridges. One example is the medium girder bridge (MGB), shown in Figure 35. The MGB is a military design that uses a high-strength zinc-magnesium-aluminum alloy to limit the weight of all components to 600 lb or less. The bridge is designed for rapid hand assembly. Like the Bailey bridge, it is supported by rollers that allow it to be launched from one side of a waterway or ravine.



Michael Haggerty / U.S. Navy

Figure 35. MGB.

Other Prefabricated Steel Truss and Girder Bridges. Introduced in 1935, the Callender-Hamilton bridge, shown in Figure 36, is a medium-span truss. It is built up from standardized truss bars that can be bolted to gusset plates by unskilled laborers, with no need for welding. The design has been used in both temporary and permanent applications. Due to the time required for bolt tightening, assembly is slower than the Bailey-type designs, which are held together by pins.

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Figure 36. Callender-Hamilton bridge (permanent application).

Prefabricated modular steel beam bridges such as that shown in Figure 37 are available from various manufacturers. Some models incorporate prefabricated decks and side rails, as shown in Figure 38. Portable steel or aluminum tub girder designs could also be considered but do not appear to be in commercial production.

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Figure 37. Prefabricated temporary bridge (viaduct application).

Vermont Agency of Natural Resources

Figure 38. Prefabricated temporary girder bridge.

Adaptive Reuse. Rapid response situations require ingenuity. For example, some practitioners have utilized salvaged steel beams to build temporary bridges, as shown in Figure 39. Railroad flat cars, gondola cars, and boxcars have also been repurposed as temporary bridges, as have flatbed semi-trailer frames (Blinn et al. 1998). A bridge constructed from a railroad flatcar is shown in Figure 40.

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Figure 39. Temporary bridge under construction featuring salvaged steel beams.

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Figure 40. Railroad flatcar converted to a temporary bridge.

Flat racks (officially called "flat folding wall end containers") are a type of intermodal shipping container with fold-down ends or folding corner posts and are produced in 20 ft and 40 ft lengths. The ends or end-posts fold inward, allowing them to be stacked when not in use. With their substantial load capacity, they are useful as temporary girder bridges, as shown in Figure 41 (Parker 2019).

Chuck Henry Sales, Inc., used with permission

Figure 41. Flat racks (ISO folding end wall containers) have been used as bridges.

Scissor bridges. Various types of scissor bridges have been designed for very rapid deployment in battlefield applications (Russell and Thrall 2013). Although these designs usually require a specialized launch vehicle such as that shown in Figure 42, the underlying principle of a hinged portable bridge is transferrable to civilian rapid response applications, for example, the roll-up wheelchair ramp shown in Figure 16.

Kevin Quihuis, Jr. / U.S. Marine Corps

Figure 42. M60A1 armored vehicle landing bridge.

Researchers in Japan developed a multi-section scissor bridge, shown in Figure 43, for rapid response to earthquakes and other disasters (Chikahiro et al. 2017). The bridge resembles a scissor lift turned on its side, with a horizontal pantograph that supports telescoping deck segments. The pantograph is launched by hydraulic actuators mounted on a mobile platform.

Hiroshima University / https://www.youtube.com/watch?v=9RL9IB90M20

Figure 43. Scissor-type mobile bridge.

Floating bridges. Various types of floating bridges have long been used to cross calm or slow-moving water. For instance, barges are sometimes repurposed as temporary bridges; Figure 20 shows a barge that has been converted into a floating bridge serving pedestrians and light wheeled traffic.

Pontoon bridges can be used to cross wide expanses of calm or slowly moving water. In their simplest form, they are simply a set of boats or floats anchored side by side and connected by planks or gangways. This type of bridge has probably been used for more than 2,000 years and features prominently in the military histories of Ancient China, Ancient Greece, and Ancient Persia, among other civilizations. Major technical advances were made during the American Civil War (1861 to 1865), as demonstrated in Figure 44, and again in the World War II era (1939 to 1945). The design remains in military use, as shown in Figure 45.

Matthew Brady / U.S. National Archives

Figure 44. Civil War pontoon bridge across the James River in Virginia.

C.W. Griffin / U.S. Marine Corps

Figure 45. Type M4T6 prefabricated pontoon bridge.

The weight that can be supported by a pontoon bridge is mainly a function of the size and spacing of the pontoons. The military Lightweight Modular Causeway System, shown in Figure 46, combines inflatable pontoons with prefabricated deck panels that are usually installed with an all-terrain forklift. Pontoon bridges are also used in civilian applications. For example, Figure 47 illustrates a pontoon system that was used to detour highway traffic around a rockslide.

U.S. Army Corps of Engineers

Figure 46. The Lightweight Modular Causeway System is designed for heavy loads.

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Figure 47. Pontoon bridge bypassing a rockslide.

In the 1980s, a rapidly deployable, modular, truck-transportable pontoon bridge was developed in the former Soviet Union. The United States copied and upgraded the design as the Improved Float Bridge (Ribbon), a triple-hinged pontoon with an integral deck (U.S. Army 1988). The design is shown in Figure 48 and Figure 49. Individual bays (segments) are offloaded from the delivery vehicle in folded position and unfold in the water. Motorized rafts are then used to position the bays for connection and anchorage.

Robert Farrell / U.S. Army (released)

Figure 48. Improved Float Bridge (Ribbon), a prefabricated pontoon bridge designed for military applications.

Sgt. Francis Horton / U.S. Army (released)

Figure 49. Deployment of an Improved Float Bridge (Ribbon).

Abutments for Temporary Bridges

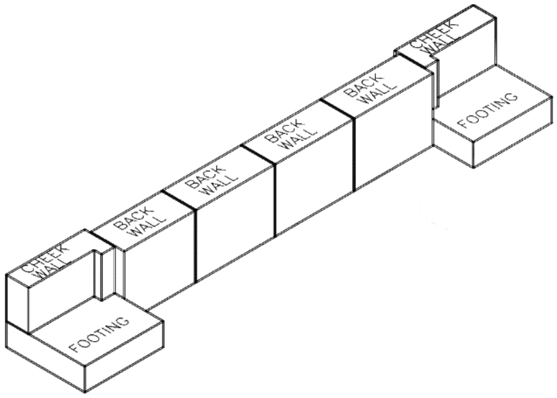
When the use of a temporary bridge is planned in advance, conventional bridge abutments such as steel or timber pilings, caissons, sheet pilings, concrete footings, or geotextile-reinforced soil (GRS) can be designed and installed. In some cases, a set of existing bridge abutments can be reused.

In rapid response situations, the time available for the design and construction of temporary bridge abutments or footings is limited. As illustrated in Figure 30, many of the military rapid bridging systems incorporate prefabricated spread footings that can be used on unimproved soil. Other methods that have been used to support expedient bridges include the following:

- Sill abutments
    - Timber sills, shown in Figure 50
    - Prefabricated concrete abutments, illustrated in Figure 51
    - Gabions (wire baskets filled with stones), shown in Figure 52
- Spread footings
    - Wooden pads or mats
    - Assemblies of heavy timbers or railroad ties
    - Concrete slabs on grade
    - Extension of the bridge superstructure over a large gravel pad or area of native soil to spread the abutment load
- Helical anchors (also called screw piles), shown in Figure 53

U.S. Department of Agriculture, Forest Service

Figure 50. Timber sill abutment.



Mabey Bridge & Shore, Inc. 2008

Figure 51. Precast temporary footing blocks used on county projects in New York State.

Chris Bielecki / U.S. Department of Agriculture, Forest Service

Figure 52. Preparation of gabion for use as a temporary bridge footing after a forest fire.

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Figure 53. Helical anchors (screw piles).

Removal of Temporary Fills, Bridges, and Culverts

Expedient fills, bridges, and culverts are often implemented using emergency authority that bypasses the normal requirements for public consultation and environmental review. As a result, it is important to ensure that their appearance, function, and management do not convey a false sense of permanence.

When the facility is no longer needed, it should be promptly removed, and the site should be restored to substantially its original condition. To assist with this process, the predeployment conditions should be documented with photographs or videos. Good documentation and attention to detail during removal and restoration can help avoid disputes with landowners and resource agencies.

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