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Temporary Bridging to Avoid or Minimize Impacts to Waters and Wetlands During Highway Construction

DETAILS

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TEMPORARY BRIDGING TO AVOID OR MINIMIZE IMPACTS TO WATERS AND WETLANDS DURING HIGHWAY CONSTRUCTION

This digest presents the results of NCHRP Project 25-30, "Temporary Bridging to Avoid or Minimize Impacts to Waters and Wetlands During Highway Construction." Temporary bridging includes prefabricated, portable, and reusable bridging as well as built-in-place structures. The digest is based on successful practices used by U.S. federal and state agencies and Canadian provincial agencies. The research was conducted by a team led by Charles Bruton of Mulkey Engineers & Consultants.

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SUMMARY

Road construction or maintenance work near waterways has the potential to create unintended environmental impacts. Typical practice has involved the use of culverts or riprap in or across streams to create detours or provide access to the site for equipment and personnel. However, this approach discharges fill and, as a result, requires environmental permitting. The use of temporary bridging is an alternative that can save time and money while minimizing or avoiding impacts on the environment. In this study, the research team reviewed relevant regulations, types of temporary bridging, and factors influencing the use of temporary bridging. A decision matrix was then developed, providing a straightforward set of criteria to assist in selecting the most appropriate alternative. This digest will be useful for any transportation professionals involved in the design, construction, or maintenance of road facilities in proximity to waters and wetlands.

INTRODUCTION

Road and highway construction work, especially bridge construction, may have impacts on the value and function of waters and wetlands. Construction projects over waterways frequently involve traffic detours or temporary construction access consisting of riprap and culverts built into or completely across a stream. Because these methods discharge fill, they are subject to environmental permitting. Waters and wetlands permitting is a process that often takes significant time, limits design and construction options, and results in costly mitigation efforts.

An alternative construction practice is to use temporary bridging—such as floating or prefabricated bridging—or built-in-place structures to avoid or minimize wetlands and waters impacts. These steps can minimize the impact of permits on the timing and costs of a transportation project. Using current methods, state departments of transportation (DOTs) expend significant resources on environmental permitting and compensatory mitigation. If the use of temporary bridging is practicable in avoiding or minimizing impacts, there is an opportunity to protect the environment and to reduce costs.

NCHRP Project 25-30, "Temporary Bridging to Avoid or Minimize Impacts to Waters and Wetlands During Highway Construction," provides an overview of state practices in the use of temporary bridging. The study includes the results of a web-

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based survey distributed to 107 potential respondents, including AASHTO-affiliated DOT representatives from each of the 50 states, the District of Columbia, and Puerto Rico; U.S. DOT members and associate members from bridge, port, and toll organizations; the U.S. Department of Agriculture (USDA); Alberta; British Columbia; and Saskatchewan. A total of 34 survey responses were received. Follow-up phone surveys were conducted with the states of Texas, Oregon, Washington, Florida, Virginia, Massachusetts, Michigan, and North Carolina to provide further context for the analysis and evaluation of the survey responses.

This digest incorporates key information culled from the survey results to present a straightforward set of criteria to assist decisionmaking with regard to the selection and use of temporary bridging for traffic detours or construction access, with the objective of avoiding or minimizing the environmental impacts of roadway construction over or adjacent to rivers, wetlands, and other waters of the United States. The digest offers an overview of the main types of temporary bridging, factors that influence their selection, a decision matrix for determining the applicability of temporary bridging types to various conditions, state examples of lessons learned, and recommendations for the future. A list of resources and contacts for more information is provided for additional reference at the end of the digest.

Respondents to the survey reported that their use of temporary structures on transportation construction projects is determined by a variety of traffic, safety, and construction access priorities; environmental determinants; and monetary constraints. Feasibility and cost were cited most often as the primary considerations. Although there may be clear reasons to provide for both construction access and detoured traffic flow on temporary structures, there can be prohibitive costs that will override those priorities. In those cases, project sponsors indicated they may accept less than ideal construction access and disruptions to traffic. Also, constructing a temporary structure on a project site may simply not be possible due to limited available space, unsuitable substrate, spans beyond what are possible with available materials, or other physical limitations.

Project sponsors are bound by permit conditions or other regulatory restrictions that seek to minimize environmental disturbance, particularly impacts to wetlands. Project permits often specify that no permanent fills are allowed in wetlands beyond those needed for the actual constructed facility. That means that any work platforms, traffic detours, staging areas, or other elements of the construction project must be temporary installations and must avoid permanent loss of wetland acreage. Both wetland quality and quantity are used to determine the level of potential impact, although compensation for lost acreage is still predominantly the case. Bridging and other structures that are removed at the conclusion of the construction activity are options cited that allow the construction to proceed while meeting the regulatory requirements for wetland protection.

Many states utilize acreage and wetland-type thresholds when making decisions about the use of temporary structures. Small and particularly solitary wetland areas are more easily avoided than larger interconnected complexes. In the case of small wetlands, states generally choose to avoid these sites with traffic detours or work access areas. Wetland type and quality (as related to resource value to local ecosystems) were also cited as factors considered when decisions are made to use temporary structures. Depending on the region of the country, wetland types—forested bottomlands, bogs and fens, vernal pool complexes, and others—can trigger the need for either total avoidance or the use of elevated temporary structures during construction. Coordination with regulatory and resource agencies typically results in what would be allowed and what must be included under a granted permit.

The survey indicated that regardless of whether temporary structures are used, mitigation response is always a part of projects involving wetlands. The overall sequencing approach is used: avoidance as the first consideration, then minimization, and finally compensation when unavoidable impacts remain. In the cases where temporary bridges or causeways were used, restoration of the site in some form is always ensured when the structure is removed at the completion of project construction. In some cases, the affected wetlands regenerate on their own if impacts caused by the temporary structures were minor. Examples of this may be short-term shading, small footprint areas for piles or other supports, and minor fills using a geotextile base. In the cases where temporary structures caused more severe impacts, the states reported that complete restoration would be required, including vegetative plantings, regrading to return substrate elevations to pre-project levels, and other measures.

Mitigation and restoration plans also typically included short- to long-term management and record-keeping and follow-up to correct deficiencies, if they arise. Although factors such as wildlife presence are also used, determining the success of mitigation and restoration is generally based on the three-parameter approach for the existence of wetlands (i.e., hydrology, vegetation, and soils).

HOW TO USE THIS DIGEST

The purpose of this digest is to guide decisionmaking with regard to the use of temporary bridging in a way that helps achieve engineering objectives, environmental objectives, and cost concerns. This digest does not attempt to provide a "formula" for decisionmaking or a "scorecard" of temporary structure attributes. Rather, it offers an overview of the general criteria that should be considered when evaluating various temporary bridging options for use in waters and wetlands during highway construction. Although the project team was directed to develop this manual with a global approach, users of this digest must consider the information presented herein within the context of their state and local laws and regulations, as well as applicable federal laws and regulations. In addition, licensed professional engineers and environmental professionals with appropriate competencies should be consulted to determine applicability of this information to a specific project.

For the purpose of this digest, *temporary bridging of waters and wetlands* is defined as the use of methods and materials that lessen the impact to waters and wetlands to facilitate the construction of a permanent facility.

PROTECTION REQUIREMENTS FOR WATERS AND WETLANDS RELATING TO THE USE OF TEMPORARY BRIDGING

Federal Laws and Regulations

Although wetlands are typically discussed as separate transition areas between uplands and other waters, this document uses the terms *waters and wetlands* in combination for areas subject to various federal laws, Executive Orders, and regulatory programs that specifically control activities in "waters of the United States." The use of temporary bridging, work platforms, and other structures during construction of transportation improvement projects may avoid and minimize impacts to waters and wetlands and provide important measures in meeting the objectives of laws and regulations protecting aquatic habitats.

The recognized values of the nation's waters and wetlands have led to a variety of federal protection measures, most notably the policies and regulatory programs operating under the Clean Water Act of 1972 (CWA) and Section 10 of the Rivers and Harbors Act of 1899 (RHA). Federal authorities beyond the CWA and the RHA include Executive Order 11990, (42 FR 26961). Under this Executive Order, federal agencies and their partners receiving federal assistance must strive to avoid the destruction or modification of wetlands and the support of new construction in wetlands wherever reasonably possible. The order further requires that mitigation be included as a part of any action where impacts to wetlands cannot be reasonably avoided. Other federal programs designed to conserve and protect wetlands include the North American Waterfowl Management Plan, the Emergency Wetlands Protection Resources Act of 1986, and the Wetlands Reserve Program.

Regulatory programs under the CWA and RHA are the principal federal mechanisms providing protection to water and wetland resources in the United States. The CWA establishes regulatory and enforcement authorities administered by the Environmental Protection Agency (EPA) and/or the U.S. Army Corps of Engineers (USACE) that operate in concert with the state and tribal water quality protection programs. The authorities under Section 404 of the Act seek to control the discharge of dredged or fill materials into U.S. waters and wetlands. Indirectly, Section 404 has been used to control and mitigate the historic loss of wetlands in the United States. Section 10 of the RHA controls the installation of fills and other structures having the potential to obstruct navigation and waterborne commerce in the nation's waters. USACE commonly authorizes activities subject to Section 10 in combination with Section 404 permitting.

Section 404 prohibits discharges of dredged and fill material into waters and wetlands, unless the discharge is authorized by a permit issued under the section. The responsibility for implementing the Section 404 program is divided among several agencies. At the federal level, USACE is responsible for reviewing permit applications and authorizing discharges when appropriate. EPA is responsible for establishing the guidelines that USACE must follow when making permitting decisions. In addition, EPA has authority under some circumstances to veto permits issued by USACE. State agencies also play an important role. Before USACE can issue a permit, the project applicant must obtain certification under Section 401 of the CWA from the water quality agency in the state where the proposed activity is located. Section 401 certification confirms that the proposed discharge meets applicable state water quality standards.

The CWA also allows USACE to delegate its Section 404 permitting authority to a state agency having an approved assumption program. The CWA provides that the states may assume administration of Section 404 in certain waters within the state. Thus far only two states, Michigan and New Jersey, have assumed administration of the federal permit program. Michigan implements separate EPA regulations, while New Jersey administers its own Freshwater Wetlands Protection Act Program throughout most of the state in place of the federal Section 404 Program.

The EPA has issued regulations under Section 404 to guide the permitting process executed by USACE. The regulations are commonly known as the "Section 404(b)(1) Guidelines." The guidelines establish criteria that must be met before USACE can issue a permit. The criteria prohibit USACE from authorizing a proposed action that will discharge dredged or fill materials if there is a practicable alternative that causes less harm to the aquatic ecosystem. This requirement is commonly referred to as the "Least Environmentally Damaging Practicable Alternative" or "LEDPA" requirement. USACE may authorize only the LEDPA requirement unless that alternative results in other significant adverse environmental consequences. In situations where there are significant impacts beyond those anticipated to wetlands and other applicable waters, USACE may authorize an alternative that is not the LEDPA, but results in the least overall environmental damage.

USACE regulations implementing the Section 404 permitting program establish the process for filing permit applications and describe the information that needs to be included in those applications. The regulations allow for both permits for individual actions and general permits that cover actions by category or type. General permits can be used for categories of projects that have similar and, more often than not, minor impacts on wetlands. General permits include both regional programmatic permits and nationwide permits (NWP). USACE division offices issue regional permits for activities in the geographic area covered by the division. These general permits are for activities involving specific types and amounts of fill or dredged material. USACE headquarters issues nationwide permits that can be used in all areas of the country subject to individual state approval and other specific restrictions and conditions. Applicants are free to proceed with the activities that fit the conditions of regional and nationwide authorizations unless the permit being used requires prior notification of USACE. These situations are referred to as preconstruction notices (PCNs). Typically, on temporary construction actions such as crossings, the PCN must include a restoration plan of reasonable measures to avoid and minimize permanent adverse affects to wetlands and other aquatic resources. The plans are implemented with removal of the temporary structure following the construction of the permanent facility.

A number of general permits may allow the use of temporary fills and other structures to complete the work authorized. An example is work conducted under NWP 3: Maintenance. This NWP authorizes temporary structures, fills, and work necessary to conduct the maintenance activity in wetlands and other waters. Any temporary fills must be constructed with materials that will not be eroded by ordinary high flows. Any time temporary structures and fills are used in association with a Section 404 general authorization, the affected location must be restored to preconstruction elevations and vegetative conditions.

District offices of the USACE can also authorize work under Section 404 with what are called "letters of permission." Letters of permission may apply in situations where the USACE District Engineer determines that a proposed action would not have significant individual or cumulative impact on wetlands and would not generate significant opposition. The District Engineer can issue a letter of permission only in cases where USACE has previously approved similar activities under its letter of permission procedures. Using the authorization granted under a letter of permission may be an appropriate and expedient way to comply with Section 404 for localized and noncontroversial actions, particularly those involving relatively non-disruptive temporary structures.

The implementation of the Section 404 regulations has had a great impact on the state departments of transportation and the transportation industry as a whole. Transportation improvement projects are now routinely planned and designed to avoid and minimize wetland losses through a variety of engineering and environmental measures. Permits needed under the Section 404 program cannot be granted without such attention to impact mitigation. These avoidance and mitigation steps by highway project developers are environmentally appropriate, but they also may save the transportation department significant time and money by speeding the permitting process and minimizing mitigation costs. Early and continued coordination with resource agencies and USACE on impact and mitigation issues is critical to successfully obtaining permit authorizations. The use of temporary structures during project construction is one tool available to transportation agencies for meeting wetland protection objectives under the permit program. In some instances, temporary bridging may result in qualifying for less restrictive permits, a circumstance that suits both the DOT and USACE.

Temporary bridges can also be subject to Section 9 of the RHA and the General Bridge Act of 1946. These statutes function to preserve the public right of navigation and to prevent interference with interstate and foreign commerce. The U.S. Coast Guard must approve the location and plans of bridges and causeways across waters that are tidal and used by larger commercial vessels (not solely by recreational boating, fishing, and other small vessels) or, if non-tidal, that are used as a means to transport interstate or foreign commerce of the United States. Approval of plans is through a Section 9 bridge permit. Project sponsors should consult the Coast Guard guidance on bridge permits. The guidance discusses the need for permits to ensure navigational and environmental objectives are met and includes a section on temporary structures. If a planned temporary structure requires a bridge permit prior to construction because of navigational issues, the same engineering and environmental information and procedures required of a permanent bridge proposal will apply.

Development activities in waters and wetlands may be subject to federal guidelines and directives under the National Flood Insurance Program (NFIP). Project sponsors should consult with local, state, and federal water resources and floodplain management agencies to determine whether any proposed temporary structure will be consistent with existing watershed and floodplain management programs in the area of the action. As part of this consultation, project sponsors may need to conduct location studies that include evaluation and discussion of alternatives to any significant encroachments into floodplain limits designated under the NFIP. These studies may include flooding risks associated with implementation of the temporary structure, impacts on natural and beneficial floodplain values, measures to minimize floodplain impacts, and measures to restore and preserve the natural and physical features of the area temporarily impacted by the action.

Project sponsors must recognize that the potential for impacts to cultural resources may also be a factor in any decision to use temporary bridging on their transportation improvement projects. Legislative and executive mandates on the need to examine, protect, and enhance historic, archeological, and Native American cultural resources have been expressed in various federal laws, rules, and guidance. For example, the National Historic Preservation Act of 1966 and the Advisory Council on Historic Preservation regulations (36 CFR, Part 800) ensure that effects on historic and archaeological resources are considered in the development of federal and federally assisted actions. Many states also have specific requirements to minimize impacts on cultural resources identified as important.

State and Local Laws and Regulations

There are scores of state and local wetland protection programs and regulations that, depending on location, must also be met when planning and building transportation projects. Although the sections on state case study examples and results of the nationwide survey conducted with this study provide some insight into these localized requirements, this document does not provide a comprehensive list of all state and local requirements. There are simply too many to cover in the available space, and many may apply only under limited situations. Nevertheless, such requirements can be important considerations during the development of transportation improvements and need to be followed according to state and local procedures. The offices of state and local environmental agencies are recommended sources for information on such programs. The websites of these agencies are also suggested for wetland protection program requirements, information, and direction.

Wetland Mitigation

Avoidance, minimization, and compensation of impacts are key requirements of federal, state, and local authorities that protect wetland resources. Temporary bridges and other similar structures when used on projects having the potential to impact wetland resources can contribute to the overall avoidance and minimization objectives. Temporary bridges and work platforms preclude the use of earthen fills and keep construction equipment away from wetlands and other sensitive aquatic sites.

As mentioned above, Executive Order 11990, Section 404(b)(1) guidelines, and Section 404 permitting regulations are the primary directives that require wetland mitigation from the federal perspective. There are various other supporting policies and rules at all levels that project sponsors must also recognize and implement. USACE and EPA have issued national guidance on wetland mitigation pursuant to CWA requirements.

The Federal Highway Administration (FHWA) implements the regulatory and national policy requirements related to wetlands contained in transportation legislation, as well as the CWA. The Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and previous national transportation legislation recognized the wetlands protection objectives of the CWA and included important new and specific authorities for participation in costs of wetlands mitigation with federal transportation funds. The SAFETEA-LU includes compensatory mitigation activities, such as natural habitat and wetland banks; contributions to statewide and regional efforts to conserve, restore, enhance, and create natural habitats and wetlands; and the development of statewide and regional natural habitat and wetlands conservation and mitigation plans as eligible projects. These activities are eligible for federal-aid highway funds and may be concurrent with or in advance of project construction.

TYPES OF TEMPORARY BRIDGING

This section presents the six most commonly used types of temporary bridging, with brief descriptions of their design, installation, and maintenance/removal; potential environmental impacts; and benefits and limitations of use. For each temporary bridging type, a licensed professional engineer and environmental professional with appropriate competencies should be consulted to determine applicability of this information to specific projects and site conditions.

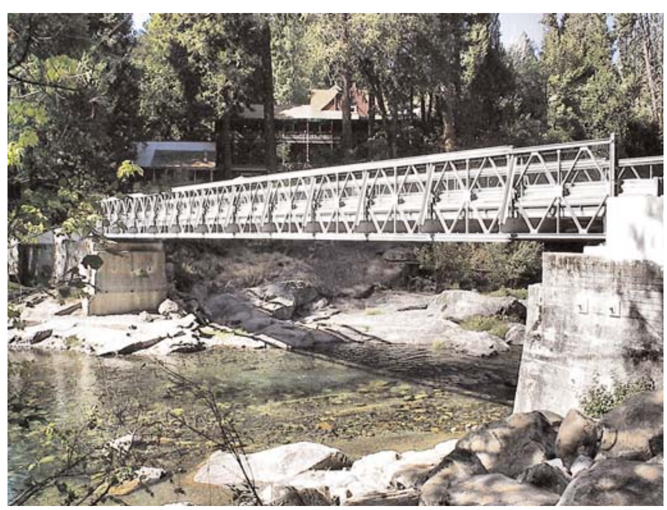
Panel Bridges

Several "brands" of panel bridges are available in the marketplace. However, the original is the Bailey bridge, which was designed for use by military engineering units to bridge up to 60-m (200-ft) gaps. It requires no special tools or heavy equipment for construction, the bridge elements are small enough to be carried in trucks, and the bridge is strong enough to carry tanks, so panel bridges may be placed to handle virtually any traffic or construction equipment load. Advances on the original design have been made by other manufactures. See Figure 1.

Design

The basic bridge consists of three main parts. The "floor" of the bridge consists of a number of *transoms* that run across the bridge, with *stringers* running between them on the bottom, forming a square. The bridge's strength is provided by the *panels* on the sides, which are cross-braced rectangles. These are placed standing upright above the stringers, and clamps run from the stringers to the panels to hold them together. *Ribands* are placed on top of the completed structural frame, and wood planking is placed on top of the ribands to provide a roadbed. As an alternative to wood planking, steel plates or grating can be used. Where a wooden or steel-plated roadbed will be used to carry public traffic, it will most likely be desirable to place an asphalt wearing surface on a geotextile engineering fabric. The fabric will assist in preventing reflection cracking of the asphalt surface.

For added strength, up to three panels (and transoms) can be bolted together on either side of the bridge. Another solution is to stack the panels vertically. With three panels across and two high, the



Mabey Bridge & Shore

Figure 1 Mabey panel bridge structure in El Dorado National Forest, Placerville, CA.

Bailey bridge can support tanks over a 60-m (200-ft) span installation.

The panel bridges can be "launched" from one side of a gap. The foremost portion of the bridge is angled up with wedges into a *launching nose,* and most of the bridge is left without the roadbed and ribands. The bridge is then placed on rollers and simply pushed across the gap, using manpower or a truck or track vehicle, at which point the rollers are removed (with the help of jacks) and the ribands and roadbed installed, along with any additional panels and transoms that might be needed.

Applicability to Spanning Wetlands

While the basic Bailey panel bridge sets are suitable for spanning distances up to 60 m (200 ft), longer lengths can be reached by the addition of interior bents. The Acrow bridge, a variation of the Bailey bridge, is capable of spanning 137 m (450 ft).

Potential Environmental Impacts

Because these panel bridges can be launched from one side of the gap or high ground, environmental impacts resulting from construction operations should be minimal depending on the width of the riparian wetlands adjacent to the crossing. For long-span requirements exceeding single span lengths, intermediate bents can be constructed. These situations may require the contractor to place equipment in the wetland, which creates an adverse, short-term impact. Notwithstanding the construction, other negative impacts to wetland vegetation may be caused by shading, which decreases plant growth rates and vigor thereby reducing primary productivity. In long-span situations, since the placement of temporary piles will destroy some wetland vegetation and could result in the alteration of the land surface, filling of holes and restoration of vegetation may be necessary upon pile removal. The height of the temporary structure and its orientation relative to the path of the sun will determine the degree of impacts due to shading. Impacts to fish and wildlife are usually minimal when designated moratoria (if any) are observed.

Benefits of Use

The primary benefit of this type of structure is the fact that it can be launched from one side of the gap or high ground, thus lessening impacts to the wetland. Another major benefit is that these panel structures can be leased or rented from vendors; therefore, the contractor does not have a capital investment. Accordingly, the contractor may be able to pass along any financial savings to the project sponsor.

Limitations of Use

Availability of the components to construct these panel structures may limit their use. Also, the contractor must take into consideration the height of the panel and its effect on the ability of equipment, such as cranes, to operate properly.

Contractor Designed

One of the most widely used methods of spanning wetlands to facilitate construction of a permanent structure is to place timber mats on steel girders supported by temporary pile bents. This method has minimal impact on the wetland; the construction, dependent upon span length, can be accomplished by "top-down" methods.

"Top-down" methods allow the contractor to advance a structure by working from the previously completed portion of the same structure. This is normally accomplished by limiting span lengths so that erection equipment, such as cranes, can place the next span components from the previously completed span (see Figure 2).

Component Design, Construction, and Maintenance

Piles. Steel pipe piles, steel H-piles, or other materials must be driven to sufficient bearing to support both the dead load of the trestle and the live load. In determining the live load, not only the equipment

Metro King County DOT

Figure 2 Temporary contractor designed trestle bridge used for construction of Tolt bridge, King County, WA.

but also the materials the equipment will be handling must be taken into consideration.

Girders and bents. The contractor may choose to use standard steel shapes—for example, I-beams—for girders and bents. Span lengths between 7.6 and 18.3 m (25 and 60 ft) allow for top-down construction. Thus, the contractor can advance the trestle one span at a time from the previously completed span.

Roadbed. Various materials may be used for the roadbed. Typically, timber mats consisting of five or six 12-in. × 12-in. (30.5-cm × 30.5-cm) timbers lashed together to form a single unit placed across the girders will make up the roadbed. Alternately, the contractor may choose to use other materials, such as steel plates or steel grating.

Maintenance. Throughout the life of the project, protection of the wetland from falling debris is a primary consideration. For example, in cases where a contractor uses timber mats for the roadbed, constant care may be required to keep materials, earth, and other debris from falling through the cracks onto the wetlands.

Removal. Removal of this type of construction is basically deconstruction. In other words, spans are removed in reverse order to their construction. By following such a procedure, the contractor is able to ensure the least impact on the wetlands.

Restoration. The effect of long-term shading of the wetlands may have a negative impact on native vegetation. Accordingly, environmental permit requirements may necessitate planting complementary vegetation in the areas impacted by the trestle.

Potential Environmental Impacts

Since span lengths are generally short—typically 25 to 60 ft (7.6 to 18.3 m)—construction of the temporary structure can be accomplished by "top-down" methods, thus minimizing the impact to the wetland. Primary impacts will result from shading; however, the degree of shading can be affected by the height of the structure above the surface and the orientation of the structure with respect to the path of the sun. Shading decreases plant growth rates and vigor, thereby reducing primary productivity. Since the placement of temporary piles will destroy some wetland vegetation and could result in the alteration of the land surface, filling of holes and restoration of vegetation may be necessary upon pile removal. There may also be limited disturbance to the wetland due to pile placement. Impacts to fish and wildlife are usually minimal when designated moratoria (if any) are observed.

Benefits of Use

The biggest benefit is derived from the fact that the contractor is responsible for the design as well as the construction. The contractor is able to customize the design to match the materials that are available and the wetland site conditions—resulting in a lower cost to the project and potentially more expeditious construction since the contractor is not dependent upon vendors or other suppliers. The contractor also has the ability to minimize environmental impacts.

Limitations of Use

The primary limitation of use is dependent upon the contractor's ability to design and procure the materials necessary to construct the temporary structure. While unstable subsurface soil conditions will affect the length of piles, most contractors who choose this option should be able to handle these conditions.

Floating Structures and Vessels

For open water situations, the contractor may elect to mount construction equipment on barges with the ability to move the barge along the axis of the permanent construction. In most instances, such location will be in the areas classified as navigable water and will require permits issued by the Coast Guard.

Potential Environmental Impacts

Barges placed over submerged aquatic vegetation (SAV) will result in shading, which decreases plant growth rates and vigor, thereby reducing primary productivity. Shading of SAV, as well as construction noise emanating from the barges, may also reduce this important plant community's use by fish and other aquatic animals.

Benefits of Use

The use of floating structures or vessels is normally the primary means of providing construction equipment access in open water areas. Their mobility allows the contractor to work throughout the length of the new bridge that spans the open water. See Figure 3.

Limitations of Use

This method is suitable only for open water conditions of suitable depths to accommodate barge drafts. The Coast Guard will generally not permit use of barges for bridge construction if open waters are tidally influenced. Water depths must be sufficient to maintain buoyancy of the barge to prevent impacts to sediments along the bottom of the open water system. In addition, Coast Guard permit conditions may require that barges be certified as free of invasive species such as zebra mussels.

Causeways

Temporary causeways, when permitted by environmental agencies, may be constructed across wetlands or into, but not blocking, open waterways. It should be noted that temporary causeways are not permitted by some state and federal environmental agencies at some locations. Even where temporary causeways may be considered, permitting will likely take more time, and mitigation requirements will be significant. See Figure 4.

Design and Construction

When the decision is made to pursue the use of a temporary causeway for construction access in wetlands, an environmental permit or permit modification, if applicable, must be obtained. The permit requirement must then be taken into consideration in the design of the causeway. In many cases, it is desirable to place the causeway on an engineering fabric when crossing wetlands. The fabric will distribute the loading of the fill material across the interface between the fill and the wetland, facilitating removal of the fill material and the restoration of the wetland. The selection of the fill material for the construction of the causeway must also be considered. It is generally preferred that granular, non-erosive material—such as plain riprap sized from 5 to 8 in. (12.7 to 20.32 cm)—be used for the base. The surface may then be constructed of a coarse graded aggregate. Through use of such materials water can seep not only down through the fill, but also across the causeway, thus minimizing a damming effect by the structure.

In areas subject to flooding, provisions should be made to allow flood water to pass through the causeway. This can be accomplished by the use of cross drainpipes at strategic locations along the project. Throughout the life of the causeway, the performance must be monitored to ensure that the fill materials are not contaminated and that any rutting that occurs is promptly repaired.

Removal and Restoration

When the use of the temporary causeway is no longer required, the contractor should remove it and restore the wetland as soon as possible. Based upon permit requirements, the contractor may be required to fill in any excavations made for drainage, to restore

Texas DOT

Figure 3 While barges are used typically to provide construction equipment access in open water situations, this Dura-Base composite mat system was used to provide worker access at the Cavasso Creek bridge project in Aransas County, TX.

Eric Burns, Michigan DOT

Figure 4 Temporary causeway fill with filter fabric, sheet piling, and concrete barrier used in Michigan.

the original grade, and to replace native vegetation. Additional compensation may be required for the wetland functions temporarily lost during the period the causeway was in place.

Potential Environmental Impacts

The placement of causeways in wetlands, even temporarily, has greater potential for adverse environmental impact than any of the other bridging alternatives considered in this digest. Causeways temporarily eliminate the habitat provided by the vegetation and substrate and crush or smother animals such as mollusks and insect larvae dwelling within and upon the surface of the substrate covered by the construction materials. Causeways temporarily eliminate the water quality enhancement functions provided by the vegetation that is displaced. Causeways may affect hydrologic patterns within the wetland even when openings are placed in the causeway to mitigate for this impact. Temporary causeways having limited pipe and culvert installation can act as a barrier to wetland faunal movement (e.g., amphibians, anadromous fish, reptiles, and small mammals). Some species are reluctant to enter and move through pipes and culverts—for example, in the Southeast, causeways have the potential to block anadromous and other fish species' access to critical spawning habitat provided by bottomland hardwood wetlands. Causeways may also force larger animals to cross temporary embanks increasing the potential for vehicle strikes resulting in injury or death. Long-term impacts may remain once causeways are removed. Compaction of the substrate by the causeway can alter the variety and density of fauna living within it as well as change the community structure of the plants living upon it. Upon removal of the causeway, vegetation will have to be re-established. Depending upon the degree of subsidence due to the weight of the causeway materials, re-grading of the substrate may also be required to obtain elevations that restore previous hydrologic conditions.

Benefits of Use

The earth, stone, and fabric materials used for the construction of temporary causeways are usually locally available; therefore, this method may prove to be the most expeditious and cost-effective method for providing construction access within the wetland boundary.

Limitations of Use

Temporary causeways will normally require that the underlying subsurface be fairly stable in order to support the weight of the material. Also, the use of causeways will necessitate more extensive restoration efforts than those required by other methods, such as temporary bridges constructed over and not in direct contact with the wetland. Causeways are not generally considered for long-term applications, especially in areas prone to flooding or tidal influence.

Railroad Flat Cars

Temporary spans constructed from flat cars that have been retired from railroad service are available (e.g., Railspan®) because the moving parts under the flat cars may have reached a point where they will require more replacement, repair, and maintenance than the flat car unit is worth. See Figure 5.

Design and Installation

Typical unit sizes. The typical size of flat car units is 89 ft long × 8-1/2 ft wide (27.1 m long × 2.6 m wide). Each of the units is modular in that whole or partial length units may be placed side by side or end to end as many times as is required to achieve the required bridge dimensions.

Substructure design considerations. A typical bridge substructure might consist of one of the following systems:

Skip Gibbs Co.

Figure 5 Lee Road detour bridgeover Harkins Slough in Santa Cruz, CA, constructed of 16 Railspan® units.

- Driven steel piling (H-piles, pipe, prestressed concrete, timber, or sheet piles) with steel or concrete pile caps;
- Cast-in-drilled structural concrete columns with a structural concrete abutment cap/seat; or
- Structural concrete spread footing/stemwall combination with an integral concrete abutment seat.

A registered professional engineer with expertise in bridge design including abutments as well as expertise as to the site location should be engaged to design the substructure for flat car installation.

Design and installation of the superstructure. A full-length flat car bridge module will weigh approximately 44,000 lb (16,420.8 kg). Shorter versions will weigh approximately 500 lb (186.6 kg) per linear foot (.3048 m). These figures reflect the weight before any other features, such as bridge railings, are added to the module. Flat car bridge units, placed side by side for spans up to 80 ft (24.4 m) have been calculated to support HS20-44 loading. Flat car bridge units come to the job site on trucks and will be equipped with steel lifting eyes to facilitate the removal of the unit from the truck and the placement on the substructure. A large crane will be required to remove the unit and set it on the substructure.

There are two main options for the bridge crossing surface: (1) existing steel decking covered with an asphalt concrete overlay and (2) exposed existing steel decking. A third option, which is less desirable, is pressure-treated wood plank decking; this option is not recommended as the wood over the steel deck traps moisture resulting in the rusting of the steel and rotting of the wood. All flat car bridge modules come with a smooth steel deck which is integral to the railroad flat car design.

Potential Environmental Impacts

Primary impacts will result from shading, which decreases plant growth rates and vigor, thereby reducing primary productivity; however, the degree of shading can be affected by the height of the structure above the surface and the orientation of the structure with respect to the path of the sun. Since the placement of temporary piles will destroy some wetland vegetation and could result in the alteration of the land surface, filling of holes and restoration of vegetation may be necessary upon pile removal. Impacts to fish and wildlife are usually minimal when designated moratoria (if any) are observed.

Benefits of Use

For very short spans and stable foundations areas, railroad flat cars provide an expeditious means of spanning a wetland or waterborne course.

Limitations of Use

Due to the weight of these components, shipping costs may make the use of railroad flat cars non-economical. As noted, the railcars weight approximately 500 lb (186.6 kg) per linear foot (.3048 m).

Mats on the Ground

Historically, contractors have used timber mats in wet areas to perform short-term operations such as ditching and clearing. Modular mats are also available and have been used successfully. Normally, the mats are advanced as the required construction equipment is moved forward to perform the required operations. In such cases, a very limited number of mats is required. See Figure 6.

Potential Environmental Impacts

Due to the weight of the mats and the equipment bearing directly on them, most of the native vegetation will be damaged or destroyed, and some small animal life could be smothered. However, since the mats will be in place for a very limited time, some types of vegetation may re-establish on their own. Depending on the stability of the underlying subsurface soil,

Texas DOT

Figure 6 A composite mat system provides construction equipment access at the Cavasso Creek bridge project in Aransas County, TX.

the resulting subsidence may need to be corrected by re-grading.

Benefits of Use

For a short-time need, this method is very expeditious and most likely the least costly.

Limitations of Use

Timber and modular mats are not suitable in areas prone to tidal influence or permanent, semi-permanent saturated conditions. Also, weak subsurface conditions could be a problem with their use. Some organic soils are subject to severe compression regardless of the brief time period that timber or modular mats and equipment may be used. Regulatory agencies may require some type of mitigation to offset impacts from soil compression.

FACTORS THAT INFLUENCE THE USE OF TEMPORARY BRIDGING

New Highway Bridge Length

Three Spans or Fewer

On sites of three or fewer short spans, no temporary bridging may be required. The contactor could construct the end and interior bents from "high ground" and launch the girders. The center span could then be constructed from the two completed end spans.

More than Three Spans

Where the bridge length is more than three spans, working entirely from the "high ground" will most likely not be practical or even feasible. Accordingly, some method of bridging will be required unless the entire structure will be constructed via "top-down" construction. "Top-down" construction is a highly specialized construction method normally associated with post-tensioned, segmental type methods. For normal construction, total bridge length plus site environment will be the determining factors in the type of temporary bridging that will be required.

Site Environment

Wetlands Only

A site consisting of wetlands only will not require consideration for open water issues such as Coast Guard permits, etc. Therefore, temporary bridging methods may be low level and short span, such as timber mats placed on steel beams supported by steel or wood pile bents. Such temporary construction is probably the least costly and most likely the most environmentally sensitive method in use. The temporary bridging can be easily constructed by "top-down" methods as the spans are normally short such that the succeeding bent can be driven and erected from the previous span. Decking may consist of wooden mats or steel grating/sheeting. Consideration must be given to preventing spillage for construction materials/debris from the temporary structure onto the underlying or adjoining wetlands. Therefore, a solid surfaced decking may be preferable to an open grated material.

Navigable Water Only

In situations where the structure will cross navigable water, consideration must be given to allowing the passage of marine traffic. This requirement will dictate the use of movable/removable spans, high spans, or marine construction equipment such as barges and barge-mounted cranes. In designing such temporary structures, consultation and permitting will most likely be required by the U.S. Coast Guard and/or USACE.

Combination of Wetlands and Navigable Water

Where a combination of wetlands and navigable water exists, the most practical solution may be a combination of a temporary bridge across the wetlands portion and the use of barges in the navigable waters. Where this option is chosen, the considerations listed for each situation (e.g., wetlands only and navigable water only) must be applied to this combined situation.

Temporary Structure Design

Flooding Potential

Wetlands and waterways prone to flooding require special consideration. When a wetland/waterway is in flood stage, the movement of water may carry debris that could be lodged against a low temporary structure. Such an occurrence may result in the combination of the structure and the debris acting as a dam. Should this occur, the lateral forces applied to the structure by the force of the water could cause a failure of the temporary structure. Where the temporary structure is carrying public traffic, the failure of the structure due to flooding or other causes will have an adverse effect on the traveling public. In addition, flooding and subsequent damming will probably cause scour issues that may cause environmental damage to wetlands/waterways. For either issue, the design height considerations of the temporary structure must include possible flooding scenarios.

Size and Weight of Equipment

Structural and size design must take into consideration the weight and size of the equipment that will be using the temporary structure. When considering design loading (equipment weight), one must include the weight of materials that the equipment will be handling such as piles, girders, loaded concrete buckets, and so forth. Equipment size will also determine the width of the structure and the placement of positive fall prevention devices such as hand rails and toe boards.

Geotechnical Considerations

Strength of soils. No matter the type of temporary bridging used, the engineer must consider the strength of underlying soils that will be supporting the structure. This may require some geotechnical exploration to predetermine pile lengths or other substructure features.

Vegetation. Most permits for temporary structures in wetlands will allow only the absolute minimum of the existing vegetation to be removed. The use of heavy equipment operating directly on the wetland soils must be avoided. This may be accomplished in a "top-down" method as the temporary structure moves forward. Therefore, hand clearing may be required coupled with the use of cranes to move the downed material out of the way of the construction.

Use of Temporary Structure

Public traffic. Where public traffic is to utilize the temporary structure, the roadway surface must be designed to accommodate that traffic. That is, the normal expectations of the public for safety, visibility, ride, and geometrics must be adhered to. This will limit the use of such materials as timber mats and will require rails or barriers sufficient to keep an errant vehicle on the structure. In some cases, the owner may actually design such a structure and have that design included in the project plans. In other cases, the contractor may be required to design the temporary structure and submit it to the owner for review.

Construction personnel and equipment. Where construction personnel and/or equipment are the only users of the temporary structure, the owner may require design review other than a possible review to determine environmental suitability. In the design of such structures, the designer must be aware of and take into consideration safety requirements as outlined in the applicable Occupational Safety and Health Administration (OSHA) regulations. These would include fall prevention/protection, operation in close proximity to equipment, and crane operations.

Access and Right-of-Way Constraints

Easement or Right-of-Way Furnished by Owner

Where an easement or right-of-way is to be furnished by the owner and included in the environmental permits, the temporary structure shall be designed and constructed within the confines of the easement. Should this not be possible, additional easements and permit modifications will most likely be required.

Easement To Be Acquired by Contractor

In those cases where the owner has not made provisions within the right-of-way or easements acquired by the owner for the temporary structure, the contractor will have to acquire the necessary easement and most likely an environmental permit or permit modification. The permitting process can be a time-consuming process that will require advance preparation.

Permit Considerations

Owner's Permit Provides for Temporary Structure—Type Predetermined

Where the owner has predetermined the type of temporary structure to be furnished by the contractor, the owner will normally have secured all the necessary permits. The contractor will still have to be responsible for the actual design and construction of the structure.

Owner's Permit Provides for Temporary Structure—Type Not Determined

Where the owner has provided the permit, the contractor must take the permit conditions into consideration in the design and construction. Should the contractor not be able to meet the permit conditions with the temporary bridging design, then the contractor, through the owner, will need to apply for and receive a permit modification. This can be a time-consuming effort and may possibly delay the construction of the project.

Contractor Required To Obtain Permit or Permit Modification

Where the contractor is required to obtain the permit or a permit modification, the time to acquire the permit should be taken into consideration in setting up the contract time. The advantage in having the contractor acquire the permit is that the permit conditions will more accurately meet the needs for the construction. On the other hand, the contractual requirement for the contractor obtaining the permit will require the owner to anticipate the permitting time requirements and build that time into the overall project schedule.

Seasonal Limitations or Work Type Restrictions Contained in Environmental Permits

Some environmental permits mandate seasonal limitations for natural occurrences such as spawning. Such permits may place limitations on allowable activities in wetlands and/or adjacent waters. Accordingly, the owner and/or the contractor must anticipate the impact of these limitations and schedule the letting of the contract and allowable contract time in the development of the project.

Temporary Bridging of Wetlands for Other Operations

Temporary Project Access

Access to remote sections within a project's limits may require crossing over wetlands. In such cases, the responsibility for acquiring such permits must be determined. If a permit has already been obtained by the owner and it does not cover the needed crossing, then the contractor or the owner may need to get a permit modification of the owner's original permit. Many environmental agencies are reluctant to grant such changes to permits unless no other alternative is appropriate and practicable.

Access to Borrow/Disposal Sites or Other Materials

The contractor may want haul roads to cross wetlands and waters outside project limits to access borrow or disposal sites. In those cases, the contractor may choose to construct a temporary structure to provide that access. In these situations, the burden will be on the contractor to obtain the necessary environmental permit(s), and the contractor may have to demonstrate to the satisfaction of the agencies that the proposed plan is the only appropriate and practicable alternative. The contractor must also demonstrate to the satisfaction of the state DOT engineer that permits have been obtained and that the conditions of the permit are being met before the contractor's vehicles use the haul road to access the project limits.

Cost of Various Alternatives

The owner and/or the contractor may have several alternatives from which to choose (e.g., temporary structures, temporary causeways, or mats), and the cost of each alternative will vary. While the tendency will be to choose the least expensive alternative from the viewpoint of the owner/contractor, environmental agencies generally do not place a high emphasis on the relative cost of alternate approaches. Their primary concern and responsibility is protection of the resource. Therefore, environmental agencies are primarily interested in the method or approach that will have the least negative impact on the resource. When applying for a permit for temporary construction, the owner/contractor will need to demonstrate to the satisfaction of the agencies that there is no other appropriate and practicable alternative to impacting the wetland and that the method chosen will cause the least damage to the resource. Where two or more methods are equal with respect to negative impact, only then is the cost issue likely to be a consideration that will concern the review agencies.

DECISION MATRIX FOR DETERMINING THE USE OF TEMPORARY BRIDGING

This section of the digest includes a decision matrix for determining the use of temporary bridging based on the following criteria categories: (1) duration; (2) subsurface soil; (3) wetland hydrology; and (4) other considerations, including environmental sensitivity and relative cost factor. A brief narrative of the criteria categories is provided below, followed by a matrix showing the applicability of each of the six temporary bridging types to the factors that may influence their selection and use.

Duration

Duration refers to the length of time a temporary structure must remain in place, and it can significantly impact the selection of the temporary structure for a given site. For instance, if the temporary structure only needs to be in place for a few months, then it may be possible to schedule the construction project to avoid seasonal/temporal wetlands or protected species restrictions/moratoria, thus allowing the use of a wider range of crossing options. In the decision matrix, the project team specifies duration periods of greater than and less than 1 year to cover the wide variations in construction season length.

Subsurface Soil

Underlying or subsurface soil(s) is the soil material that warrants important consideration when constructing temporary structures across wetlands. If the subsurface conditions are poor (i.e., highly compressible/unstable soils), then deep foundations, such as piles or drilled shafts, will be required in order to reach soils that are capable of supporting the weight of the temporary structure. In these situations, panel, contractor-designed, or railcar-type bridges will most likely be required. If the subsurface soils are firm/stable, then this may open the door for the use of a wider range of crossing options.

Wetland Hydrology

Tidally Influenced

Flooding periodicity and amplitude in tidally influenced wetlands are largely determined by oceanic tides. Tidal wetlands are characteristic of estuarine and marine areas and are periodically exposed or flooded by tides.

Some palustrine, lacustrine, and riverine wetlands can also be affected by tidal action. They may be regularly or irregularly flooded with tidal waters depending on their location. Regularly flooded wetlands generally experience daily tidal flooding of the land surface. Irregularly flooded wetlands experience tidal flooding of the land surface less often than daily. Examples of tidally influenced wetlands include salt marshes, intertidal mud flats, mangrove swamps, and tidal fresh marshes.

Permanent/Semi-Permanent/Saturated

In permanently flooded wetlands, non-tidal water covers the land surface throughout the year in all years. Vegetation is composed of obligate hydrophytes. A semi-permanently flooded wetland has non-tidal surface water that persists throughout the growing season in most years. On occasion when surface water is absent, the water table is usually at or very near the land surface. Wetlands characterized by saturated conditions have a substrate that is saturated to the surface for extended periods during the growing season, but surface water is seldom present. Examples of permanent, semi-permanent, and saturated wetlands include freshwater marshes, cypress swamps, red maple/black gum swamps, willow swamps, sphagnum bogs, Atlantic white cedar swamps, and montane meadows.

Seasonal/Temporary

When a wetland is seasonally flooded, it has non-tidal surface water regularly present for extended periods especially early in the growing season, but none by the end of the season in most years. When surface water is absent, the water table is often near the land surface. Wetlands that are temporarily flooded have surface water present for brief periods during the growing season, but the water table usually lies well below the soil surface during most of the season. Facultative plants that grow both in uplands and wetlands are characteristic of the temporarily flooded condition. Examples of seasonal and temporary wetlands include bottomland hardwoods, vernal pools, and playa lakes.

Intermittently Flooded

Intermittently flooded wetlands have soil that is usually exposed, but surface water is present for variable periods without a detectable, regular seasonal pattern. Unpredictable and highly variable amounts of time may intervene between periods of inundation. Plant communities under this condition can change as soil moisture conditions vary. Examples of intermittently flooded wetlands include arroyos, dry washes, and ephemeral streams.

Other Considerations

Navigable Water

In this document, navigable waters are defined as those open water areas that are subject to marine traffic.

Combination Navigable Water/Wetland

This category describes situations that require the temporary spanning of both wetlands and navigable water together. In freshwater environments, an example would be a navigable river bordered by floodplain forested or emergent wetlands. A similar situation in marine environments would be a shipping channel bordered by salt marshes or mangrove swamps.

Potential for Flooding

Wetland flooding and the associated movement of water must be a consideration in the type and height of a temporary structure selected for use in a wetland. When a wetland is in flood stage, the movement of water may carry debris that could be lodged against a low temporary structure or in causeway openings. Such an occurrence may result in the combination of the structure and the debris acting as a dam. Should this occur, the lateral forces applied to the structure by the force of the water could cause a failure of that structure. Flooding and subsequent damming may result in scour issues that may cause environmental damage to the wetlands. Thus, the design height considerations of the temporary structure must include possible flooding scenarios.

Environmental Sensitivity

Table 1 lists five general categories of environmental considerations that should be evaluated when determining the most appropriate temporary bridging alternative. The listing of specific considerations under each category is not intended to be comprehensive but is representative of the types of environmental issues requiring evaluation.

Table 1 Environmental sensitivity considerations

Fish and Wildlife

- Protected species moratoria
- Presence of rare, threatened, or endangered animal species
- Designated endangered species "critical habitat"
- Nesting habitat
- Breeding habitat
- Feeding habitat
- Migratory pathways and areas of seasonal dependence
- Anadromous/catadromous fish spawning area

Plant Communities

- Rare or declining community type
- Maintenance of primary productivity
- Presence of rare, threatened, or endangered plant species
- Restoration potential
- Areas subject to invasive plant introduction and spread

Hydrology

- Maintenance of sheet flows
- Floodway restrictions
- Water quality maintenance
- Hydrologic connectivity
- Unique aquatic sites
- Wet weather runoff

Geomorphology

- Soil structure, complexity, and erosion potential
- Restoration potential
- Karst
- Groundwater recharge zones/sole-source aquifers
- Contaminated properties

Cultural Resources

- Historic sites
- Archaeological resources
- Native American sacred sites

Fish and wildlife resource agencies in many parts of the United States have evaluated the impact of construction-related activities on rare, protected, and sensitive species and have established *moratoria,* or specifically defined periods when construction activities are prohibited at specific locations. For example, it is recognized that certain aquatic species during various life stages can be adversely impacted by changes in water quality resulting from increased sediments from erosion caused by surface disturbance, runoff carrying construction-related chemicals, and increased water temperatures resulting from vegetation removal. For some species, construction noise can have a negative impact at specific times. To protect aquatic species during reproductive cycles or spawning seasons and other critical migration periods, state and federal wildlife agencies often enact moratoria that will limit or restrict work in surface waters. Examples of moratoria include the North Carolina Wildlife Resources Commission moratorium that restricts in-water work between January 1 and April 15 to protect rainbow trout spawning, or the U.S. Fish and Wildlife Service (USFWS) Southeast Region's moratorium on in-water work along the south Atlantic coast between June and October that requires work stoppages when manatees are present. Pile driving has been prohibited by the USFWS near bald eagle nest sites during the breeding season in order to avoid disturbance impacts from noise. The USFWS, National Marine Fisheries Service (NMFS), and local/state wildlife or marine protection agencies should be contacted prior to commencing construction activities for information about moratoria in the proposed project area.

Expert advice regarding each environmental category is readily available through the consultation process with state and federal natural resources agencies. Additional information regarding sensitive fish, wildlife, and plant communities is available from the USFWS; the state's fish and wildlife resources agency; the state's Natural Heritage Program; and, in some cases, from non-government organizations like The Nature Conservancy. Hydrology issues can be identified with the help of the U.S. Geological Survey (USGS) and the state's water resources agency. USGS and the state geologic resources agency can help identify concerns related to geomorphology. Sites with associated cultural resource concerns can be identified with the aid of the state's Historic Preservation Officer.

The environmental sensitivity matrix (Table 2) shows the relative applicability of each bridge type alternative when considering the range of environmental sensitivities that should be evaluated when making a selection.

Although a "generalized" score has been assigned to each bridge type for the environmental sensitivity category shown in the decision matrix for determining the use of temporary bridging applications, care should be taken to evaluate each of the five major environmental sensitivity considerations identified in Table 1 when selecting a bridging alternative. A single environmental issue in any category could be of such sensitivity or importance to be the key determinant when selecting a bridging alternative. For example, the presence of a Native American burial ground or other important archeological site may preclude the use of an alternative that would cause even minimal disturbance to the site. Likewise, the need for maintaining uniform sheet flows across a wetland could preclude the use of the causeway alternative or other alternative that alters hydrologic flow patterns.

Table 2 Environmental sensitivity matrix

Type of Temporary Structure	Fish and Wildlife	Plant Communities	Hydrology	Geomorphology	Cultural Resources
Panel Bridges	+	+	+	+	+/−
Contractor Designed	+	+	+	+	+/−
Floating Structures/ Vessels	+	+	+	+	+
Causeways	−	−	−	+/−	−
Railcars	+	+	+	+	+/−
Mats on Ground	−	−	+	+	+/−

+ May be applicable; − may not be applicable; and +/− may or may not be applicable.

Cost of Temporary Bridging Installations

Once the limiting environmental considerations are known, six cost factors should be considered in determining the financial impact of installing a temporary facility to bridge wetlands or waters in order to accommodate the construction of the permanent facility. These cost factors include lease or rental, capital, mobilization and installation, maintenance, demobilization and deinstallation, and site restoration:

1. ***Lease or rental costs:*** In cases where the contractor or the owner does not possess the temporary structure or the materials to construct the temporary structure, contractors often must lease or rent such a structure. For example, the contractor may choose to rent a panel bridge in lieu of buying the structure in order to avoid excess cash outlay.
2. ***Capital costs:*** Capital costs include cash outlays for materials and other incidentals that are necessary to design and construct the tempo-

rary structure. Such materials may include steel girders, piles, and timbers.

3. ***Mobilization and installation costs:*** Once the arrangements for the procurement of the temporary structure or materials have been made, the contractor must transport those materials to the site and erect/construct the temporary structure. These costs will also include the cost to design and build an appropriate substructure.
4. ***Maintenance costs:*** Temporary structures used to facilitate construction personnel and equipment or to handle public traffic must be maintained in a satisfactory manner. Maintenance is crucial to protect the environment from falling debris or damage caused by structural failure.
5. ***Demobilization and deinstallation costs:*** When the temporary structure is no longer required, it should be removed from the site as expeditiously as possible. The cost of removing the structure (and the associated shipping costs) must be taken into consideration.
6. ***Site restoration costs:*** Upon removal of the temporary structure, the site should be restored in accordance with the environmental permit requirements. The costs associated with the restoration effort, including any monitoring required, must be taken into consideration.

Table 3 shows the overall relative costs associated with each factor noted above. These cost factors were rated on a scale of 0 to 3, with 0 being generally the least costly and 3 being generally the most costly. The *relative cost factor* is an average of the six individual factors for a given temporary structure type. As with all aspects of this guide, this table should be used with the advice of professional engineers and environmental professionals with appropriate competencies in all the elements of the work.

Table 4 is the decision matrix. Please note that as a decisionmaking tool, the data provided in this matrix should be considered only in concert with a careful review of the general criteria narrative (i.e., duration, subsurface soil, wetland hydrology, and other considerations, including environmental sensitivity and cost effectiveness), which precedes the matrix and provides important qualifying information. Again, this table should be used with the advice of professional engineers and environmental professionals with appropriate competencies in all the elements of the work.

STATE EXAMPLES OF LESSONS LEARNED

Temporary bridges have been in use for decades, first for military operations and more recently by transportation agencies. They have been used for maintaining traffic when maintenance or construction activities on permanent bridges require onsite detours, for equipment or worker access during maintenance or construction activities, and for quick access in emergency situations when permanent bridges have been damaged or destroyed. Temporary bridging has also been used to minimize permitting time and mitigation costs.

Table 3 Relative cost factor of temporary structure types*

Type of Temporary Structure	Lease or Rental Cost	Capital Cost	Mobilization & Installation Cost	Maintenance Cost	Demobilization and Deinstallation Cost	Site Restoration Cost	Relative Cost Factor
Panel Bridges	2.9	1.3	2.1	1.1	2.0	1.0	**1.73**
Contractor Designed	0.7	2.6	2.6	1.1	2.4	1.3	**1.78**
Floating Structures/Vessels	2.0	1.7	2.0	1.4	2.0	0.4	**1.58**
Causeways	0.1	1.3	1.7	1.4	1.9	3.0	**1.57**
Railcars	3.0	1.0	2.6	1.3	2.4	1.3	**1.93**
Mats on Ground	0.4	1.4	1.3	1.7	1.3	2.6	**1.45**

*Scale: 0 = the least costly and 3 = the most costly. The *relative cost factor* is the average of the six cost factors shown for a given temporary bridging type.

Table 4 Decision matrix for determining the use of temporary bridging applications*

	Duration		Subsurface Soil			Wetland Hydrology			Other Considerations				
Type of Temporary Structure	Equal to or Less than 1 Year	Greater than 1 Year	Stable Condition	Unstable Condition	Tidally Influenced	Permanent/ Semi-Permanent/ Saturated	Seasonal/ Temporary	Intermittently Flooded	Navigable Water	Combination—Navigable Water/ Wetland	Potential for Flooding	Environmental Sensitivity	Relative Cost Factor (see Table 3)
Panel Bridges	+	+	+	+	+	+	+	+	+	+	+	+	**1.73**
Contractor Designed	+	+	+	+	+	+	+	+	+	+	+	+	**1.78**
Floating Structures/ Vessels	+	−	−	−	−	−	−	−	+	+	−	+	**1.58**
Causeways	+	−	+	−	−	−	+/−	+/−	−	−	−	−	**1.57**
Railcars	+	−	+	+	−	−	+	+	−	−	−	+	**1.93**
Mats on Ground	+	−	+	−	−	−	+	+	−	−	−	+/−	**1.45**

\+ May be applicable; − may not be applicable; and +/− may or may not be applicable.

*Please note: This table should be used with the advice of professional engineers and environmental professionals with appropriate competencies in all the elements of the work. Please review the general criteria narrative (i.e., duration, subsurface soil, wetland hydrology, and other considerations) that precedes the decision matrix in this digest.

State agencies like the Florida DOT and Kansas DOT maintain inventories of temporary bridge components that are easily transportable and can be reused as needs occur. For instance, when Hurricane Katrina destroyed bridges in Louisiana and Mississippi, Florida DOT made its temporary bridge panels available so that roadways could be reopened for emergency response access and to reconnect communities affected by the storm. California DOT (Caltrans) has developed a system of interlocking railroad flat cars that were used for temporary bridging when a permanent bridge structure was destroyed during a flash flood.

Over time, as temporary bridges have been used, lessons have been learned about what works best in certain situations, about how temporary bridges can be more easily installed, or about how to minimize or avoid impacts to natural systems when they are used to cross surface waters or wetlands. This section provides additional information developed over time from temporary bridge construction. Please note that as with other information presented in this digest, qualified engineers and environmental professionals should be consulted to determine applicability of this information to a specific project. Coordination with regulatory agency personnel should be conducted to ensure proper avoidance and minimization of impacts to streams, wetlands, and sensitive or protected species.

Methodologies

Examples of methodologies are as follows:

- Incremental launching of superstructures that have been erected on one side of the waterway and rolled longitudinally into place can reduce impacts. When using launch methods for temporary bridge structural components, cantilever movements may place stress on girders or connecting plates. Heavy-duty rollers or other sliding bearing system with a pad beneath the structure have been used on other launched bridge projects. A reversible launch system is also recommended so that the structure can be retrieved in case of problems.
- Use of construction assembly systems (for instance, the RoboCrane® system) facilitate assembly of modular bridge components when sensitive resources like wetlands or streams are present and equipment or construction access is not allowed.
- Half-pipes set over small stream beds and covered with filter fabric and fill material can provide work access across the channel when adjacent wetlands are not present.
- Causeways may be more acceptable to permitting agencies if they include large-diameter, full-sized pipes that will maintain water flow and reduce pooling of stagnant water.

Restrictions

Examples of restrictions are as follows:

- In some states, pile driving is severely restricted (and in some areas, even prohibited) due the potential for impacts on fish and other sensitive aquatic species. Many of these organisms are protected under the Federal Endangered Species Act. Restrictions are particularly acute in western states where commonly there are year-round requirements to avoid the underwater sound pressure impacts associated with driving piles. A number of elaborate mitigation measures are used to minimize such impacts, including the use of bubble curtains created by injecting pressurized air below the water surface and surrounding the pile to disrupt the sound pressure waves resulting from each hammer blow. In other states, pile driving is still generally allowed without such restriction, except in some cases where particularly large piles are being installed and when seasonal or species-related moratoria are in effect.
- Coffer dams may be required for hydraulic jetting of piles or for minor dredging activities when moratoria are in place.
- Underwater blasting is normally not allowed during moratorium periods. Rubble removal is usually prohibited during moratorium periods because of turbidity impacts.

Project Examples and Citations

On occasion, use of temporary bridging can require unique designs and the use of innovative methods for construction, or the temporary bridging may be used at highly visible or significant sites. Examples of such projects using temporary bridging include the following:

- As part of the SE 17th Street causeway bridge replacement project in Ft. Lauderdale, Florida DOT used a temporary Dutch-style (Bascule) draw bridge at the site to maintain marine traffic along the Intracoastal Waterway during construction. A specialized crane barge was brought from Louisiana to lift the nearly 400-ton (406.4-metric-ton) steel bridge deck and balance frame into place on the temporary drawbridge. The moveable span uses an overhead counterweight and was selected for use because the major elements could be prefabricated and relocated as modular sections, because it had low initial and maintenance costs, and because it eliminated the need for excavation of a pit pier.

- The historic Bridge of Lions in St. Augustine spans the Intercoastal Waterway and is listed on the National Register of Historic Places. As part of a rehabilitation project, Florida DOT constructed a temporary bridge with a vertical lift panel system span to maintain marine, vehicular, and pedestrian traffic along the north side of the existing structure (see Figure 7). The temporary bridge—which is over 1,750 ft (533.4 m) long and supported by 24-in. (61-cm) driven piles—will remain in place for nearly 5 years. The temporary structure has a 27-ft (8.2-m) vertical clearance over the waterway (above mean high water) while the vertical lift span provides an 80-ft (24.4-m) vertical and 125-ft (38.1-m) horizontal clearance for marine vessels. Use of the vertical lift span eliminates the need for dredging or excavation of a large counterweight pit in the channel. Construction of the temporary bridge included monitoring of pile driving activities by vibration-measuring equipment.

Figure 7 Acrow temporary vertical lift span, Bridge of Lions, St. Augustine, FL.

- Arising from a need to quickly restore a bridge section on Interstate 5 that collapsed during an extreme flooding event in 1995, Caltrans used recycled rail flat car beds to breach the failed span and reopen the Interstate to traffic within 8 days of the disaster. Given adequate consideration of the support systems, the use of recycled rail flat cars has proved to be a quick and relatively inexpensive solution to temporary bridging needs under emergency situations. Flat cars should also provide temporary bridging solutions under non-emergency conditions where environmental protection may be the primary purpose of their use. Flat cars could be used to temporarily span sensitive wetlands, riparian areas, and streambeds during construction of permanent facilities, providing both platforms for construction access and bridges that could accommodate detoured traffic. Caltrans suggests that the costs of using rail flat cars be thoroughly examined prior to moving ahead with this kind of temporary bridging. Major cost considerations include transport to the construction site, cranes to place the flat-car sections, field welding, and other onsite structural modifications that may be needed to ensure proper fit of flat cars to each other and to the support system, as well as dismantling activities and the transport of the used flat cars when the temporary structure is no longer required.
- The Maryland Department of Environment has issued a guideline on the use of temporary access bridges to minimize disturbance of stream and riparian corridors. Also, similar protection would be provided to small wetland areas either associated with such corridors or as occurring in isolated situations. The guideline covers structures made of timber, metal, and other appropriate bridging materials that will be installed for up to 1 year of service. Temporary access bridges are the preferred method for short-term crossings because they typically cause less damage to stream banks and shallow water areas and should also minimize disturbance to aquatic animal species' survival, migration, and so forth. Bridge stringers should be of logs, timbers, concrete beams, metal beams, or other appropriate materials. Decking

may be of any material of sufficient strength and durability to accommodate anticipated loads, traffic levels, and the duration of the temporary bridge. The guideline also includes direction on construction sequencing and support specifications—for example, erosion and sediment transport control measures should be in place and stabilized prior to construction of the temporary crossing. This includes any necessary re-vegetation of disturbed soils. All abutments should be parallel to the watercourse and be of sufficient height to prevent entrapment of debris during high flow conditions. Spanning the entire channel is preferred, but the placement of intermediate bridge supports in the watercourse is appropriate when necessary. All bridge decking materials must be sufficiently butted together or covered to prevent soil tracked onto the structure from falling in the watercourse or wetland. Curbs and sidewalls may be necessary for safety purposes. When the bridge is no longer needed, removal of the structure and restoration of the site should be accomplished within 14 calendar days.

- The USDA Forest Service installed a temporary 78-ft (23.8-m) portable steel bridge over Eel Creek in the Oregon Dunes National Recreation Area after a culvert failed. A 200-ton (203.2-metric-ton) crane was used to lift two sections of the bridge into place. The bridge length allows the structure to span the creek while a permanent bridge is being constructed (USDA FS 2007a).
- The Forest Service has also developed a temporary skidder bridge for equipment crossing of streams and drainages. The temporary bridge is 16 ft (4.8 m) long, 12 ft (3.7 m) wide, and constructed from three 4-ft-wide (1.2-m-wide) laminated panels. The structure attaches to 4 × 8-in. (10.2 × 20.3-cm) sills and has a 27,000-lb (10,076.4-kg) load capacity (USDA FS 2007b). Another type of temporary wood bridge structure is fabricated from glulam deck panels. A glulam structure tested for the Forest Service by Auburn University was 16 ft wide and 30 ft long (4.9 m wide and 9.1 m long) and consisted of four glulam deck panels that were 10.5 in. (26.7 cm) thick (USDA FS 2007c).
- Since preservatives may be present in wood used in prefabricated wood and glulam type bridges, consideration should be given to their use in aquatic environments. To assist with consideration of potential impacts, the American Wood Preservers Institute and American Wood-Preservers' Association have developed a best management practices guide for use in Michigan that addresses wood preservative treatment concerns (USDA FS 2007d).
- North Carolina's Division of Forest Resources maintains an inventory of temporary bridge components (wood mats and steel bridging) for use by timber logging companies; these temporary bridges will reduce impacts to stream banks and beds (NCDFR 2007).

Citations for the project examples discussed above are as follows:

- Bridge of Lions Rehabilitation Project. Florida DOT: www.fdotbridgeoflions.com/index.htm (as of March 27, 2008).
- Maryland Department of Environment. MGWC 4.8: Temporary Access Bridge (Guideline): www.mde.state.md.us/assets/document/wetlandswaterways/sec4-8.pdf (as of November 13, 2007).
- North Carolina Division of Forest Resources 2007. Temporary Bridging: www.dfr.state.nc.us/water_quality/wq_draglinemats.htm and www.fpl.fs.fed.us/documnts/pdf1995/taylo95a.pdf (as of November 13, 2007).
- Temporary Dutch-Style Bascule Bridge. Structures Design Office, Florida DOT: www.dot.state.fl.us/structures/botm/17thstreet/TempDrawBridge.htm (as of March 27, 2008).
- USDA Forest Service 2007a. Siuslaw National Forest, Temporary Bridge at Eel Creek Campground Entrance: www.fs.fed.us/r6/siuslaw/news/2007/05-29-07eelcreekbridge.shtml (as of November 12, 2007).
- USDA Forest Service 2007b. National Wood in Transportation Program: www.fs.fed.us/na/wit/ (as of November 13, 2007).
- USDA Forest Service 2007c. "Portable Glulam Timber Bridge Design for Low-Volume Forest Roads." *6th International Conference on Low-Volume Roads, Minneapolis, Minnesota, Proceedings Vol. 2* (1995) pp. 328–338: www.fpl.fs.fed.us/documnts/pdf1995/taylo95a.pdf (as of November 13, 2007).
- USDA Forest Service 2007d. "Best Management Practices for the Use of Preservative-Treated Wood in Aquatic Environments in Michigan, with Special Provisions and Design Criteria for Engineers." 2002: www.fs.fed.us/

na/wit/pdf/WIT-05-0029.pdf (as of November 13, 2007).

RECOMMENDATIONS FOR THE FUTURE

Transportation agencies should consider the following elements in their programs that may include the use of temporary structures:

1. **Institute agency policies that clearly state that the use of temporary structures extends to environmental protection purposes and is not just for construction access or the accommodation of traffic flow.** There should be an understanding that temporary structures could be used to protect wetland resources that would otherwise be impacted by the construction of traffic detour roadways and construction access areas.
2. **Adopt wetland resource protection goals such as those currently in use by several states that specifically indicate when temporary structures may be warranted.** These goals may be based on wetland type, scarcity, the presence of rare species, or other factors that could warrant special protection measures. When state or federal policies are not specific in this regard, the transportation agency may consider teaming with their counterpart resource agencies to develop specific statewide goals or those goals applying within specified regional boundaries.
3. **Standardize the analysis of impacts to wetlands, identifying those potential disturbances and case-specific conditions that could typically trigger a decision to use temporary structures.** The analyses would consider temporary structures as one mitigation approach to be used in concert with other avoidance and minimization measures. Include thresholds based on wetland quality and quantity in the analysis of impacts.
4. **Quantify impacts and the mitigation response on projects involving temporary structures.** Maintain databases of this type of information for use on future projects of a similar type. This would require adoption of monitoring approaches to assess the outcome of temporary structure use and subsequent mitigation measures. Likewise, develop management approaches jointly with resource and regulatory agencies to define monitoring within agreed-upon timeframes.
5. **Establish clear measures of mitigation success that can support future decisions to use temporary structures.** Measures should be jointly developed with resource and regulatory agencies. When needed, establish commitments to correct deficiencies as identified during the monitoring process.
6. **Establish information for internal agency use on successful applications of temporary structures.** Develop similar information for resource and regulatory agencies providing educational materials on the types of temporary structures that could be used depending on project specifics and wetland resource potentially impacted. Include information on feasibility, cost, footprint impacts, estimated time of construction and dismantling, maintenance requirements, ability to maintain existing traffic, safety, public acceptance, and other controlling factors.
7. **Stay abreast of technological and engineering advances that may result in greater opportunities to include temporary bridges in highway construction projects.** New materials and improved construction techniques may provide lower-cost temporary structures that can protect sensitive resources and help ensure that highway development activities will meet ever-changing environmental regulations and other requirements.

RESOURCES FOR MORE INFORMATION

"Bridge Decks, Tire Mats, and Pole Rails. Forest Management Practices Fact Sheet Crossing Options, Series 13." Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7013.html

"Expanded Metal Grating." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 11.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7011.html

"Final Report: Prefabricated Steel Bridge Systems." 2006. *Bridge Technology,* U.S. DOT, FHWA: www.fhwa.dot.gov/bridge/prefab/psbsreport03.cfm

Goodwin, Ken. 1997. "RoboCrane Construction of Bridges," *Transportation Research Record 1575,* Transportation Research Board, National Research Council, Washington, DC; pp. 42–46.: www.isd.mel.nist.gov/documents/goodwin/RoboCraneconstruction.pdf

"PCV or HDPE Pipe Bundle Crossings." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 7.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7007.html

Portable Bridges for Forest Road Stream Crossings. 2007. Alabama Cooperative Extension System: www.aces.edu/pubs/docs/A/ANR-1074.

"Railroad Car, Steel, and Prestressed Concrete Bridges." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 6.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7006.html

"Protecting Water Quality." 1995. Chapter 5 in *Temporary Stream Crossing. The St. Charles County Soil and Water Conservation District, St. Charles, MI and the Dam and Reservoir Safety Program,* Division of Geology and Land Survey, Missouri Department of Natural Resources, Rolla, MO: www.dnr.mo.gov/env/wpp/field-guide/fg05_08_streamprotection.pdf

Taylor, S. E., Ritter, M. A., Keliher, K. P., and J. D. Thompson. 1996. "Portable Glulam Timber Bridge Systems." *International Wood Engineering Conference, New Orleans, Louisiana, Proceedings Vol. 2,* Gopu, Vijaya K. A., Ed.; pp. 368–375.

"Temporary Stream Crossing (NS-4)." 2003. In "Section 4: Non-Stormwater Management and Material Management BMPs," *California Stormwater Best Management Practice Handbook, Construction Handbook.* California Stormwater Quality Association: www.cabmphandbooks.com/Documents/Construction/NS-4.pdf

"Temporary Stream Crossing Options." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 1.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7001.html

"Temporary Wetland Crossing Options." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 8.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7008.html

"Timber Bridges." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 5.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7005.html

"Wood Mats." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 9.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7009.html

"Wood Panels and Pallets." 2002. *Forest Management Practices Fact Sheet Crossing Options Series 10.* Regents of the University of Minnesota. Communication and Educational Technology Services, University of Minnesota Extension: www.extension.umn.edu/distribution/naturalresources/DD7010.html

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