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Property Type: Concrete Arch Bridges

Description: Concrete arches are generally defined as one of two structural types: closed spandrel and open spandrel arches. The older and more common of the two, closed spandrel arches feature solid concrete walls between the deck and the arch ring. These sidewalls act as spandrels to help support the deck's outer edges, and they also act as retaining walls to hold in the load-bearing fill material (e.g., earth, rubble, sand) between the deck and ring. The spandrels may be poured integrally with the arch rings or as separate members. In their massive profiles, closed spandrel arches resemble traditional stone arches, and some have been sided with stone veneers or formed with faux stone faces. They are typically used for relatively short span lengths, ranging from less than 20 feet up to over 200 feet. The longest closed spandrel arch known to have been constructed in Arizona is the Holbrook Arch Bridge, a Luten arch with a span of 174 feet.

In contrast with the closed spandrel arch, open spandrel arches feature pierced or open spandrel walls with no fill material. The live and dead loads of the deck is transferred to the arch ring by means of concrete columns or, in some cases, secondary arches. The arch ring may extend continuously over the width of the bridge or may be subdivided into separate ribs. Although open spandrel arches require more intricate formwork than closed spandrels, they consume less concrete material, and their lighter weight allows for greater span lengths.

With either open or closed spandrels, the concrete arch is a structural type that traces its origins to Roman precedents. Although the Romans had developed a form of hydraulic cement, there is no evidence to suggest that they used it for bridge construction. After Rome fell, concrete technology was lost to the Western world for over a thousand years, until it later reappeared in England. British engineer George Semple was apparently the first to use hydraulic cement for bridge construction, on pier foundations for the Essex Bridge in Dublin, built in the mid-16th century. In 1824 Englishman Joseph Aspdin developed an artificial cement composed of a calcinate mixture of limestone and clay. Aspdin called his concoction Portland cement after Portland on Devonshire, the source for his limestone. Almost 50 years later, American David O. Saylor patented his own type of Portland cement and built the country's first cement manufacturing plant near Copely, Pennsylvania.

The first documented use of concrete on an American bridge, like Semple's Essex Bridge, was not for a superstructure at all, but for the foundations of the Erie Railroad's Starrucca Viaduct, completed in 1848. John Goodrich was probably the first in this country to use concrete as the principal material for the spans of a bridge. A modest 31-foot structure built in 1871, his Cleft Ridge Park Bridge in Brooklyn's Prospect Park used concrete because it was intended to be an ornamental structure and concrete was cheaper than stone. Soon other concrete spans began to appear in this country. From 1890 to 1900, over 150 reinforced concrete spans were built on scales ranging from minimal to monumental.

These early structures were built of unreinforced, or mass, concrete, which has the same structural properties as stone. Although far stronger than either iron or wood in compression, unreinforced concrete has virtually no tensile strength. Its use in bridge work was therefore limited to an ancient structural form derived from stonemasonry—the arch. The arch rib or ring functioned essentially as an extended curved column, under compression over its entire length. Further, as a beam it had to resist the bending and shear stresses caused by shifting live loads applied to the bridge deck and differential expansion and contraction caused by weather. "It was a comparatively easy change from the stone voussoir arch to the concrete monolithic or voussoir construction," engineer Frank Barber stated in 1911.[92]

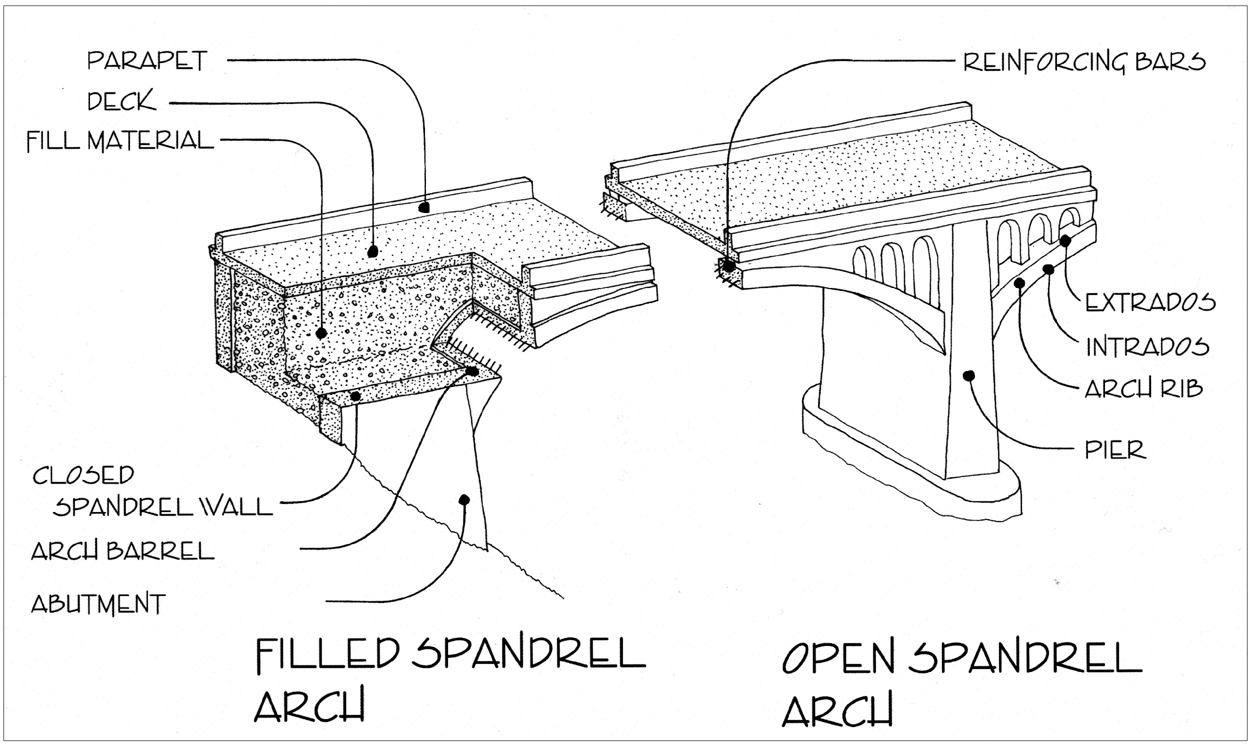

Figure 116. Concrete arch diagram.

It would not be until the end of the 19th century that engineers would begin to understand and develop the plastic properties of concrete and use it as something more than just a cheap imitation of stone. To address concrete's inherent tensile shortcoming, American engineer W.E. Ward demonstrated in 1871 that the material could be strengthened to resist tension by embedding iron bars in it. Such a composite configuration would combine the compressive strength of concrete with the tensile properties of steel. The concrete would thus protect the reinforcing from corrosion and would provide an economical technological alternative to

[92] Frank Barber, "Characteristics of Long-Span Concrete Bridges," *Engineering Record* (8 April 1911): 397.

an all-metal solution by reducing the amount of steel needed to bear the weight. The application of this discovery to large-scale bridge construction should have been immediately apparent. It was not until ten years later, however, that S. Bissel received the first American patent for concrete reinforcing. The first reinforced concrete bridge built in this country was the Alvord Lake Bridge in San Francisco's Golden Gate Park, designed by Ernest Ransome and completed in 1889.

It was only after the turn of the 20th century that concrete began to rival stone for long-span archbuilding. Engineers by then had begun to stretch the technological limits of concrete construction dramatically with new methods of forming, centering and reinforcing the arches. In 1908 American engineer George Webster completed the Walnut Lane Bridge in Philadelphia. Called the largest concrete arch in the world at its completion, it featured an unreinforced 233-foot main arch. By the end of 1910, nineteen concrete arches had been built in the world with spans in excess of 150 feet. *Engineering Record* described the progress that American engineers had made in concrete bridge construction:

> When it is considered that the first reinforced concrete arch bridge in the United States was built only 21 years ago, the development which has taken place in the design and construction of bridges of this type seems very remarkable. Moreover the greater part of this growth has been brought about in the last decade. That this movement is still going on is shown by the fact that at frequent intervals descriptions appear in the engineering press of structures which embody new ideas or material modifications of old ones. It is interesting to watch this progress, and especially to see the influence which the materials used have had on the development.[93]

Despite this auspicious beginning, American bridge engineers soon lagged behind their European peers. The principal reason for this lay in the differences in engineering standards between the two continents. Traditionally more conservative than their European counterparts, U.S. engineers in the 1880s labored under more restrictive structural rules that called for lower working stresses and higher loading conditions for railroads. Initially these standards left little room for the graceful concrete spans that characterized European bridgebuilding at the time. It would not be until highway bridge construction eclipsed railroad work in the 1890s that long-span concrete arches would come to the fore in America.

One aspect that all long-span concrete arches shared was their open spandrel design. For shorter spans, engineers typically employed filled spandrel arches, with the roadway supported by earth fill poured over the continuous arch ring. But these would be inordinately heavy over long spans, so engineers used open spandrel arches, which substituted a series of concrete columns for the earth fill, on long spans. The earliest open spandrel arches employed single, relatively thin arch ribs that extended continuously over the width of the bridge. Around 1910 engineers began to experiment with multi-rib arches that used several individual ribs in lieu of continuous ribs. There were several advantages to this new structural form. First, less material was used in the individual ribs. Additionally, the floor of a multi-rib bridge could be supported by a single row of columns on each rib, whereas on a continuous-rib design, several rows of columns or even continuous

[93] "The Present Status of Reinforced Concrete Bridges," *Engineering Record* (13 August 1910), 169-170

walls were necessary to distribute the weight of the deck over the arch rib. Finally, on ribbed-arch bridges, the outer edge of the floor could be cantilevered beyond the outside ribs, allowing for narrower sub-deck configurations with narrower, more economical abutments.

After 1905 concrete bridge construction in America experienced a marked increase, due largely to the efforts of one engineer, Daniel B. Luten of Indianapolis. According to bridge historian James L. Cooper, "Daniel B. Luten did more than any other single person to advance the movement from concrete-steel to reinforced concrete bridge design." Patterned loosely after the patented arch reinforcing design of Josef Melan, the Luten arch featured a filled spandrel configuration with a highly elliptical profile [Figure 117]. Luten's arches were clearly innovative. They were sophisticated in their reli-

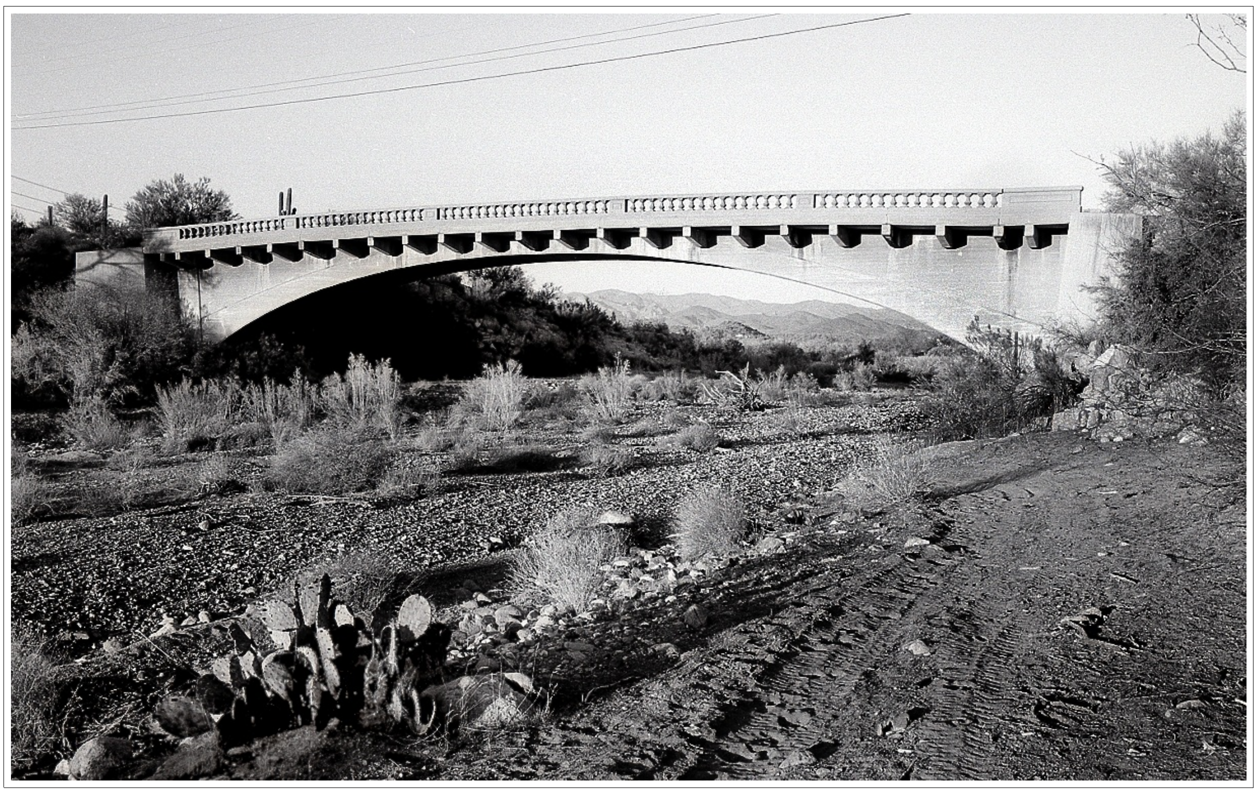

Figure 117. Queen Creek Bridge (08440), Pinal County, 2002.

ance on steel reinforcing and allowed relatively thin concrete sections at midspan. "The Luten System combines numerous improvements in arch reinforcement and construction," Luten stated in a 1908 brochure, "increasing the strength and durability of the structure, and decreasing its cost. Great strength combined with minimum material, resulting in low cost, has been the constant aim in these improvements."[94] In an engineering article Luten explained his arch philosophy:

> An arch of concrete reinforced with embedded steel has all the permanence of stone; in fact it is more permanent than the usual building stones, and has none of the limitations of steel, such as corrosion and crystallization; for concrete is but slightly affected by the elements, and the embedded steel is protected from rust and vibration. No painting or repairs are ordinarily required, and inspection is superfluous. A properly-designed reinforced-concrete arch will be in equilibrium under the fixed load. Reinforcement will be required in the arch ring to resist moving load stresses only, and the moving loads are small in comparison with the fixed load. Such a structure, therefore, displays its material in an efficient form, and because of its useful application presents a beautiful appearance. Everyone knows that concrete is a material strong in compression. Its use in the arch without ornamentation, consequently appeals to the eye. This is wholly apart from the relation of the bridge to its surroundings, in which harmony must be secured ordinarily by ornamentation of spandrels and railings. There is no harmony, for example, in adopting a segmental curve or parabolic arc for an earth-filled arch merely because it carries railway loading, when such curves are not the curves of equilibrium, for the loading.
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> Since the concrete arch is of pleasing form when properly designed, all that is necessary to make it harmonize with its surrounding is to limit the design to dignified details for rugged surroundings, and to embellish it with ornamentation for cultivated surroundings. No other bridge structure harmonizes so readily with its surroundings, no matter what they may be. . . For spans of less than 100 ft., dignity of design can usually be best secured for an arch bridge of moderate rise by the use of the earth-filled type with solid spandrels. But a semi-circular arch can hardly be made to present a satisfactory appearance with solid spandrels, unless the depth of load over the crown be proportional to the rise, not an economical arrangement. For spans greater than 100 ft., especially with great rise, the open-spandrel is usually to be preferred, and this accords fairly well with economy in this country, at the present cost for labor and materials.[95]

The key to Luten's arches lay in the reinforcing, which he patented. He received his first U.S. patent for steel reinforcing in 1900 and over succeeding years took out a series of wide-ranging patents for reinforced concrete arches. By the 1920s Luten had obtained nearly fifty patents, covering virtually all aspects of concrete arch construction. "The Luten System is the result of eight years of experience in the design and erection of reinforced concrete arches," Luten stated in 1908. "Upwards of forty improvements have been made for the purpose of decreasing its cost and increasing its strength, until now we have a stronger arch by fifty per cent than any other type that can be erected at the same cost. We have been to great expense in developing this structure and in advertising its advantages. We have consequently applied for patents on every improvement, and we now own more cost-saving patents on reinforced concrete arches than all other builders."[96]

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[94]Topeka Bridge & Iron Company, *Reinforced Concrete Bridges: Luten Patents Owned by National Bridge Company* (Topeka, Kansas: D.B. Luten, 1908), 115.

[95]Daniel B. Luten, "Arch Design; Specialization And Patents," *Journal of the Western Society of Engineers* XVII: 7 (September 1912), 579-581.

[96]Topeka Bridge & Iron Company, 129. The brochure outlined the royalty procedure:

> The steel reinforcement in our bridges, to be effective, must be of good quality and workmanship and properly placed in the arch. We will furnish the steel as specified, with the working drawings and engineering advice and

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Luten's patents were so wide-ranging that it was almost impossible for a contractor to build a reinforced concrete arch without infringing on one of his designs. For several years in the early 20th century, Luten virtually controlled the concrete bridge industry in America. He protected his patents aggressively, demanding royalty payments from companies such as the Pueblo Bridge Company of Colorado, N.M. Stark in Iowa and the Topeka Bridge & Iron Works of Kansas or collecting payments from the raft of lawsuits that his attorneys filed around the country. Luten's grip on the industry became so onerous that many in the engineering, construction and legal professions joined in protest in the 1910s. Finally, in 1918 his dominance of the industry was broken in an Iowa court when many of his patents were ruled invalid. Luten continued designing and building concrete arches into the 1920s, but his dominance in the industry had been broken. As a result, with royalties no longer being paid to Luten by bridge companies, the reinforced concrete arch received increased use as a vehicular bridge type in America.

Arizona followed national trends in the construction of its reinforced concrete arches. The first arches were relatively short-span structures with filled spandrel designs. The three oldest datable vehicular bridges in Arizona (the Alchesay Canyon Bridge (**01532** [Figure 6]) and the Solomonville Road Overpasses (**08150** and **08151** [Figure 4]) are concrete arches. The second concrete bridge built by the Territorial Engineer (the Lowell Arch Bridge —**00130** [Figure 10]) was also a filled spandrel arch. The Tempe Bridge [Figure 12], Arizona's first nationally noteworthy concrete arch bridge, involved both filled and open spandrel configurations. "The original plans and specifications called for a nine span solid arch ring bridge 1,225 feet in length," State Engineer Lamar Cobb stated. "Later these plans and specifications were revised to call for an eleven span arch rib type bridge for 18-foot roadway with open spandrel walls."[97]

During the 1910s the State of Arizona contracted for several Luten arches. These structures were built sometimes by the Topeka Bridge and Iron Company and sometimes by local contractors. The first Luten arch in the state was the Canyon Padre Bridge [Figure 37], a 140-foot span built in 1914 in Coconino County. These ranked among the longest Luten arches ever built in the United States. In fact the Holbrook Arch Bridge [Figure 118], with a 174-foot span, was probably the longest Luten arch ever built. The last Luten arch constructed in Arizona was probably the Mineral Creek Bridge, a 125-foot span built circa 1923.

In a move to provide an alternative to the Luten arch for long-span applications, the AHD bridge department in 1919-1920 designed three almost identical open-spandrel concrete arches. The Cienega Bridge (**08293** [Figure 59]), a 146-foot arch with a concrete girder viaduct over a branch of the Southern Pacific Railroad, was built on the Borderland Highway in Pima County. The other bridges were located over Queen Creek in Pinal County and Hell Canyon in Yavapai County. The design of the Hell Canyon Bridge [Figure 68] was later

the license to erect any particular bridge for an agreed amount dependent upon the design, which will be named in the specifications, thus throwing our plans open to general competition. Or we will supply the working drawings and the license for a royalty of ten per cent of the contract.

[97]*Report of the State Engineer*, 1912-1914, 155.

changed, but the Cienega Bridge and Queen Creek Bridge [Figure 53] were constructed as drawn in 1920-1921. The bridges proved expensive and difficult to erect, however, and the highway department shelved the design permanently. The Mill Avenue Bridge, (**09954** [Figure 85]) built in 1930-1931 over the Salt River in Tempe, was a special situation, which would be the only other open spandrel arch designed by AHD.

Figure 118. Holbrook Arch Bridge, Navajo County, 2003.

The Arizona State Engineer's Office used Luten arches and open spandrel arches for long-span applications, but for short- to medium-span concrete arches the engineers developed another standard design. This featured a filled spandrel configuration, with the roadway cantilevered beyond the spandrel walls and reinforcing clustered in a manner similar to Luten's patent. The major difference between the Luten arch and what the highway department termed as its "common arch" was the arch profile. Luten's bridges were distinguished by their distinctive horseshoe shape. The highway department's common arches were more truly elliptical.

The oldest AHD common arch found in the state is the Devil's Canyon Bridge [Figure 52], a well-proportioned structure built in 1921-1922 on the Miami-Superior Highway. The Devil's Canyon Bridge was soon followed by other common arches, including the Lynx Creek Bridge (**08256**) and the Verde River Bridge (**08236** [Figure

119]) in Yavapai County, the Pine Creek Bridge (**00031** [Figure 120]) on the Apache Trail in Maricopa County, and the Fossil Creek Bridge (**03215**) in Gila County. The concrete arch as a structural type was eventually superceded by other, more efficient concrete bridge designs. Other than the Mill Avenue Bridge (**09954** [Figure 85]) and the Arizona Spillway Bridge (**03003**), the latter built as part of the Boulder Dam, only a few concrete arches were built in Arizona during the 1930s and 1940s.

Figure 119. Verde River Bridge (08236), Yavapai County, 2018.

Significance: For a concrete arch bridge to be considered NRHP eligible, its history and its significance must be definitively documented through archival means. Concrete arch bridges in Arizona may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, this refers to bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of an area. For example, a structure might be significant by its association with a particular route, such as the Borderland Highway, because it was built by the State Highway Department in its formative years, or because it was built by a federal Depression-era relief program.

A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Arizona qualify under Criterion C as structures of engineering significance. This can encompass a broad range of considerations. For instance, a bridge can qualify under Criterion C as a well-preserved example of a common type, or as a unique or unusual type.

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Figure 120. Pine Creek Bridge (00031), Maricopa County, 2018.

The only concrete arch bridge in Arizona that would have been considered nationally significant was the Tempe (Ash Avenue) Bridge, which has subsequently been demolished. Those dateable concrete arches with physical integrity that were built by the territorial or state engineers or the Arizona Highway Department are generally considered to have state-level significance. Most of the locally built concrete arches are also considered eligible on a state level, by virtue of their significant features. Otherwise, small-scale arches built by local entities are considered locally eligible. Superlative concrete arch bridges include:

Lowell Arch Bridge	(Cochise)	earliest territory-built arch
Canyon Padre Bridge	(Coconino)	earliest Luten arch
Solomonville Road Overpasses	(Greenlee)	earliest and only toll-road arches
Gila River Bridge	(Greenlee)	well-preserved two-span Luten arch
Alchesay Canyon Bridge	(Maricopa)	earliest dateable arch
Mill Avenue Bridge	(Maricopa)	longest multiple-span arch
Holbrook Bridge	(Navajo)	longest Luten arch
Cienega Bridge	(Pima)	one of two oldest AHD open-spandrel arches
Winkelman Bridge	(Pinal)	well-preserved, multiple-span Luten arch
Queen Creek Bridge	(Pinal)	one of two oldest AHD open-spandrel arches
Devil's Canyon Bridge	(Pinal)	oldest AHD common arch

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Significance Criteria

Criterion A: In 1912 the Arizona State Legislature established the State Engineer's Office, and this evolved into the State Highway Department in the 1920s. Several concrete arch bridges were designed by the State Engineer or the Highway Department in the 1910s, 1920s and 1930s, and many remain in place today. Subject bridges may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. According to *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation*, "To be considered for listing under Criterion A, a property must be associated with one or more events important in the defined historical context. Criterion A recognizes properties associated with single events, such as the founding of a town, or with a pattern of events, repeated activities, or historic trends, such as the gradual rise of a port city's prominence in trade and commerce. The event or trends, however, must be clearly important within the associated context: settlement, in the case of the town, or development of a maritime economy, in the case of the port city. Moreover, the property must have an important association with the event or historic trends, and it must retain historic integrity."[92]

Bridges eligible for National Register listing under Criterion A most often have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. These structures would be considered eligible either under the area of significance of Transportation (the process and technology of conveying passengers or materials) or Exploration/Settlement (the investigation of little known regions; the establishment and earliest development of new settlements or communities).

To be considered eligible for Criterion A under either of these areas of significance, a bridge must display demonstrable importance, whether as a singular example or as a representative example of its specific area of significance. Singular examples, for instance, may form important crossings over major waterways, such as the Gila or the Colorado Rivers; bridges that facilitated the opening of definable geographic areas; structures, such as major viaducts in urban areas, that impacted the social fabric of their surrounding area; or bridges that precipitated, or resulted from, important trends in Arizona Department of Highways administration. Representative examples may be bridges that function as well-preserved, integral parts of highway systems. Generally speaking, minor highway structures (e.g., small-scale grade separations, culverts or bridges on an interstate highway) are not considered individually eligible for listing under Criterion A but potentially as contributing resources to nomination of a larger linear resource or district.

Criterion B: A bridge may, in addition, be eligible under Criterion B for its association with a significant person whose specific contributions to history can be identified and documented. "Persons 'significant in our past' refers to individuals whose activities are demonstrably important within a local, State, or national historic context," states *Bulletin 15*. "The criterion is generally restricted to those properties that illustrate (rather than

[92] U.S. Department of the Interior, National Park Service, *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation* (Washington, D.C.: U.S. Department of the Interior, 1990), 12. The following section relies on this publication and U.S. Department of the Interior, National Park Service, *National Register Bulletin 16: How to Complete the National Register Registration Form* (Washington, D.C.: U.S. Department of the Interior, 1990) for discussion of National Register criteria and areas of significance.

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commemorate) a person's important achievements."[93] Consideration of the significance of a bridge under Criterion B involves establishing two aspects—the significance of the individual and the nature and importance of the relationship of the bridge to that person.

Criterion C: Most eligible bridges in Arizona qualify, at least in part, under Criterion C as structures of architectural or engineering significance. According to *National Register Bulletin 15*:

> To be eligible under Criterion C, a property must meet at least one of the following requirements:
> - Embody distinctive characteristics of a type, period, or method of construction.
> - Represent the work of a master.
> - Possess high artistic value.
> - Represent a significant and distinguishable entity whose components may lack individual distinction.
>
> The first requirement, that properties "embody the distinctive characteristics of a type, period, or method of construction," refers to the way in which a property was conceived, designed or fabricated by a people or culture in past periods of history. "The work of a master" refers to the technical or aesthetic achievements of an architect or craftsman. "High artistic values" concerns the expression of aesthetic ideals or preferences and applies to aesthetic achievement. Resources "that represent a significant and distinguishable entity whose components may lack individual distinction" are called "districts."[94]

Bridges eligible under Criterion C generally fall under one or two areas of significance: Architecture (the practical art of designing and constructing buildings and structures to serve human needs) and Engineering (the practical application of scientific principles to design, construct and operate equipment, machinery, and structures to serve human needs).

Specific requirements under Criterion C:

1. Early and/or representative concrete arch bridge: Although they are generally considered among the highest forms of bridge design, concrete arches were never built in abundance in Arizona. Those arch bridges with spans in excess of 30 feet (i.e., true bridges and not arch culverts) that remain with a high degree of structural integrity are sufficiently rare and noteworthy that most are considered significant.

2. Representative example by an important engineer, architect or bridge company: Proprietary concrete arches such as those developed by Daniel Luten are considered a significant aspect of bridge design in the early 20th century.

[93] *Ibid.*, 14.

[94] *Ibid.*, 17.

3. Bridge with exceptional aesthetic merit: Most bridges built by the state are strictly utilitarian. Occasionally, however, a structure stands out by virtue of its design or because of the quality displayed in its construction. This does not include standard-design concrete guardrails by the Highway Department. The interrelationship of a bridge and its site can also have aesthetic value as well.

Criterion D: Subject bridges may be eligible for listing in the National Register under Criterion D for their potential to reveal important information. According to *Bulletin 15:*

> Criterion D encompasses the properties that have the potential to answer, in whole or in part, questions about human history that can only be answered by the actual physical material of cultural resources. The most common type of property nominated under this Criterion is the archaeological site (or a district comprised of archaeological sites). Buildings, objects, and structures (or districts comprised of these property types), however, can also be eligible for their information potential.
>
> Criterion D has two requirements, which must *both* be met for a property to qualify:
> - The property must have, or have had, information to contribute to our understanding of human history or prehistory, and
> - The information must be considered important.
>
> Under the first of these requirements, a property is eligible if it has been used as a source of data and contains more, as yet unretrieved data. A property is also eligible if it has not yielded information but, through testing or research, is determined a likely source of data.[95]

Registration Requirements: The general period of significance for concrete arch bridges in Arizona begins in 1905, the date for the state's earliest example of this structural type. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Although the functionality of many of the bridges continues to the present—with the majority still in active use—the period of significance for purposes of this study, generally ends in 1978, the cutoff date for the statewide historic bridge inventory. Reinforced concrete bridges from the subject group are considered significant if they can be definitively documented and they exhibit noteworthy physical or historical features and/or integrity. The issue of physical integrity of a bridge's character-defining elements (listed above) is important for bridges significant under Criteria A, B or C (and to a lesser degree, Criterion D), but it is particularly important for structures eligible under Criterion C for their representation of structural or architectural trends.

Alterations that diminish the structure's integrity often can disqualify it from National Register eligibility. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design. Integrity of the structure's historic materials, design and setting is essential for a bridge to qualify for the National Register under any criterion. Since none of

[95] *Ibid.*, 21.

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Arizona's concrete arch bridges has been moved, integrity of location is a given. Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains its character-defining features. Character-defining features of an arch structure include the concrete superstructure, deck, railing, and abutments, wingwalls and—if present—piers. The term "deck" in this instance is defined as the traffic-carrying component of a bridge, which is supported by the bridge's superstructure. In most bridges it is a discreet structural element, built and maintained separately from the superstructure.

Alterations to the individual elements of a reinforced concrete bridge have a relative impact on the design integrity of the bridge itself. For instance, widening a structure by adding extensions onto one or both sides and replacing the guardrails impinges more on a bridge's integrity than patching the concrete surfaces or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction. Replacement of guardrails, even when original steel beam or tube guardrails are replaced with other steel guardrails (e.g., Thrie beams) outside of the period of significance generally represents a diminution of a bridge's physical integrity. The installation of steel beams over original guardrails is considered reversible and represents a less serious alteration than outright replacement. Replacement of original steel guardrails with concrete Jersey barriers represents the worst loss of guardrail integrity. Installation of an asphalt overlay over the original concrete deck is generally considered to be a maintenance-related activity, which does not seriously diminish a bridge's physical integrity.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the highway's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge under consideration conveys a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or person that characterize it as historically significant. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association. Moreover, not all aspects of integrity must be present in equal measure.

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2 Property Type: Concrete Culverts, Slabs, Girders and Rigid Frame Bridges

Description: The most common structural type for drainage structures on Arizona highways is the reinforced concrete box culvert. Box culverts are rectangular-barreled spans with integrally cast walls, ceilings, floors and wingwalls. They are generally located at minor streams or drainage channels under the roadway. Typically spanning less than twenty feet, a concrete box culvert could be built in a single-barrel iteration or ganged in a multiple-barrel configuration. (Most of the culverts in the historic bridge inventory feature more than one span, to qualify as bridges under the FHWA's 20-foot minimum structure length requirement.) A culvert is bound by angled or straight wingwalls at the upstream and downstream faces and is constructed with the roadway lying directly over the concrete structure or beneath varying-depths of earth overburden. "The length of culverts should be sufficient to prevent the embankment material from encroaching on a culvert end," stated AASHO in its 1965 *Standard Specifications*. "Headwalls and endwalls with cutoff walls and aprons are used to protect the fill slopes and stream beds from erosion and to secure the culvert end against hydraulic forces. Where needed, debris control devices should be constructed to prevent clogging. If backfill and embankment materials are subject to piping, consideration should be given to the use of cutoff walls or impervious material placed at the entrance."[96]

Among the structures on Arizona highways identified by the inventory, there are 2,355 reinforced concrete box culverts. These share common characteristics, with only relatively small variations in span length, span number, barrel length and degree of skew. All are plain-faced structures, devoid of architectural detailing. A representative concrete box culvert from the study period would feature one to six barrels, with a barrel width and barrel height ranging from 10 to 25 feet. The barrel lengths vary considerably, because the culverts carried from one to six lanes of traffic and sometimes extended over the median between lanes; all are considered representative. Detailing is minimal, with no architectural features beyond a date stamped into the concrete on one of both spandrels. The roadway may be carried directly by the culvert or separated from the concrete culvert structure by earth overburden.

Since the culvert is a rigid frame, with the base formed by the concrete slab that constitutes the barrel floor, the substructure consists of the culvert barrels themselves. Wingwalls that could be considered representative are either perpendicular to the structure or flared from the corners; the tops of most wingwalls are angled downward from the structure. Culverts built in the 1950s and 1960s generally did not incorporate guardrails into their design. Since the 1970s, ADOT has been installing Thrie beam guardrails on all but the widest structures, so that many of the culverts found in the study are bounded by simple Thrie beams on steel or timber supports. These guardrails typically extend beyond the structure itself to form approach guardrails, which are not considered a diminution of integrity.

[96] American Association of State Highway Officials, *Standard Specifications for Highway Bridges* (Washington, DC: AASHO, 1966), 3.

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With its concrete deck and superstructure poured integrally in a single flat sheet over steel reinforcing, the concrete slab is the simplest of the concrete bridge types. A slab bridge incorporates a rigid monolithic concrete slab with embedded steel reinforcing as both the superstructural member and bridge deck. The current FHWA Bridge *Inspector's Reference Manual* marks the distinction between the terms "slab" and "deck," often incorrectly interchanged:

> A deck is the traffic-carrying component of a bridge that is supported by the bridge superstructure, which can be composed of beams (girders), arches, or other structural units. A slab, however, is a superstructural unit supported by a substructure unit, such as an abutment, bent, pier, column, etc. Many of the design characteristics of decks and beams are similar, but the bridge inspector should be mindful of the confusion that can be caused by tendencies to use the terms indiscriminately. In the case of the structures that properly belong in the category of cast-in-place, flat slab bridges, the slab is both the superstructure and the deck.

Common for short spans up to 30 feet in length, slabs offer simplicity of construction and maintenance, and they have the advantage of being able to accommodate skewed crossings. The earliest flat slabs in America date to the end of the 19th century. Technology historian Carl Condit attributes the first flat-slab construction to Swiss engineer Robert Maillart in 1900, but American builders had been constructing small-scale slab bridges using empirical methods a few years before that. These short-span structures were built with the steel reinforcement along the bottom edge, in what eventually became a conventional system that acted one way in flexure. This one-way flexure tended to limit the bridges to short-span applications.

Between 1905 and 1909, however, civil engineer C.A.P. Turner experimented with alternative means of reinforcement, creating structures that acted in flexure in both directions. In an article in *Cement Age* in January 1910, Turner described four reinforced concrete bridges built the previous year in Minneapolis, which used his trademark "mushroom head" column design. Turner's work led directly to the advancement of flat-slab technology for longer spans. Reinforced concrete slab bridges—particularly those with one-way flexure systems—gained popularity in the 1910s. Although two-way flat slabs were used frequently in buildings, their use on bridges soon diminished.

With the endorsement of the Bureau of Public Roads and the American Concrete Institute, the highway departments of most states adopted concrete slabs among their standard designs. These structures typically featured relatively short, one-way spans, applicable in two-foot span increments up to a maximum length of 20 or 30 feet. These were starkly utilitarian structures; architectural detailing, if any, was limited to the concrete parapets or guardrails. When used for short crossings, these bridges proved to be economical and easy to build. Increasing the span length meant increasing the deck thickness, which increased the materials cost. And the relatively short spans meant that supporting piers were necessary for anything beyond the smallest streambed.

During the 1930s and early 1940s, standard designs were promulgated by AASHO and various trade organizations, and drawings for slab bridges could be readily found in engineering texts and technical circulars distributed by government highway agencies. Easily built, the slab was perceived as an economical bridge type that offered relative stiffness and resistance to temperature-related expansion and contraction. Moreover, it offered a high degree of flexibility and could by widened simply by extending the existing slab over lengthened abutments and piers. The early slabs were all simply supported, which is to say, the individual spans were poured and supported by the abutments and piers, independent of adjacent spans. Later advances in engineering sophistication and reinforcing technology allowed the slabs to be poured continuously over the piers, allowing greater span length and materials economy for multiple-span structures.

After World War II and into the 1950s and 1960s, the Arizona Highway Department continued its common use of concrete slabs for short-span applications. These structures differed relatively little from their predecessors, offering only incremental changes to the reinforcing and guardrails to accommodate heavier and faster highway traffic. The guardrails were invariably standard-plan, which in the 1950s and 1960s meant steel beams or rails on cast-steel supports bolted either to the spandrel walls of the concrete superstructure or to concrete curbs that flanked the roadway.

A concrete girder bridge [Figure 121] looks something like a slab and features parallel lines of concrete beams poured integrally with the deck slab. Also called concrete T-beams or concrete slab-and-girder bridges, girder structures are generally built with the beams aligned beneath the roadway. A step up from the slab in terms of technological advancement, girders could economically reach longer spans than slabs. Both

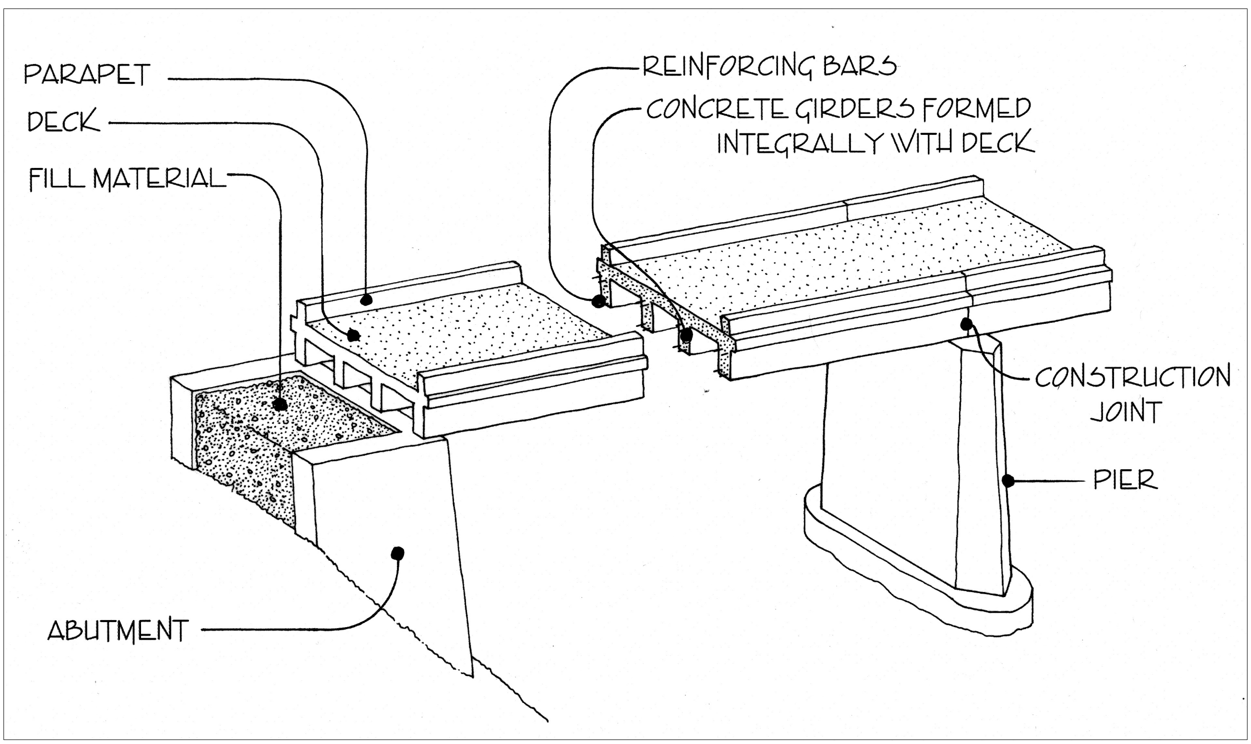

Figure 121. Concrete girder bridge diagram.

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structural types were built in single-span iterations with simply supported bearing, or with multiple spans strung together either simply or continuously over concrete piers. The main advantage of concrete girders—like slabs—are their structural rigidity and ease of subsequent widening by adding girders onto the existing bridges. Like concrete slab bridges, Arizona's concrete girder bridges are plain-faced structures, which employ AHD standard concrete, metal beam or tube guardrails, attached either to the tops of the concrete curbs or to the concrete spandrels. The deck is reinforced concrete, with or without asphalt overlay. According to the current FHWA *Bridge Inspector's Reference Manual*:

> Reinforced concrete girder bridges (non-prestressed) generally consist of cast-in-place, monolithic decks and girder systems. The primary members of a girder bridge are the girders, the deck, and, in some cases, floorbeams. The deck or travel surface is cast on top of the girders in deck girder bridges, and the deck is cast between the girders in through girder bridges. In either case, the deck slab does not contribute to the strength of the girders and only serves to distribute live loads to the girders. If floorbeams are used, they are part of the superstructure and not the deck. In through girder bridges, the deck is cast between the girders and the girders extend above the deck, thus forming the bridge's parapets. This arrangement of members makes it virtually impossible to widen a through girder bridge.

The first reinforced concrete girder bridge was built in France in 1893. Spans of up to 85 feet appeared by 1904 in Europe, the leader in this design, and in America concrete girders began to receive acceptance for highway use between 1900 and 1910. Because concrete acts well under compressive loading but poorly under tension, concrete slabs and girders rely heavily on steel reinforcing along their lower surfaces, where the tensile stress is greatest. This reinforcing typically takes the form of square, twisted or deformed reinforcing bars that extend the length of the span. While concrete slabs are generally limited in span length, girders can be built with spans in excess of 100 feet, but in Arizona girder bridges built before the 1950s—other than the earliest two-girder structures—rarely exceeded 50 feet.

The first concrete rigid frame bridge was designed in 1922 by engineer Arthur G. Hayden for the park commission of Westchester County, New York. It was the last major type of cast-in-place concrete bridge developed. Comprised of a concrete beam superstructure tied rigidly to the abutments with steel reinforcing bars, rigid frame bridges differed materially from conventional simply supported spans. "A clear conception of a typical rigid frame concrete bridge may be obtained by first visualizing an ordinary simple span bridge supported by bearing on two abutments," a 1935 concrete manual stated. "If the bearing is replaced with concrete that continues monolithically from the abutments to the deck, the altered structure becomes a frame with rigid corners—a structure generally called a *rigid frame concrete bridge*."[97]

Rigid frame bridges were considered an efficient use of material, best suited for spans of between 40 and 120 feet. They were a relatively inexpensive alternative to steel or concrete girder bridges in the 1930s and 1940s. Rigid frame bridges could be built in single-span or multiple-span iterations. The cross section of the beams or vertical sections were usually shaped like I-beams or boxes, but there could be great variety of shape. The horizontal component or slab was often haunched, thicker at the ends than at the middle, presenting the

[97] *Analysis of Rigid Frame Concrete Bridges* (Chicago: Portland Cement Association, 1935), 5.

appearance, if not the function, of a shallow arch. Because its construction was relatively labor-intensive, this bridge configuration became popular for federal relief programs in the 1930s. Both picturesque and practical, the flat-arch design appealed to proponents of urban beautification, and rigid frames found widespread use in city parks and landscaped boulevards. By 1935 more than 300 rigid frames had been built in America, most in urban areas. Early rigid frame bridges were limited in span length, but by 1937 the Schmitz Park Bridge in Seattle featured a single 175-foot span.

Concrete rigid frame bridges were well suited to urban applications with large traffic volumes and moderate span lengths, where rigidity under load is of prime importance. Their design was easily changeable as well. Using a set profile and reinforcing configuration, a series of bridges could be built over a wide range of spans. They could be readily skewed to accommodate angled intersections. Their flat or slightly arched undersides provided under-bridge clearance at grade separations in constricted urban spaces. And they could be later widened to accommodate increased traffic by extending the deck and abutments. Further, the bridges could be cast plainly or adorned with a variety of applied concrete or metal ornamentation.

Figure 122. Broadway Bridge, Yavapai County, 2018.

In Arizona the territorial engineer built several reinforced concrete slabs between 1909 and 1912. After 1912 the state engineer continued using flat slabs for short-span applications, and in 1919 the state engineer's office drafted a set of standard plans for small-scale concrete bridges, to be used on state and county roads. Designed to BPR specifications, these concrete slabs ranged from 6 to 24 feet in span length. The state's earliest dateable concrete slab bridge is a small span built in 1909 by the U.S. Reclamation Service as part of the Laguna Dam [Figure 7]. Although ostensibly a slab structure, this bridge features an arched roadway, blurring the structural difference between slab and arch. One of the state's earliest and most distinguished flat slab bridges is the Broadway Bridge in Clarkdale (**08488** [Figure 122]), a five-span structure built in 1917. The state engineer's office experimented briefly in the 1910s with what it called a "rail top" slab design. Featuring a concrete slab poured in place over a series of parallel steel railroad rails, this represented a classic one-way slab configuration. A handful of rail top slab bridges, including the Jacks Canyon Bridge [Figure 123] and the Old Trails Wash Bridge (**08594** [Figure 48]), remain in place. The experiment lasted only a brief time, however, before the state reverted to more conventional steel reinforcing bars, as illustrated by the Pinal Creek Bridge in Globe (**09711** [Figure 124]).

Figure 123. Jacks Canyon Bridge, Navajo County, 2018.

During the 1930s and early 1940s, the flat slab received widespread use, both in Arizona and around the country. Standard designs were promulgated by AASHO and various trade organizations, as the slab was perceived as economical bridge type that offered ease of construction, resistance to temperature cycles, stiffness and resistance to shrinkage. The earliest slabs were all simply supported, which is to say the individual spans were supported by the abutments and piers, independent of adjacent spans. Later advances in engineering sophistication and reinforcing technology allowed the slabs to be poured continuously over the piers, allowing greater span length and materials economy for multiple-span structures. The Arizona Highway Department employed continuous-span slabs on its bridges after World War II, with the slab thickness increased over the supports.

The first concrete girder bridge of note constructed in Arizona was the multiple-span structure over the Gila River at Florence, built by the Territorial Engineer in 1910 [Figure 9]. This was followed by immense girder structures over the Gila River at Antelope Hill (**abd.**), over the Agua Fria River at Coldwater (**demolished**) and over the Santa Cruz River near Beyerville (**08166** [Figure 24]). These earliest structures employed two deep girders per span cast integrally with the deck. This allowed relatively long span lengths and thus reduced

Figure 124. Pinal Creek Bridge (09711), Gila County, 2018.

the number of concrete piers, but the long spans proved uneconomical in their use of concrete and steel. When the highway department developed a set of standard plans for concrete girders in 1919, AHD engineers dropped the two-girder design in favor of a new span with three somewhat shallower beams. "The slab spans become uneconomical for spans greater than about 24'," State Bridge Engineer Merrill Butler stated in 1920. "For greater spans, the three girder deck is the more economical up to about 50'."[98]

The state's implementation of this configuration proved short-lived, however. According to Butler's successor W.C. Lefebvre in 1922, "A set of 4-girder reinforced concrete decks, ranging in span from 20 feet to 40 feet, have been worked up and are being used in the place of the old 3-girder standard plan which has become obsolete. These new spans, although designed for heavier loads than the old, are more economical in materials and have been used exclusively in the past two years where such spans were required."[99] AHD engineers designed only ten three-girder bridges before shelving this standard, and fewer were actually constructed. Only two are known to have survived—the Cordes Bridge (**08249** [Figure 54]) and a bridge over Granite Creek (**00042** [Figure 50]) in Yavapai County. The four-girder design, illustrated by the Cottonwood Draw Bridge (**00060** [Figure 125]) formed the standard used through the 1920s, 1930s and 1940s.

In the 1930s AHD experimented with rigid frame design, building a few relatively small-scale structures at rural locations around the state. Where this structural type found its voice in Arizona was for urban grade

98 *Fourth Biennial Report of the State Engineer*, 65.

99 *Fifth Biennial Report of the State Engineer*, 57.

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Figure 125. Cottonwood Draw Bridge (00060), Cochise County, 2018.

separations built during the 1930s and early 1940s. Structures such as the Winslow Underpass (**00194** [Figure 94]), the 17th Avenue Underpass (**07770** [Figure 126]), and the Washington Street Underpass (**00535**), combined rigid frame structures with applied ornamentation to create successful architectural expressions. Although constructed during the Depression, these structures were all funded using traditional contracting procedure and built by private companies under contract with AHD, rather than work relief agencies.

Figure 126. 17th Avenue Underpass, Maricopa County, 2017.

Significance: The State Engineer's Office delineated standardized designs for concrete box culverts and slab and girder bridges as early as 1912, updating them occasionally in subsequent years. As the state assumed greater responsibility for bridge design and construction, these structural types received widespread use on Arizona's roads in the 1910s, 1920s and 1930s. There were no noteworthy technological advancements made on these structural types during the 1940s. In the 1950s AHD engineers were able to increase slab span lengths by thickening the slab depth over the piers.

Concrete box culverts and slab, girder and rigid frame bridges in Arizona may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. For example, a structure might be significant by its association with a particular route, such as the Ocean-to-Ocean Highway, because it was built by the State Highway Department in its formative years, or because it was built by a federal Depression-era relief program. A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Arizona qualify under Criterion C as structures of engineering significance. This can encompass a broad range of considerations. For instance, a bridge can qualify under Criterion C as a well-preserved example of a common type, or as a unique or unusual type.

None of Arizona's concrete girder, slab or rigid frame bridges are considered to have national significance. Those dateable structures with physical integrity that were built by the territorial or state engineers or the Arizona Highway Department are generally considered to have state-level significance. Most of the locally built concrete arches are also considered eligible on a state level, by virtue of their significant features. Otherwise, small-scale arches built by local entities are considered locally eligible. Superlative concrete girder, slab and rigid frame bridges include:

Concho Bridge	(Apache)	earliest and only through girder
Water Holes Canyon Bridge	(Coconino)	well-preserved example of singular structural type
Pinal Creek Bridge	(Gila)	well-preserved early AHD multiple-span slab
Negro Canyon Bridge	(Greenlee)	well-preserved prototype of slab design
Rattlesnake Canyon Bridge	(Greenlee)	well-preserved prototype of girder design
17th Avenue Underpass	(Maricopa)	well-preserved Depression-era rigid frame
Winslow Underpass	(Navajo)	well-preserved Depression-era rigid frame
Stone Avenue Underpass	(Pima)	well-preserved Depression-era rigid frame
Sacaton Dam Bridge	(Pinal)	well-preserved multiple-span girder
Casa Grande Underpass	(Pinal)	well-preserved Depression-era rigid frame
Santa Cruz River Bridge	(Santa Cruz)	only intact two-girder bridge
Old Trails Wash Bridge	(Mohave)	well-preserved early example of uncommon slab

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Jacks Canyon Bridge	(Navajo)	well-preserved early example of uncommon slab
Side Hill Viaduct	(Navajo)	well-preserved example of singular slab type
Hell Canyon Bridge	(Yavapai)	outstanding early multiple-span example of girder
Granite Creek Bridge	(Yavapai)	well-preserved three-girder bridge
Cordes Bridge	(Yavapai)	well-preserved three-girder bridge
Broadway Bridge	(Yavapai)	well-preserved early slab bridge
Antelope Hill Bridge	(Yuma)	earliest girder bridge

Registration Requirements: The Registration Requirements for concrete slab, girder and rigid frame bridges are similar to those for concrete arch bridges, discussed in pages 138-140. The general period of significance for concrete slab, girder and rigid frame bridges in Arizona begins in 1909, the date for the state's earliest datable example of this structural type. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Although the functionality of many of the bridges continues to the present—with the majority still in active use—the period of significance for purposes of this study, generally ends in 1978, the cutoff date for the state-wide historic bridge inventory. Reinforced concrete bridges from the subject group are considered significant if they can be definitively documented and they exhibit noteworthy physical or historical features and/or integrity. The issue of physical integrity of a bridge's character-defining elements (listed above) is important for bridges significant under Criteria A, B or C (and to a lesser degree, Criterion D), but it is particularly important for structures eligible under Criterion C for their representation of structural or architectural trends.

Alterations that diminish the structure's integrity often can disqualify it from National Register eligibility. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design. Integrity of the structure's historic materials, design and setting is essential for a bridge to qualify for the National Register under any criterion. Since none of Arizona's concrete arch bridges has been moved, integrity of location is a given. Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains its character-defining features. Character-defining features of an arch structure include the concrete superstructure, deck, railing, and abutments, wingwalls and—if present—piers. The term "deck" in this instance is defined as the traffic-carrying component of a bridge, which is supported by the bridge's superstructure. In most bridges it is a discreet structural element, built and maintained separately from the superstructure.

Alterations to the individual elements of a reinforced concrete bridge have a relative impact on the design integrity of the bridge itself. For instance, widening a structure by adding extensions onto one or both sides and replacing the guardrails impinges more on a bridge's integrity than patching the concrete surfaces or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction. Replacement of guardrails, even when original steel beam or tube guardrails are replaced with other steel guardrails (e.g., Thrie beams) outside of the

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period of significance generally represents a diminution of a bridge's physical integrity. The installation of steel beams over original guardrails, left in place, is considered reversible and represents a less serious alteration than outright replacement. Replacement of original steel guardrails with concrete Jersey barriers represents the worst loss of guardrail integrity. Installation of an asphalt overlay over the original concrete deck is generally considered to be a maintenance-related activity, which does not seriously diminish a bridge's physical integrity.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the highway's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge under consideration conveys a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or person that characterize it as historically significant. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association. Moreover, not all aspects of integrity must be present in equal measure.

Integrity of the structure's historic materials, configuration and setting is essential for a bridge to qualify for the National Register under any criterion. Since none of Arizona's concrete slab, girder or rigid frame bridges has been moved, integrity of location is a given. Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains the features that defined its character during its historic period. Character-defining features of a girder, slab or rigid frame bridge include the concrete superstructure, deck, railing or parapet, and abutments, wingwalls and—if present—piers. The term "deck" in this instance is defined as the traffic-carrying component of a bridge, which is supported by the bridge's superstructure. In most bridges it is a discreet structural element, built and maintained separately from the superstructural beams or truss. In the case of concrete slabs and concrete girders, however, the deck and the superstructure are one in the same.

Because of their relative simplicity and below-deck superstructures, slabs, girders and rigid frames are generally visually undistinguished, and it is the guardrails that, more than anything, define the character of the bridge from the roadway. Alterations to the individual elements of a slab or girder bridge have a relative impact on the design integrity of the bridge itself. For instance, widening a slab by adding extensions onto one or both sides and replacing the guardrails impinges more on a bridge's integrity than patching the concrete surfaces or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the railroad's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Registration Requirements under Criterion C for concrete culverts, slabs, girders and rigid frames:

1. Early and/or representative concrete box culvert or slab and deck girder bridge: Culverts and slab and girder bridges built before 1925 are sufficiently rare in Arizona that any definitively documented example that has maintained physical integrity is considered eligible for the National Register. Those built after 1925 with definitive documentation are considered significant on the basis of superlative features (e.g., exceptionally long span length, unusual number of spans, uncommonly good state of preservation). Concrete variable-depth slabs or parabolic girders built after 1950 are considered significant if they were prototypes for these structural configurations.

   Concrete box culverts and slab and girder bridges in Arizona tend to have been subsequently widened by adding onto the deck on one or both sides. This widening is considered a serious loss of integrity, especially if it entails the replacement or substantial alteration of one or both guardrails, which are considered character-defining elements. Similarly, the subsequent replacement of one or both guardrails with steel Thrie beams is considered a serious loss of integrity, though the installation of steel beams over original guardrails is considered reversible and represents a less serious alteration.

2. Example of concrete through girder, two- and three-beam concrete deck girder and rail-top slab: Only one concrete through girder bridge (the Concho Bridge (**08480** [Figure 55]) remains intact in Arizona. It is considered eligible for the National Register as a singular example of its structural type. Similarly, only two two-beam deck girder bridges (the Antelope Hill Bridge [Figure 22] and the Santa Cruz Bridge (**08166** [Figure 24]) and two three-beam deck girder bridges (the Cordes Bridge (**08249** [Figure 54] and the Granite Creek Bridge (**00042** [Figure 50]) are still extant. Only three concrete rail-top slabs (Jacks Canyon Bridge [Figure 123], Black Gap Bridge (**08534** [Figure 36]) and Old Trails Wash Bridge (**08594** [Figure 48]) are known to exist. They are all considered eligible for the National Register as the last intact examples of their significant structural types.

3. Early and/or representative concrete rigid frame bridge: Concrete rigid frame bridges built before 1940 are sufficiently rare in Arizona that any definitively documented example that has maintained physical integrity is considered eligible for the National Register. Bridges built after 1940 are considered significant if they can be definitively documented and they exhibit superlative features (i.e., exceptionally long span length, noteworthy architectural treatment, uncommonly good state of preservation). Concrete rigid frame bridges in Arizona tend to have been subsequently altered by installation of steel Thrie beam guardrails. This is considered a serious loss of integrity, though the installation of steel beams over the original guardrails is considered reversible and represents a less serious alteration.

4. Bridge with exceptional aesthetic merit: Most bridges built by the state are strictly utilitarian. Occasionally, however, a structure stands out by virtue of its design or because of the quality displayed in its construction. This does not include standard-design concrete guardrails by the Highway Department. The interrelationship of a bridge and its site can also have aesthetic value as well. Concrete rigid frame bridges, more than any other structural type in Arizona, have been used as monumental structures in urban settings. These are considered significant as uncommon forays into bridge aesthetics by the State Highway Department. The interrelationship of a bridge and its site can also have aesthetic value as well.

3 Property Type: Steel Stringer and Girder Bridges

Description: Steel stringer bridges are the most rudimentary type of all-metal spans. Comprised of several parallel rows of relatively shallow, rolled I-beams placed longitudinally over piers and abutments with a continuous deck laid on top, steel stringer bridges were regularly used by Arizona railroads in the late 19th and early 20th centuries. Also termed multi-beam bridges or I-beam bridges or (incorrectly) steel girder bridges, they were used only rarely by the counties for short-span bridges, often eschewed for similarly scaled concrete bridges. (None of these earliest steel bridges is known to exist.) Substructural support for steel stringer bridges ran the gamut from stone masonry or concrete abutments to timber or steel pile bents. Like timber stringers, steel stringer bridges could consist of single-span structures over minor watercourses, or the spans could be multiplied over piers to cross wider rivers. And like timber stringers, they could be designed and built using standard tables or empirical judgment, without the need for extensive engineering [Figure 127].

Although fabricated in Eastern rolling mills as early as the 1850s, rolled steel beams were not generally used as vehicular bridge superstructures until well into the 20th century. More than any other bridge type, steel stringer technology has depended closely on the capacity of rolling mills that provided the steel. Reliant upon the mills' output of shallow beams, early Arizona stringer bridges were limited to spans shorter than 50 feet. It was necessary, therefore, to use other structural types such as steel plate girders, trusses or concrete arches for crossings requiring greater spans. The industry was able to increase spans to 75 feet in 1928, when the mills began to roll 33- to 36-inch-deep I-beams.

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The longer spans made steel more economical than concrete in many highway applications, signaling the decline of long-span concrete arches in Arizona. Even more than timber stringer or concrete girder bridges, steel stringer structures were flexible in span length, span number, roadway width and substructure configuration. They could be built with simply supported bearing conditions or with the beams extending continuously over the piers. Moreover, they could be subsequently widened simply by extending the abutments to the sides and adding more stringers outside of the original ones. So suitable were steel stringers to widening that they have often been used to widen the decks on other structural types such as concrete girders.

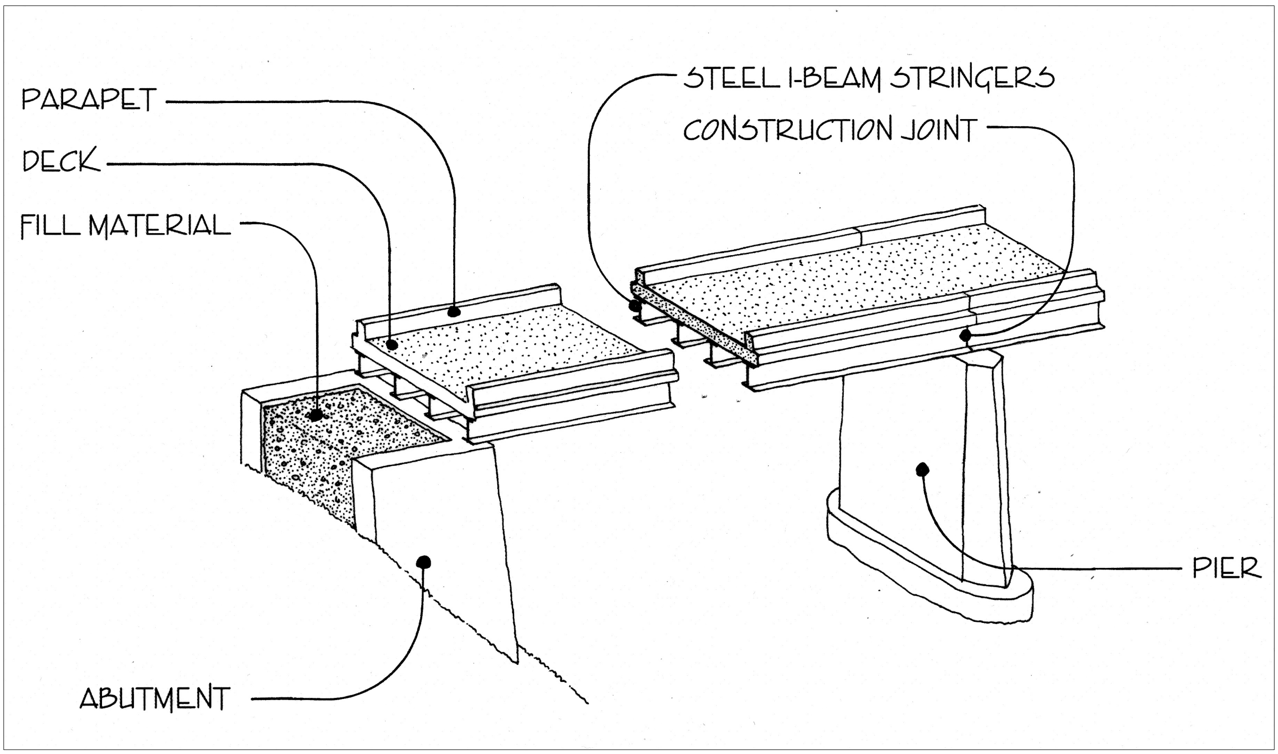

Figure 127. Steel stringer bridge diagram.

Steel girders employ a technology similar to that of stringers, substituting two or more deep-profile beams for the row of relatively shallow stringers. Like concrete girder structures, they could be configured with two or more beams located beneath the roadway (deck girders) or two relatively deep beams on both sides of the roadway (through girders). With their more complicated bearing conditions, beam arrangement and floor system connections, steel girder bridges represent a step up the technological scale from stringers. It was this increased technology—along with relatively heavy superstructural weight and the physical limitation of transporting heavy, factory-fabricated girders—that limited the application of steel girders for highway use in America in the early 20th century.

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The first plate girder bridge in the United States was a 50-foot span built for the Baltimore & Susquehanna Railroad in 1846. Fabricated in the Bolton Station, Maryland, shops of James Millholland, the 14-ton structure was shipped by rail to the site and erected in a piece. Railroads were well suited for girder construction, because they constituted their own transportation system capable of carrying large, heavy loads. By the late 19th century, built-up, riveted plate girders had been put to use on vehicular bridges as well. Their cost of fabrication and difficulty in hauling the heavy, cumbersome girders precluded their widespread use, however. For medium- to long-span crossings, trusses were still the preferred alternative. Since the 1930s, I-shaped plate girders have been used to span beyond the range of rolled I-beams. These were fabricated by riveting flange angles to a web plate and adding cover plates to the top and bottom edges. The most common configuration featured two relatively deep, longitudinal girders joined by transverse rolled I-beam floor beams and topped with a one-way concrete slab.

The earliest girder bridges employed simply supported beams that acted independently over the piers. By the 1930s engineers had begun to carry the beams continuously over the piers, alternating anchor and cantilevered spans. Using either riveted or hinged splices, these long-span structures permitted greater lengths than simply supported beams could provide. By the 1950s, as fabrication and welding techniques improved, welded girders began to replace riveted built-up beams. These typically featured I-shaped girders that increased in web depth over the bearing points. The welding on these earliest structures later proved through ultrasonic testing to be prone to fatigue and stress cracking at the weld lines, however. The use of this type of girder was discontinued in lieu of bolted connections and splices. By the late 1960s steel stringer and girder bridges had been superceded by more efficient prestressed concrete beams. Their recent use has been limited to specialized conditions.

Despite their structural advantages over concrete, steel stringer bridges did not receive widespread acceptance in Arizona until more recent years. Neither the territorial engineer nor the early state engineers developed standard plans for steel stringer bridges, instead preferring concrete for short- and medium-span applications. The earliest dateable steel stringer bridge in Arizona is the Dry Wash Bridge (**00015** [Figure 128]) built by the state engineer in 1923 on the Apache Trail. A single short span supported by stone abutments, it was an anomaly among Arizona bridges.

The Bureau of Public Roads developed the first standard drawings for steel stringer bridges as early as 1917. The earliest I-beam structures featured timber decks, but cast-in-place concrete soon followed. The Arizona Highway Department did not begin erecting steel stringer bridges with any regularity until the 1930s. During the Depression AHD built numerous steel stringer bridges, usually short-span iterations with concrete substructures [Figure 99]. After World War II AHD built steel stringers in abundance with spans of up to 160 feet.

Arizona's earliest steel girder bridges are all railroad structures, either underpasses or, in one case, a railroad bridge converted for vehicular use. During the Depression, the highway department built a handful of steel girders—both simply supported and cantilevered—but it was not until the 1940s and 1950s that the state began

see continuation sheet

building these spans with regularity [Figure 129]. In the early 1960s AHD experimented briefly with long-span, variable-depth welded beams, but only erected a handful of these prototypical structures [Figure 114].

Significance: Steel stringer and girder bridges in Arizona may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. For

Figure 128. Dry Wash Bridge (00015), Maricopa County, 2003.

example, a structure might be significant by its association with a particular route, such as the Apache Trail, or because it was built by the State Highway Department in its formative years. A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Arizona qualify under Criterion C as structures of engineering significance. This can encompass a broad range of considerations. For instance, a bridge can qualify as a well-preserved example of a common type, or as a unique or unusual type.

Steel stringer and girder bridges are sufficiently common in Arizona that to be considered eligible for listing in the National Register under Criterion C, a structure from this property type must have definitive historical documentation and some superlative feature about it that distinguishes it from its peers. Some examples of

Figure 129. Benson Bridge (00350), Cochise County, 2003.

this are notably early construction date, exceptionally long span length, high span number, or well-executed architectural design. None of Arizona's steel stringer or girder bridges are considered to have national significance. Those dateable stringer and girder structures with physical integrity that were built by the state engineer, the Arizona Highway Department or the Bureau of Public Roads are generally considered to have state-level significance. Most of the locally built steel beam bridges are also considered eligible on a state level, by virtue of their significant features. Otherwise, small-scale steel beams built by local entities are considered locally eligible. Superlative steel stringer and girder bridges include:

Benson Bridge	(Cochise)	well-preserved multiple-span cantilevered girder
Dry Wash Bridge	(Maricopa)	earliest steel stringer
Peoria Underpass	(Maricopa)	well-preserved, rare through girder
Gila Bend Overpass	(Maricopa)	earliest AHD use of steel stringer on grade separation
Winslow Bridge	(Navajo)	well-preserved multiple-span cantilevered girder

see continuation sheet

Black Jack Canyon Bridge	(Greenlee)	well-preserved example of uncommon subtype
Wilbur Canyon Bridge	(Yavapai)	rare welded girder
Black Canyon Bridge	(Yavapai)	rare welded girder

Registration Requirements: The Registration Requirements for steel stringer and girder bridges are similar to those for concrete arch bridges, discussed in pages 138-140. The general period of significance for steel stringer and girder bridges in Arizona begins in 1923, the date for the state's earliest example of these structural types. Although the functionality of many of the bridges continues to the present—with the majority still in active use—the period of significance generally ends in 1978, the cutoff date for the statewide historic bridge inventory. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Once the resource has ceased to serve the function that makes it historically important, its period of significance has ended. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design.

Steel stringer and girder bridges from the subject group are considered significant if they can be definitively documented and they exhibit noteworthy physical or historical features and/or integrity. The issue of physical integrity of a bridge's character-defining elements is important for bridges significant under Criteria A, B or C (and to a lesser degree, Criterion D), but it is particularly important for structures eligible under Criterion C for their representation of structural or architectural trends.

Alterations that diminish the structure's integrity often can disqualify it from National Register eligibility. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design. Integrity of the structure's historic materials, design and setting is essential for a bridge to qualify for the National Register under any criterion. Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains its character-defining features. Character-defining features of a steel stringer or girder structure include the steel superstructure, deck, railing, and abutments, wingwalls and—if present—piers. The term "deck" in this instance is defined as the traffic-carrying component of a bridge, which is supported by the bridge's superstructure. In most bridges it is a discreet structural element, built and maintained separately from the superstructure. Because of their relative simplicity and below-deck superstructures, steel beam bridges are generally visually undistinguished, and it is the guardrails that, more than anything, define the character of the bridge from the roadway.

Alterations to the individual elements of a reinforced concrete bridge have a relative impact on the design integrity of the bridge itself. For instance, widening a structure by adding extensions onto one or both sides and replacing the guardrails impinges more on a bridge's integrity than patching the concrete surfaces or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction. Replacement of guardrails, even when original steel beam or tube guardrails are replaced with other steel guardrails (e.g., Thrie beams) outside of the period of significance generally represents a diminution of a bridge's physical integrity. The installation of steel beams over original guardrails, left in place, is considered reversible and represents a less serious alteration than outright replacement. Replacement of original steel guardrails with concrete Jersey barriers represents the worst loss of guardrail integrity. Installation of an asphalt overlay over the original concrete deck is generally considered to be a maintenance-related activity, which does not seriously diminish a bridge's physical integrity.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the highway's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge under consideration conveys a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or person that characterize it as historically significant. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association. Moreover, not all aspects of integrity must be present in equal measure.

Specific requirements under Criterion A:

1. **Early and/or prominent product of the Arizona Highway Department:** In the 1920s the Highway Department began using steel stringer and girder bridges around Arizona. One of these, the Dry Wash Bridge (**00015**), remains in place in intact condition.

2. **Outstanding example of federal work relief programs of the Depression era:** Federal work programs in the 1930s and early 1940s, particularly those funded by the Works Progress Administration, led to construction of a number of steel beam bridges in the state. The most significant display careful craftsmanship and creative design.

Specific requirements under Criterion C

1. **Early and/or representative steel stringer and girder bridge:** Steel stringer and girder bridges are considered significant if they can be definitively documented and they exhibit superlative features (i.e., exceptionally long span length, unusual number of spans, uncommonly good state of preservation).

Steel stringer and girder bridges in Arizona tend to have been subsequently altered by installation of steel Thrie beam guardrails. This is considered a serious loss of integrity, as is the replacement of original guardrails, which are considered character-defining elements. The installation of steel beams over the original guardrails is considered reversible and represents a less serious alteration. Steel beams built after World War II are considered significant if they were prototypes or earliest examples in the state for their type.

2. **Bridge with exceptional aesthetic merit:** Most bridges built by the State of Arizona are strictly utilitarian. Occasionally, however, a structure stands out by virtue of its design, its architectural detailing or because of the quality displayed in its construction. This does not include standard-design concrete guardrails by the Highway Department. The interrelationship of a bridge and its site can also have aesthetic value.

4 Property Type: Steel Truss Bridges

Description: Beginning in the late 1870s, the pin-connected wrought iron truss was the bridge of choice for medium- and long-span roadway crossings in America. Made up of numerous built-up timber or metal members connected at their ends to form series of triangles in a variety of web configurations, trusses functioned essentially as complex, long-span beams. They carried traffic in three different positions: the through configuration, with the roadway positioned between two tall webs and overhead struts spanning between the webs for rigidity; the pony configuration, with the roadway positioned between two relatively short webs, without overhead struts; and the deck configuration, with the roadway carried completely on top of the truss webs.

Following their introduction in the 19th century, trusses underwent an evolution of form that reflected other technological developments. For instance, cylindrical pins were first used to connect metal truss members in 1859. Two years later, a complementary truss member—the forged iron eyebar—was introduced. Steel eyebars appeared in the 1870s as a higher-strength, more consistent alternative to iron. Production of Bessemer and open-hearth steel improved in both quality and economy in the 1880s, making bridges more reliable; by the early 1890s all-steel bridges had largely superseded wrought iron structures.

Trusses were typically fabricated by manufacturers in large-scale shops, purchased by government entities by competitive bidding, shipped in pieces to the bridge sites and assembled over temporary wooden supports, called falseworks. The bridge companies that proliferated through the Ohio River Valley and Midwest competed enthusiastically for county bridge business, marketing an ever-changing array of truss types through networks of regional sales representatives. Both patented in the 1840s, the Pratt and Warren web configurations—with their various subtypes—formed the basis for virtually all of the all-metal trusses built in Arizona in the late 19th and early 20th centuries. These structures were fabricated by such national firms as the

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Midland Bridge Company of Kansas City, the Missouri Valley Bridge and Iron Works of Leavenworth, Kansas, and the Omaha Structural Steel Bridge Company of Nebraska.

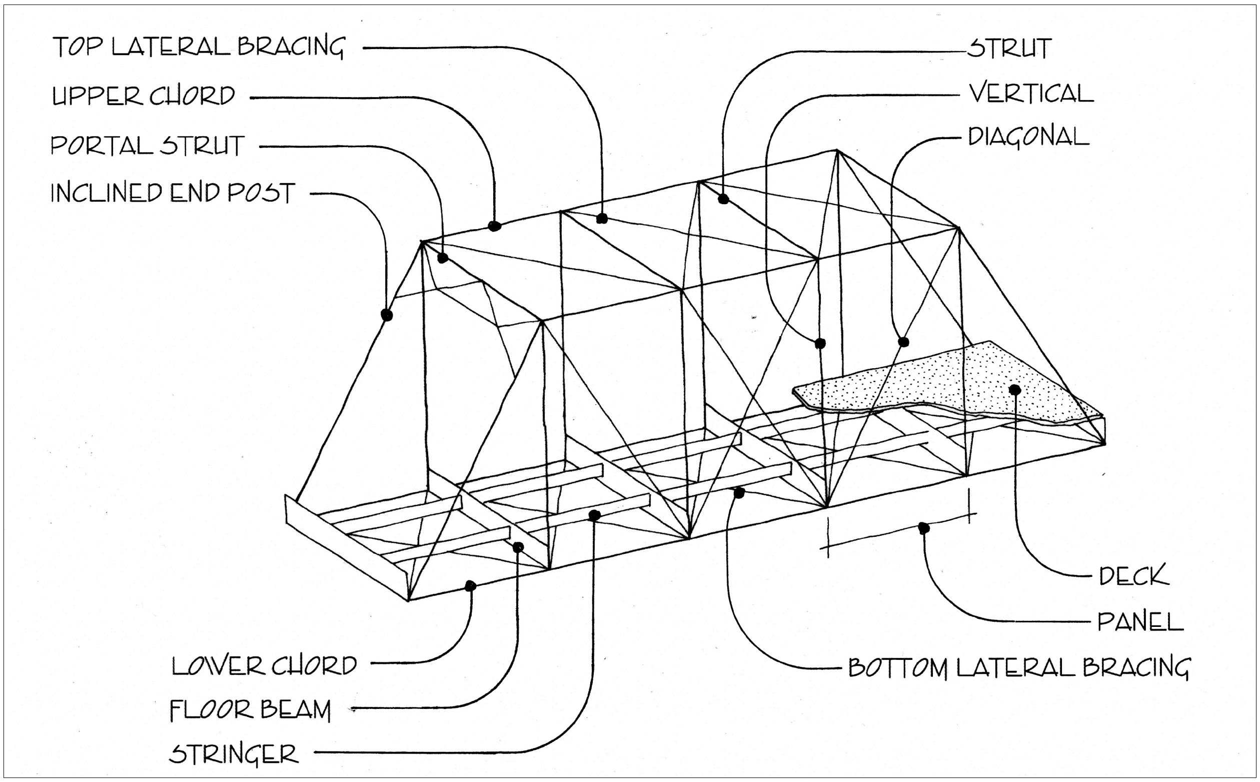

Figure 130. Steel truss bridge diagram.

The earliest metal truss bridges in America featured pinned and bolted connections in some combinations. These were largely superseded by all-pinned trusses in the 1880s. Because of their relatively quick erection and easy fabrication, pin-connected trusses dominated the market until well into the 20th century. But they lacked long-term rigidity and could loosen over time from vibrations caused by traffic and wind. Rigid connections in trusses, with stiffening gusset plates at the joints in lieu of pins, created stronger, sturdier connections, but field riveting was not practical before portable pneumatic riveters became available after the turn of the century. In Arizona rigid-connected trusses began to overshadow pinned for highway spans around 1910.

Without question the most popular truss type of the period was the Pratt truss. Patented by Thomas and Caleb Pratt, the Pratt design was characterized by upper chords and vertical members acting compression and

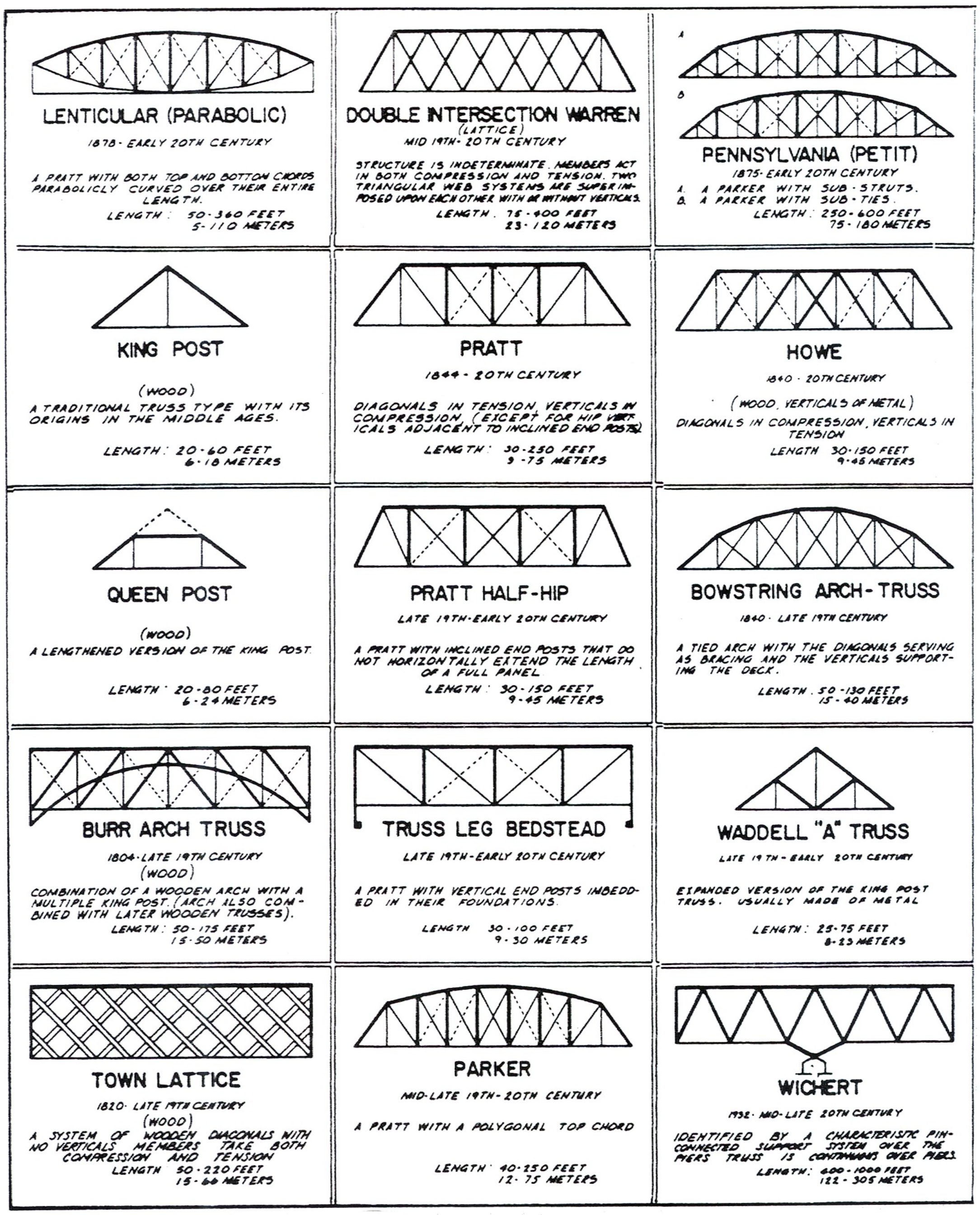

Figure 131. Truss bridge types. Historic American Engineering Record.

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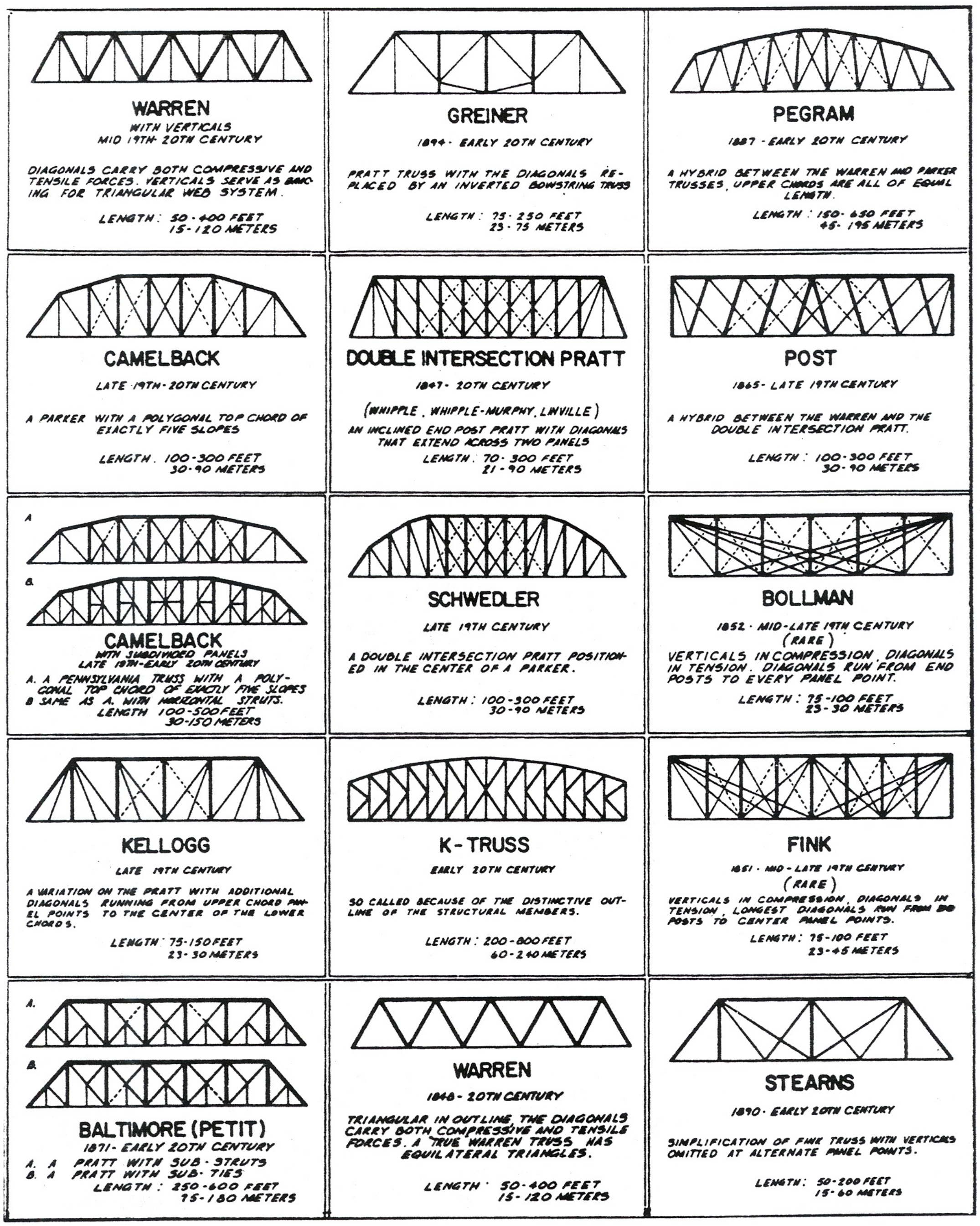

Figure 132. Truss bridge types. Historic American Engineering Record.

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chords and diagonals that functioned in tension. (Compression members in a truss are distinguishable by their relatively heavy construction, typically two channels joined by lacing or batten plates; tension members are distinguishable by their relatively lighter construction, typically one or two angles on a rigid-connected truss.) The Pratt's parallel chords and equal panel lengths resulted in standardized sizes for the verticals, diagonals and chord members, making fabrication and assembly relatively easy. "The Pratt truss is the most commonly used in America for spans under two hundred and fifty feet in length," noted bridge engineer J.A.L. Waddell wrote in his influential *Bridge Engineering*. "Its advantages are simplicity, economy or metal, and suitability for connecting to the floor and lateral systems."[100]

In the highly competitive bridge manufacturing industry, in which efficiency equated with profit, Pratt trusses received almost universal use. Virtually all of the major regional fabricators manufactured Pratt trusses and marketed them to Arizona counties in the late 19th and early 20th centuries. As a result, the Pratt truss was the structure of choice in the state for medium- and long-span wagon bridges. From the straight-chorded Pratt design arose a variety of structural subtypes in the 19th century. The most common Pratt subtype was the Parker truss. Developed in the 19th century by C.H. Parker, the Parker truss was characterized by upper chords and vertical members that acted in compression and lower chords and diagonals acting in tension. In this

Figure 133. White River Bridge (03129), Gila County, 2003.

[100] J.A.L. Waddell, *Bridge Engineering* (London: John Wiley and Sons, 1916), 468.

see continuation sheet

it resembled the venerable Pratt and was, in fact, regarded by civil engineers as a Pratt subtype. Waddell gave the Parker only passing mention in his book, stating: "[The Pratt's] chords are not necessarily parallel, but may be inclined. This latter form is frequently known as the Parker truss [Figure 134]."

Figure 134. Walnut Canyon Bridge (08741), Coconino County, 2003.

The inclined upper chords of the Parker truss afforded a degree of efficiency on long-span trusses, where bending moment stresses at mid-span greatly exceed the shear stresses at the ends. As literal manifestations of stress analysis, polygonal-chorded trusses placed the heaviest amount of metal at the point where the stresses were the greatest—in the middle. The Parker's drawback was that, unlike the straight-chorded Pratt truss, the polygonal chords necessitated different length verticals and diagonals at each panel point, increasing its fabrication and erection costs somewhat. Because trusses were generally priced on the basis of their superstructural steel weight, the lighter overall weight of a polygonal-chorded truss more than offset the slight increase in fabricating costs in spans greater than 150 feet.

A Camelback truss is a Parker with exactly five facets in its upper chord. With its distinctive profile, the Camelback configuration was disdained by many engineers for its ungainly appearance and its tendency under certain conditions to reverse compressive and tensile forces acting on individual members. As a result,

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Figure 135. Sanders Bridge (03074), Apache County, 2003.

Camelback trusses never received widespread acceptance in the 19th and early 20th centuries. The Whipple truss resembles the Pratt in its array of compression and tension members. Its primary difference lies in its diagonals, which extended over two panels. Patented in 1847 by esteemed civil engineer Squire Whipple, this eponymous truss was a popular choice for longer-span bridges—generally in excess of 150 feet—between 1850 and 1900. Although more costly than the single-paneled Pratt, this variation provided greater lateral support for the diagonals, a critical consideration in deep, long-span trusses. As the Whipple represents a subdivided Pratt, the Pennsylvania truss is a subdivided Parker.

Most of Arizona's historic highway spans employ Pratt designs—either the straight-chorded Pratt itself or its later subtypes. The White River Bridge (**03129** [Figure 133]), Perkinsville Bridge (**09474**) and Walnut Creek Bridge (**08741**) are all conventional rigid-connected Pratt through trusses. The Sanders Bridge (**03074** [Figure 135]) and Woodruff Bridge (**abd.**) are all rigid-connected Pratt pony trusses, and the Allentown Bridge (**03073** [Figure 136]) is a Pratt deck truss with end panels that cantilever over the piers. Arizona's two remaining pin-connected vehicular trusses—the Ocean-to-Ocean Bridge (**08533** [Figure 45]) and the Park Avenue Bridge (**09633** [Figure 137])—both employ polygonal-chorded Pratt web configurations. Three rigid-connected Parkers have also been identified in the state by the inventory: the Walnut Canyon Bridge (**09225** [Figure 62]), Salt River Bridge (**00037**) and the Boulder Creek Bridge (**00193**), which employs both polygonal- and straight-chorded Pratt spans. Additionally, three rigid-connected Camelback through trusses have been identified: the Gillespie Dam Bridge (**08021** [Figure 73]), Walnut Grove Bridge (**08227**) and the Mormon Flat Bridge (**00026**).

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Figure 136. Allentown Bridge (03073), Apache County, 2003.

In Arizona the Pratt and its various modified designs rode a wave of popularity well into the 20th century. The other principal truss category that competed with the Pratt in the late 19th and early 20th centuries was the Warren truss. Patented in 1848 by Captain James Warren and Theobald Monzani, the Warren truss in its classic form features a web configuration that relies on simple triangulation for its rigidity. Warrens were built sparingly in the United States in the 19th century, a period in which the pin-connected Pratt dominated the bridge industry. After about 1910, however, rigid-connected Warren pony trusses began to compete with earlier Pratt configurations for use on short- to intermediate-span highway bridges. Although these bridges displayed variations in their web configurations (some were "pure" Warrens without verticals, others had verticals at all or alternating panel points), virtually all of these early Warrens featured straight upper chords.

Fifteen Warren trusses have been identified in the Arizona inventory. One of these—the Woodruff Bridge (**08156** [Figure 138])—features a polygonal upper chord and through truss configuration. Five—the Dead Indian Canyon Bridge (**00032** [Figure 63]), Black River Bridge (**03128** [Figure 11], Little Hell Canyon Bridge (**03381**), Sand Hollow Wash Bridge (**08662**) and Querino Canyon Bridge (**08071**)—are configured as deck trusses; and the remainder are pony trusses. Erected between 1913 and 1934, these all featured rigid connections and—with one exception (Chevelon Creek Bridge (**08158** [Figure 17])—straight upper chords.

Figure 137. Park Avenue Bridge (09633), Greenlee County, 2003.

The Arizona Highway Department did not develop standard truss designs in the 1920s or 1930s, instead concentrating on concrete bridge types. As a result, steel trusses never received widespread use in Arizona. The earliest trusses were all medium-length, simply supported spans, typically carried on concrete abutments or piers. These were constructed using traditional formworks, which were dismantled after the trusses' completion. The Ocean-to-Ocean Bridge in Yuma, which was assembled on a barge and floated into place, was the notable exception. In the 1950s the highway department engineered a handful of long-span deck trusses, which cantilevered over the piers. Built without formworks over steep canyons, these structures featured Pratt web configurations and resembled steel arches with their polygonal lower chords. Three of these latter bridges— the Cameron Truss Bridge (**00532**), Hell Canyon Bridge (**00483**), and the Guthrie Bridge (**00352**)— were included in the first statewide bridge inventory but all have been recently demolished.

Significance: Steel truss bridges in Arizona may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. For example, a structure might be significant by its association with a particular route, such as the Borderland Highway, or because it was built by the State Highway Department in its formative years. A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Arizona qualify under Criterion C as structures of engineering significance. This can encompass a range of considerations. For instance, a bridge can qualify under Criterion C as a well-preserved example of a common type, or as a unique or unusual type.

Figure 138. Woodruff Bridge (08156), Navajo County, 2003.

Although their numbers are substantially diminished by attrition, metal trusses are still sufficiently common in Arizona that to be considered eligible for listing in the National Register, a structure from this property type must have definitive historical documentation. Only one of Arizona's steel truss bridges—the Ocean-to-Ocean Bridge (**08533**) in Yuma—is considered to have national significance. Those dateable trusses that were built by the state engineer, the Arizona Highway Department or the Bureau of Public Roads are generally considered to have state-level significance. Most of the locally built steel beam bridges are also considered eligible on a state level, by virtue of their significant features. Otherwise, small-scale steel beams built by local entities are considered locally eligible. Superlative steel truss bridges include:

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Querino Canyon Bridge	(Apache)	well-preserved multiple-span truss
Allentown Bridge	(Apache)	earliest cantilever truss
Sanders Bridge	(Apache)	well-preserved example of early AHD truss
Dead Indian Canyon Bridge	(Coconino)	well-preserved example of uncommon truss
Black River Bridge	(Gila)	well-preserved truss on territorial substructure
Salt River Bridge	(Gila)	longest and oldest rigid-connected through truss
Park Avenue Bridge	(Greenlee)	well-preserved pin-connected truss
Boulder Creek Bridge	(Maricopa)	well-preserved multiple-span truss
Gillespie Dam Bridge	(Maricopa)	longest multiple-span truss
Sand Hollow Wash Bridge	(Mohave)	well-preserved multiple-span truss
Chevelon Creek Bridge	(Navajo)	well-preserved, early state-built truss
Woodruff Bridge	(Navajo)	only example of rare truss type
Little Hell Canyon Bridge	(Yavapai)	well-preserved example of uncommon truss

Registration Requirements: The Registration Requirements for steel truss bridges are similar to those for concrete arch bridges, discussed in pages 138-140. The period of significance for trusses in Arizona generally begins in 1889, the date for the state's earliest example of this structural type. Although the functionality of many of the bridges continues to the present—with the majority still in active use—the period of significance generally ends in 1978, the cutoff date for the statewide historic bridge inventory. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Once the resource has ceased to serve the function that makes it historically important, its period of significance has ended. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design.

Integrity of the structure's historic materials, configuration and setting is essential for a bridge to qualify for the National Register under any criterion. Because location is of primary importance under Criterion A, a structure will rarely qualify under this criterion if it does not remain on its original site. Location can also have significance under Criterion B, but the correlation is not as universal. When focusing on engineering significance under Criterion C, the mobility of metal truss bridges is an important trait, since the structures were considered moveable. Movement of the beam superstructure under this criterion might not necessarily detract too seriously from its historic integrity. On the other hand, structural integrity is of vital importance for those bridges considered under Criterion C.

Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains the features that defined its character during its historic period. In engineering terms, a truss bridge is considered to be comprised of a group of distinct structural subsystems, rather than a single entity. These systems, in general order of importance under Criterion C, are the superstructure, the

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substructure, the floor, guardrails and approach spans, if any. The super- and substructure of a bridge, for instance, may have retained a high degree of physical integrity, while the floor system and approach spans may have been altered, replaced, or even removed, and the bridge may still be considered NRHP eligible.

Loss of physical integrity may also be mitigated by technological significance for unique or rare structural types. Alterations to the individual elements of a truss bridge have a relative impact on the design integrity of the bridge itself. For instance, replacing the deck or guardrails impinges more on a bridge's integrity than repairing truss members or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction. Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the railroad's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge under consideration and adjacent roadway convey a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or personage that characterize it as historic. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association.

Specific requirements under Criterion A:

1. **Early and/or prominent product of the Arizona Territorial Engineer's Office, Arizona State Engineer's Office or Arizona Highway Department:** The Arizona Territorial Engineer designed a timber truss bridge (Black River Bridge (**03128**), which was later replaced with a steel truss, and the Arizona State Engineer began delineating steel trusses (e.g., Chevelon Creek Bridge (**08158**) soon after the office was created. Several of the state's oldest remaining vehicular bridges, which provided important crossings on Arizona's most significant highways, are steel trusses designed by the state highway department or the federal Bureau of Public Roads in their formative years.

Specific requirements under Criterion C:

1. **Early and/or representative iron and steel truss bridges:** Truss bridges built before 1930 are sufficiently rare that all documentable examples that retain structural integrity are considered significant. All trusses in Arizona—rendered rare by subsequent attrition—are considered generally significant.

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2. Exceptional example of work by an important engineer, architect or firm: This includes local, regional and national companies and designers.

3. Bridge with exceptional aesthetic merit: Most bridges built in the state are strictly utilitarian. Occasionally, however, a structure stands out by virtue of its design or because of the quality displayed in its construction. This does not include standard-design concrete guardrails by the Highway Department, however. The interrelationship of a bridge and its site can also have aesthetic value.

5 Property Type: Long-Span Steel Arch and Suspension Bridges

Description: Steel arch and suspension bridges are among the most dramatic and esoteric structural types developed for vehicular use. Relatively few were ever built in America. Both bridge types were typically constructed where topographic or navigational concerns precluded construction of conventional structural types, with their falseworks (trusses) or multiple spans (concrete girders). In Arizona, keeping the rivers open for navigation was not really an issue, but many of the river crossings featured deep, steep-walled canyons or extreme fluctuations of stream flow, which required long-span bridges. Arches and suspension bridges generally did not require falseworks in their erection; the arches relied on cantilev-ering and suspension bridges were hung from the suspension wires that spanned the watercourse. First built before the Civil War, both structural types were able to reach monumental lengths, and both continue to be built today.

The world's first all-iron bridge, a single-span arch structure, was built in Coalbrookedale, England, in 1779.[101] This was followed eventually by other cast iron arches in Europe in the late 18th century. The first all-metal bridge built in America was an 80-foot arch made up of five cast iron tubular rings, built in 1836 on the National Road in Pennsylvania. The iron arch was never popular in 19th century America, however, because few foundries had the capacity for such large and intricate castings. As a structural type, it was superseded by the wrought iron truss.

Steel arches, also termed hinged arches, are classified by their type of articulation. Structures with continuous arches hinged at the end bearing points are termed two-hinge arches. Structures with hinges at the bearing points and an additional hinge at mid-span are termed three-hinge arches. Arches have been erected with a single hinge—typically at mid-span—but this is rare. The three-hinge-arch was considered generally too flexible for use on railroad spans, and was restricted to highway structures. The two-hinge arch is by far the most common hinge configuration and is the type used on most of Arizona's bridges. Arches are also classified by their structural configuration. They are either termed spandrel-braced arches, with relatively lightweight arch ribs reinforced by extensive lateral bracing, or girder-ribbed arches, with relatively deep I-beam

[101] Remarkably, the Coalbrookedale Bridge still stands and has been restored as an internationally significant engineering site.

arch ribs that require considerably less lateral bracing. The latter arch type is more rigid under load than the former and has been used more often in Arizona.

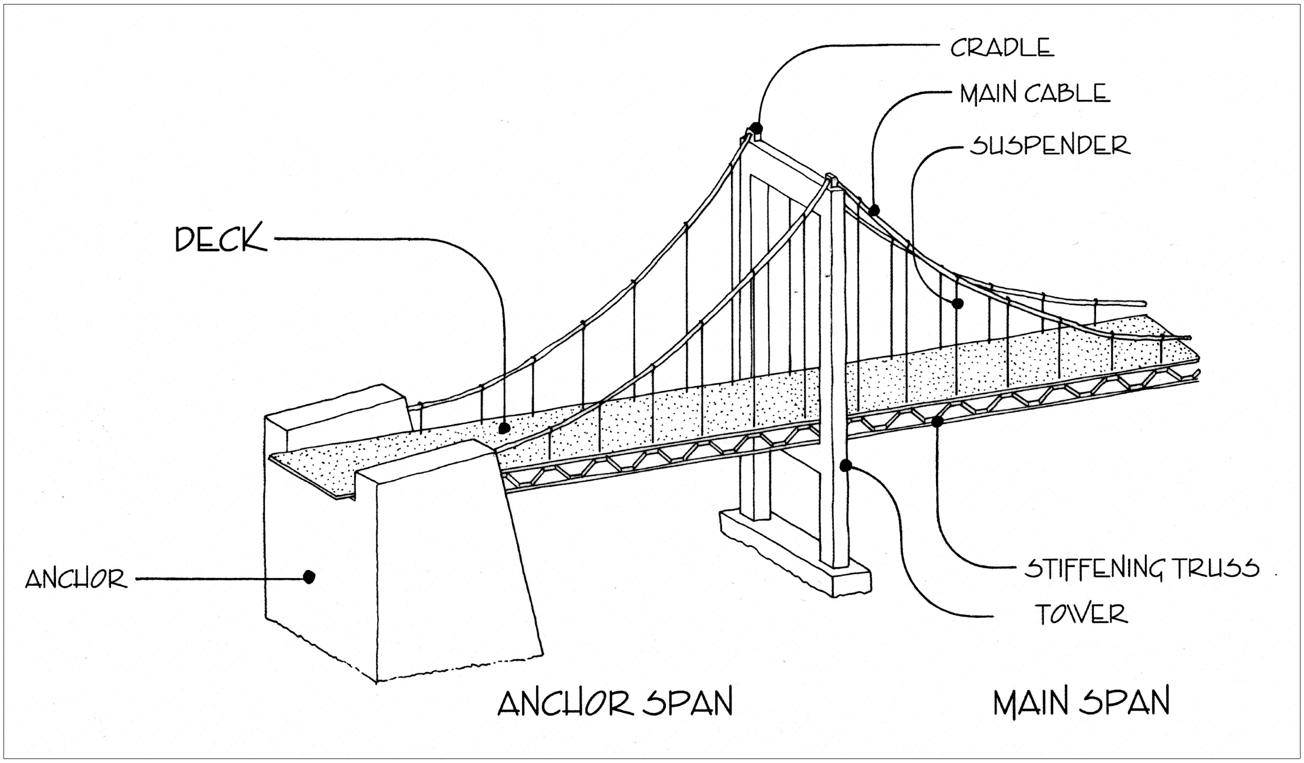

Figure 139. Suspension bridge diagram.

According to historian David Plowden, "even though the truss was the logical choice for most bridges, the suspension bridge was the only one practical for very long spans."[102] As a structural type, a suspension bridge generally features a roadway or deck hung in place by means of vertical suspenders from two or more ropes, chains, eyebars or cables, which were draped parabolically over tall towers at each end of the span [Figure 139]. The towers acted in compression; the cables acted in tension and were anchored at the ends to massive stone or concrete anchorages, commonly known as deadmen. Since the cables and suspenders do not provide much in the way of lateral stability under loads or in high winds, suspension bridges usually featured either stiffening trusses around the deck or ancillary cables that attached the deck at various points to side anchorages. Relatively easy and economical to build, short- and medium-span suspension bridges were erected in the late 19th and early 20th centuries at secondary crossings where traffic was relatively light. Suspension bridges are best suited for long-span crossings, however, and many of America's longest and most significant spans (e.g., the Golden Gate Bridge, Brooklyn Bridge, Mackinac Bridge) are suspension bridges.

[102]Plowden, *Bridges: The Spans of North America*, 68.

The suspension bridge is a structural type that dates to antiquity, and iron-chain suspension bridges were built in China as early as 200 B.C. It was used intermittently in the East but rarely in the West, and the first recorded use of iron in a Western suspension bridge was a chain bridge built in 1734 near Glorywitz, Prussia. The first suspension bridge built in America was located in western Pennsylvania. Constructed by James Finley over Jacob's Creek in 1801, the 70-foot-span structure was one of the first suspension bridges in the world built with a rigid, level deck suitable for vehicular traffic. This was followed by other chain structures in Pennsylvania, Maryland and Massachusetts. These earliest bridges used linked chains for their main suspenders and tended to collapse with distressing frequency. The country's first wire suspension bridge was a footbridge built in 1816 over the Schuykill Falls near Philadelphia, which replaced an earlier chain bridge at this location.

Figure 140. Old Trails Bridge, Mojave County, 2003.

Steel arch and suspension bridges were never built in abundance in America, and fewer than twenty were ever built in Arizona. The first arch bridge was the Old Trails Bridge [Figure 140], a steel three-hinge, spandrel-braced through arch built over the Colorado River at Topock in 1916. It was a nationally significant structure—a dead ringer for the Bellows Falls Arch Bridge (1905) in Vermont. At the time of its completion, the Old Trails Bridge was the longest steel arch in America and also the

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country's lightest and longest three-hinged arch. A year after its completion, the Arizona State Engineer proposed building a similar arch over the Gila River near Clifton, but that design was scrapped in favor of a more conventional two-span Luten arch (**08152** [Figure 40]). In 1924 the U.S. Bureau of Public Roads proposed another long-span through arch, this time over the Colorado River at the Grand Canyon. That design was also scrapped, in favor of a deck arch that was eventually built as the Navajo Bridge (**00051** [Figure 141]), completed in 1929.

Figure 141. Navajo Bridge (00051), Coconino County, 2003.

The Navajo Bridge was the second steel arch built in the state. As its designer, AHD Bridge Engineer Ralph Hoffman himself allowed, its design contained little in the way of engineering innovation. Despite this, the Navajo Bridge did mark an important milestone of engineering design, logistical planning and construction supervision. It was the first steel deck arch built in Arizona and a nationally prominent example of this uncommon structural type. What makes this bridge technologically noteworthy is its immense scale, its inspired logistical planning and its breathtaking span over one of the most spectacular bridge sites in America. Although Hoffman was concerned primarily with the functional aspects of the Navajo Bridge and not its appearance, this handsomely proportioned structure ranks among the country's most dramatic bridges. Flying high over the Grand Canyon, the Navajo Bridge is Arizona's most aesthetically and functionally successful example of civil engineering.

The Navajo Bridge was followed in 1934 by the Salt River Canyon Bridge (**00129** [Figure 142]), a two-hinge girder-ribbed deck arch. This formed the prototype for subsequent arches in the state, including the Cedar Canyon and Corduroy Creek Bridges (**00215** [Figure 104]), the Pinto Creek Bridge (**00351** [Figure 110]) and the Queen Creek Bridge (**00406**). Other noteworthy steel arches built in the state include the Glen Canyon Bridge (**00537** [Figure 113]), the Midgley Bridge (**00232**), and the Clear Creek Bridge (**01038**) [Figure 112]).

Figure 142. Salt River Canyon Bridge, Gila County, 2003. (The original 1934 bridge is in the foreground, and a 1997 replacement is in the background.)

Arizona's first vehicular suspension bridge was built over the Little Colorado River at the Cameron Trading Post in 1911. In the early 1900s the U.S. Indian Irrigation Service and the Office of Indian Affairs had made a concerted effort to improve commerce on the extensive Navajo and Hopi Reservations in northeastern

Arizona Territory. Key to this was a proposed bridge over the Little Colorado river to link the reservations with Flagstaff. OIA contracted with the Midland Bridge Company of Kansas City, Missouri, to engineer and build the long bridge. The canyon at this location was both wide and deep with steep-sided walls, requiring a single-span structure that could be erected without falsework. To solve the problem, Midland Chief Engineer W.H. Code designed this 660-foot-long suspension structure. The main suspension cables were comprised of seven woven steel cables clamped together, which were tied into massive concrete deadmen at the four corners. These cables passed over cast steel cradles at the tops of the braced steel towers. The suspended span was stiffened by a pin-connected Pratt through truss with a roadway width of 14 feet [Figure 143].

Figure 143. Cameron Suspension Bridge, Coconino County, 2002. (The Cameron Truss Bridge in the background has been recently demolished.)

This was followed in the 1920s by the state's only other steel suspension vehicular bridge—the McPhaul Bridge over the Gila River. When Arizona State Engineer Lamar Cobb first looked for a crossing location of the Gila River for the Ocean-to-Ocean Highway in Yuma County, he inspected sites at Dome and Antelope Hill and chose the latter. The Antelope Hill Bridge [Figure 22], a multiple-span concrete girder structure, was completed in 1915 and immediately began suffering damage with almost every flood on the Gila. Eventually, after years of repairs, it was abandoned altogether. The highway had already been rerouted through Telegraph Canyon, eliminating the need for the bridge altogether, when the Highway Department decided to replace

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the existing ford at Dome with a bridge. Soundings were taken, a site selected near a granite outcrop, and in 1927 the engineers decided to avoid the scouring problems of the Antelope Hill Bridge by free-spanning the river completely with a long suspension bridge.

Figure 144. McPhaul Bridge, Yuma County, 2003.

In January 1928 AHD contracted with the Levy Construction Co. to build the structure. Although AHD engineers had outlined the bridge's location and span, Levy engineered the bridge with the assistance of nationally known consulting engineer Ralph Modjeski. Construction began in mid-1928 and was completed in December 1929 [Figure 144]. The McPhaul Bridge carried traffic on US 95 until its replacement in 1968. It was abandoned in place and, though closed, still spans the Gila River in unaltered and relatively good condition [Figure 144].

Significance: Steel arch and suspension bridges in Arizona may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. For example, a structure might be significant by its association with a particular route, such as the Old Trails Highway, or because it was built by the State Highway Department in its formative years. A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Arizona qualify under Criterion C as structures of engineering significance. This can encompass a broad range of considerations. For instance, a bridge can qualify under Criterion C as a well-preserved example of a common type, or as a unique or unusual type.

Steel arch and suspension bridges in Arizona are rare enough and technologically significant enough that all examples from the historic period that have retained their character-defining elements are considered eligible for the National Register. Three of these—two of which no longer carry vehicular traffic—are considered to have national significance. These are the Old Trails Bridge, the Navajo Bridge and the McPhaul Bridge. All of the state's examples of these rare structural types were built either by the state (the state engineer or AHD) or by the Bureau of Public Roads, and all are therefore eligible for the National Register on at least a state level. Superlative steel truss bridges include:

Navajo Bridge	(Coconino)	Arizona's most important vehicular bridge
Cameron Bridge	(Coconino)	oldest and longest suspension bridge
Midgley Bridge	(Coconino)	well-preserved example of rare structural type
Salt River Canyon Bridge	(Gila)	oldest steel ribbed arch
Old Trails Bridge	(Mohave)	oldest and only steel through arch
McPhaul Bridge	(Yuma)	well-preserved example of rare structural type

Registration Requirements: The general period of significance for steel arch and suspension bridges in Arizona begins in 1916, the date for the state's earliest example of this structural type. Although the functionality of many of the bridges continues to the present—with the majority still in active use—the period of significance generally ends in 1964, the cutoff date for the statewide historic bridge inventory. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Once the resource has ceased to serve the function that makes it historically important, its period of significance has ended. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design.

Integrity of the structure's historic materials, configuration and setting is essential for a bridge to qualify for the National Register under any criterion. Because location is of primary importance under Criterion A, a structure will rarely qualify under this criterion if it does not remain on its original site. Location can also have significance under Criterion B, but the correlation is not as universal. When focusing on engineering significance under Criterion C, the mobility of metal arch bridges is an important trait, since the structures were considered moveable. Movement of the arch superstructure under this criterion might not necessarily detract too seriously from its historic integrity. On the other hand, structural integrity is of vital importance for those bridges considered under Criterion C.

Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains the features that defined its character during its historic period. In engineering terms, an arch or suspension bridge is considered to be comprised of a group of distinct structural subsystems, rather than a single entity. These systems, in general order of importance under Criterion C, are the superstructure (the arches or suspender cables and towers), the substructure, the floor, guardrails and the approach spans, if any. The super- and substructure of a bridge, for instance, may have retained a high degree of physical integrity, while the floor system and approach spans may have been altered, replaced, or even removed, and the bridge may still be considered eligible for registration.

Loss of physical integrity may also be mitigated by technological significance for unique or rare structural types. Alterations to the individual elements of a truss bridge have a relative impact on the design integrity of the bridge itself. For instance, replacing the deck or guardrails impinges more on a bridge's integrity than repairing truss members or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the railroad's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge and adjacent roadway convey a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or personage that characterize it as historic. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association.

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6 Property Type: Timber Stringer Bridges

Description: Also termed timber beam bridges, timber stringers are among the simplest and most economical bridge types to build. A timber stringer bridge consists of a wood plank deck attached to a row of longitudinally placed, sawn wood beams or stringers [Figure 145]. The spans are supported by a variety of substructural configurations, including timber pile bents, timber cribs, concrete abutments and piers, even timber sills laid directly on grade. Timber stringer bridges are rudimentary structures limited in their span length by the practical lengths of the stringers, typically between 10 and 30 feet. Because of their susceptibility to weathering, they were generally considered impermanent structures, with a lifespan of less than 20 years.

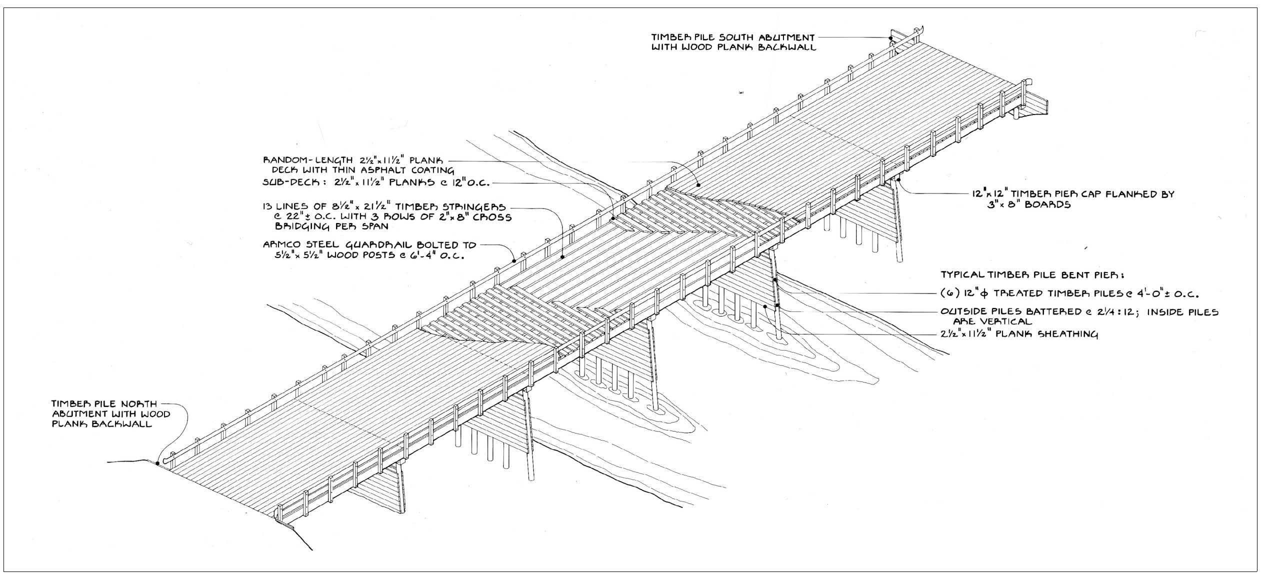

Figure 145. Timber stringer bridge diagram.

The timber stringer bridge is a structural type that dates to antiquity. First used in Colonial America and throughout the Midwest and West, timber has been used for bridge construction in Arizona for as long as there have been bridges. The railroads used timber extensively when building through the desert in the 19th century, constructing multiple-span trestles when stream conditions allowed for many pile bent piers. Bridges built for roadway use followed the same structural principles and took many of the same forms as railroad bridges. Like the railroads, early Arizona vehicular roads used timber for bridges, and for the same reasons. Early toll-road operators and county road crews typically avoided building bridges when they could, but when they could not, they built as cheaply as possible, and timber bridges were the cheapest and most quickly completed structures that could be built in the 19th and early 20th centuries.

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Wagon bridges were configured similarly to railroad structures, with parallel lines of wooden beams laid over the piers and abutments in single- or multiple-span iterations. The substructures were typically timber pile bents, but stone masonry, concrete steel pile bents or log crib bents were used as well. Timber stringer structures rarely exceeded 30 feet in span length. Those stringer bridges with longer spans were sometimes reinforced with metal tension rods attached under the beams to form what were called "jack trusses." The decks and guardrails of timber trestles were almost always made up of wooden members.

Figure 146. Packer Wash Bridge (08142), Greenlee County, 2003.

During the 1910s the Arizona State Engineer's office generally eschewed timber trestles in favor of concrete and steel construction, and the state directed the counties away from timber construction as well. By the 1930s, however, when the Arizona Highway Department needed to build numerous small-scale drainage structures over thousands of miles of newly developed highways, the state embraced timber work, if not enthusiastically, then certainly comprehensively. During the Depression, when labor was more plentiful than materials, and during World War II, when strategic materials such as concrete and steel were embargoed by the government, timber was used by the Highway Department

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for bridge construction [Figures 146 and 147]. That trend continued into the 1970s, and timber pile bridges continue to be built today at secondary locations.

Virtually all of the earliest roadway structures in Arizona were built of timber, and many were dangerously flimsy. Often poorly constructed and unevenly maintained, these rudimentary timber structures typically washed out in floods or collapsed under load. Because of their inherently short life spans, no timber trestles for vehicular use are known to have survived from the 19th or early 20th centuries. The timber bridges found today on Arizona's roads typically date from the 1930s and later. The superstructural technology between the early and later bridges has remained essentially unchanged, with the only difference being the sizes of

Figure 147. East Carrizo Bridge, Navajo County, 2002.

the members. The bridges of the mid-20th century tend to be more substantial, relying more on concrete substructures than their predecessors. During the 1930s timber was relatively easy to obtain and treat against decay, and it was an ideal construction material for use by gangs of sometimes poorly trained men.

Significance: Timber stringer bridges in Arizona may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. For example, a structure might be significant by its association with a particular route, such as the Old Trails Highway, because it was built by the State Highway Department in its formative years, or because it was built by a federal Depression-era relief program. A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Arizona qualify under Criterion C as structures of engineering significance.

None of Arizona's timber stringer bridges are considered to have national significance. Those dateable timber structures with physical integrity that were built by the Arizona Highway Department or the Bureau of Public Roads are generally considered to have state-level significance. Most of the locally built timber stringer bridges are also considered eligible on a state level, by virtue of their significant features. Otherwise, small-scale timber bridges by local entities are considered locally eligible. Superlative timber bridges include:

Carrizo Bridges	(Navajo)	longest multiple-span timber stringer bridges

Registration Requirements: The Registration Requirements for timber stringer bridges are similar to those for concrete arch bridges, discussed in pages 138-140. The period of significance for timber stringer bridges in Arizona generally begins in 1880, the earliest construction date covered in this MPDF. Although the functionality of many of the bridges continues to the present—with the majority still in active use—the period of significance generally ends in 1964, the cutoff date for the statewide historic bridge inventory. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Once the resource has ceased to serve the function that makes it historically important, its period of significance has ended. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design.

Integrity of the structure's historic materials, configuration and setting is essential for a bridge to qualify for the National Register under any criterion. Because location is of primary importance under Criterion A, a structure will rarely qualify under this criterion if it does not remain on its original site. Location can also have significance under Criterion B, but the correlation is not as universal.

Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains the features that defined its character during its historic period. Character-defining features of a steel stringer or girder bridge include the steel beam superstructure, deck, railing or parapet, and abutments, wingwalls and—if present—piers. Because of their relative simplicity and below-deck superstructures, stringer and girder bridges are generally visually undistinguished, and it is the guardrails that, more than anything, define the character of the bridge from the roadway. Alterations to the individual elements of a stringer or girder bridge have a relative impact on the design integrity of the bridge itself. For instance, widening a stringer by adding extensions onto one or both sides and replacing the guardrails impinges more on a bridge's integrity than adding lateral braces to the beams or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the railroad's environs. Cultural character in this case generally delineates the built environment, but it can additionally indicate the socioeconomic or ethnic composition of the bridge's location. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance. Are the salient features of the structure's environs still discernable and intact? The setting is usually defined as the viewshed from the bridge, which is to say all the natural and cultural features visible from the structure itself.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge and adjacent roadway under consideration convey a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or personage that characterize it as historic. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association.

Specific requirements under Criterion A:

1. Early and/or prominent product of the Arizona State Engineer or State Highway Department: In 1912 the Arizona State Legislature established the State Engineer's Office, and this evolved into the State Highway Department in the 1920s. Numerous timber stringer bridges were designed by the Highway Department in the 1920s and 1930s, and a few remain in place today.

Specific requirements under Criterion C

1. Early and/or representative multiple-span timber stringer bridge: Timber stringer bridges built before the Great Depression are sufficiently rare in Arizona that any definitively documented example that has maintained physical integrity is considered eligible for the National Register. Additionally, although Arizona once had numerous multiple-span timber bridges, only four such structures with five or more spans have been identified from the historic period by the statewide historic bridge inventory. These are considered the most significant examples of their type.

2. Bridge with exceptional aesthetic merit: Most bridges built by the state, particularly timber stringer structures, are strictly utilitarian. Occasionally, however, a structure stands out by virtue of its design or because of the quality displayed in its construction. The interrelationship of a bridge and its site can also have aesthetic value as well.

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7 Property Type: Prestressed Concrete Beam Bridges

Description: Typical of most reinforced concrete technology, prestressing was first developed in Europe. In this case, it was French engineer Eugene Freyssinet who introduced the prestressed concrete bridge in the 1940s, "making enormous contributions to the ideas and practice of bridge making in concrete," according to historian Martin Hayden. The first prestressed concrete girder bridge in the United States—the Walnut Lane Bridge in Philadelphia—was designed in 1947 by Gustave Magnel, a Belgian engineer, and completed in 1951. With a center span measuring 130 feet, it was built by the Preload Company using steel tensioning cables fabricated by the venerable John A. Roebling Sons. The Walnut Lane Bridge received widespread attention among American engineers, and soon thereafter other prestressed spans were erected. Magnel's structure was studied by American engineers, and prestressed concrete soon became widely accepted for highway spans up to 130 feet. They typically employed precast, pretensioned I-beams, eventually increasing spans to 150 feet, the longest beams that could be transported to the sites.

In 1954 the Bureau of Public Roads published its *Criteria for Prestressed Concrete Bridges*, the seminal work on the subject, and two years later AASHO developed four standard I-beam sections for use on prestressed concrete bridges. "The implications of Freyssinet's techniques have been enormous, "states historian Martin Hayden, "and have led to pre-stressed concrete being used for cast numbers of the short and medium spans necessary in the construction of modern motorways." Pre-stressing allows improvements in quality and cost control, since "such construction uses at least 70 percent less steel and between 30 and 40 percent less concrete than ordinary reinforced concrete."[103] According to the National Research Council's *A Context for Common Historic Bridge Types*:

> Although pre-stressing was first used in the United States in application to an I-beam bridge, pre-stressing can also be applied to several other bridge types, including slabs, T-beams, girders, box beams and rigid forms. In prestressed concrete bridges, the tensile forces caused by the application of loads are reduced in the main structural members by inducing internal compressive forces by means of high tensile strength wires, cables of (occasionally) bars. The compressive forces may be applied during fabrication of the member by stretching the steel reinforcement prior to casting and curing of the concrete. After the concrete has cured, the tension on the steel is released, thus transferring the load to the concrete. The concrete is in direct contact with the steel so that bonding of the two materials can occur. When external loads (traffic and the weight of the deck and other bridge components) are applied to the member, tensile forces that are thus created are counterbalanced by the internal compressive forces induced by the pre-tensioning of the steel. This method of pre-stressing is called pre-tensioning.
>
> Another method of pre-stressing, called post-tensioning, involves placing sleeves or ducts in the concrete member during fabrication, into which steel reinforcement is placed after curing of the concrete. The reinforcement is then stretched (stressed) by jacking, and locked in place by anchor plates or other locking devices. If bonding is desired, grout

[103]Martin Hayden, The Book of Bridges—The History, Technology and Romance of Bridges and Their Builders (New York: Galahad Books, 1976), 137.

> may be injected into the sleeves. In some cases, however, a protective covering is applied to the steel to de-bond it from the concrete in order to control cracking in end sections. Occasionally, though usually in more modern bridges that have not yet achieved "historic age," a combination of pre-tensioning and post-tensioning is used. But, whatever the method employed, when compressive forces are properly calculated and proper fabrication methodology is followed, the prestressed bridge members will not develop stress cracks.[104]

The evolution of prestressing technology and the development of firms that could produce the beams coincided with the construction boom in America on the interstate highway system. In the AASHO standards and on drawing boards at highway departments across the country, prestressed girder bridges competed with cast-in-place concrete girders and steel beams for use on interstate bridges and grade separations. Prestressed concrete beam bridges—and, to a lesser extent, slabs— were used routinely on Arizona highways in the 1960s and 1970s. Though not as common as cast-in-place concrete for bridge construction, prestressed highway bridges became a highway department staple during the 1970s.

Property Subtypes

Prestressed concrete girder: A general axiom for concrete performance is that it handles compression very well but performs poorly under tension. For steel bars, the converse holds true. The combination of steel with concrete, with one material taking up the deficiencies of the other, is a basic principal behind reinforced concrete. Prestressed concrete takes this characteristic feature one step further by application of a tensile force to reinforcing tendons. This effectively increases internal compression in the concrete beam where tension is anticipated under loading, and thus reducing or eliminating stresses due to tension once the beam is loaded. The prestressing force may be applied after the concrete is cast *in situ* (i.e., poured in the field) or before the beam is cast in a factory.

When the force is applied to the reinforcing tendons before the concrete is poured, the beam is said to be pretensioned. If the force is applied after the concrete has cured, the beam is called post-tensioned. In post-tensioning, the tendons are encased in tubes to prevent bonding with the surrounding concrete. After curing, jacking devices are used to apply the tensile force. To allow the beam to act as a transformed section in resisting loads (i.e., transforming the concrete and steel into a single equivalent section) the space inside the ducts where the tendons are placed (for post-tensioned beams) must be grouted before any live loads are placed on the girder. Prestressed concrete girders come in a variety of cross-section geometries. The pretensioning strands are dependent on the length of the span and the type of loading to which the structure is subjected.

In addition to the I-girder and bulb T-girder, prestressed girders can come in the form of a box girder, conventional T-girder, voided slab or solid slab. Each geometry has its own particular advantages, and, like steel, the goal is to economize material whenever possible without compromising the integrity of the design.

[104] Parsons Brinckerhoff, A Context for Common Historic Bridge Types (National Research Council et al., October 2005), 3-100-101.

As is the case with any design, a variety of factors influences the type of element selected. From an aesthetic standpoint, it is definitely more pleasing to the eye to have all girders be of a constant depth. A maintenance perspective almost always demands the elimination of as many deck joints as possible to preserve the deck and substructure elements as well. Therefore, most bridges are designed using continuous spans to reduce the material usage, and to eliminate expansion joints over piers [Figure 148].

Figure 148. Agua Fria River Bridge (09145), Maricopa County, 2016. ADOT.

Prestressed concrete box girder: Like steel box girders, prestressed concrete box girders are good at resisting the effects of torsion and typically do not require the introduction of bracing elements. Compared with prestressed I-beams, box girders have less creep deformation and are easier to position tensile reinforcement. Because of these characteristics, concrete box girders are well suited for large span lengths. Since large prestressed box girders are relative newcomers, maintenance issues have recently come to the forefront. Deterioration of concrete box girders begins when the post-tensioning relaxes. If tension in the strands is reduced, the concrete will begin to lose compression, causing existing cracks to widen and new cracks to form. Corrosion of post-tensioning strands is another major problem concrete box girders face [Figure 149].

Prestressed concrete slab: Adjacent prestressed concrete slab units can be used for short spans up to 18 meters. A 75mm to 100mm concrete overlay with reinforcement is usually cast over the slab units. Slab units are transversely post-tensioned prior to placement of overlay to form a single bridge deck. The advantage of this type of bridges is the rapid construction and low costs, which make it popular for short span bridges.

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Although a small number of these slabs were constructed within the study period for this inventory, none of them remains in place.

Arizona followed national trends in its use of prestressed concrete girder bridges, using them both for freeway structures in the late 1950s and also for other highways. Among the post WWII bridges on Arizona highways identified by this study, there are 45 prestressed concrete girder structures. Eleven of these feature continuous bearing over the piers; the remainder are simply supported. The bridges display slight variations in design, involving, principally the girder configuration and method of prestressing. Span numbers for these vary between one and 20; span lengths average around 20 meters.

A representative prestressed concrete girder bridge from the study period would feature between one and ten spans, with individual span lengths falling in the 12-35-meter range. Virtually all feature reinforced concrete substructures, typically with solid abutments or footings and spill-though piers. Pier heights vary considerably due to the differences in the watercourses or underpasses they span, but a representative bridge would feature piers between 5 and 20 meters in height. A representative prestressed concrete bridge would be plain-faced, without architectural detailing and with AHD-standard steel or aluminum beam or tubular guardrails, attached either to the tops of the concrete curbs or to the concrete spandrels. The deck is reinforced concrete, with or without asphalt overlay.

Although grade separations had been used on Arizona highways regularly since the 1910s, the wholesale construction of limited-access freeways increased their construction and use tremendously during the 1950s and 1960s. They generally followed the same design principles as bridges over waterways in terms of span lengths and superstructural carrying capacities, but their substructures differed from traditional bridges, and

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their overall design was influenced by the fact that they had to accommodate traffic both on top of the structure and passing underneath. The AASHO *Policy on Geometric Design of Rural Highways* describes their design at length:

> The type of structure best suited to grade separations is one which gives drivers little sense of restriction. Where drivers take practically no notice of a structure, their behavior is the same, or nearly so, as at other points on the highway. Sudden erratic changes in speed and direction are unlikely. A structure of this character has liberal clearances on the roadways at both levels. All piers, abutments, walls, etc., are suitably offset from the traveled way.
>
> A grade separation structure should conform to the natural lines of the highway approaches in alinement (sic), profile, and cross section. The structure should be designed to fit the highway, and not the highway to fit the structure. Fitting the structure to the highway sometimes may result in variable structure widths, flared pavements and parapets, and nonsymmetrical abutments. Such dimensional variations at interchanges are recognized as essential by both highway and bridge engineers, resulting often in individual design for each separation structure. This does not preclude standardization, particularly in structural elements.
>
> For the overpass highway the deck type structure is most suitable. The supports are underneath and out of sight. It has unlimited clearance vertically and the clearance laterally is controlled only by locations of curbs and railings. These should present an appearance of strength yet be of a total height and openness to give little feeling of narrowness. For the underpass highway the most desirable structure, from the standpoint of vehicular operation, is one which will span the entire highway cross section, say from top to top of slopes when the road is in cut. Such spans are generally not practicable, and considerable savings in cost and vertical depth is effected by providing supports nearer the edges of the roadway. On divided highways, center supports should be used only where the median is wide enough to provide adequate clearances.
>
> A grade separation structure should be made pleasing and should be properly adapted to the site. A pleasing structure usually can be produced without extra cost if conscious thought is given; first, to the type of structure so that it fits surroundings; second, to the general outline so that it is pleasing yet simple, with an appearance or serving its intended purpose; and third, to functional details which also enhance the general appearance. Collaboration between engineer and architect throughout the various stages of planning and design shows excellent results in this regard.[105]

The numerous grade separations built on Arizona's freeways in the 1950s and 1960s generally adhered to these precepts. Whether using steel, reinforced concrete or prestressed concrete, they were, as a rule, simply detailed structures, with relatively unobtrusive superstructural profiles that were well hidden beneath the roadways. Although aesthetics have rarely intruded historically into bridge design, the beam bridges of the 1950s, 1960s and 1970s, with their austere engineering, enjoyed a certain cleanliness of line and clarity of purpose, which generally escaped notice of the travelers passing over and under them.

[105] American Association of State Highway Officials, *A Policy on Geometric Design of Rural Highways* (Washington, DC: AASHO, 1965), 501-505.

see continuation sheet

Significance: The period of significance for prestressed concrete girder bridges in Arizona considered under this MPDF begins in 1955, the date of the earliest prestressed structure in the study. Although the functionality of many of the bridges continues to the present—with virtually all still in active use—the period of significance generally ends in 1978, the cutoff date for this statewide historic bridge inventory. The period of significance for an individual structure begins with the date that significant activities or events began giving the property its historic significance (typically, initial construction). Once the resource has ceased to serve the function that makes it historically important, its period of significance has ended.

Any prestressed concrete structure may possess significance if it retains its character-defining features, which include reinforced concrete superstructures and substructures, decks and guardrails. Prestressed concrete girder bridges built between 1955 and 1978 are sufficiently important as structural types that representative examples (described in the previous section) may be considered significant if they display integrity. Prestressed concrete girder bridges feature monolithic deck and support systems (e.g., girders) and abutments, piers and wingwalls, as components of the original design.

Subject bridges may be eligible for listing in the National Register under Criterion A for their association with events that have made a significant contribution to the broad historical patterns of the country, the state or the region. Specifically, bridges that have played an important role in the development of the state's highway transportation system and, hence, in the settlement of the area. Generally speaking, minor structures built as integral components of a statewide system (grade separations or small-scale bridges on an interstate highway) are not considered individually eligible for listing under Criterion A but potentially as a contributing resource to nomination of a larger linear resource. A bridge may, in addition, be eligible under Criterion B for its association with a significant person, as long as the "significant person" was not the designer or builder of the bridge. A bridge can be eligible by virtue of its designer or builder, but this falls under Criterion C. Indeed, most eligible bridges in Colorado qualify under Criterion C as structures of engineering significance. This can encompass a broad range of considerations. For instance, a bridge can qualify under Criterion C as a well-preserved example of a representative type of design or construction, or as a unique or unusual type.

Registration Requirements: The Registration Requirements for prestressed concrete bridges are similar to those for concrete arch bridges, discussed in pages 138-140. Given the relatively large number of prestressed concrete bridges, physical integrity is an important aspect of their historical significance. Alterations that diminish the structure's integrity often can disqualify it from National Register eligibility. Alterations made during the period of significance may be considered part of the bridge's historic fabric, if they are in keeping with the bridge's original design. Integrity of the structure's historic materials, design and setting is essential for a bridge to qualify for the National Register under any criterion. Since none of Arizona's prestressed concrete bridges has been moved, integrity of location is a given. Integrity of design, materials and workmanship are key to a bridge's eligibility, particularly if that eligibility is stated in Criterion C terms. The principal consideration when evaluating integrity of design and materials is whether the bridge retains its character-defining features. Character-defining features of a prestressed girder structure include the concrete superstructure, deck, railing, and abutments, wingwalls and—if present—piers. The term "deck" in this instance is defined as the traffic-carrying component of a bridge, which is supported by the bridge's superstructure. In most bridges it is a discreet structural element, built and maintained separately from the superstructure.

Alterations to the individual elements of a prestressed concrete bridge have a relative impact on the design integrity of the bridge itself. For instance, widening a structure by adding extensions onto one or both sides and replacing the guardrails impinges more on a bridge's integrity than patching the concrete surfaces, installing pulpits under the girders or repairing the abutments. Integrity of workmanship is closely related to design and materials but relates to the skill and craftsmanship involved in a bridge's construction. Because of their relative simplicity and below-deck superstructures, prestressed concrete bridges are generally visually undistinguished, and it is the guardrails that, more than anything, define the character of the bridge from the roadway. Replacement of guardrails, even when original steel beam or tube guardrails are replaced with other steel guardrails (e.g., Thrie beams) outside of the period of significance generally represents a diminution of a bridge's physical integrity. The installation of steel beams over original guardrails is considered reversible and represents a less serious alteration than outright replacement. Replacement of original steel guardrails with concrete Jersey barriers represents the worst loss of guardrail integrity. Installation of an asphalt overlay over the original concrete deck is generally considered to be a maintenance-related activity, which does not seriously diminish a bridge's physical integrity.

Retaining a sense of setting is an important consideration for a bridge's overall integrity. Setting is defined as the topographic, vegetative and cultural character of the highway's environs. The principal consideration of integrity of setting is whether the extent to which the general environment or any particular aspect of that environment that affected the bridge's original design and construction remain intact from the bridge's period of significance.

Integrity of feeling for a bridge is an amalgamation of the integrities of location, design, materials, workmanship and setting. It is a subjective appraisal of the overall experience conveyed by the structure. The principal consideration of integrity of feeling is whether the bridge under consideration conveys a visceral sense of what it would have been like to travel over it during its historic period. Integrity of association relates to the link between a bridge and the distinctive events or person that characterize it as historically significant. The alteration or loss of one or more of these integrities may be mitigated by other aspects of integrity of feeling and association.

8 Glossary

Abutment	the outermost end supports of a bridge, which carry the weight of the superstructure and usually retains the approach embankment
Anchorage	massive, secure fixing on or under the ground, usually comprised of concrete, to which cables in a suspension bridge are fastened; also called deadman
Approach	roadway leading up to the end of a bridge
Approach span	relatively short span on either or both ends of a main span that connects the main span with the abutments, using piers
Arch barrel	surface of the inner arch that extends the full width of the structure
Arch ring	outer sourse of stone or brick; also called voussoir
Balustrade	concrete or stone railing system that includes the top rail balusters and sometimes a lower rail
Beam	rigid, usually horizontal structural element
Built-up	structural member (usually metal) that is comprised of smaller members joined together by means of riveting, bolting or welding
Cantilever	structural beam or element that projects beyond its vertical support (i.e., a diving board)
Cast-in-place	concrete that is poured within site-built formworks to create a structural element (e.g.; pier, arch, girder, slab); also called poured-in-place
Centering	temporary wooden frame used to provide support and hold masonry or concrete for an arch bridge under construction
Chord	horizontal member of a truss web; usually referred to as upper or lower chord
Column	vertical structural element that is rigid to withstand compressive forces
Compression	force that pushes along the axis of a structural element, acting to make it shorter
Concrete	mixture of water, sand, stone aggregate and a binding cement, which, when cured into a rock-like consistency, is used for both substructural and superstructural construction; may be used in units (e.g., concrete blocks) or poured in place; may be combined with steel reinforcing bars or beams to form reinforced concrete or may be used without steel reinforcing to form mass concrete
Continuous span	superstructure designed to extend continuously over one or more intermediate supports

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Dead load	static load acting vertically downward cause by the weight of the bridge itself
Deck	supported roadway on a bridge that directly carries both vehicular and pedestrian traffic
Deck truss	bridge in which the superstructural truss is positioned entirely beneath the roadway
Diagonal	sloping member of a truss web
End post	end compression member of a truss, either vertical or inclined
Eyebar	long metal tension member of a pin-connected truss with holes punched or forged on one or both ends to accommodate the metal pins at the chord connections
Expansion joint	mechanical device that provides for movement within a structure to accommodate expansion or contraction cased by temperature changes, load and other forces
Falsework	temporary wooden frame used to provide support for a bridge span under construction
Floor beam	horizontal beam that transfers the weight of the deck to the superstructure
Footing	lowermost part of substructure that is enlarged beyond the footprint of the abutments or piers to distribute the weight of the structure, either to piles or the earth
Force	push (compression) or pull (tension) applied to an object
Foundation	structural component that distributes the weight of a bridge to the earth
Girder	main support beam that usually received loads from floor beams or stringers; also any large beam, especially if built up
Gusset plate	metal plate (usually in a truss) used to connect structural members by means of riveting, bolting or welding
Hanger	tension member that suspends an attached member
Hinge	point in a structure at which a member is free to rotate
I-beam	rolled steel member with a cross-sectional shape similar to an "I"
Lateral bracing	secondary structural member connected to main members to provide rigidity and brace against lateral loads (e.g., wind)
Live load	dynamic load caused by the weight of vehicular or pedestrian traffic on a bridge deck
Main span	the longest span of a bridge, usually located over the main channel of a watercourse
Parapet	low wall along outside edge of a bridge deck
Pier	vertical supporting structure that carries the superstructure of a multiple-span bridge between the abutments; a pier may be configured as a pile bent (several steel or timber piles joined by horizontal or diagonal braces), a crib (horizontal members stacked to form the full height, solid concrete or masonry, spill-through concrete or concrete pile

Pile	vertical structural member made of wood, steel or concrete, which is driven forcibly into the ground to support the abutments or piers
Pin connection	connection of metal members on a truss by means of cylindrical metal pins
Plate girder	Rigid beam comprised of a relatively deep steel sheet with flange plates attached by flange angles of fillet welds
Panel	portion of a truss between adjacent points of intersection of web and chord members
Pony truss	bridge in which the roadway is positioned over the lower chords, with the truss webs positioned on either side but without overhead struts
Portal	unobstructed space forming the entrance to the structure on either end of a bridge
Precast concrete	concrete that is cast (usually with reinforcing steel) into a structural member away from the bridge site, cured and shipped to the site for erection
Reinforced concrete	concrete with steel rods or beams embedded within to provide tensile strength and durability
Rigid connection	connection of metal members (usually on a truss, usually using metal gusset plates) by means of rivets or bolts
Simple span	span of a bridge that is carried by longitudinal members (e.g., abutments, piers) without being connected structurally to adjacent spans
Skew	the acute angle between the alignment of the bridge and centerline of the substructure on a bridge where the superstructure is not perpendicular to the substructure
Span	distance a bridge extends between two supports
Stringer	longitudinal beam supporting the bridge deck; may be a primary superstructural element, as on a steel or timber stringer bridge, or a secondary element as part of the deck
Strut	structural member that acts to resist compressive stress
Substructure	foundation of a bridge that supports the superstructure (e.g., footings, piles, anchorages)
Superstructure	spanning portion of a bridge
Tension	force that pulls along the axis of a structural element, acting to make it longer
Thrie beam	modern steel guardrail with a cross-sectional shape similar to a "W"
Through truss	bridge in which the roadway is positioned over the lower chords, with the truss webs positioned on either side and joined by overhead struts
Truss	rigid beam superstructure comprised of short, straight pieces that form triangles or other stable shapes

Geographic Data: State of Arizona

Summary of Identification and Evaluation Methods

The Arizona Historic Bridge Inventory, which forms the basis for this Multiple Property Documentation Form [MPDF], is part of an ongoing effort to identify those bridges in the state that are eligible for listing in the National Register. By inventorying structures on a statewide basis, the study provides a database and the contextual background by which individual structures can be evaluated for historical and technological significance. This information will aid long-range policy and funding decisions at the outset of the planning process and allow enlightened, streamlined review of proposed maintenance, rehabilitation and replacement projects. Additionally, it will help to guide mitigation measures for future construction projects that effect eligible structures.

This survey is a sequel to earlier studies completed in 1987 and 2008. Employing 1945 as the cut-off date, the original 1987 study included 610 structures. The consultant surveyed some 150 of the most important of these in the field and recommended 83 as NRHP eligible. As part of the inventory, these were listed of the National Register using a Multiple Property Documentation Form. The 2008 inventory involved 2,504 bridges built before 1964, including all of the extant structures from the original 610-bridge group surveyed in the 1987 study. When Fraserdesign produced the 2008 update, all of the bridges listed on the National Register from the 1987 inventory were revisited in the field to ascertain their condition (and in some cases, existence) as it pertained to National Register eligibility. The firm also reviewed bridges that had been determined non-eligible in the 1987 inventory. Out of the 2,504 structures, Fraserdesign selected about 200 to include in the field survey sample. Several bridges that had been determined non-eligible in the original inventory were reclassified as eligible in light of changes in the bridge numbers due to attrition. Trusses, for example, are a prime example of this sort of reconsideration, as a structural type particularly vulnerable to replacement efforts. Of the original 83 NRHP-listed bridges, 72 were found to be extant and substantially unaltered. Additionally, 53 other bridges were identified as eligible for the National Register. The total number found eligible between the two inventories was therefore 125.

The second study inventoried and evaluated all of the pre-1964 vehicular bridges and grade separations maintained in ADOT's Structure Inventory and Appraisal [SI&A] listing. It included all structures of all structural types then in use on the state, county and city road systems. Additionally, it included selected bridges on federal lands, which had been NRHP listed from the original inventory. Generally not included were railroad bridges other than highway underpasses; structures maintained by federal agencies (e.g., National Park Service) other than those included in the SI&A; structures in private ownership; and structures that have been dismantled or permanently closed to vehicular traffic. There are exceptions to this, however, and several abandoned and/or privately owned structures of particular importance were included at the discretion of the consultant.

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The bridges included in the 2018 inventory, which number 4,019 pre-1979 structures , follow the same parameters for inclusion as those from the 2008 study. They have not been evaluated as parts of larger road structures or historic highway districts, although they are clearly integral parts of larger highway resources. Similarly, some of the bridges listed here may be considered as contributing elements to larger historic districts for reasons other than their significance as transportation- or engineering-related resources, but this consideration lies outside the scope of this Inventory. Rather, the bridges in this inventory have been evaluated individually for National Register eligibility strictly on the basis of the criteria enumerated in Section F.

This inventory began with production of a customized computer database from ADOT's Structure Inventory and Appraisal general database. With the general list of bridges in hand, the next step was to conduct literature research that would establish a historical context and would delineate important historical and technological trends to provide a point of comparison for evaluation of individual structures. Preparation of the historical context required extensive research at a number of repositories in Arizona. Contextual information relating to Criteria A and C provided the parameters for sorting the bridge database to identify a cross-section of possibly eligible bridges that merited intensive-level field survey.

The survey list was further refined by a review of photographs of every bridge in Arizona built before 1979, maintained by ADOT. This review of the photos eliminated bridges with obvious integrity problems (e.g., major super- or substructural modifications, deck widening, guardrail replacement) and added bridges to the survey list with aesthetic features (e.g., decorative steelwork or concrete forming) that could not be identified by the computer database. Using this methodology, about 300 structures were selected to include in the field survey sample. As a list of all the possibly eligible structures in Arizona, the survey sample formed the basis for the intensive documentation phase of the bridge inventory.

Two government programs instituted since the last inventory have had a profound effect on the bridges considered NRHP eligible in 2018. In 2004, the Advisory Council for Historic Preservation approved an exemption that would relieve federal agencies from the requirement of taking into account the effects of their undertakings on the Interstate Highway System under Section 106 of the National Historic Preservation Act. (Although the exemption went into effect in March 2004, it was not instituted by ADOT until after the 2008 inventory.) As a result, all bridges on interstate highways in Arizona are considered exempt from National Register evaluation and are therefore considered not eligible for NRHP listing unless specifically excepted. These excepted bridges are those that have been previously listed or determined eligible as part of the statewide inventories and certain structures in Mohave County that had been erected on Interstate 15.

The other program, instituted by the Advisory Council in November 2012, relieves all federal agencies from Section 106 requirements on certain common bridges and culverts built of steel and/or concrete after 1945. Called the Program Comment for Common Post-1945 Concrete and Steel Bridges, this exempts all such "cookie cutter" structural types—e.g., steel stringers, concrete slabs and girders, concrete box culverts, prestressed concrete beams—from consideration for National Register eligibility. With the majority of interstate bridges comprised of common structural types, the two programs overlap considerably. Combined, they account for the exemption of 3,138 structures from the 4,019 bridges included in the 2018 inventory.

Among the bridges that have been considered for National Register eligibility under the 2018 inventory, such eligibility for each bridge has been evaluated according to registration requirements outlined in Section F of this MPDF. To assist with the evaluation, a numerical rating system has been developed. This assigns values to such aspects of significance as construction date, span length, role in transportation and subtracted value for loss of physical integrity. Following is a statement of the numerical rating system:

Documentation (maximum 30 points)	
Date of Construction	
pre-1918	15
1918-1932	12
1933-1945	8
1946-1968	4
1955-present	0
Builder	
known, significant AZ builder	10
known, significant out-of-state builder	8
known, AZ builder	6
known, out-of-state builder	4
unknown	0

(Give half points for estimated construction date; add 5 points for earliest example of type)

Historical Significance (Criteria A and B; maximum 35 points)	
Important early structure on important AZ route	35 max
Important structure for agency history	35 max
Important Depression-era relief agency structure	35 max
Structure with significant association to important personage	35 max
Important late structure on important AZ route	25 max
Important early structure on regular AZ route	20 max
Regular early structure on regular AZ route	15 max
Regular late structure on important AZ route	10 max
Important late structure on regular AZ route	10 max
Regular late structure on regular AZ route	5 max
Non-significant structure	0

Technological Significance (Criterion C; maximum 35 points)	
Geometry / configuration	
1-4 surviving examples of type in AZ	20
5-10 surviving examples of type in AZ	15
11-20 surviving examples of type in AZ	10
21-40 surviving examples of type in AZ	5
greater than 40 surviving examples	0

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Number of spans	
1 point for each span, up to 10 points	10
Length of individual span	
steel through truss 150 feet or greater	5
steel through truss 120 feet or greater	3
steel pony or deck truss 80 feet or greater	5
steel pony or deck truss 60 feet or greater	3
steel stringer or girder 60 feet or greater	5
steel stringer or girder 40 feet or greater	3
steel arch or suspension 300 feet or greater	5
concrete arch 80 feet or greater	5
concrete arch 60 feet or greater	3
concrete slab or rigid frame 40 feet or greater	5
concrete slab or rigid frame 30 feet or greater	3
concrete girder 50 feet or greater	5
concrete girder 40 feet or greater	3
timber stringer 20 feet or greater	5
prestressed concrete girder 60 feet or greater	5
prestressed concrete girder 50 feet or greater	3

(Add 5 points for special features, such as architectural treatment, bridge builder's plate, patented features)

Structural Integrity (maximum 20 points subtracted)

Superstructure replaced	20 subtract
Substructure replaced	15 subtract
Superstructure moved after historic period	15 subtract
Deck widened / guardrails or deck replaced	10 subtract
Superstructure moved in historic period	5 subtract
Minor repairs or in-kind replacement	5 subtract

The consultant places a high value on archival documentation for the individual bridges. This is the reason that the Documentation section of the numerical system rates almost as highly as Historical Significance or Technological Significance. Under Documentation the points are halved for estimated construction dates, and no points at all are assigned to unknown builders. The system clearly includes a high degree of subjectivity in its application to individual structures. The assignment of points for the aspects of significance is, by definition, arbitrary. And the determination of "significant" builders and routes is placed within the province of the consultant, based on his understanding of Arizona road and bridge history. In this, the numerical system relies on the learned judgment of its user for determination of National Register eligibility—much like the National Register process itself. For this reason the rating system was not intended to be a hardline arbiter of importance, but rather a means to quantify an array of factors that contribute to relative significance.

All the structures that scored more than 50 on the 100-point scale were considered by the consultant to be definitely NRHP eligible. Many of those that scored between 40 and 50 were considered eligible, but others were not, depending on the judgment of the consultant. Only one structure that rated below 40—the Pumphouse Wash Bridge [00079]—was included among the eligible bridges. It was originally listed in the National Register as part of the earlier study and has subsequently undergone substantial alterations, which accounts for its relatively low numerical rating. One structure—the Hereford Bridge [09214] in Cochise County—has been destroyed in an accident since it was listed on the National Register in the original inventory. And fifteen structures that were designated NRHP listed or eligible in the 2008 inventory have since been replaced with newer structures. These are indicated in the following list.

Following the 2018 inventory, 68 structures were identified as having been previously listed in the National Register as part of the original bridge inventory. And using the criteria for significance and integrity, 62 structures have been were identified as eligible for the National Register, either in the 2008 or 2018 inventories. Following is a list of 130 vehicular bridges in Arizona deemed eligible for or listed on the National Register.

Bridge Name	Str. No.	Score	NRHP	Significance
Apache County				
Allentown Bridge	03073	76	listed	well-preserved example of uncommon structural type, located on major route
Sanders Bridge	03074	70	listed	well-preserved example of uncommon structural type, located on major route
Querino Canyon Bridge	08071	74	listed	well-preserved example of uncommon structural type, located on important interstate route
Concho Bridge	08480	83	eligible	well-preserved, early example of singular structural type
Cochise County				
Wash Bridge	00058	49	eligible	well-preserved example of AHD standard bridge design
Tex Canyon Bridge	00059	46	eligible	well-preserved example of AHD standard bridge design
Cottonwood Draw Bridge	00060	46	eligible	well-preserved example of AHD standard bridge design
Jack Wood Wash Bridge	00061	48	eligible	well-preserved example of AHD standard bridge design
Horseshoe Canyon Bridge	00063	44	eligible	well-preserved example of AHD standard bridge design
Wash Bridge	00068	43	eligible	well-preserved example of AHD standard bridge design
Mulberry Canyon Bridge	00069	43	eligible	well-preserved example of AHD standard bridge design
Wash Bridge	00071	42	eligible	well-preserved example of AHD standard bridge design
Lowell Arch Bridge	00130	63	eligible	one of Arizona's earliest bridges, modified by WPA
Benson Highway Underpass	00262	46	eligible	well-preserved example of ASHD architectural treatment on urban grade separation
Benson Railroad Underpass	00264	51	eligible	well-preserved example of ASHD architectural treatment on urban grade separation
Benson Bridge	00350	58	eligible	long-span example of uncommon structural type, altered
Lowell Underpass	01033	55	eligible	well-preserved Depression-era architecture on grade separation
Leslie Creek Bridge	08115	47	eligible	well-preserved example of now-rare standard structural type
Hereford Bridge	09214			structure destroyed
Coconino County				
Dead Indian Canyon Bridge	00032	77	listed	well-preserved example of uncommon structural type, located on important route
Navajo Bridge	00051	91	listed	Arizona's most technologically significant highway bridge
Pumphouse Wash Bridge	00079	39	listed	aesthetically distinguished example of common structural type, altered
W.W. Midgley Bridge	00232	70	listed	outstanding, large-scale example of rare structural type

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Water Holes Canyon Bridge	00508	54	eligible	outstanding example of uncommon structural type, altered
Cameron Truss Bridge	00532			structure replaced
Glen Canyon Bridge	00537	69	eligible	outstanding example of uncommon structural type; major crossing of major watercourse
Walnut Canyon Bridge	09225	53	listed	well-preserved example of uncommon structural type
Cameron Suspension Bridge	priv.	89	listed	one of Arizona's most historically and technologically significant vehicular spans
Canyon Padre Bridge	aban.	84	listed	Arizona's first Luten arch, located on important route
Canyon Diablo Bridge	priv.	79	listed	well-preserved, long-span example of uncommon structural type, located on important route
Gila County				
Salt River Bridge	00037	68	listed	longest and oldest riveted through truss in Arizona
Salt River Canyon Bridge	00129	77	listed	well-preserved, oldest example of rare structural type; pivotal crossing
Pinto Creek Bridge	00351	59	eligible	outstanding, well-preserved example of rare, long-span structural type
Black River Bridge	03128	70	listed	outstanding steel truss mounted on piers of early territorial bridge
White River Bridge	03129	69	eligible	steel truss mounted on piers of Arizona's last covered bridge
Fossil Creek Bridge	03215	46	listed	well-preserved, relatively early example of AHD concrete arch construction
Reppy Avenue Bridge	08585	45	listed	well-preserved, short-span application of patented bridge type
Cordova Avenue Bridge	08586	45	listed	well-preserved, short-span application of patented bridge type
Inspiration Avenue Bridge	08587	45	listed	well-preserved, short-span application of patented bridge type
Keystone Avenue Bridge	08588	45	listed	well-preserved, short-span application of patented bridge type
Miami Avenue Bridge	08589	45	listed	well-preserved, short-span application of patented bridge type
Broad Street Bridge	09710	50	eligible	well-preserved example of common structural type, earliest of type
Pinal Creek Bridge	09711	47	eligible	well-preserved, relatively early example of AHD standard bridge design
Graham County				
Bylas Bridge	00498			structure replaced
Safford Bridge	09333			structure replaced
Greenlee County				
Black Jack Canyon Bridge	00258			structure replaced
Negro Canyon Bridge	00267	45	eligible	well-preserved example of standard bridge type, one of a group of prototypical bridges
Rattlesnake Canyon Bridge	00270	40	eligible	well-preserved prototype of standard structural type
Guthrie Bridge	00352			structure replaced
Packer Wash Bridge	08142	43	eligible	well-preserved example of early standard structural type; built during Depression
Goat Camp Canyon Bridge	08146	43	eligible	well-preserved example of early standard structural type; built during Depression
Solomonville Road Overpass	08150	61	listed	one of Arizona's two oldest datable vehicular bridges, associated with early toll road
Solomonville Road Overpass	08151	61	listed	one of Arizona's two oldest datable vehicular bridges, associated with early toll road
Gila River Bridge	08152	82	listed	outstanding long-span Luten arch, built by convict labor on regionally important route
Black Gap Bridge	08534	73	listed	rare early structural standard, built by convict labor on regionally important route
Park Avenue Bridge	09633	81	listed	one of Arizona's most important early vehicular spans
La Paz County				
				no bridges listed

VEHICULAR BRIDGES IN ARIZONA

Maricopa County				
Dry Wash Bridge	00015	59	eligible	well-preserved, early example of common structural type, located on significant early route
Mormon Flat Bridge	00026	73	listed	well-preserved example of rare structural type, located on significant early route
Fish Creek Bridge	00027	62	listed	well-preserved example of rare structural type, located on significant early route
Lewis and Pranty Creek Bridge	00028	62	listed	well-preserved example of rare structural type, located on significant early route
Pine Creek Bridge	00031	59	listed	well-preserved example of rare structural type, located on significant early route
Gila Bend Overpass	00118	57	listed	earliest remaining example of AHD architectural treatment on urban grade separation
Peoria Underpass	00160	58	eligible	well-preserved example of ASHD architectural treatment for an urban grade separation
Wickenburg Bridge	00161	55	eligible	well-preserved example of long-span structural type; major crossing on major route
Boulder Creek Bridge	00193	74	listed	well-preserved example of uncommon structural type, located on significant early route
Wickenburg Underpass	00195	61	eligible	uncommon structural type, altered, on major highway route
Alchesay Canyon Bridge	01532	76	listed	oldest documented vehicular bridge in Arizona
17th Avenue Underpass	07770	65	eligible	handsomely detailed, well-preserved example of Depression-era bridge construction
Gillespie Dam Bridge	08021	94	listed	outstanding multiple-span truss bridge; major crossing on important highway
Central Avenue Underpass	09168			structure replaced
Mill Avenue Bridge	09954	86	listed	one of Arizona's most historically and technologically significant bridges
Mohave County				
Burro Creek Bridge	00846	64	eligible	well-preserved example of uncommon structural type; major crossing on major route
Virgin River Bridge	01089	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01236	62	eligible	well-preserved example of standard structural type; major crossing on major route
Old US 91 Overpass	01612	62	eligible	well-preserved example of standard structural type; major crossing on major route
Old US 91 Overpass	01613	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01614	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01615	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01616	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01617	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01618	62	eligible	well-preserved example of standard structural type; major crossing on major route
Virgin River Bridge	01619	62	eligible	well-preserved example of standard structural type; major crossing on major route
Arizona Spillway Bridge	03003	72	listed	designated as part of Hoover Dam NHL complex
Old Trails Wash Bridge	08594	64	eligible	well-preserved example of early standard structural type
London Bridge	08630	63	eligible	unique adaptation of European bridge to Western setting
Sand Hollow Wash Bridge	08662	77	listed	well-preserved example of uncommon structural type, on regionally important highway
Old Trails Bridge	priv.	94	listed	outstanding early large-scale bridge, located at major interstate crossing
Navajo County				
Side Hill Viaduct	00145	52	eligible	well-preserved example of singular structural type
Winslow Underpass	00194	70	listed	well-preserved Depression-era grade separation
Cedar Canyon Bridge	00215	40	listed	outstanding example of rare structural type, essentially reconstructed
Winslow Bridge	00229			structure replaced
Ruby Channel Bridge	00275			structure replaced
Clear Creek Bridge	01038	51	eligible	well-preserved example of rare structural type
West Carrizo Bridge	02057	53	listed	outstanding multiple-span example of common structural type
Woodruff Bridge	08156	67	listed	unique example of structural type, once part of regionally important crossing
St. Joseph Bridge	08157			structure replaced
Chevelon Creek Bridge	08158	94	listed	one of Arizona's most historically and technologically important vehicular spans

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Tanner Wash Bridge	08160			structure substantially altered
East Carrizo Bridge	abd.	63	listed	outstanding multiple-span example of common structural type
Holbrook Bridge	priv.	81	listed	longest known Luten arch built in the country
Jacks Canyon Bridge	abd.	81	listed	well-preserved example of early AHD concrete bridge design
Woodruff Bridge	abd.	59	eligible	remnant of once-important multiple-span truss bridge
Pima County				
Wash Bridge	01020	44	eligible	well-preserved example of early ASHD standard bridge design; on major route
Stone Avenue Underpass	07987	68	listed	well-preserved example of 1930s AHD architectural treatment on grade separation
Sixth Avenue Underpass	07988	54	listed	well-preserved example of architectural treatment on urban grade separation
Cienega Bridge	08293	64	listed	well-preserved, long-span example of uncommon structural type
Wash Bridge	08294	41	eligible	well-preserved example of early ASHD standard bridge design; on major route
Wash Bridge	08306	42	eligible	well-preserved example of early ASHD standard bridge design; on major route
Fourth Avenue Underpass	08453			structure replaced
Pinal County				
Casa Grande Underpass	00143	60	eligible	well-preserved example of Depression-era architectural detailing on grade separation
Forman Wash Bridge	00223	46	eligible	well-preserved example of Depression-era design and construction
Olsen Wash Bridge	00223	47	eligible	well-preserved example of Depression-era design and construction
Queen Creek Viaduct	00406	59	eligible	outstanding, well-preserved example of rare, long-span structural type
Florence Bridge	00501	49	eligible	one of the most important river crossings in the state
San Tan Canal Bridge	03164	45	listed	well-preserved example of early concrete bridge construction
Sacaton Dam Bridge	03165	77	listed	outstanding large-scale concrete bridge; part of important Indian irrigation project
Queen Creek Bridge	08440	70	listed	well-preserved example of patented structural type, built in regionally important route
Kelvin Bridge	08441	57	listed	well-preserved example of patented structural type, built in regionally important route
Winkelman Bridge	08442	62	listed	well-preserved example of patented structural type, built in regionally important route
Devils Canyon Bridge	abd.	61	listed	well-preserved example of early AHD concrete bridge design
Mineral Creek Bridge	abd.	55	listed	well-preserved example of early proprietary bridge type
Queen Creek Bridge	abd.	83	listed	well-preserved example of early AHD concrete bridge design
Santa Cruz County				
Santa Cruz River Bridge	08166	90	listed	earliest and longest concrete girder structure in use on state road system
Nogales Wash Bridge	08167			structure replaced
Portrero Creek Bridge	08171	45	eligible	well-preserved, early example of standard structural type, on important route
Yavapai County				
Granite Creek Bridge	00042	51	eligible	excellent example of early state standard bridge type
Hell Canyon Bridge	00483			structure replaced
Black Canyon Bridge	00758	43	eligible	well-preserved example of welded steel construction
Wilbur Canyon Bridge	00781	44	eligible	well-preserved example of welded steel construction
Granite Creek Bridge	01489			structure replaced
Little Hell Canyon Bridge	03381	82	listed	well-preserved example of uncommon structural type, located on regionally important route
Walnut Grove Bridge	08227	66	listed	well-preserved early example of county-level truss bridge construction
Verde River Bridge	08236	64	listed	well-preserved, relatively early standard structural type, located on important highway
Cordes Bridge	08249	51	eligible	well-preserved example of early AHD bridge design
Lynx Creek Bridge	08256	57	listed	well-preserved early example of AHD bridge design

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Broadway Bridge	08488	51	listed	outstanding early example of common structural type
Willis Street Bridge	08550	45	eligible	well-preserved, early example of Depression-era bridge construction
Walnut Creek Bridge	08741	69	listed	outstanding example of early truss construction
Perkinsville Bridge	09474	80	listed	outstanding example of early standard truss bridge type
Hell Canyon Bridge	priv.	63	listed	outstanding example of early concrete girder design and construction
Yuma County				
Ligurta Underpass	08406	43	eligible	well-preserved example of AHD architectural detailing on grade separation
Wash Bridge	08408			structure replaced
Ligurta Wash Bridge	08410	47	eligible	well-preserved example of standard structural type, on important route
Ocean-to-Ocean Bridge	08533	93	listed	one of the most important wagon bridges in Southwest
Antelope Hill Bridge	abd.	80	listed	one of state's most important early wagon bridges, located on important route
McPhaul Bridge	abd.	91	listed	extraordinary long-span example of uncommon structural type, located on important route

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National Register of Historic Places Continuation Sheet

Inventory Forms

On the following pages are Arizona Historic Bridge Inventory forms for the structures that appear eligible for listing in the National Register. Included are bridges that were listed under the first and second Arizona Historic Bridge Inventories and those that appear eligible for listing under this current Inventory. The structures are organized in the same manner as the list in Section H: by Structure Number within each county.