United States Department of the Interior
National Park Service

National Register of Historic Places
Multiple Property Documentation Form

This form is for use in documenting multiple property groups relating to one or several historic contexts. See instructions in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 16B). Complete each item by entering the requested information. For additional space, use continuation sheets (Form 10-900-a). Use a typewriter, word processor, or computer to complete all items.

____ New Submission __x__ Amended Submission

A. Name of Multiple Property Listing

Vehicular Bridges in Arizona 1880 - 1978

B. Associated Historic Contexts

Vehicular Bridges in Arizona 1880 - 1978

C. Form Prepared By

name/title Clayton B. Fraser, Principal

organization FRASER design date 31 October 2018

street & number 5700 Jackdaw Drive telephone 970.744.1207

city or town Loveland state Colorado zip code 80537

D. Certification

As the designated authority under the National Historic Preservation Act, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards for Archeology and Historic Preservation. (__ See continuation sheet for additional comments.)

Signature of certifying official date

State or Federal agency or bureau

I, hereby, certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

Signature of commenting or other official date

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Provide the following information on continuation sheets. Cite the letter and the title before each section of the narrative. Assign page numbers according to the instructions for continuation sheets in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 16B). Fill in page numbers for each section in the space below.

Primary Location of Additional Data

____ State Historic Preservation Office
__x__ Other state agency (Arizona Department of Transportation)
____ Federal agency
____ Other

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1 Introduction

The Arizona Historic Bridge Inventory, which forms the basis for this Multiple Property Documentation Form [MPDF], was produced for the Arizona Department of Transportation [ADOT] by Fraserdesign of Loveland, Colorado, under a subcontract agreement with EcoPlan Associates, Inc., of Mesa, Arizona. The study was undertaken with the cooperation of the Arizona State Historic Preservation Office. This inventory is a sequel to an earlier study completed in 2008 by Fraserdesign that focused primarily on identifying National Register-eligible bridges constructed before 1965. This follow-up study broadened the scope of work of the original inventory to examine bridges built before 1979. The earlier study culminated with the production of a National Register Multiple Property Documentation Form entitled "Vehicular Bridges in Arizona." This MPDF is intended to function as an amendment to the earlier document.

It is structured in conventional manner, with the Statement of Historic Contexts as Section E, followed by Associated Property Types as Section F. The former is a narrative discussion of vehicular bridges in Arizona, organized more-or-less chronologically beginning with early bridge building in America and ending with construction of the interstate highway network in Arizona. The latter section lists the major structural types encountered in Arizona, discussing for each its history and aspects of National Register significance and registration requirements. This discussion of National Register eligibility is exhaustive because, even though the Historic Bridge Inventory has identified and documented what appear to be Arizona's NRHP-eligible structures, other structures may emerge in the future that require evaluation for significance and eligibility.

Section F is followed by Geographical Data (Section G) and a Summary of Identification and Evaluation Methods (Section H). Section H includes a listing of the 135 eligible and listed structures as well as a comprehensive listing of all 4,019 structures included in the Inventory. The MPDF concludes with Section I, which presents a Bibliography of sources used in the Inventory. Section I also contains the inventory forms for structures identified by the Inventory as NRHP-eligible and -listed. All the sections—including the inventory forms—are numbered sequentially, beginning with this page. The bridges listed in Sections H and I are organized by structure number within each county.

The bridges identified in the Inventory as NRHP-eligible generally exhibit a degree of historical or technological significance that is clearly greater than others within their class or structural type. To maximize the bridges' interpretive value, premiums have been placed on thorough historical documentation and maintenance of physical integrity. As discussed in the National Register guidelines given in Bulletin 16, bridges can be considered eligible for their representation of general trends—either transportation or engineering—or for their exemplification of outstanding—or at least noteworthy—technological achievement. Many of the structures listed here have been identified as NRHP-eligible for their well-preserved representation of standard structural types. Others have been selected as superlative examples (e.g., oldest, longest, best-preserved of type) of bridge construction in Arizona. The superlative examples have been listed in Section F with each structural type.

2 Bridge Development in America

Bridges, as integral elements of a developing transportation network, have played a pivotal part in the development of America. Generally the most sophisticated components of any overland transportation system, they are also the most prominent. Bridges not only function as gauges of technological advancement in design and construction, they reflect the tenets, values and ambitions of the people who erected them. "There can be little doubt that in many ways the story of bridge building is the story of civilization," President Franklin Roosevelt stated in 1932. "By it we can readily measure an important part of a people's progress." While descriptive of the United States in general, this was especially true for Arizona, a state in which overland transportation forms a central historical theme. From the earliest wooden spans on the territorial toll roads to the later steel trusses and concrete arches on early state routes to the precast bridges on the interstate highway network, bridges have facilitated, and in some instances created, settlement across the state.

A plethora of bridge forms, variously employing such materials as stone, timber, iron, steel and concrete, has been developed in America through years of empirical usage. The first wooden bridges were merely plank structures—the equivalent of a log thrown across a stream. Limited in span to the wooden beam's length and carrying capacity, they were used for only the shortest crossings. Without proper support, they became unduly strained by bending moment forces, leading to structural failure: i.e., the log broke. An advancement over this was the first significant bridge form used extensively in America, the pier bridge, also called the pike-and-beam bridge. Another ancient bridge type, it consisted of heavy timber or log stringers spanning between timber pile bent piers, spaced at intervals of between 10 and 30 feet. In places where loose or shifting sediment proved unsuitable or was too deep for stone foundations, vertical wooden piles were driven into the riverbed to support the roadwork and joined to form bents. A variation on the pile design, the crib bridge, used stacked logs for the piers in lieu of driven piles, often with stone ballast in the piers' centers. Timber stringer bridges were used extensively throughout America and continue to be commonly used for minor bridges.

The use of stone as a building material was also transferred to America from Europe. Long known for its superior compressive strength, stone (or more specifically the mortar joints between the stones) has virtually no tensile strength and must rely on compressive forces through arching. Although used extensively in Europe, stone was largely eschewed in this country in favor of timber and was used only marginally for bridge superstructures. While some stone bridges were built in situations in which strength and permanence outweighed the importance of initial cost, the use of stone was generally restricted to substructural work. There its rigidity and resistance to scouring from water made it the preferred material for piers and abutments until the development of concrete early in the 20th century.

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Though by far the most common structural type, the timber stringer bridge was not really very sophisticated. More technologically innovative was a bridge type that has been termed "primarily an American achievement"—the truss. The introduction of the truss marked the beginning of more involved bridge design in America. As with other structural types, the truss form had been imported from Europe. First employed in ancient Greece and Rome as a roof support, the truss was not formally associated with bridge design in Europe until the Renaissance. But while the first timber trusses were erected there, the greater development of truss design occurred in America during the 19th century.[1] Between 1820 and 1850 truss design evolved from empirically based craftsmanship into a science. Several major truss patents were issued during this period, a fact directly attributable to railroad development and the concurrent need for bridges of increased strength, capacity and rigidity.

These patents described a wide variety of truss configurations, the Town lattice, Burr arch-truss, bowstring and Howe being the most commonly employed in timber and iron configurations. By the time that Arizona began building trusses on its roads in the late 19th century, the number of bridges practically available had been winnowed down considerably to include two basic truss families—the Pratt and the Warren. The Pratt was more common. Patented in 1844 by Thomas and Caleb Pratt, this truss type featured verticals and upper chords that acted in compression (that is, the forces pushed inward along the members' lengths) and diagonals and lower chords in tension (the forces tended to pull outward). These were built using a combination of wood for compression members and iron for tension. Because of their large use of cast or wrought iron components, which were expensive to manufacture in the mid-19th century, Pratt trusses did not gain widespread popularity until the 1870s and 1880s, when the improved quality and decreased cost of iron made feasible the construction of all-metal trusses. The Warren truss was introduced four years after the Pratt by two British engineers in 1848 and quickly adopted in America. With its web comprised of repetitive triangles, the Warren in its classic form included only diagonal members (and no verticals) that carried alternating compressive and tensile forces. Its straightforward design made it a standard form for later all-metal trusses.

The Pratt and Warren became the truss types of choice for bridge engineers in the late 19th and early 20th centuries. The Warren featured minor variations in its web configuration and its upper chord shape, but its general profile was unmistakable. The basic Pratt design was split into a variety of sub-types—the Parker, with its polygonal upper chord; the Pennsylvania, so named for its extensive use by the Pennsylvania Railroad; the Baltimore, used by the B&O Railroad; the Camelback, a Parker variant described by one influential engineer as "uncompromisingly ugly"; the Kellogg; and the lenticular truss— which as a group constituted the overwhelming majority of vehicular trusses fabricated in the 19th century.[2]

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[1]David Plowden, *Bridges: The Spans of North America* (New York: Viking Press, 1974), 34. Plowden states: "It is probable that most literate men among [Americans] were aware of European developments. It is also conceivable, however, that the truss, such an obvious device to anyone familiar with the rudiments of roof framing, may have evolved independently in America."

[2]J.A.L. Waddell, *Bridge Engineering* (London: John Wiley and Sons, 1916), 23-27.

The evolution of truss components and connection methods in America paralleled that of truss design. Cylindrical pins were first used to connect metal truss members on a Lehigh Valley Railroad bridge in 1859. Two years later a complementary truss member—the forged iron eyebar—was introduced. Steel eyebars, made using the Bessemer and open-hearth forging processes, appeared in the 1870s. Pinned connections, assembled over falseworks in what was termed the "American style" of truss construction, allowed quick erection, but they lacked rigidity and could loosen from vibrations caused by traffic and wind. Riveting created stronger, sturdier connections but was not practical in the field before portable riveters became available in the late 1880s.[3]

After the turn of the century the pattern was well-set, and no new truss designs of significance were patented. Truss design was by then a matter of refinement and expansion of existing ideas. The only major change in truss erection occurred after 1910, when rigid connections began to supercede pinned. Bridge companies used both structural types—occasionally combining the two on a single structure—during the transitional period in the early 1910s. By 1920 erection of pin-connected bridges had virtually ceased. Concurrent with this was the emergence of the Warren truss for vehicular use. Pratt trusses were inherently better suited to American style pin-connected erection, but Warren trusses proved more difficult to assemble in the field using pinned connections. When rigid-connected trusses became more feasible in the 1910s, Warrens came into their own, receiving more widespread acceptance among American bridge engineers.

Although the truss received much of the attention from the engineering profession, other types of metal bridges were undergoing simultaneous development in the 19th century. One of these was the girder structure. An elaboration on the simple stringer bridge, with two to six main spanning beams to which floor beams are attached perpendicularly, the girder form was associated primarily with railroad construction. The first patent for an all-iron bridge was taken out by August Canfield in 1833, and as early as 1846 an iron plate girder railroad bridge had been erected. As the cost of wrought iron decreased, girders began to proliferate during the 1870s and 1880s. With their deep profiles made up of iron or steel plates to which rolled metal flanges and web stiffeners were riveted, girders were ideally suited for railroad use because of their inherent rigidity and relative ease of construction.

Their drawbacks were that they weighed more than similar-length trusses and they were typically built in-shop and hauled and assembled to the sites, limiting their effective span to the length of a railroad flatcar. Nonetheless, deep-profile girders were used extensively for short- to medium-span railroad bridges from the 1880s to the 1920s. Although roadway girders were also built at that time, they tended to be significantly less economical than other bridge types and were employed principally for special-use situations such as heavily trafficked urban bridges and viaducts.

[3]Waddell; Donald C. Jackson, *Great American Bridges and Dams* (Washington, D.C.: Preservation Press, 1988), 28.

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Two other metal bridge types that received use during the late 19th and early 20th century were suspension and cantilever bridges. The first suspension bridge in America was erected in 1786; by 1808 over 40 had been built. Used only intermittently by the railroads due to their inherent lack of rigidity, suspension spans received increasing vehicular use through the end of the 19th century and the early 20th century. The Kentucky River Bridge at Dixville, Kentucky, built in 1876, marked the beginning of long-span modern cantilever construction. Like the suspension bridge, it is a design that received only limited use in the early 20th century.

After the turn of the century, another structural form—the reinforced concrete arch—began to receive widespread usage among American engineers. Concrete arches relied on two ancient technologies—concrete construction and the arch form—to allow a material that ordinarily acts poorly in tension to carry loads over long spans. Used since ancient times, concrete consists of two parts—binder (i.e., cement) and filler (which for road work is usually crushed rock, sand or gravel. Essentially calcium oxide, cement is usually created by burning finely broken limestone. The resulting product is then mixed with water to form cement, which is either soluble in water (non-hydraulic) or, with the addition of silica and alumina, impervious to water (hydraulic). Obviously, only hydraulic cement was appropriate for use in road and bridge work.

If the silica and alumina occurred naturally in the limestone, "natural" cement was created. While sometimes used for bridge building, natural cement tended to be structurally unpredictable. It was supplanted in the United States in the 1880s by Portland cement, in which silica and alumina were artificially introduced to achieve consistent quality. The first use of Portland cement in America is attributed to David O. Saylor, who 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 was the foundation of the Erie Railroad's Starrucca Viaduct, completed in 1848. John Goodrich was probably the first in this country to use concrete in a bridge superstructure in 1871. He was soon followed by others, so that by 1900 some 150 concrete arches had been built in America.

These early structures were built of unreinforced, or mass, concrete. In 1871 W.E. Ward was the first to embed steel bars in a concrete bridge to add tensile strength. By the early 1890s, this technology was being applied to bridge construction, resulting in the development of several proprietary reinforcement systems. The type chosen for a structure affected its appearance as well as its strength and bearing characteristics. Regardless of the structural type, quality control continued to be a problem until well into the 20th century, when aggregate was more carefully selected and washed. Ascertaining correct proportions of water, cement and aggregate was more of an art than a science during concrete's formative years, and mistakes caused structural failures. Around 1900 engineers began building ever longer reinforced concrete arch structures, reaching spans in excess of 250 feet by 1908. Both open- and filled-spandrel concrete arch bridges were ideally suited for the memorial bridges being erected by cities across the country to replace earlier iron trusses. As indicated by an article in *Engineering Record*, the truss was by then considered an eyesore on the urban landscape:

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> There is one feature of city (truss) bridge building that still remains in the dark ages, and engineers ought to give it more attention. The usual criticism of our public works is that they are needlessly utilitarian and consequently ugly. Now it must be admitted that an ordinary highway truss bridge is not so charming as a well proportioned masonry arch.[4]

Aesthetics thus became an important consideration in bridge design and detailing in the 1910s, particularly for urban structures. To conceal the stark concrete planes of their bridges, engineers often covered them with façades of real or imitation stone or formed and textured the concrete to resemble coursed masonry. Ernest Ransome had chosen to disguise the Alvord Lake Bridge, a structure at the forefront of technological innovation, with a veneer of imitation stone. "As often as not, the results were less pleasing than the structures they replaced," David Plowden states. "These bogus structures satisfied the aesthetic requirements of the turn of the century and cost much less to build than an all-stone bridge, despite the over ornamentation some of them received."[5]

As they gained experience with the material, bridge designers became more creative. "There is little excuse for building an ugly concrete bridge," Waddell insisted. While immediately appreciating the arch form in concrete, the public was initially unimpressed by the sparse look of concrete girder and beam spans. A contemporary wrote that "frequent objection has been made to the use of them for the reason that they are not susceptible to artistic treatment." While the writer maintained that this objection was diminishing, conventional wisdom held that if there had been a popularity contest for bridges in the early 20th century, concrete arches would have won hands down.

After 1905 concrete bridge construction experienced a marked increase, due largely to the efforts of one engineer, Daniel B. Luten of Indianapolis. Using a series of broadly stated patents for reinforced concrete arches, Luten largely controlled the concrete bridge industry in America. His lawsuits for patent infringement were routinely upheld in the courts, forcing many arch builders to pay royalties to Luten. Luten's arches were innovative. Featuring sometimes highly elliptical profiles, they were sophisticated in their dependence on steel reinforcing and allowed relatively thin concrete sections at midspan. Termed Luten arches—or horseshoe arches for their distinctive profile—they were built extensively from 1905 through the mid-1920s. Luten claimed to have built some 17,000 concrete arches, including several in Arizona.

Luten's stranglehold on the industry was finally broken in January 1918 when a Des Moines judge ruled that the broadly worded patents were invalid. The Iowa location was significant, for the suit challenging Luten's patents was initiated by America's other most significant bridge designer, James B. Marsh of Des Moines. The ruling opened up arch building in the country, and the concrete arch received increased use as a vehicular

[4] "City Bridges." *Engineering Record*, 3 June 1911.

[5] Plowden, 298.

bridge type. Marsh himself had patented a reinforced concrete arch design in 1912, called the Marsh, or rainbow, arch. Marsh arches were essentially steel bridges sheathed in concrete, with the deck carried between two parallel arches. Costly to construct, they were built sparingly for highway use. One is known to have been built in Arizona—the Santa Cruz River Bridge in Pima County (demolished).

The dull color of concrete bridges and the enormity of steel trusses sparked debate within the bridge profession on aesthetics and scale. To engineers interested in technological achievement, the monumental skeletal structures of steel illustrated perfectly the relationship of form and function. Moreover, those such as Thomas Clarke saw utility and not sculptural art as of primary importance. "Where so many bridges had to be built in a short period of time, aesthetic considerations are little regarded," he stated. "Utility alone governs their design. So long as they are strong enough, few care about how they look."[6]

On the other side were those that held the arch to be the highest form of bridge design. Concrete arches provided the opportunity for applied ornamentation in the form of incised panels or classical balustrades that starkly functional trusses did not. Moreover, proponents argued that the arch was structurally superior, more rigid under traffic and more resistant to flooding. Ultimately, however, the decision to build a concrete or steel bridge was often an economic one, and in most applications concrete cost more than steel. Concurrent with the increased use of concrete for arches after the turn of the 20th century was the use of reinforced concrete for beam and slab bridges. Concrete slabs were the simplest to construct, comprised of a single slab floor with steel reinforcing rods embedded within the concrete. Although relatively inexpensive, they were limited in their spans to 20 feet or so.

Concrete beam bridges could span greater distances—up to 40 feet, generally. They were configured with two to four relatively deep beams or with a greater number of shallower stringers. The girders could be positioned in deck (below the roadway) or through (above the roadway) configurations. Deck girders protected the bridge's structural members from accidental collision and they allowed subsequent widening of the roadway by adding beams outside the original line.. Through girders were somewhat lighter in weight and allowed the girders to double as guardrails, but they were vulnerable to collision damage and their decks could not be widened. Unlike arches, these concrete beam bridges were generally regarded as utilitarian structures and were rarely festooned with ornamentation.

A common thread that ran through all the major metal bridge types was the method of their construction. With the rise of industrialization, the settlement of the West and the resultant proliferation of overland transportation networks, a new industry—bridge fabrication—sprang up in 19th century America. A number of companies formed after 1850 to fill the demand for roadway and railroad truss bridges. After the Civil War, their numbers jumped from a total of just five to 75 in 1870, 137 in 1890 and almost 200 by 1900. Few civil engineers at the time fully understood stress analysis and truss design, allowing national firms such as the King Bridge Company and the Wrought Iron Bridge Company to accrue influence in a rapidly expanding market.

[6] As quoted in Plowden, 166.

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These firms often published catalogues of standard structural types and bid competitively on construction contracts let by the counties and municipalities. Several firms in the Midwest and the Ohio River Valley specialized in bridge fabrication and erection. Constantly on the road, their salesmen contacted counties where rapid population growth produced a demand for large numbers of bridges. When an order for a bridge was received, its components were assembled at the fabrication plant, using iron or steel members rolled in the immense forges of Pennsylvania or Illinois. Bridge fabricators sometimes erected the parts at the site as well. Other firms received bridge contracts but were responsible for erection only, purchasing steel superstructures from fabricators such as the Minneapolis Steel & Machinery Company or the Omaha Structural Steel Works (builder of the Ocean-to-Ocean Bridge in Yuma).

In 1900 the complexion of the industry changed radically. That year financier J.P. Morgan created the enormous American Bridge Company by consolidating two dozen smaller firms, including the Wrought Iron Bridge Company (Canton, OH), the Edge Moor Bridge Works (Wilmington, DE), the Milwaukee Bridge & Iron Works (Milwaukee, WI), the Groton Bridge & Manufacturing Company (New York, NY) and the Youngstown Bridge Company (Youngstown, OH). This effectively molded most of the competing firms into one gargantuan company, which then fabricated and erected thousands of railroad and vehicular bridges across the country. Against this giant of the industry several smaller firms still managed to compete, mostly from the West and Midwest. These included companies such as the Missouri Valley Bridge & Iron Works (Leavenworth, KS), the Midland Bridge Company (Kansas City, MO), and the Canton Bridge Company (Canton, OH).

After 1900 the bridge companies had two more decades of intense activity before the industry was again transformed. Following passage of the Federal Aid Highway Act in 1916, the responsibility for bridge design generally fell to the state highway departments or to the federal government. While bridge design thus became more centralized, bridge contracting became more localized. National bridge firms offering design/build services to the counties could no longer remain competitive in this changing market, and an entirely new group of bridge builders quickly developed. Additionally, the industry transformation marked a shift from the design of wagon bridges in the 1910s to those intended specifically for automobile use. These two trends amounted to what was essentially an evolution from 19th century to 20th century practice.

As recent as America is in terms of bridge development, Arizona is far younger still. In the 1840s, when most of the major truss types were invented, Arizona was not even a part of the United States territory. When the rest of the country was experiencing what was probably the greatest period of roadway bridge construction in the 1880s and 1890s, Arizona was not yet a member of the union. When Indiana engineer Daniel Luten patented his first horseshoe arch in 1900, Arizona Territory had built only a few permanent crossings. And by the time Arizona was admitted as a state in 1912, bridge technology was already well developed in America. Despite this, a number of outstanding bridges have been constructed on Arizona's roads and highways, principally by the state highway department. Fortunately, many of the best of these have survived.

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3 Territorial Road and Bridge Construction in Arizona: 1880-1912

From 1848, when much of Arizona territory was acquired from Mexico by the Treaty of Guadalupe, until 1863, with the enactment of the Federal Organic Act that designated the Territory after its separation from New Mexico, Arizona was crossed by only two major overland routes. Both traversed the region from east to west and both had been developed by the military. The first wagon road through the area was built in 1846 as a route between Santa Fe and San Diego. This road, constructed hurriedly by Capt. Phillip Cooke and the Mormon Brigade during the war with Mexico, entered the territory in the southeast corner, extended north to the Gila River and then west to the Yuma Crossing of the Colorado River. Known as Cooke's Wagon Road or simply as the Gila Trail because it largely paralleled the Gila River, this southern route was later made popular by those traveling to California in search of gold.

The northern route followed Lieutenant Edward Beale's 1857 survey along the 35th parallel for a wagon road between Fort Smith, Arkansas, and the Colorado River. With camels as pack animals, Beale's troops traversed the region as they charted a wagon road between Fort Defiance in New Mexico Territory to the Colorado River. In 1859 Beale's expedition returned to construct a 10-foot-wide track, largely by clearing vegetation and loose rocks from the route they had scouted two years earlier. Called Beale's Road, this route was used by hunters, trappers and military troops before construction of a railroad along the route in 1883. Beale reflected the prevailing view of the area when he reported back to Congress in 1858: "The region is altogether valueless. After entering it, there is nothing to do but leave." Other secondary routes—no more than trails, really—developed across the region through intermittent use. Road maintenance, such as it was, was performed on these routes by travelers as the need occurred. Bridges were virtually nonexistent.

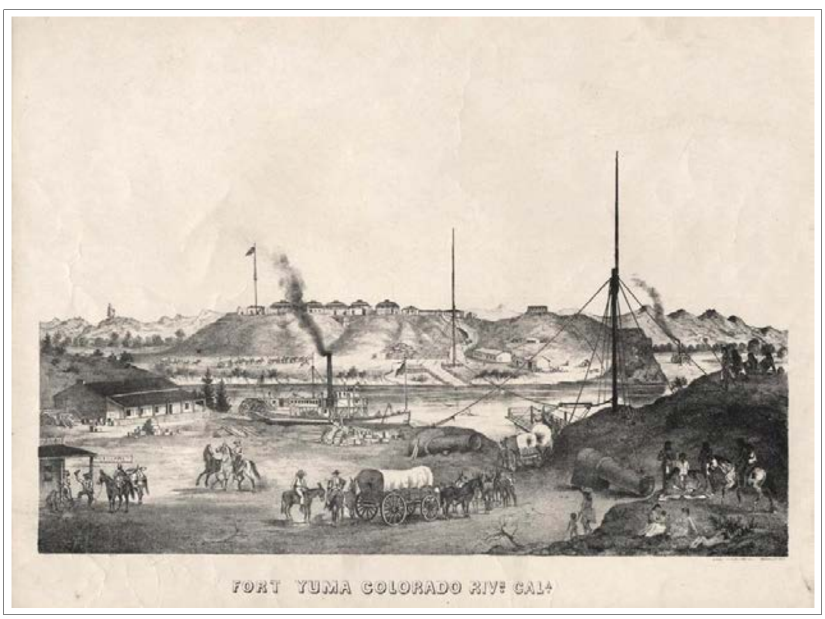

Figure 1. Fort Yuma, 1875. California Historical Society.

At the point where the Gila Trail crossed the Colorado River, John Gallatin built a toll ferry in 1849, supplanting earlier Indian-operated ferries at this point. Louis Jaeger started his own ferry service here a year later, after the Indians exacted their own toll on

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Gallatin by scalping him. A settlement called Jaegerville soon developed on the California side of the ferry. In December 1850 the U.S. Army established a small encampment, called Fort Yuma, a mile upriver [Figure 1]. The town of Colorado City was platted on the Arizona side of the river four years later. This community changed names three times before its incorporation in 1871 as Yuma. In addition to its role as a port for riverboats that plied the Colorado River, Yuma served as a funnel for overland travelers between southern California and the East. Thousands of immigrants traveled westward on foot, wagons or horseback across the Gila Trail, and the Butterfield Overland Stage followed the trail through Yuma on its route between St. Louis and San Francisco. The arrival of the Southern Pacific to Yuma, with the construction of the new railroad bridge over the Colorado, further bolstered the small city's role as a Southwestern transportation nexus [Figure 2].

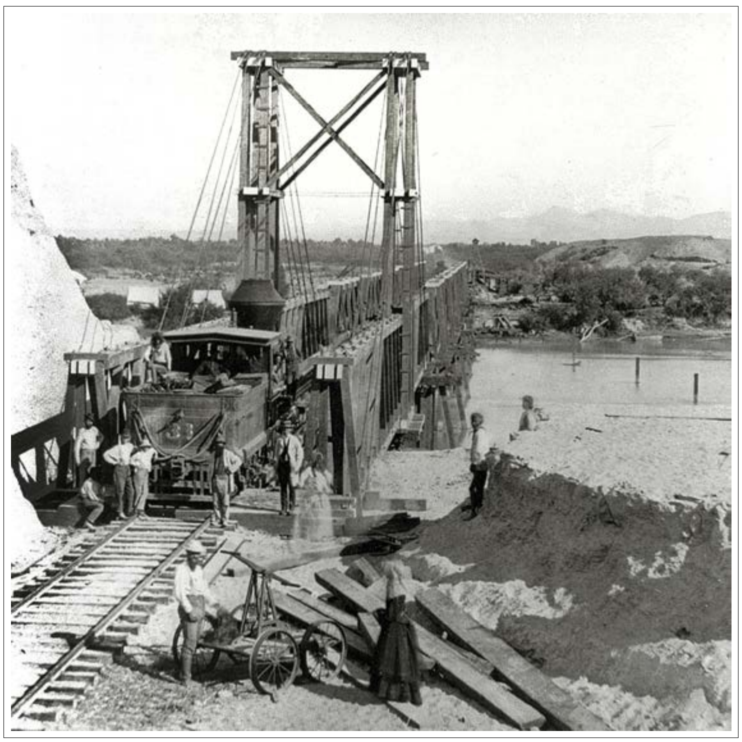

Figure 2. First railroad bridge over Colorado River in Yuma, 1877. Library of Congress.

Meanwhile, in the Salt River Valley some 180 miles east, another colony was growing around an agriculturally based economy. The origins of Anglo settlement in central Arizona date from 1867. That year William John Swilling, flamboyant Confederate army officer, prospector, Indian fighter and entrepreneur, formed the Swilling Irrigation Canal Company with John Y.T. "Yours Truly" Smith, the post sutler at Fort McDowell. They opened the Swilling Ditch by clearing an ancient Hohokam Indian canal, supplying water to a growing number of farms that sprang up along the ditch's length. Three years after the inception of the Swilling Ditch, the townsite of Phoenix was platted. Phoenix grew steadily with the rest of the Central Valley through the 1870s and 1880s [Figure 3]. The city's future as Arizona's central metropolis was guaranteed when in 1889 the Arizona Territorial Capital was moved to Phoenix from Prescott. Although not directly on the Gila Trail, Phoenix was close enough to connect it by a relatively short wagon road to the south. The Gila Trail thus served to link Phoenix with Yuma and points west, and eventually the northern swing through Phoenix became the main line through common use.

After its formation in 1863, the Arizona Territorial Assembly immediately recognized the need for transportation routes to connect the widely scattered settlements and foster

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Figure 3. Pioneer Hotel in Phoenix in early 1880s. Picryl.

economic growth. Money for road construction was scarce, however. The First Territorial Assembly did what government bodies have traditionally done when short of funds themselves: it licensed others to build the roads and bridges for profit. Privately held toll companies were given exclusive rights to build and administer toll roads and collect fees based upon predetermined price rates. To raise capital for construction, they were allowed to issue stock. To protect their investments, the companies were granted franchises for specified periods of time. In return for these exclusive rights, the territorial auditor collected a part of the gross proceeds from each road, to be applied to the school fund. During the first legislative session, six toll road ventures, such as the Santa Maria Toll Road Company and the Arizona-Central Toll Road Company, were thus chartered, most of which extended from the territorial capital at Prescott.

Toll rates were generally set on a per-mile basis, depending on the mode of transportation. As a free-market function, the tolls varied from road to road, but usually reflected the road's use, location and difficulty of construction. The acts of incorporation were similarly structured for all toll companies, containing the same general provisions: Roads were to be completed and improved within a designated period. Water wells were to be dug and maintained and facilities provided for use by both people and animals. The roads were to be kept safe and passable. Finally, exclusive rights to maintain the roads and collect tolls would be granted as long as they did not encroach on other existing toll roads.

The law did little to encourage excellence in road construction, however, and the toll road operators tried to avoid bridge construction as an unnecessary expense. The bridges that were built rarely lasted beyond the statutory limits of the franchises. Poorly constructed and unevenly maintained, these rudimentary timber or masonry structures typically washed out in floods or collapsed under load. Only two such structures from the territorial period are known to exist still. Both were built in 1907 in Graham (now Greenlee) County on the Clifton-Solomonville Road [Figure 4]. The Solomonville Road Overpasses (**08150** and **08151**) are unusual in that they were built to carry wagon traffic over railroads (the earliest datable grade separations in Arizona), they used concrete arch construction, and they were built relatively late in the toll road milieu.

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Figure 4. Solomonville Road Overpass (08150), 2018.

In a region in which government revenues were minimal, toll roads were generally regarded as a necessary evil, a costly but temporary way to develop a much-needed road system. But the First Territorial Assembly was also aware of the need for free roads to promote transportation and settlement. The Assembly tried to legislate a balance between routes built by private capital and supported by tolls and those over which no tolls could be extracted. To prevent toll operators from monopolizing travel by incorporating every road in the territory, the lawmakers designated several existing roads—developed solely by prior use—as free routes. This formed the basis for a free-highway network in Arizona, which subsequent legislatures would expand by incorporating toll road companies and simultaneously declaring other roads as toll-free.

Arizona's territory-level management soon proved burdensome, however. In 1866 the Assembly began transferring responsibility for building roads to the individual counties by authorizing the counties to establish road districts and appoint overseers to supervise roads and bridges within each district. To fund construction and maintenance, the county boards of supervisors were empowered to issue bonds of indebtedness. Additionally, they could assess a yearly road tax of $6 on every able-bodied man, which could be defrayed by labor on the roads. In 1871 the Assembly transferred even more autonomy to the counties, giving them the right to incorporate toll road proprietors themselves.

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The conditions for incorporation were generally the same as those for the territory, and the counties retained the option to purchase the privately built roads after five years. With this, the county administrators possessed all the tools needed to pursue active road and bridge programs. They rarely used them well. Seldom following a premeditated plan, county supervisors authorized the surveying and clearing of roads and construction of bridges as needed, usually in response to urgent local petitions. Arizona State Engineer Lamar Cobb later characterized the situation:

> Every two years the personnel of the various boards of supervisors is almost completely changed. They go in imbued with the idea that their predecessors squandered the county road funds and go out with the public equally confident that they have. With both more or less correct in their opinions, but it has not been the fault of the supervisors. With county road funds of limited proportions to repair hundreds of miles of road, and with every man in the county clamoring for work in his locality, it has been next to impossible for them to set aside a sum, in any amount, for permanent work.[7]

As one of the most populated counties, Maricopa could afford a degree of road improvement and bridge construction, and in 1877 the Territorial Assembly authorized the county to issue $15,000 in bonds to finance construction of four wagon roads. In the sparsely populated areas outside of the major cities, however, few vehicular bridges were erected before the turn of the century. Many of these earliest county-built bridges, like those on the toll roads, tended more to the flimsy than the substantial. Some consisted of little more than two parallel boards laid across a streambed to carry the vehicles' tires. Often made up of wood stringer spans on timber piles or crude concrete abutments and piers, these questionable structures failed with distressing regularity. Only a handful proved more permanent. For longer spans, the counties erected simple kingpost or queenpost pony trusses, with timber compression members and wrought iron tension rods. None is known to have survived.

During the 1870s and 1880s, the Territorial Legislature seemed content to leave road and bridge construction to the individual counties. Between 1877 and 1881, the territory issued bonds totaling only $70,000 to fund road construction. Other than this tentative step, the territorial government made only minimal impact on overland transportation in Arizona. Indeed, no territorial organization or staff had even been established to administer roads and bridges. In an uncharacteristic act of largesse, however, the Thirteenth General Assembly in 1885 appropriated $15,000 toward construction of a bridge over the Gila River at Florence in Pinal County. The bridge was constructed that year. That, along with a $12,000 appropriation for a wagon road, prompted Territorial Governor Conrad Zulick to comment that the expenditure of funds on road and bridge work represented a "wanton misappropriation of public funds."[8]

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[7] Arizona State Engineer, *Report of the State Engineer of the State of Arizona: July 1, 1909, to June 30, 1914* (Phoenix: Arizona State Press, 1914), 72.

[8] As quoted by Jay J. Wagoner, *Arizona Territory 1863-1912: A Political History* (Tucson: University of Arizona Press, 1970), 239.

Part of Zulick's apprehension lay with the Gila River itself. Once called the muddiest river in the world, the Gila had few rivals in the West for its sheer destructiveness. Variously known as the Rio del Nombre de Jesus (river in the name of Jesus), Rio de los Santos Apostoles (river of the sainted Apostles), Rio de las Balsas (river of the rafts), Rio del Coral (red river), Brazo de Mirafloras and Gila River (from the Spanish "a steady going to or from a place"), this storied watercourse had its headwaters in the mountains of western New Mexico. The Gila entered Arizona from the east at Duncan and disgorged itself from its mountainous canyon before meandering through Greenlee and Graham Counties. It flowed beneath the Florence Bridge and snaked its way westward through Pinal, Maricopa and Yuma Counties, where it emptied into the Colorado River immediately upriver from Yuma.

The Gila River was notorious for its radical shifts in character. It could range from barely perceptible trickle to violent flood and back within a day's time. The river's relatively shallow descent, wide flood plain and

Figure 5. Unidentified pin-connected Pratt through truss, n.d. ADOT. (Bridge has been demolished.)

sandy bed permitted fording during low-water stage throughout much of Arizona. But during floods, all traffic across the Gila virtually stopped. The river flooded to some extent almost every year. Monumental floods, cresting far higher than usual, were logged in 1862, 1869, 1884, 1891 and 1905. After the flood of 1905, the legislature authorized a $19,000 bond issue to fund repairs of the wagon bridge at Florence, but in truth parts of the bridge were carried away with almost every flood. This prompted Arizona Senator Marcus Smith in 1916 to call the hapless structure "a monument to the treachery of the river." During the downpour just before Christmas 1914, the river actually washed away approaches on both sides of the bridge, isolating it in the middle of the roaring channel.

Construction of the Florence Bridge marked a watershed event in Arizona bridge history. Not only was it the first wagon bridge undertaken wholly by the territory, it was probably the earliest all-metal wagon truss in Arizona. The structure consisted of two 180-foot Pratt spans, with an extensive timber trestle over an island and slough. Consuming 30 tons of iron and 174,000 feet of lumber, the Florence Bridge was soon followed by other wagon trusses. Apache County built a pinned Pratt truss over Clear Creek south of Winslow. After its separation from Apache County in 1895, Navajo County erected a Pratt through truss to carry the Winslow-Holbrook road over Clear Creek and another span over the Little Colorado River. Similarly, Greenlee County built a four-span Pratt through truss over the Gila River at Duncan to replace an earlier wooden structure. Virtually all of the early metal trusses built by the counties featured modest dimensions, standard Pratt configurations and prefabricated, pin-connected detailing [Figure 5]. None is known to have survived.

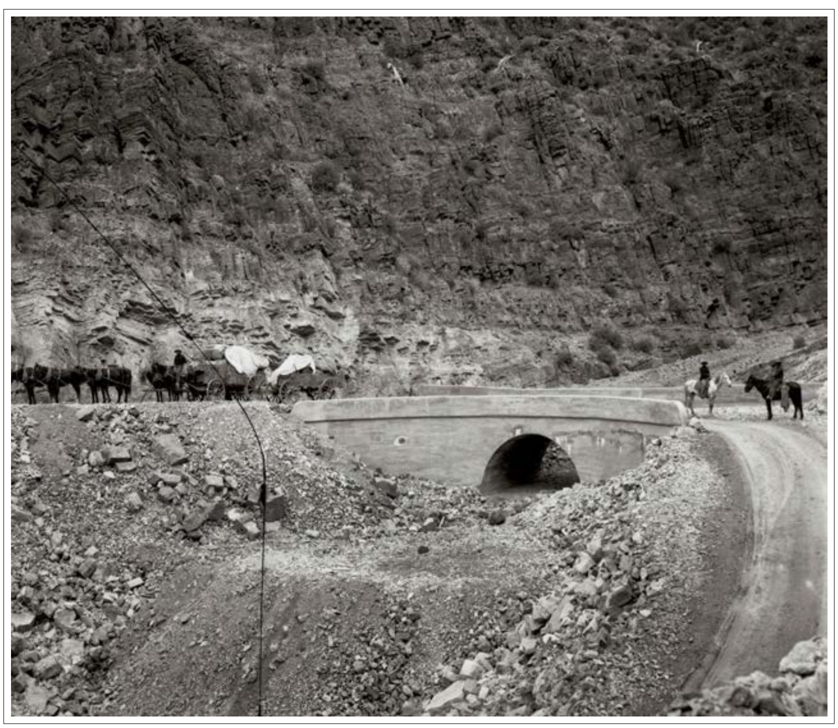
Figure 6. Alchesay Canyon Bridge (01532), 1905. National Archives.

Two surviving bridges from the territorial period were constructed, not by the territorial government or by a county road district, but by the federal government—specifically the U.S. Reclamation Service (USRS, predecessor to the Bureau of Reclamation). In 1902 the USRS began planning a dam over the Salt River, the first authorized by Congress under the Newlands Act. The site for what would become the Theodore

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Roosevelt Dam was located in the mountains east of Phoenix. Before construction could begin on the immense structure, an access road had to be graded from the railhead at Mesa to the damsite. Routed along the ancient Apache Trail, the road wound its way through the rugged mountain range.

Located close to the top of the road near the damsite, the road crossed a switchback curve in Alchesay Canyon. Here the Reclamation Service constructed a small-scale concrete arch bridge as one of the last structures completed on the route. The bridge—little more than a culvert, actually—spanned only 18 feet between abutments and featured simple concrete detailing, crude formwork and extended concrete wingwalls on its downstream side to accommodate a switchback curve in the narrow canyon. The Apache Trail was completed in March 1905 for a total cost of $206,000. Soon millions of tons of materials and equipment began rumbling over it to the dam, which was completed in 1911. The Alchesay Canyon Bridge (**01532**) has stood in place since then, in unaltered condition. It is today Arizona's oldest dateable vehicular bridge [Figure 6].

Figure 7. Laguna Bridge, 2018.

At about the same time, on another irrigation project in Arizona, the Reclamation Service constructed a dam across the Colorado River on the western edge of the territory. Located upriver from Yuma, the rockfill Laguna Dam was intended to divert water to the Yuma Main Canal, which watered agricultural lands on both the Arizona and California sides. Construction began in July 1905 and, after numerous delays, the dam was completed in 1909.

At its east end a small vehicular bridge spanned an irrigation canal. Built somewhat later than the Alchesay Canyon Bridge, this was configured as a concrete slab with an arched, variable-depth slab. The dam was based on "Indian weir" design, which its designers copied from similar structures observed in India. There the engineers "came across a symbol that represented a Hindu goddess with power over water. They thought it would be appropriate to place the symbol on the Laguna Dam," according to the *Yuma Sun*.[9] The engineers had the symbol impressed into the bridge's spandrels. It was not until years later that Adolf Hitler appropriated the symbol as the swastika for the Nazi Party, an unfortunate association for the dam and bridge [Figure 7].

[9]National Park Service, "Laguna Dam District, Arizona."

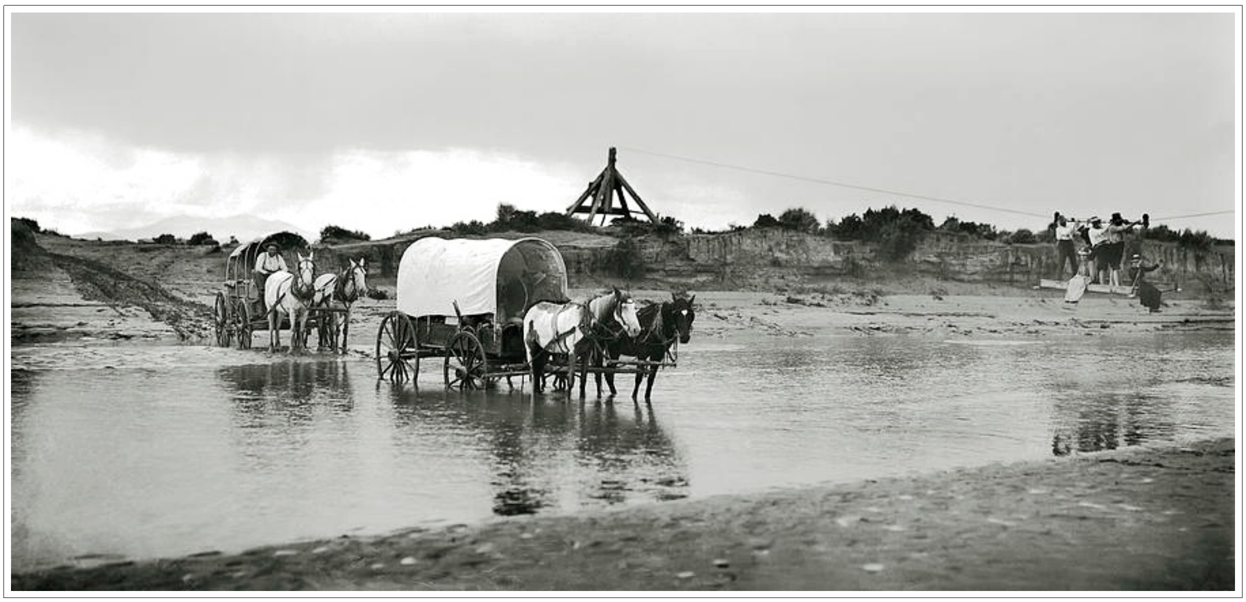

Figure 8. Wagons crossing Little Colorado River alongside cableway, 1903. National Archives.

After the turn of the century, it became apparent that many major road and bridge projects were beyond the capacity of the individual counties. Further, the counties were building roads on a piecemeal basis, without regard to the roads in adjacent counties. Many river crossings had no bridges at all [Figure 8]. This tended to create an uneven patchwork of dissimilar routes, making travel difficult for all but a few destinations. To fund the development of regional highways, the Territorial Assembly in March 1909 levied a property tax varying from 5 to 25 mills. (A mill is .001 or 1/1,000th of a dollar; a five mill tax is equivalent to five dollars per one thousand dollars.) The 5 mill tax was fixed in counties in which no highway work was contemplated, and the higher rates were applied proportionately to counties in which work was to be undertaken. In force until June 1912, this tax raised about $519,000.

The Assembly also created the office of the territorial engineer to administer design and construction of territorial roads. Appointed by the governor, the position carried a two-year term. J.B. Girand was Arizona's first (and only) Territorial Engineer.[10] His staff consisted of a clerk and a draftsman. Soon after his appointment,

[10] James Bell Girand (1873-1949) studied engineering at Texas A&M and practiced in west Texas before taking a position in 1899 with the Santa Fe & Grand Canyon Railroad. There he engineered some 45 miles of route between Williams and the Grand Canyon. Girand opened his engineering practice in Prescott and in 1907 formed a contracting engineering company in which he designed and built the Bisbee & Warren Electric Railway. As Arizona territorial engineer, he designed highways and bridges that proved pivotal in the territory's transportation network. Later he designed a number of single and multiple arch dams in the state, including the Cave Creek Dam, the Gillespie Dam and the Fry Canyon Dam. Girand's plan to pump water into central Arizona from a pump station in Parker formed the seminal concept for the Central Arizona Project.

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Girand began the planning and construction of several territorial highways in Arizona. The strategy was to link the county seats and more populous towns through a network of graded roads that would vary in width from 16 to 24 feet according to terrain and traffic. "Inadequate and crude as the law is," Girand stated in 1911, "much progress has been made in establishing a system of highways, which, if continued, will result in this department being the most important of all, from the standpoint of revenue."[11] In connection with this highway construction, Girand supervised construction of a handful of bridges over key crossings on the territorial network. Curiously, none of these bridges resembled each other even remotely.

This prompted Arizona Senator Marcus Smith in 1916 to call the hapless structure "a monument to the treachery of the river." During the downpour just before Christmas 1914, the river actually washed away approaches on both sides of the structure, isolating it in the middle of the roaring channel. One of the first territorial bridges was a replacement structure for the trusses at Florence, built in 1885 and then rebuilt in 1905. In November 1909 Girand designed a multiple-span, concrete girder structure, submitted the plans and specifications to the Board of Control and advertised for competitive bids. Five contractors responded, with proposals ranging from $48,000 to $62,000. Girand then rejected all bids and convinced the board to build the Florence Bridge using convict labor. With a territorial prison in nearby Florence, the idea had merit. In March a small force of prisoners began excavating for the foundations. The crew was increased to 36 men in April, when full-scale construction began, and averaged 55 men as the work continued on the bridge throughout the rest of the year.

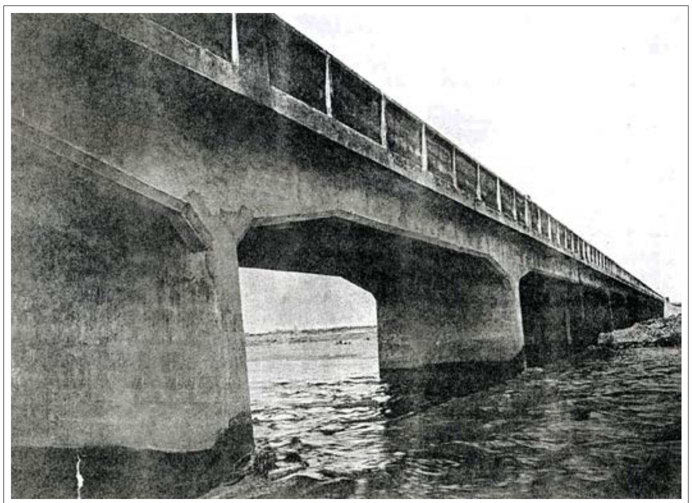

Figure 9. Florence Bridge, 1911. Arizona Magazine.

The Florence Bridge was completed in December 1910 [Figure 9]. In observing the prison laborers, W.A. Crossland of the Bureau of Public Roads commented:

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[11]J.B. Girand, "Arizona Roads," *Arizona*, July 1911, 2. Girand continued:

> Nearly one thousand miles of roads have been surveyed and mapped, running through various counties, as follows: Cochise, Gila, Graham, Maricopa, Pima, Pinal, Yavapai and Yuma, and nearly one hundred miles of road have been actually built and in use, and in addition thereto, three bridges have been or are being constructed, across the more important streams of the territory. Already scores of letters of praise have been received, commending the good work being done, and while as usual, public enterprises of this character meet with opposition, still, as a whole, the better element is body and soul with this work and it will be crowned with success.

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> The convicts are comfortably sheltered, well fed and well treated. Guarded prisoners are kept in barbed wire stockades, under guard when not at work. Work performed by guarded convicts costs probably more than it could be done by contract, but that prison labor could compete with day labor or force account work. The fact that prison labor under guard cannot as a rule compete with contract work is due to many reasons. The work must be such as to require the employment of at least one hundred men to keep the overhead and subsistence charges to a reasonable minimum.
>
> To sum it all up, the cost of prison labor in small numbers is prohibitive. In forces of approximately one hundred, the cost (considering efficiency) per working man per day is very nearly the same as is actually paid to the hired laborer, taking into consideration contractors' profit from boarding house and commissary. Under favorable conditions, including continuous employment for long periods at or near the same place, prison labor under guard can compete with contract work. Under other conditions it is extremely doubtful if it can do so.[12]

This seemed borne out by the experience on the Florence Bridge. The total construction cost using prison labor turned out to be only $2,500 less than the lowest contractor's bid. Girand's first reinforced concrete arch, built in 1911, was a more modest structure. The year before he had designed the territorial highway that extended between Bisbee and Douglas, and in June 1911 Girand completed the drawings for a 60-foot arch over Mule Gulch east of Bisbee. Contractors R. Toohey and Son completed the Lowell Arch Bridge (**00130**) that December. The arch still carries traffic on U.S. Highway 80, though in altered form [Figure 10].

Figure 10. Lowell Arch Bridge (00130), 2018.

[12] As quoted in *Report of the State Engineer of the State of Arizona*, 1914, 8-9.

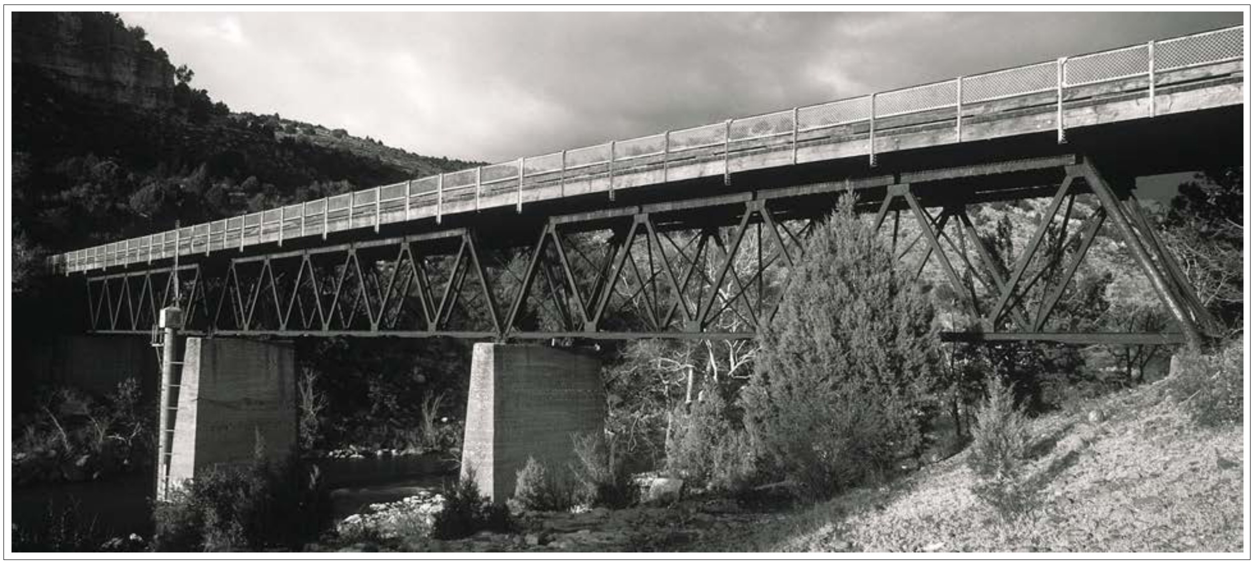

Figure 11. Black River Bridge (03128), 2002. (Trusses shown are replacement spans, erected in 1929 over original concrete piers).

What was perhaps the most unusual territorial bridge was built at the request of the U.S. Army on a remote military road. In 1911 the Territorial Assembly funded construction of a wagon bridge over the Black River to replace an existing ford near Fort Apache. For the Black River Bridge (**03128**) , Girand built two timber/ iron Howe deck trusses carried high above the river on tapered concrete piers [Figure 11].

During this time Girand surveyed for the Fairbank bridge and built three other major structures—a three-span pinned truss over the Verde River at Camp Verde, an 80-foot timber trestle at Hassayampa and a 100-

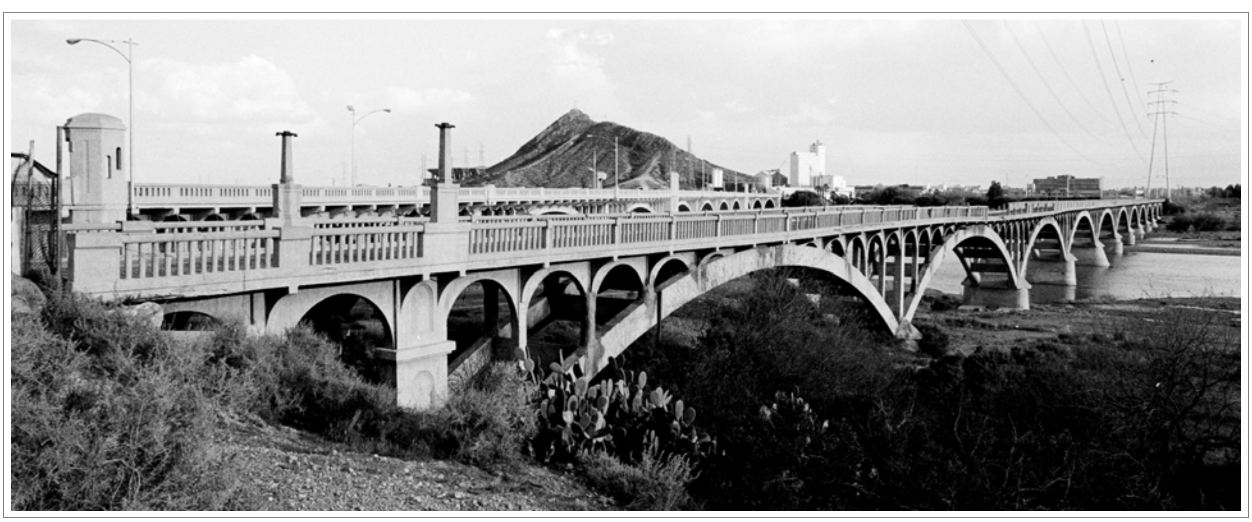

Figure 12. Tempe Bridge, 1982. (The bridge has since been demolished).

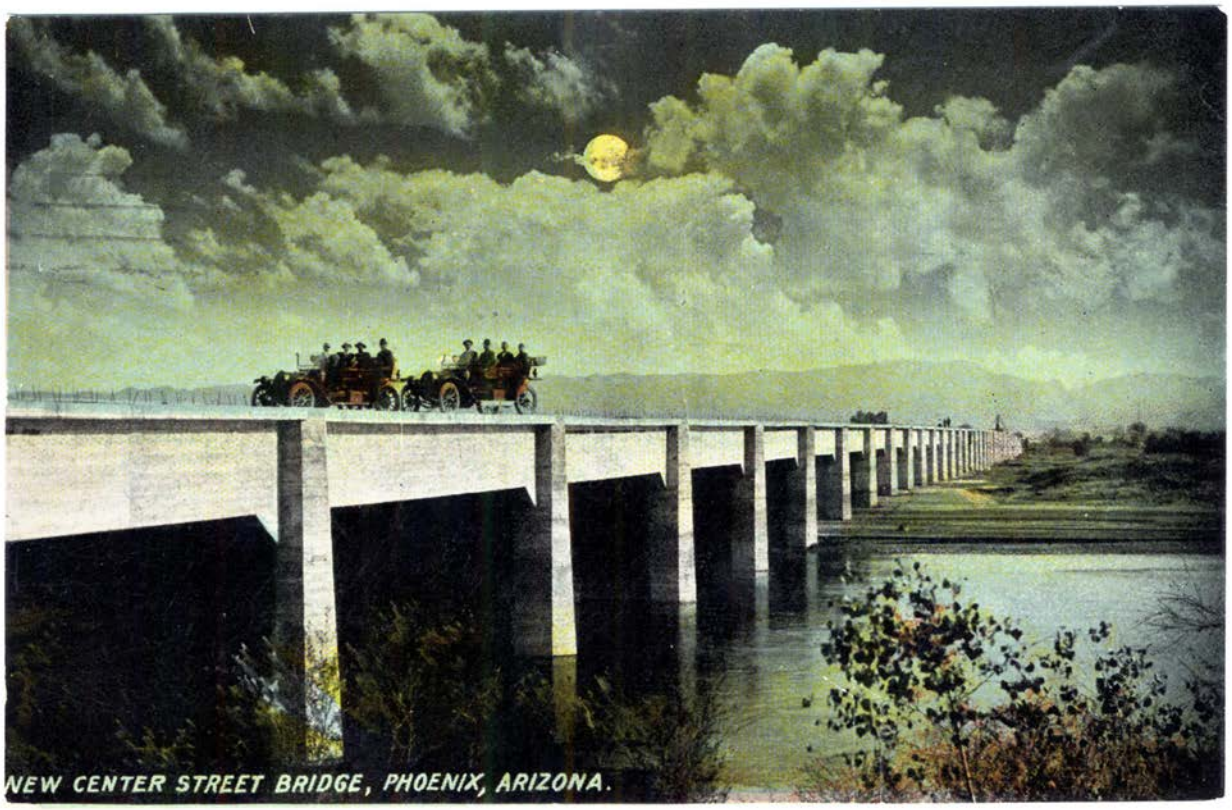

Figure 13. Center Street Bridge, 1911. Postcard. (Bridge has been demolished.)

foot timber trestle over Forest Wash—as well as several short-span concrete slabs built from standard plans. Without doubt the most spectacular, expensive and important bridge built by the territorial government, however, was the concrete structure over the Salt River in Tempe. Made up of eleven open spandrel arch spans, the Tempe Bridge was built by convict labor between 1911 and 1913 [Figure 12].

By the time Arizona was admitted to the Union on February 14, 1912, the territorial government had built over 243 miles of highway at an average cost of $2,500 per mile. Additionally, 1,812 linear feet of bridges over 100 feet in length were constructed (not including the Tempe Bridge), totaling $144,000 in value. Girand estimated that an additional 740 miles of trails and graded county roads would soon be improved to form highways, "completing the great east and west and the north and south roads." Thus, surveys and construction had been undertaken on almost one thousand miles of roads in the three years since the territory had taken an active role in highway construction. In addition to the improvements made by the territorial government, Arizona's cities and counties had been taking a greater role in road and bridge construction. The most noteworthy of these early structures was the Center Street Bridge, completed over the Salt River in Phoenix in 1911 [Figure 13].

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4 Transcontinental Highways and Early State Bridge Construction: 1912-1920

With statehood, the territorial engineer was retitled state engineer and Girand was replaced by Lamar Cobb.[13] Little else changed, as road construction continued using the same basic administrative process. In fact, several road and bridge projects begun under Girand's administration, including the major east-west and north-south highways, were taken over by Cobb without interruption. The major difference lay in the level of activity. Less than $200,000 were spent on road and bridge construction throughout the territory in the year that Girand took office. Six years later in 1915, over $500,000 were spent by the counties alone. Despite the apparent progress, the state's roads remained in dismal condition under the county administration, and Arizona ranked last in the nation in terms of its public road system. Cobb despaired in his first report to the state legislature:

> I have been over a great many roads in every county in the state except two, and I have not found a foot of properly graded and protected mountain road or road in a rolling county that was not constructed under the direction of the (territorial) engineer department. There are a few miles of graveled road in Graham, about ½ mile in Yuma and several miles of caliche road in Maricopa. I know of no other improved roads in the state, outside of the cities, towns or special road districts, though I may have missed a half mile or so elsewhere.[14]

In June 1912 the new state legislature passed enabling legislation for the state engineer's office. Like the territorial law, the state act funded the road and bridge programs through property taxes. The levy was sufficient to raise $250,000 annually—25 percent to be expended by the state engineer on state highways and the remaining 75 percent to be distributed to the counties proportionately to collections. This tax would remain in effect until the start of federal aid in 1917. To augment these revenues, the legislature passed the first of a series of acts providing for the licensing and governing of motor vehicles the following year. The legislature directed Cobb to delineate a network of state highways, encompassing some 1,500 miles of route that would link the major towns [Figure 15]. Cobb was cognizant of the need for continuity between his office and the office of the territorial engineer that had preceded him. In 1914 he wrote:

> When this administration assumed office, a tentative State Highway System had been adopted, consisting of a road from Yuma to Clifton and one from Douglas to the Grand Canyon. The routes selected had become fixed to a certain extent by the construction of several units of their length and, though not meeting with entire approval, they had also become fixed in the public mind as the State Highways. It was, therefore, thought best not to make any changes in

[13] Lamar Cobb (1870-1926) was appointed Arizona's first state engineer by Governor George Hunt in 1912. He immediately took over many of the road and bridge projects initiated by Girand, including construction of the Tempe Bridge. Cobb functioned as the state engineer, overseeing the construction of several important bridges, until 1918, at which time he announced his intent to run for governor against Hunt. "I leave my patriotism to be judged by my actions," he stated, but after a brutal campaign lost the election. Cobb then moved back to his native Georgia but soon returned to Arizona, where he worked for Portland Cement until his death.

[14] *Report of the State Engineer of the State of Arizona*, 1912-1914, 72.

their location as it would undoubtedly lead to others by succeeding administrations, resulting in State Highways "that would start nowhere and end nowhere," thus defeating one object of the State Road appropriation – a State system of roads composed of coordinating county units connecting every county seat in the State. The mileage of roads improved with the State Road Fund is small considering the total mileage of the proposed system and their completion with the present annual Road Fund is far removed; however, the worst places between counties and those bearing the greatest amount of traffic are gradually being improved by permanent construction, so, even without additional means, they will be put in much better condition year by year and some day be completed.

The value of this department to the taxpayers of the State cannot be measured by the roads that have been built under its administration, for the examples of proper road construction it furnishes in every county is of greatest value to officials charged with the expenditure of county road funds. The Boards of Supervisors in eight of the fourteen counties have called upon this office for advice relative to road and bridge construction, four for plans and specifications, and four for our engineers to locate or superintend county road construction covering expenditures of approximately $100,000. Since the creation of this department, there has been a marked improvement in the type of road work in every county in the State which is largely attributable to the demonstration work done by this office.[15]

Figure 14. Crossing the Hassayampa River without a bridge, n.d. Arizona State Archives..

"This improvement is shown both in location and construction," Lamar Cobb continued, "however, the former, which is of the greatest importance, has not received the consideration it should have. Few county roads are now located in natural water courses, grades exceeding 10% are rare and more attention is being given to protecting ditches and other drainage; however, their drainage openings are as a rule too small, as for instance a 36-inch culvert to carry the water necessitating a 50-foot railroad bridge."[16] Despite the improvements, many crossings still had no bridges at all [Figure 14] and were serviced by impromptu ferries.

[15] *Report of the State Engineer*, 5-6.

[16] *Ibid*., 6.

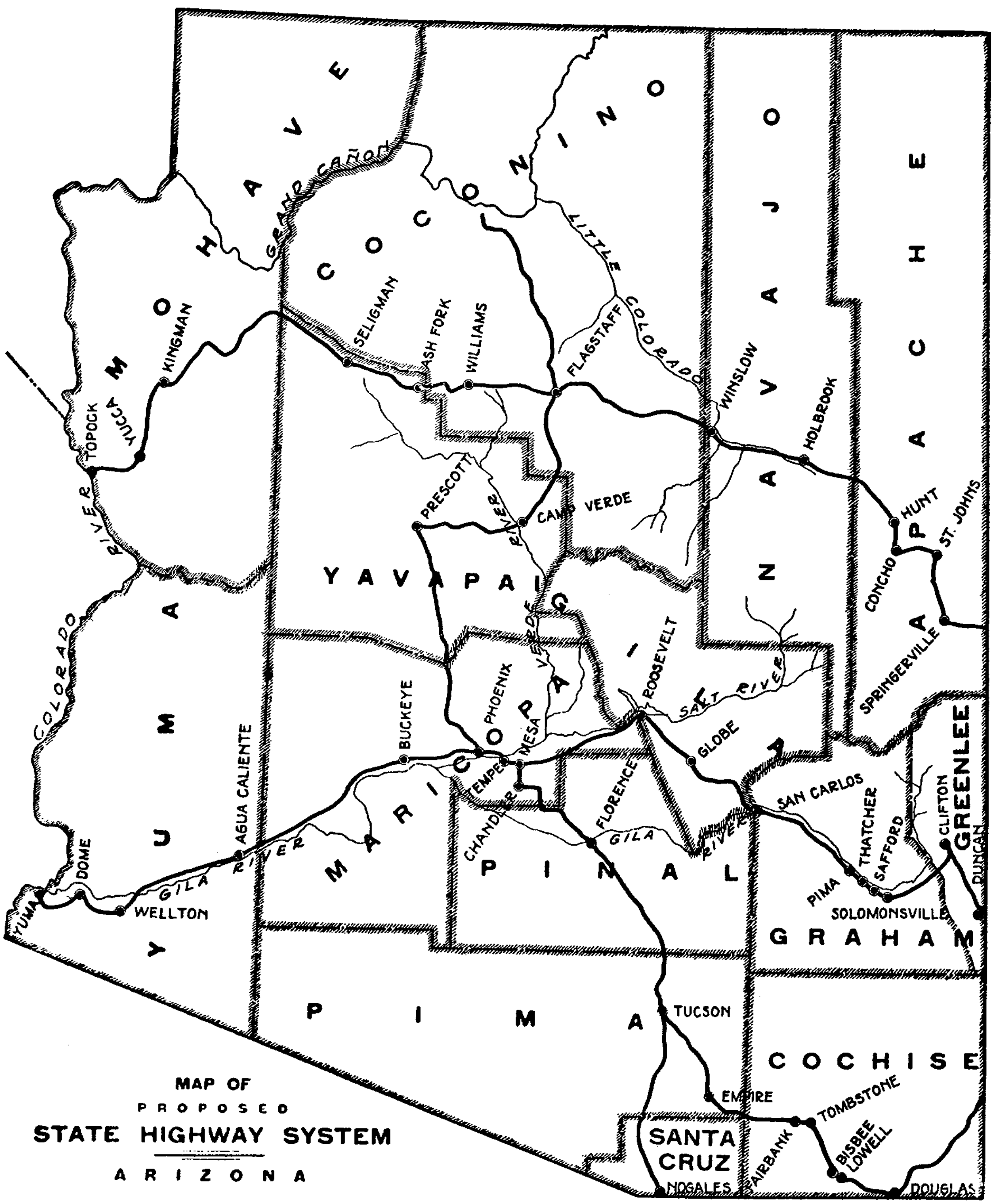

Figure 15. Map of proposed state highway system, 1912.

VEHICULAR BRIDGES IN ARIZONA

During his first two years in office, Cobb undertook several important road and bridge construction projects. Without question the largest of these was the Tempe Bridge, under construction when Arizona became a state. Built using prison labor and opened to traffic in September 1913, it had originally been designed as a nine-span filled spandrel structure, but the design was changed during the course of construction to eleven open spandrel arches. Its total cost was almost $119,000. Built over the Salt River at the state's most heavily trafficked river crossing, the Tempe Bridge was unquestionably Arizona's most historically important bridge.[17] During this biennium Cobb was also responsible for construction of a number of smaller structures—including the Fairbank Bridge designed by his predecessor [Figure 15]—that totaled 1,608 linear feet for an aggregate cost of $101,000.

Figure 16. Fairbank Bridge under construction, 1912. ADOT. (Bridge has been demolished.)

One of Cobb's earliest bridge engineering challenges was the deep, rocky canyon over Chevelon Creek in Navajo County, which formed a "practically impassible" topographic barrier to the highway across northern Arizona. The highway entered the county on the east at the Petrified Forest National Monument and extended westward to Holbrook. From there the route angled northwestward along the old Beale's Road past St. Joseph to Winslow. By keeping south of the Little Colorado River, the road missed the region's major watercourse, but steep-walled chasms at Clear Creek, Chevelon Creek and Jacks Canyon southeast of Winslow could not be avoided.

As one of the few existing wagon bridges in the area, the existing Clear Creek Bridge formed a pivotal point for the highway. The road was routed over the truss erected by Apache County in the 1880s. At Chevelon Creek, J.B. Girand first surveyed the highway crossing in 1911, at the request of the county. A year later, at Lamar Cobb's recommendation, the newly formed state legislature appropriated $5,500 from the state road fund for construction of a substantial structure there. Cobb called for a long-span pony truss for the crossing,

[17]The Tempe Bridge, later called the Ash Avenue Bridge, carried traffic until completion of the parallel Mill Avenue Bridge in 1931. Included in the first statewide historic bridge inventory in 1987, it stood abandoned in place until it was demolished in 1990. Today only the southern abutment of the bridge stands.

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and in October 1912 the state contracted with the Missouri Valley Bridge & Iron Works for the bridge. As stipulated in the contract, Missouri Valley would pour the concrete foundations and design, fabricate and erect the 100-foot span. The Leavenworth-based company delineated a Warren truss, with rigid connections and polygonal upper chords made up of built-up box beams. The concrete deck was flanked by steel lattice guardrails. In January 1913 Cobb approved the truss's design, and by the end of July construction on the Chevelon Creek Bridge (**08158**) was complete [Figure 17].

Figure 17. Chevelon Creek Bridge (08158), 2018. (Bridge has been recently rehabilitated.)

As the Chevelon Creek Bridge was nearing completion, Navajo County contacted Cobb with a request for another vehicular bridge over Jacks Canyon about 4½ miles southeast of Winslow. Named after Jack "Dishrag" DeShrandt, the narrow defile was steep and rocky and presented a serious obstacle to the east-west highway. Cobb had relied upon an outside source for the superstructural engineering of the Chevelon Creek Bridge. For the Jacks Canyon, he designed a modestly scaled concrete slab to carry the road. Cobb's concrete structure featured an innovative design. Called a rail top slab, the bridge was configured as a flat slab with steel railroad rails embedded longitudinally in the concrete as reinforcing. The rail top slab was termed structurally as a one-way slab, in that it acted only one way in flexure under load, limiting it to a short-span application—in this case 30 feet. In 1913 force account laborers on the state payroll built the structure for a cost of $1,163. The plank formwork was crude, the design simple and unarticulated, and the guardrails were threaded steel pipes—indicative of the early construction by an unskilled work crew [Figure 18].

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Figure 18. Jacks Canyon Bridge, 2018. (Bridge has been closed to traffic, and the steel pipe guardrails have been removed.)

Figure 19. Auto travel in a remote section, n.d.. Postcard.

In 1911the Arizona Good Roads Association published the state's first book of road maps and travel information. "At this time, trips to every part of the state are made by automobiles," the guide stated optimistically, "and while some difficulties are encountered in the remote sections, principally owing to lack of travel, these are rapidly being eliminated [Figure 19]."[18] During the 1914-1916 biennium, Cobb continued with the development of the state's road and bridge system. As delineated by his office in 1916, the state highway system remained essentially unchanged [Figure 20]. With the state and the individ-

[18]Arizona Good Roads Association, *Illustrated Road Maps and Tour Book* (Prescott: Arizona Good Roads Association, 1913 (Reprint Phoenix: Arizona Highways Magazine, 1978)), 6. The guide continued:

> A system of State Highways is now under construction: the counties of Yavapai, Mohave and Coconino are about to construct good roads within their boundaries with money from county bond issues and cash taxes; and in many parts of Arizona new roads are being located and old highways improved. Therefore, it will be but a short time until the whole State is gridironed with travelable roads, giving easy and comfortable access to the scenic, agricultural and industrial sections of this rich commonwealth.

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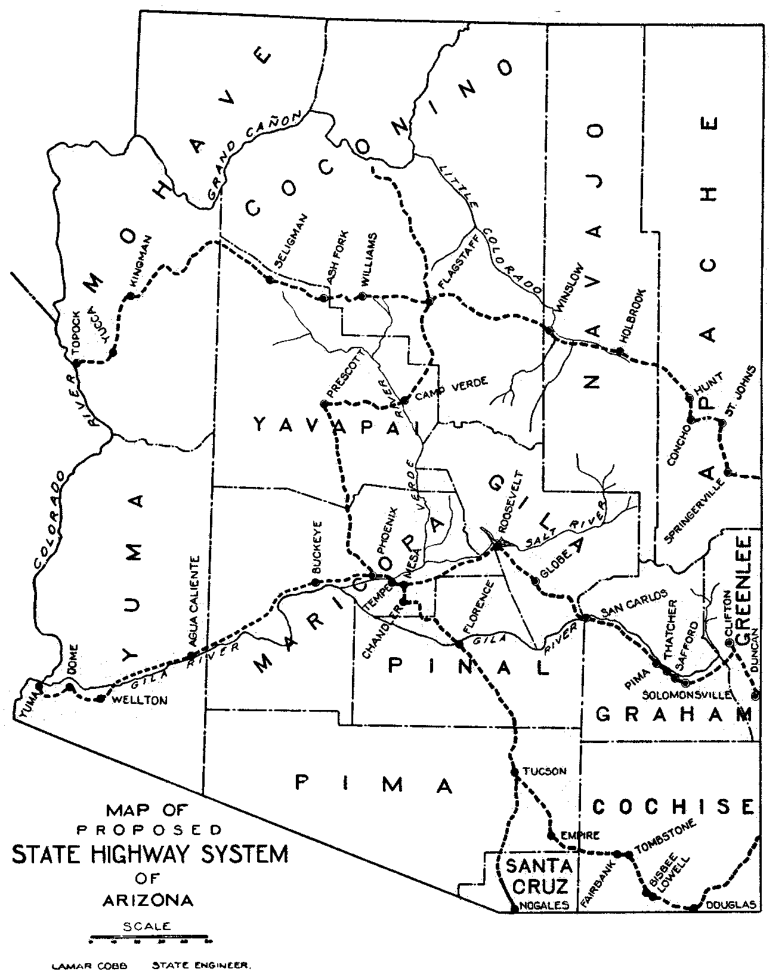

Figure 20. Map of proposed state highway system, 1916.

ual counties all undertaking the construction, road improvements were made incrementally in relatively small segments. The principal difference among the various entities lay in the amount of money spent. As funds allocated by the state for road and bridge work increased steadily—from $294,000 in 1912 to $487,000 in 1916— the construction administered by the counties almost quadrupled from $309,000 to $1.5 million over the same four-year period.

The state engineer's office was responsible for building numerous small-scale drainage structures on state highways, and for these engineers began developing standard designs for short-span concrete slabs, girders and box culverts. Cobb undertook more ambitious multiple-span structures as well, concrete girders similar in scale to the Florence and Tempe bridges. The largest bridge built during this period was a structure over the Gila River on the Phoenix-Yuma Highway in Yuma County. In 1912 Cobb had surveyed sites at Antelope Hill and the nearby town of Dome and selected the former for a bridge. The next year his office designed a concrete structure comprised of fifteen girder spans supported by bullnosed concrete piers. With two per 65-foot span, the girders were massive—more than five feet tall and two feet wide. The longest of these spans extended 65 feet; the bridge's overall length was almost 1,000 feet.

In December Cobb advertised for bids to build the immense structure. Opting instead to use prison labor, the state rejected all bids. Cobb then redesigned and rebid the project when it became apparent that not enough prison manpower would be available. In May 1914 Perry Borchers was hired to build the bridge. But Borchers was in over his head. He began construction in June but soon defaulted, and after floods damaged the partially completed structure that winter, the state once again undertook the project with prison laborers. The Antelope Hill Bridge was opened to traffic in August 1915, with a picnic attended by well-wishers [Figure 21].

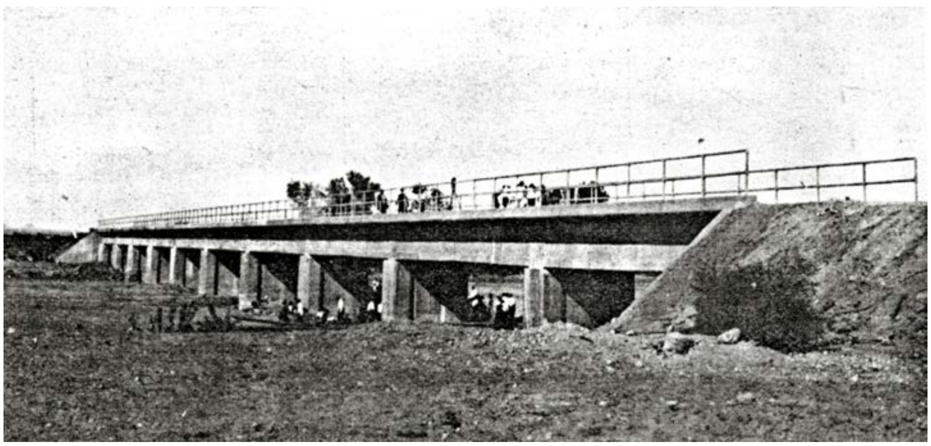

Figure 21. Antelope Hill Bridge, August 1915. State Engineer's Report.

This star-crossed structure began to fail almost immediately, revealing a dangerous and expensive weakness of the state's large concrete spans. These structures were demonstrably stronger and more stable under load than their steel truss counterparts. Their poured-in-place superstructures could carry traffic well enough, but their substructures proved woefully inadequate to withstand the changeable desert rivers. As a result, the bridges collapsed in whole or in part when the piers toppled over in flood.

In January 1916 floods washed away almost two miles of approach grading and widened the river's channel at the north end of the Antelope Hill Bridge by approximately 300 feet. To correct this, the state legislature in March 1917 appropriated $50,000 to build an extension onto the north end. The new construction consisted of five additional concrete girder spans and an extensive timber trestle. Completed in autumn 1918, the bridge carried traffic more-or-less as intended until a flood the week after Thanksgiving, 1919 destroyed some 500 feet of the north approach and shifted some of the concrete piers on the extension. Further flooding three months later dropped about 300 more feet of trestle, the north abutment and one girder.

Worse, the floodwaters caused several of the piers on the extension, already damaged by the previous flood, to further shift downstream. "The Antelope Hill Bridge is located at a point where it is impossible to control the river and keep it under the bridge at any reasonable cost," complained State Bridge Engineer Merrill Butler in 1921. "Foundation conditions are bad and a permanent extension would necessarily be long and costly with the strong possibility that the same situation would again develop in a few years." Butler concluded prophetically, "The foregoing, together with the apparent need for expensive repairs to two of the existing piers, should mitigate against anything except some form of temporary construction" [19] [Figure 22].

[19]State of Arizona, State Engineer, *Fourth Biennial Report of the State Engineer to the Governor of the State of Arizona: 1918-1920* (Phoenix: Republican Print Shop, 1921), 66-67. Within two years, AHD had rerouted the road to bypass the Antelope Hill Bridge entirely. The bridge was replaced in 1929 with the McPhaul Bridge [**abd.**]. It now stands in ruins, with several of its concrete piers and girder spans washed away.

see continuation sheet

Figure 22. Ruin of Antelope Hill Bridge, 2003.

Actually, the Antelope Hill Bridge suffered from at least three significant engineering shortcomings, which combined to make it a maintenance nightmare. First, the bridge was poorly situated on a sweep of the river prone to extensive flooding. Second, the piers were poorly founded on spread footings instead of driven piles and were provided with insufficient scour protection. Finally, without shore rectification works to constrict and guide the river, the Gila was allowed to shift channels unchecked, putting unbearable pressure on the bridge's north spans and approaches. All these problems could have been addressed properly during initial construction. But the deceptively placid nature of the Gila River at normal stage did not prepare the engineers for its radical character change in flood.

Despite the structural problems of the Antelope Hill Bridge, the deep-girder design was used on another major span soon thereafter. Following a major flood on the Santa Cruz River in 1915 [Figure 23], the state legislature appropriated $12,500 from the state's General Fund for construction of a major bridge across the river on the Nogales-Patagonia Highway. Cobb located the site for this bridge some 5½ miles northwest of Nogales and, because its construction was contingent on an equal contribution from Santa Cruz County, waited until the county appropriated its share early in 1916. He then surveyed the site and engineered a concrete deck girder bridge.

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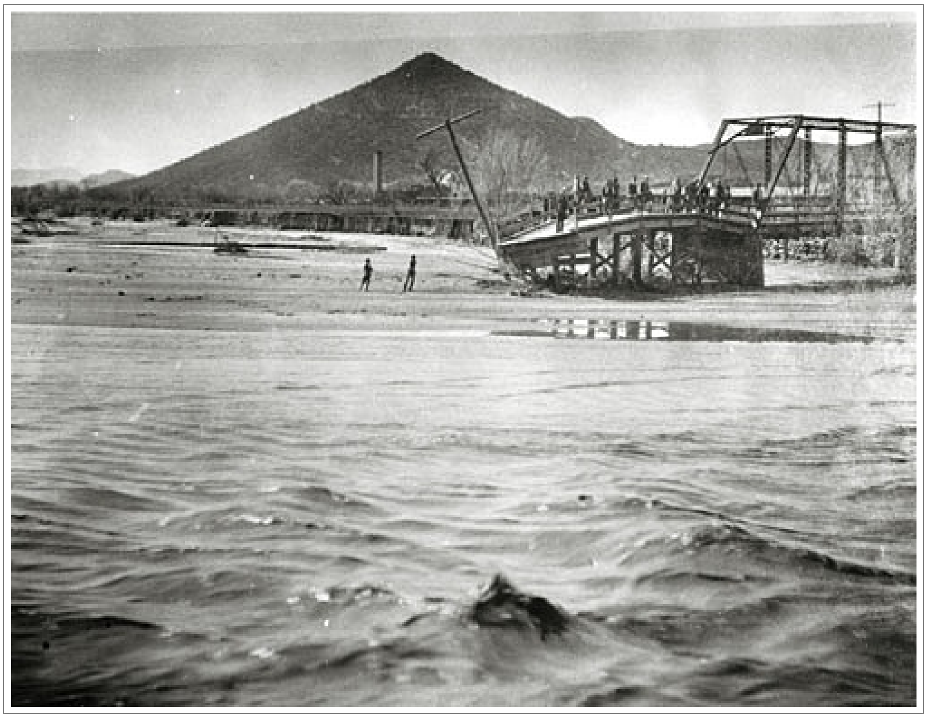

Figure 23. Flood on Santa Cruz River at Tucson, 1915. Arizona State Archives.

With a design similar to the Antelope Hill Bridge, the structure consisted of three 65-foot-long two-girder spans, with eight shallower 32-foot spans over the flood plain east of main river channel. The spans were supported by massive concrete piers built with bullnosed ends to withstand flooding on the Santa Cruz. The bridge featured a reinforced concrete deck placed integrally with the girders. The deck was flanked on both sides by steel pipe guardrails. Rather than let the bridge's construction out for bid or bring in prison laborers, Cobb instead opted to build it using day laborers under state supervision. In May workers began construction of the bridge. The crew completed the Santa Cruz River Bridge (**08166**) early the following year for a total cost of about $38,000 [Figure 24].[20]

When the automobile was introduced in the United States from Europe, it was generally believed that its widespread adoption would be delayed by the relatively poor condition of the country's roads. "Because motor vehicles for common roads are practicable in France and England, it does not follow that they would be in America," *Scientific American* stated in 1895. "The roads in those countries are almost perfection; but in this country a fairly good road is the exception. . . The roads in America are not good enough except in certain localities yet to permit of a very rapid development of the automobile carriage, but their use in great cities is likely to be rapid."[21]

[20]The Santa Cruz Bridge carried mainline highway traffic until a route realignment in 1927. It has since functioned as a county bridge in unaltered condition.

[21]"New Prizes for Motor Carriage Competitions," *Scientific American* 73:40 (20 July 1895).

Figure 24. Santa Cruz River Bridge (08166), 2018.

The first inventory of American roads, conducted in 1904, revealed that of some 2.1 million miles of roads in the country only 7 percent had any surfacing at all. Those that had any applied surface were almost all gravel, and virtually none of America's roads were sufficient to carry steady motorized traffic. The best roads were located, naturally enough, in the heavily populated New England and Middle Atlantic states. The worst were in the South and Midwest, where rain turned the roads into bottomless gumbo. The West, with its long distances between settlements that required almost universal use of horse-powered travel, offered numerous dirt roads but few that could accommodate automobiles.

Like much of the West, Arizona was slow to embrace the automobile in the early 20th century, largely due to the wretched condition of its roads. The first auto in the state was reportedly brought into Tucson by Dr. Hiram Fenner around the turn of the century. This was soon followed by cars in Phoenix; by 1913 some 646 vehicles were registered in Maricopa County. As in other states, Good Roads Associations took root in Arizona in the early 1900s, largely driven by recreational bicycle riders. The bicyclists formed clubs, which collectively organized the national League of American Wheelmen [LAW] in 1880.

As one of the leading proponents for good roads in the late 19th century, the league began publishing *Good Roads* magazine in 1892 with the slogan"Lifting Our People Out of the Mud." That year another group, the National League for Good Roads [NLGR], formed to give voice to rural farmers and ranchers weary of the deplorable condition of the nation's farm-to-market roads. These were joined by the National Good Roads Association [NGRA] at the turn of the century. Collectively known as good roaders, these groups had organized to promote better roads in cities, where they were bad enough, and in rural areas, where they were virtually impassible.

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More than any other group in America, the good roaders were responsible— both directly through "Good Road Days" volunteer construction efforts and indirectly through political lobbying among local and state officials—for the improvements made in the country's highways during the formative years. "The good roads agitation is now on a footing such as it never had in the past," stated Colonel Albert A. Pope in 1903. "For this, no doubt, much credit should be given to the various automobile clubs and associations scattered throughout the country. It was none the less creditable to these bodies that their share in the movement has been so unobtrusive that now, for the first time, the demand for better highways may be said to be in every sense a popular one."[22]

The Good Roads Movement was from its inception politically oriented. Good roaders recognized that the only way to effect wholesale improvements on the nation's roads was through the government. Partially in response to their hectoring, the federal government in 1893 established the U.S. Office of Road Inquiry [ORI] to assess the lamentable condition of the nation's highways and consider the best strategies for road management. Location of the ORI in the Agriculture Department indicated the rural thrust of the government's response to the good roaders. Though the Office did little more than study the issue of good roads, its formation marked the first acknowledgment by the federal government of the coming importance of automobile travel. Gen. Roy Stone, who headed the Office, estimated that the cost to transport goods over the roads was three times more than it should have been, had the roads been improved. He arrived at this estimate based on the additional time required to travel the poor roads and the additional wear and tear on automobiles, wagons and livestock.

President William McKinley referred to the Office in a message to Congress in 1901, when he stated: "There is a wide-spread interest in the improvement of our public highways at the present time, and the Department of Agriculture is co-operating with the people in each locality in making the best possible roads."[23] In 1903 his successor, Theodore Roosevelt, along with Roosevelt's opponent in the 1904 election, William Jennings Bryant, attended the National Good Roads Convention in St. Louis. That year the organization managed to get highway legislation before Congress. The Brownlow-Latimer Federal Good Roads Bill would have involved the federal government in road construction for the first time, had it not been defeated. In subsequent years the Automobile Club of America and the American Motor League were instrumental in undertaking ambitious programs to install signboards to warn of dangers along the highways, both through their own efforts and through lobbying state legislatures.

In 1904 the Office of Road Inquiry initiated what it called its "object-lesson" program, building relatively short segments of improved roads to demonstrate their utility. ORI representatives would travel to good roads meetings on "Good Roads Trains", construct demonstration roads and proselytize for the cause of road

[22]Colonel Albert A. Pope, "Automobiles and Good Roads," *Munsey's Magazine* 29:168 (May 1903). Pope, a Connecticut coach and bicycle manufacturer, had a vested interest in promoting good roads. He favored electrical power for autos over internal combustion, stating emphatically, "You can't get people to sit over an explosion!"

[23]Quoted in John L. Butler, *First Highways of America* (Iola: Krause Publications, 1994), 59.

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improvement. By 1905 the ORI, renamed the Office of Public Roads, had built almost 40 miles of object lesson roads in 100 separate projects.

Figure 25. Congress Street, Tucson, ca. 1910. Postcard.

The Good Roaders in Arizona were responsible for the promotion of road improvement throughout the state, though they tended to concentrate their efforts more in the urban areas, particularly Phoenix and Tucson. The group's efforts began to show results in the 1910s with the bitulithic paving of city streets and construction of the Center Street Bridge in Phoenix. This was followed by smaller-scale paving projects in Tucson, Bisbee and Flagstaff [Figure 25]. "The lesson to be drawn is manifest," a writer in *Arizona* magazine stated in 1916. "Good roads do not 'grow' in Arizona, nor elsewhere, and the fact that Arizona is getting them is license to regard them as one of our best and most promising 'manufactures,' even though they are not made in a big mill building and sent out on freight cars. Besides all their virtues in highways there is an economic consideration in the pay rolls they maintain and the attendant business they develop during construction—home money, paid to home people, and kept chiefly in home circulation."[24]

[24]"Good Roads in Arizona." *Arizona*, April 1916, 10.

Outside of the major cities, however, the roads and bridges were noticeably less developed [Figure 26]. Even the major routes were little more than wagon tracks, troubled by steep, rocky grades in the mountains and shifting sand in the desert. In its appropriations for road and bridge construction, the state legislature was responding not only to requests from its Arizona constituency but to pressure from out-of-state tourists as well. The Petrified Forest near Holbrook was designated a national monument in 1906. Grand Canyon National Park was established in 1919 and quickly became one of the county's premier scenic attractions [Figure 27]. These and a profusion of other sites drew tourists from all directions.

Figure 26. Oatman streets, ca. 1920. Postcard.

In the late 19th century, visitors to Arizona had generally arrived aboard trains or stagecoaches. The time and expense of this type of travel limited it generally to only the most well-heeled tourists. This began to change with the advent of the motorcar, however. Tourism was now within the reach of the middle class. As people gained more mobility between towns that had previously been isolated, and, perhaps more importantly, as merchants began to gauge the value of tourists taking to the Western roads in cars or motor coaches, the demand for better roads became more urgent.

Added to this was the movement for transcontinental highways. In the absence of federal participation in road building, several quasi-public organizations formed to promote specific transcontinental or regional routes in the 1910s. Capitalizing on the incipient demand for long-distance auto travel, these groups sponsored auto reliability contests and focused attention on the poor shape of the nation's roads. The most famous of these early proto-highways was the Lincoln Highway, established in 1912 as America's first coast-to-coast road between New York and San Francisco. Formed at about the same time was the National Old Trails Road between Baltimore and Los Angeles. Several other highways also took root during this formative period.

By 1922 a myriad of transcontinental highways had been routed across America. Among these were the Theodore Roosevelt International Highway between Portland, Maine, and Portland, Oregon; the Midland

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Trail between Washington, D.C., and Los Angeles; the Old Spanish Trail between Tallahassee and Los Angeles and the Dixie Overland Highway between San Diego and Savannah. Additionally, there were shorter routes, such as the Mohawk Trail between Greenfield, Massachusetts, and Schenectady, New York; and the Custer Battlefield Hiway [their spelling] between Des Moines and Glacier National Park. Most extended east-west, but a few—the Evergreen Highway between Portland and El Paso; the King of Trails Highway between Winnipeg and Brownsville, Texas; the Jackson Highway between Chicago and New Orleans and the Jefferson Highway between Winnipeg and New Orleans—ran south-north.

Figure 27. Viewing the Grand Canyon by auto. Library of Congress.

These roads were designated, promoted and maintained by local commercial and governmental organizations along their routes. Their sponsoring associations often published trail guides and newsletters extolling the virtues of their particular routes. The trail associations typically marked their routes by painting insignias on posts, rocks, telephone poles, barns or any other roadside object that would stand still. Highways in name only, these early routes typically followed existing roads, with the level of road maintenance varying widely from route to route and even from mile to mile on the same route. The named highways often overlapped confusedly as they zigzagged across the country. This was especially true in the West, where there were often several named routes but relatively few route choices available due to the daunting terrain.

Two of these early booster-sponsored highways crossed Arizona [Figure 28]. The first of these, as of 1914 part of the National Old Trails Highway (also called the Santa Fe Highway), followed the Santa Fe Railroad—which itself generally followed Beale's Road— over the width of the state. Followed by the National Park to Park Highway and later incorporated into Route 66 between Chicago and Los Angeles, this highway formed the major east-west route across northern Arizona in the 1910s and 1920s. Despite its importance to interstate commerce, the route was "just dirt all through Arizona," according to Valentine, Arizona, resident Robert Goldenstein. . "A [50-mile] trip to Kingman might take two days if the washes was running."[25] The highway entered Arizona east of Springerville, angled northwest past St. Johns, Concho and Hunt, paralleled the Rio Puerco to Holbrook, and then extended west through Winslow, Flagstaff and Kingman before crossing the Colorado River at Topock [Figure 29].

[25]Quoted by Susan Croce Kelly, *Route 66: The Highway and Its People* (Norman: University of Oklahoma Press, 1988), 60-61.

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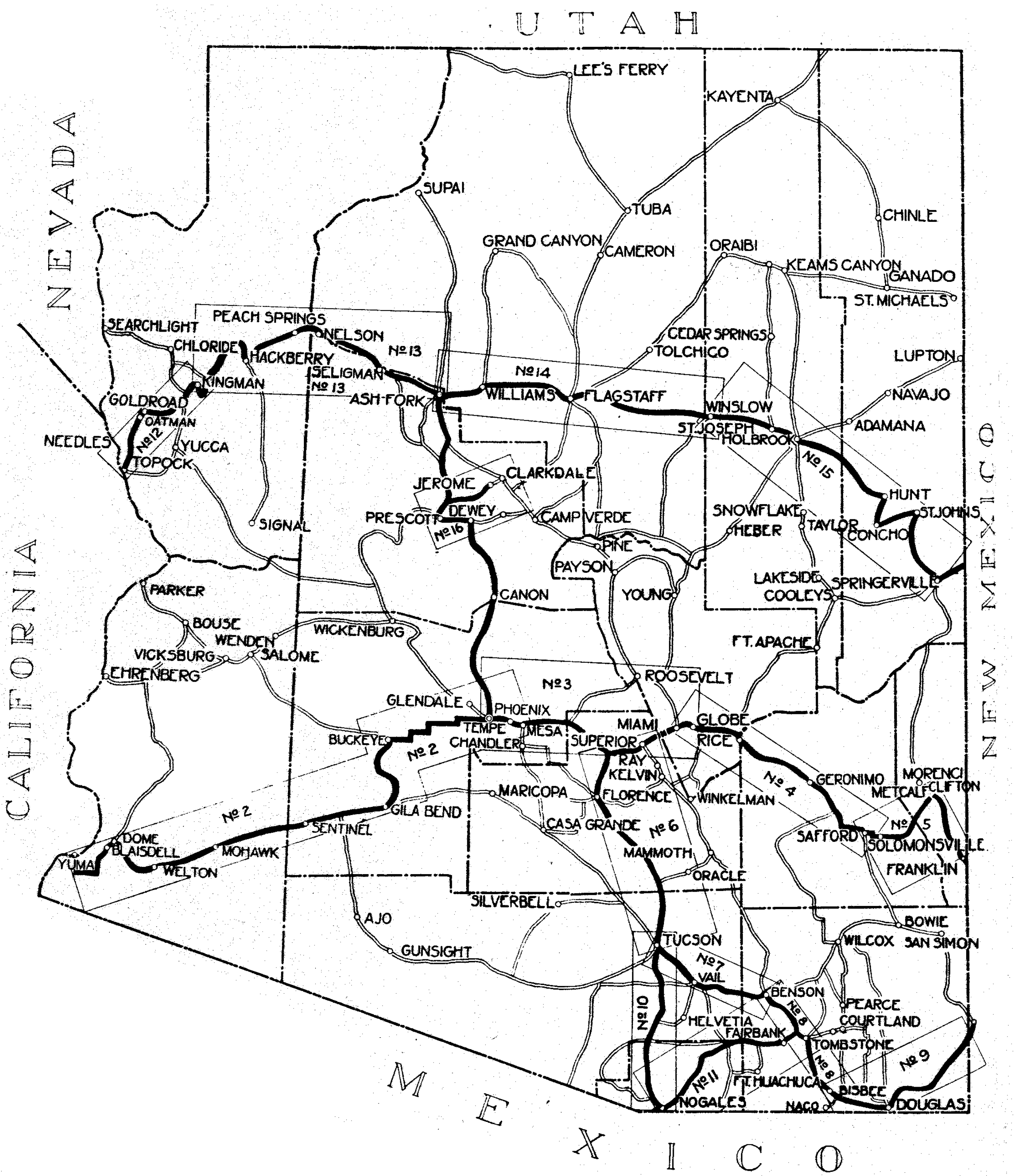

Figure 28. Arizona state highway map, 1920.

Figure 29. Crossing Arizona on the National Old Trails Highway, n.d. ADOT.

Similarly, the old Gila Trail—the original east-west territorial road and later the primary east-west state highway— was incorporated into the Pikes Peak Ocean-to-Ocean Highway. All or part of this route was overlaid in Arizona by other named highways such as the Borderland Route, the Dixie Overland Highway, the Old Spanish Trail, the Bankhead Highway, the Lee Highway and the Atlantic Pacific Highway. This road, portions of which were the most heavily trafficked in the state, passed through Douglas, Benson, Tucson, Florence, Phoenix and Yuma on its way across southern Arizona. Towns along the route that had been established to serve the railroad eventually transformed themselves into highway towns, sprouting motor courts, diners and service stations to ply the auto-bourne trade. Dome, Agua Caliente and Buckeye straddled the road between Yuma and Phoenix.

Figure 30. Riding the plank road near Yuma. Postcard.

The plank road near Yuma was part of the highway. Comprised of boards lashed together by cable, this eight-foot-wide structure crossed the desert between Yuma and Holtville, California. In some locations the road was built in 12-foot sections to permit quick disassembly and relocation around the shifting sand dunes. Other sections of the desert road were little more than parallel planks [Figure 30].

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Despite their active promotion for their highways, none of the early highway organizations had the financial wherewithal to undertake actual large-scale construction. Road and bridge construction in Arizona was still the responsibility of the state and the counties in the 1910s. During that period, both the Old Trails and the Ocean-to-Ocean Highway suffered from poor maintenance. Upkeep of the latter road from Phoenix to Yuma had been shared by Maricopa and Yuma Counties over the years, with predictably uneven results. Territorial Engineer James Girand had surveyed a 202-mile route between the two cities, with the counties sharing the engineering cost, but had not undertaken any substantial construction on the route.

Little changed during the first two years of Lamar Cobb's tenure as state engineer. In 1914-1915 Yuma County undertook repairs of the highway east of Yuma. At this time the state undertook construction of the Antelope Hill Bridge. Additionally, a long- span steel truss was erected over the Colorado River at Yuma by the federal government. The major river crossings on the route's western end had thus been addressed, but the state had yet to make improvements to the eastern section of the Phoenix-Yuma Highway. In 1914 Cobb commenced work on the section between Arlington and Agua Caliente, "on account of this section being the worst part of the road."[26] Highway engineers were faced with a choice of courses to take: the southern route through Woolsey Park and Point of Rocks (which was then in common use), or the northern route by way of Fourth of July Butte and Yellow Medicine Wash. According to Cobb:

> It was found that both routes presented many difficulties and disadvantages. The southern route would have required a great deal of heavy rock work to get through Woolsey Wash and past the Point of Rocks. It also ran for many miles through the silt bottom land of Cottonwood Wash and the Gila River—the poorest kind of material for road purposes—and the outlook for obtaining anything better for surfacing was very discouraging, as there was nothing suitable that would give a shorter average haul than about ten miles.
>
> There were also many large and unconfined washes to cross. The northern route ran through a somewhat rougher country and was a few miles longer, but the material was, in the main, of a suitable character for surfacing, and there was a great deal less drainage to be looked after. For these reasons it was decided upon as being the one that would prove most economic eventually.[27]

Most of the roadwork in this area involved the rugged stretch of the highway between Lowdermilk and Yellow Medicine Washes. In this three-mile section the crew graded the road and built two small steel bridges [Figure 31]. The highway followed the north side of the Gila River all the way from Antelope Hill to Phoenix, thus avoiding the need to build another costly bridge over the river. In 1915-1916 the highway de-

[26]State of Arizona, State Engineer, *Second Report of the State Engineer to the State Highway Commission: 1914-15 and 1915-16* . (Phoenix: The McNeil Company, 1916), 395.

[27]*Ibid.*

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partment built a multiple-span concrete girder bridge on the highway over the Agua Fria River at Coldwater and a timber-pile bridge over the Hassayampa River at the town of Hassayampa.

Figure 31. Pony truss on Ocean-to-Ocean Highway, 1923. ADOT. (The bridge has been demolished.)

It became increasingly evident, however, that rather than follow north of the Gila, the better route to take would be south of the river, along the original Gila Trail. "The greater portion of the [northern] route followed the bottom lands along the Gila River and was on light, silty soil which would have required expensive surfacing," stated Cobb's successor, Thomas Maddock, in 1920. "The floods of Thanksgiving, 1919, and those of the latter part of February, 1920, submerged a large portion of the located line and demonstrated beyond question that this location was not feasible."[28] Flooding along the Gila River had washed out a large portion of the highway between Wellton and Agua Calinete. Moreover, the Antelope Hill Bridge had become an embarrassment to the department, washing out with almost every major flood.

Another perennial problem for the state was the Agua Fria River Bridge at Coldwater, built about the same time as the Antelope Hill Bridge. In 1915 Cobb designed the bridge with 37 concrete girder spans, supported by concrete column bents. Construction began in December. Three months later, heavy flooding forged a new channel on the opposite side of an island about 1,000 feet upriver from the bridge site. Rather than redesign the bridge to accommodate the shift in channel, the engineers continued building it as drawn—now only over a dry streambed—and attempted to re-divert the river back into its earlier bed by filling the new channel. When the bridge's west approach washed out the first winter, the legislature appropriated funds for reconstruction and channel work. This lasted until the Thanksgiving flood of 1919, when seven spans and both approaches collapsed. Subsequent floods carried away five additional spans. As the state tried to keep up with the repairs, the approaches washed away with every flood. "The location and foundation conditions

[28]State of Arizona, State Engineer, *Fourth Biennial Report of the State Engineer to the Governor of the State of Arizona: 1918-1920* (Phoenix: Republican Print Shop, 1921), 56.

are both extraordinarily poor," wrote later State Engineer Merrill Butler, "but the bridge is on a main highway, a road of great economic importance, and in a section where no better site can be found within a reasonable distance."[29]

By 1920 the highway department had decided to re-route the road [Figure 32]. According to Maddock, "The survey for a complete highway from Phoenix to Yuma has been made. In view of the floods in the winter of 1919-1920 and the desire of the Yuma Highway Commission to connect with both Phoenix and Ajo, also in realization of the necessity for a highway from the Capital of the State to Ajo, this survey was run on the south side of the Gila River from Yuma to Gila Bend, thence in a northerly direction through the area proposed to be irrigated from the Gillespie Dam, now under construction, and thence to Arlington."[30]

Adoption of the southern route meant that the highway would have to cross the Gila River at some point west of Phoenix. The solution for a Gila River crossing came from an unlikely source—agriculturalist Frank A.

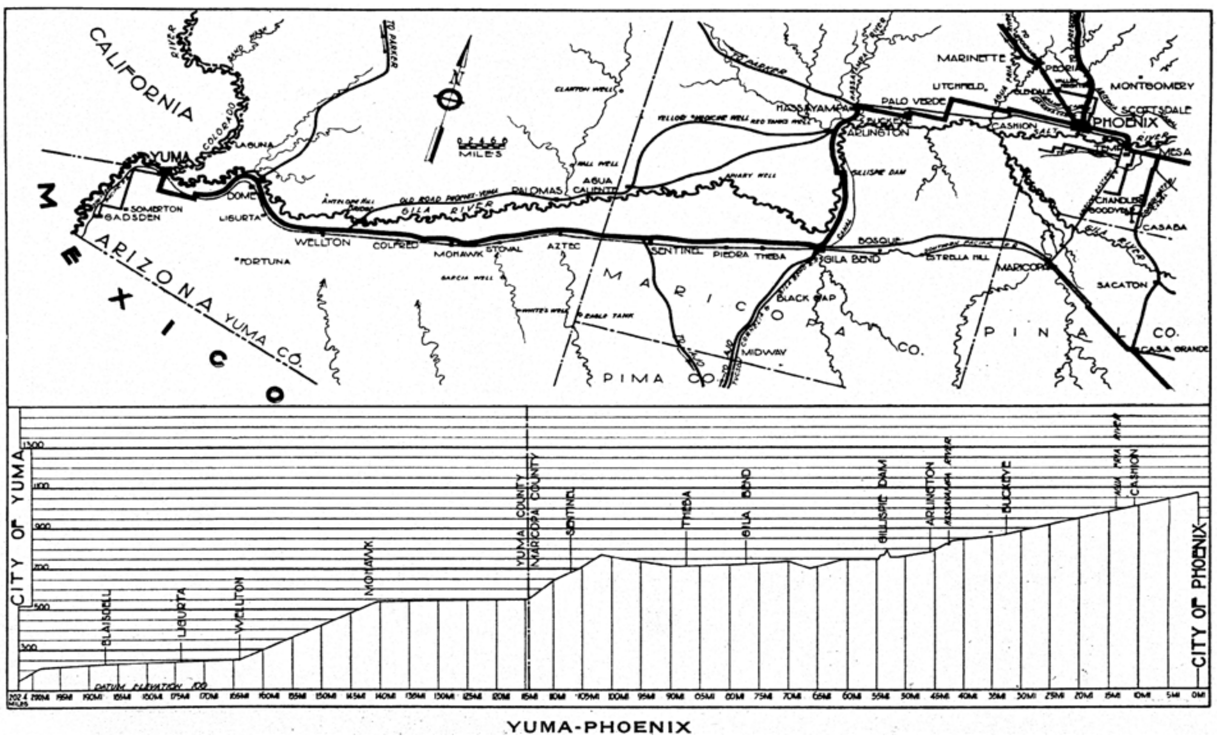

Figure 32. Map of proposed Phoenix-Yuma Highway, 1920. ADOT.

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[29]*Fourth Biennial Report of the State Engineer*, 68. Like the Antelope Hill Bridge, the Coldwater Bridge was eventually abandoned by the highway department as unsalvageable.

[30]*Ibid*., 78.

Gillespie. A native of Oklahoma, Gillespie had established the Gillespie Land and Irrigation Company to acquire thousands of acres of agricultural land between the Gila River and the town of Gila Bend. The lifeblood of his ranching and farming domain flowed through a system of irrigation canals branching from the Enterprise Canal, built in 1886.

The canal's headgate was situated on the Gila River about 45 miles southwest of Phoenix, at a narrow pass between the Buckeye Hills and the Gila Bend Mountains. Here earlier irrigators had built a diversion dam of earth, rocks and brush to impound water on the Gila River and divert its flow into the canal. Built in 1894, the Peoria Dam had washed out in 1900 and was replaced in 1906. In place of this latter structure, Gillespie proposed building a substantial concrete dam. To design the immense structure, he hired former Arizona Territorial Engineer James Girand. Girand delineated a multiple-arch structure, 1,768 feet in length and 56 feet tall, that would span the river at the existing masonry intake for the canal. Construction commenced in 1919; the Gillespie Dam was completed in 1921 for a cost of about $3 million.

Situated as it was in a relatively constricted stretch of the river, this crossing had long been in use on the old Gila Trail before the road was rerouted north of the Gila River in the early 1910s. Before the advent of automobiles, stagecoaches had used the ford south of the present-day dam. In a setup worthy of a bar joke, the *WPA Guide* described one perilous crossing at high water:

> On one occasion two nuns, a gambler, and a soldier hung on the outside and upstream side of the coach in order to counterbalance the flood current. As the story goes, this stratagem, plus the driver's goading of his struggling horses, the nuns' praying, the gambler's cursing, and the soldier's shouted encouragement, brought the coach safely to the opposite shore.[31]

The Arizona Highway Department [AHD] could not rely on the historic ford for use on a major transcontinental route, so engineers had to devise another means to cross the Gila here. A bridge would have been prohibitively expensive. "We doubt that any bridge crossing of the Gila River," stated Maddock, "from its junction with the Salt to its confluence with the Colorado, can be secured for less than between three and four hundred thousand dollars."[32] As early as the summer of 1919, Maricopa County had proposed building a vehicular bridge across the dam, using the arch piers to support the bridge superstructure. The county offered to pay $3,300 (later increased to $4,842) to defray the cost of extra foundation piles under the piers of the dam. The cost of the bridge itself would apparently be borne by the state. The offer was so insignificant that it received little serious consideration, however, either from the dam company or from the highway department. It was quickly shelved.

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[31] *The WPA Guide to 1930s Arizona* (reprint ed., Tucson: University of Arizona Press, 1989), 218. The *Guide* relates another story about the killing here of a bandit named, ironically, Innocente Valenzuela. Valenzuela and two accomplices had murdered and robbed the superintendent of the Vulture Mine, who was on his way to Phoenix. The posse caught the robbers at the Gila River ford and killed Valenzuela.

[32] *Fourth Biennial Report of the State Engineer*, 78.

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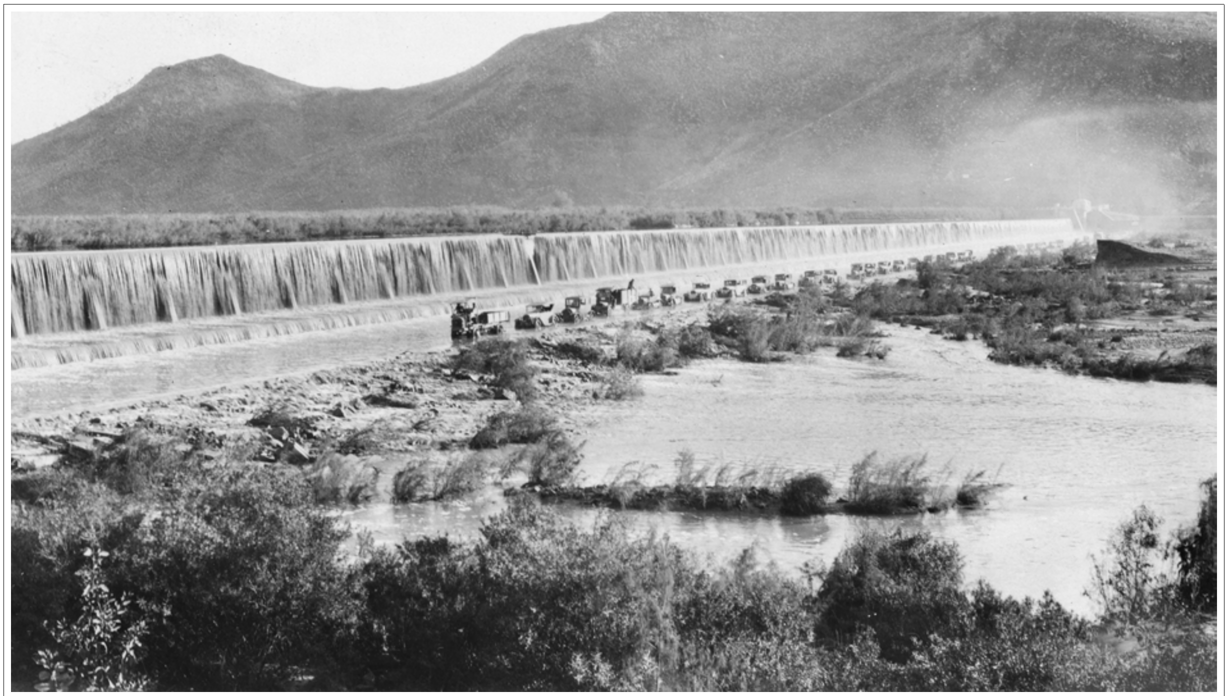

Figure 33. Truck pulling train of cars across Gillespie Dam apron, ca. 1926. ADOT.

AHD instead opted to build a concrete apron onto the downstream toe of the Gillespie Dam, the construction of which would cost some $125,000. The apron was built soon thereafter, and autos began driving behind the dam sometime in 1922. Automobiles could drive over the apron unassisted during low water, but when the Gila was in full flow, several cars would be chained together in a makeshift train and pulled across the dam by a truck [Figure 33]. When the Gila was flooded, traffic across the apron stopped altogether.

Using their share of the state road fund and adding considerable amounts of money from county road funds, the counties were undertaking most of the road work during this period. Unlike the state engineer, the counties rarely had the in-house facilities to design major bridges and could not tap the sizable labor pool in the state's prisons. Many of the bridges they built reflected this fact [Figure 34]. Despite their lack of expertise, they rarely relied on the state for engineering assistance. "Counties do not avail themselves to any great extent of the services of the State Engineer, AHD engineer W.A. Crossland stated in 1914. "This is due to no disinclination on their part, but to the fact that the engineer's organization is limited and he cannot always furnish the assistance requested of him."[33] Counties, therefore, tended to engage bridge companies or contractors for all but the smallest spans.

[33] *Report of the State Engineer*, 1912-1914, 13.

These firms marketed prefabricated steel structures, built from standard designs and purchased by the counties through competitive bidding. The steel was produced in the major foundries (Carnegie, Cambria, Lackawanna, Inland) in Illinois and Pennsylvania. The foundries supplied rolled steel parts to fabricators such as the American Bridge Company of Chicago, the Omaha Structural Steel Works on Nebraska, the Midwest Steel and Iron Works of Denver or the Phoenix-based Allison Steel Company. These firms in turn marketed complete, prefabricated trusses to bridge contractors who assembled the superstructures on the sites. Because the government entities of Arizona contracted for so few steel bridges, no indigenous steel bridge company of note ever developed. Those few local firms such as S.T. Clark of Bisbee that occasionally built steel trusses were far more dependent on other forms of contracting. The counties relied heavily upon out-of-state contractors for both design and construction of their bridges, and most of the major steel spans in the state were fabricated and built by out-of-state firms.

Figure 34. Apache County bridge, 1924. Arizona State Archive.

The same bridge contractors' names cropped up at almost every county bid letting, as a relatively small coterie of firms competed for a limited number of commissions. Among the out-of-state bridge companies active in Arizona during the 1910s and 1920s were the El Paso Bridge and Iron Company (Walnut Grove Bridge (**08227**)); the Midland Bridge Company of Kansas City (Allentown Bridge (**03073**), Cameron Bridge (**abd.**); the Monarch Engineering Company of Denver (Sanders Bridge (**03074**), Little Hell Canyon Bridge [Figure 38]; Missouri Valley Bridge and Iron Works of Leavenworth, Kansas (Chevelon Creek Bridge (**08158**), Fish Creek Bridge (**00027, [**Figure 37]), Lewis and Pranty Creek Bridge (**00028**)); Levy Construction Company (McPhaul Bridge (**abd.**)); Kansas City Structural Steel Company (Navajo Bridge (**00051**)), Topock Bridge (**abd.**)); and the Omaha Structural Steel Works of Nebraska (Saint Joseph Bridge (**08157**), Woodruff Bridge (**08156**) and Yuma Bridge (**08533**, [Figure 35]).

Given Arizona's proximity to southern California, it is surprising that almost all of the contract work went to bridge companies from the South and Midwest. Although California firms submitted proposals, only one major bridge, the Winslow Bridge, built in 1916 by Los Angeles-based Mesmer and Rice, was constructed by a California-based firm. And it was composed of trusses manufactured in Chicago by the American Bridge Company.

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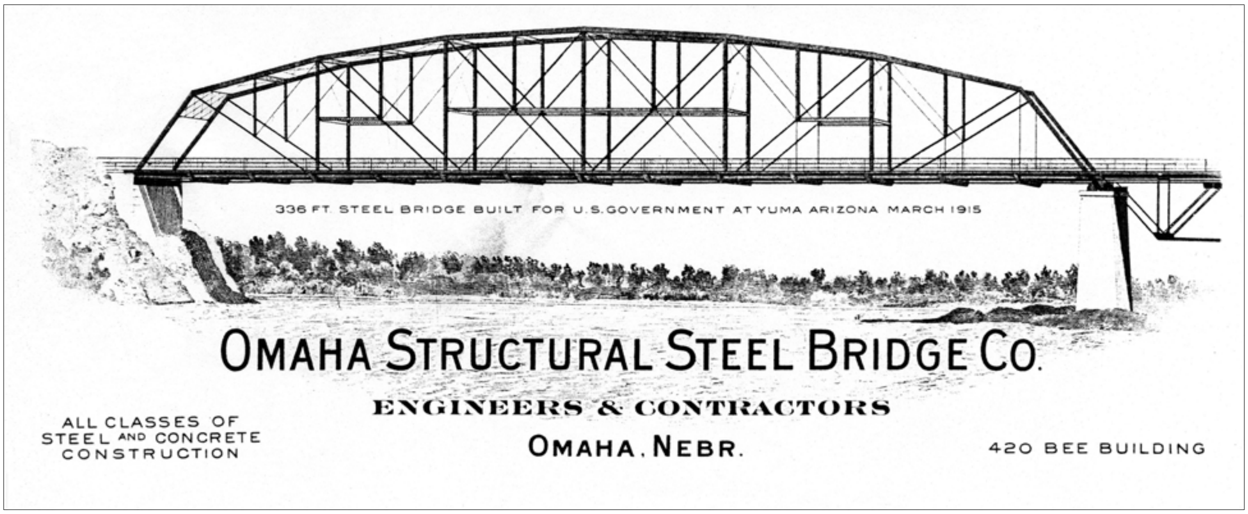

Figure 35. Letterhead of Omaha Structural Steel Bridge Company, 1919.

Each government entity had structural configurations upon which it relied principally. Counties tended to erect steel trusses and stringers because they could obtain the engineering as part of the bridge solicitation process. The state engineer, like the territorial engineer before, employed reinforced concrete for a wide range of bridge applications. Concrete has a number of advantages in Arizona. First, a properly constructed concrete bridge was considered much more substantial than a steel or wooden structure. Concrete was more flood-resistant and more stable under load. Short-span concrete structures could be built using standard specifications. This allowed a limited staff of engineers to design a disproportionately large number of drainage structures, badly needed on a rapidly growing road network. Unlike steel, which had a centralized system of manufacturing and marketing, concrete could be manufactured using locally procured materials. Finally, mass concrete technology was more rudimentary than steel, allowing the state to undertake bridge projects using small-scale contractors or unskilled crews of convicts or day laborers [Figure 36].

Structures such as the Florence, Tempe, Antelope Hill, Santa Cruz and Coldwater Bridges represented significant technological accomplishments. Most of the earliest concrete bridges in Arizona, however, consisted of relatively modest spans, either simple slab or girder, used singly or in multiple-span iterations. These served well for minor washes or for rivers with wide flood plains. When the state engineer began planning bridges for intermediate watercourses and canyons, it became evident that long-span structures would be needed. Long spans in concrete at that time meant arches. For these earliest structures, Lamar Cobb turned to the engineering of America's pre-eminent arch builder of the time, Daniel B. Luten. An Indianapolis engineer, Luten had patented a reinforced concrete arch design in 1900. His distinctively shaped design was so popular that in the first ten years he built some 4,000 Luten, or horseshoe, arches across the country.

Figure 36. Black Gap Bridge (08534), a rail top concrete slab built in 1920-1921 by convict laborers. 2018.

Arizona first associated with Luten in 1913. That year Cobb was tasked with building a bridge on the Old Trails Highway over Canyon Padre—a rock-walled chasm in Coconino County. After determining that a 136-foot span was needed, Cobb contracted with the Topeka Bridge and Iron Company, western representative of Luten's National Bridge Company, for design and construction of the bridge. Topeka Bridge designed a 140-foot Luten arch with a 16-foot roadway. As delineated by Luten himself, the arch sprang from concrete abutments and featured Luten's trademark elliptical profile. Its deck was flanked on both sides by

Figure 37. Canyon Padre Bridge, 2003.

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concrete guardrails on cast concrete balusters. A Topeka B&I crew began substructural excavation in September 1913 and completed the bridge in April 1914 [Figure 37].

A few months after the Canyon Padre Bridge was completed, Cobb contracted with Topeka B&I for design of a second arch span, over Canyon Diablo just west of Two Guns, also on the Old Trails Highway. Luten engineered the 128-foot arch himself for $500. Like the Canyon Padre Bridge, the Canyon Diablo arch featured an elliptical arch and a roadway that cantilevered from the arch walls over concrete brackets. The Canyon Diablo Bridge was completed in March 1915 by a local contractor, Thomas Maddock of Williams.[34]

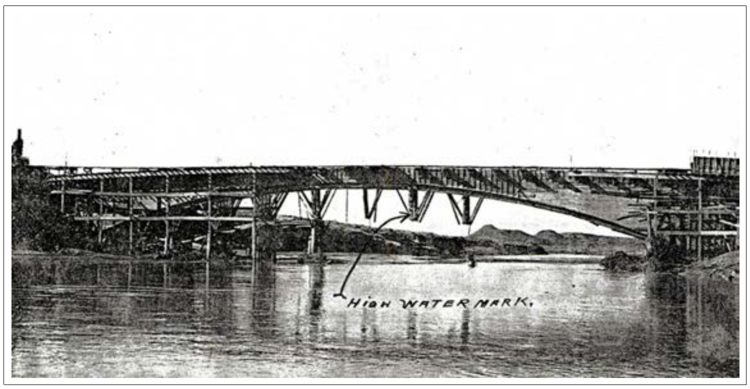

Figure 38. Holbrook Bridge under construction, showing flood damage, 1916.

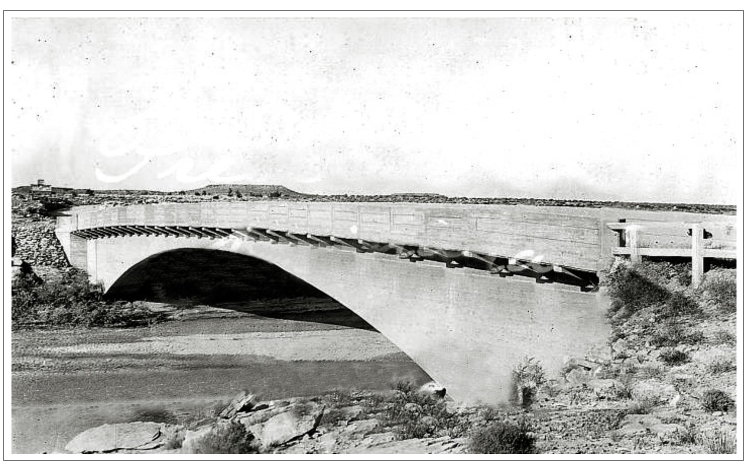

Figure 39. Holbrook Bridge, 1929. Arizona State Archives.

Cobb designed the third arch himself, with assistance from Luten. Without first consulting with the Arizona State Engineer, the Navajo County Board of Supervisors in had 1912 contracted with the El Paso Bridge & Iron Company to erect a 128-foot truss on a county road over the Little Colorado River, three miles southeast of Holbrook. Completed in 1913, the bridge lasted only until April 14, 1915, when the Lyman Dam at St. Johns burst and swept away it and four other metal bridges downstream. "The site [for the Holbrook Bridge] was a poor one and foundations faulty," stated Cobb.

He acted immediately to survey a new site 1,000 feet upstream from the original for a suitable replacement structure. That summer, with help from Luten, Cobb designed a long-span Luten arch for the replacement structure. A state work force began excavating for the foundations of the new bridge in September 1915, and work continued without incident until a flash flood washed the centering timbers away in January 1916

[34]Born in Virginia, Thomas Maddock (1883-1971) came to Arizona in 1898. He represented Coconino County on the first state legislature and as an engineer / contractor based in Williams. Maddock became Arizona State Engineer in 1917 and served until 1922. A year after that he became a member of the Colorado River Commission and then general manager of the Gila Valley Irrigation District.

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[Figure 38]. The men resumed work soon after, rebuilding the centering and eventually completing the bridge in March [Figure 39].[35]

The next year Maddock succeeded Cobb as state engineer. Like Cobb, Maddock soon enlisted the assistance of Topeka B&I for a major highway span, but the circumstances this time were quite different. One of the unfinished projects that Maddock inherited from Cobb involved a crossing of the Gila River near Clifton. Cobb had designed a steel bridge, but he did not remain state engineer long enough to see this design executed. Steel shortages caused by World War I drove the price of the metal arch well beyond the budget,

Figure 40. Gila River Bridge (08152), 2003. (The bridge has been rehabilitated, with many of the cast concrete balusters replaced.

however, and the design was scrapped. So was the design for a single long-span concrete arch. Eventually, the state hired R.V. Leeson, engineer for Topeka B&I, to design a two-span Luten arch. The Gila River Bridge (**08152**) was built by convict labor that year [Figure 40]. Maddock's successors, B.M. Atwood and W.C.

[35] With a span length of 174 feet, the Holbrook Bridge was extraordinarily long. Promotional literature published by the National Bridge Company indicates that this is the longest concrete arch ever built in America using Luten's patented technology.

Lefebvre, contracted for a handful of other Luten arches in the state. One crossed the Agua Fria River in Maricopa County. A 100-foot arch spanned Willow Creek in Yavapai County, another spanned Silver Creek in Cochise County, and a 120-foot arch spanned Queen Creek in Pinal County. All but the Queen Creek Bridge (**08440** [Figure 42]) have since been razed. Because Luten arches used a proprietary design, which was protected vigorously by Daniel Luten and his attorneys, they were perceived as more expensive than other highway bridge types. For this reason, they were rarely built by Arizona's individual counties or municipalities. Two notable exceptions were the Kelvin (**08441**, [Figure 41]) and Winkelman (**08442**) bridges, built under contract with Pinal County in 1916-1917.

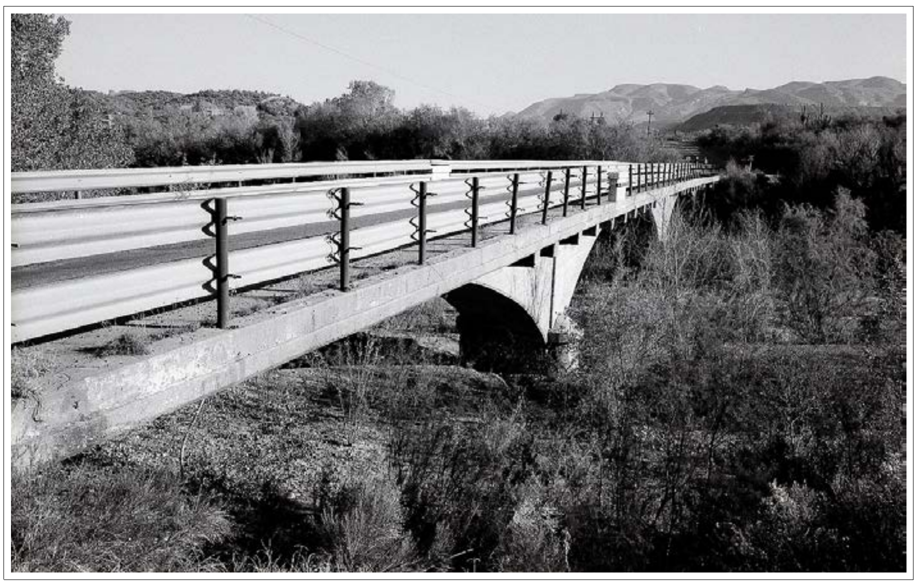

Figure 41. Kelvin Bridge (08441), 2002. (Original concrete balustrades have been replaced with Thrie beams.)

Actually, given their scale and technology, the Winkelman and Kelvin structures proved to be bargains compared with other, similarly scaled bridges. Costing almost $22,000, the 419-foot, four-span Winkelman Bridge cost almost a third as the two-span Gila River Bridge and only slightly more than the single-span Holbrook Bridge. These figures are even more remarkable given that the Winkelman Bridge was founded on driven timber piles, more expensive to build than the spread footings of the Holbrook Bridge. The Winkelman and Kelvin bridges cost about as much as a four-span through truss built near Winslow by Navajo County in 1916-1917 and almost half as much as the Santa Cruz Bridge near Nogales. Some of the last Luten arches built in Arizona were five short-span structures (**08585, 08586, 08587, 08588** and **08589**) on city streets in Miami, completed in 1920-1921.

Several of Arizona's most significant vehicular bridges date from this formative period of state history. The Chevelon Creek Bridge (**08158**) and the Jacks Canyon Bridge (**abd.**) are two of the earliest state structures. The Black Gap Bridge (**08534**) and the Gila River Bridge (**08152**) are both early convict-built structures. The Santa Cruz Bridge (**08166**) is an outstanding multiple-span concrete girder structure; the Antelope Hill Bridge (**abd.**), another concrete girder, is a magnificent ruin. And the Holbrook Bridge (**abd.**) is the longest Luten arch in the country.

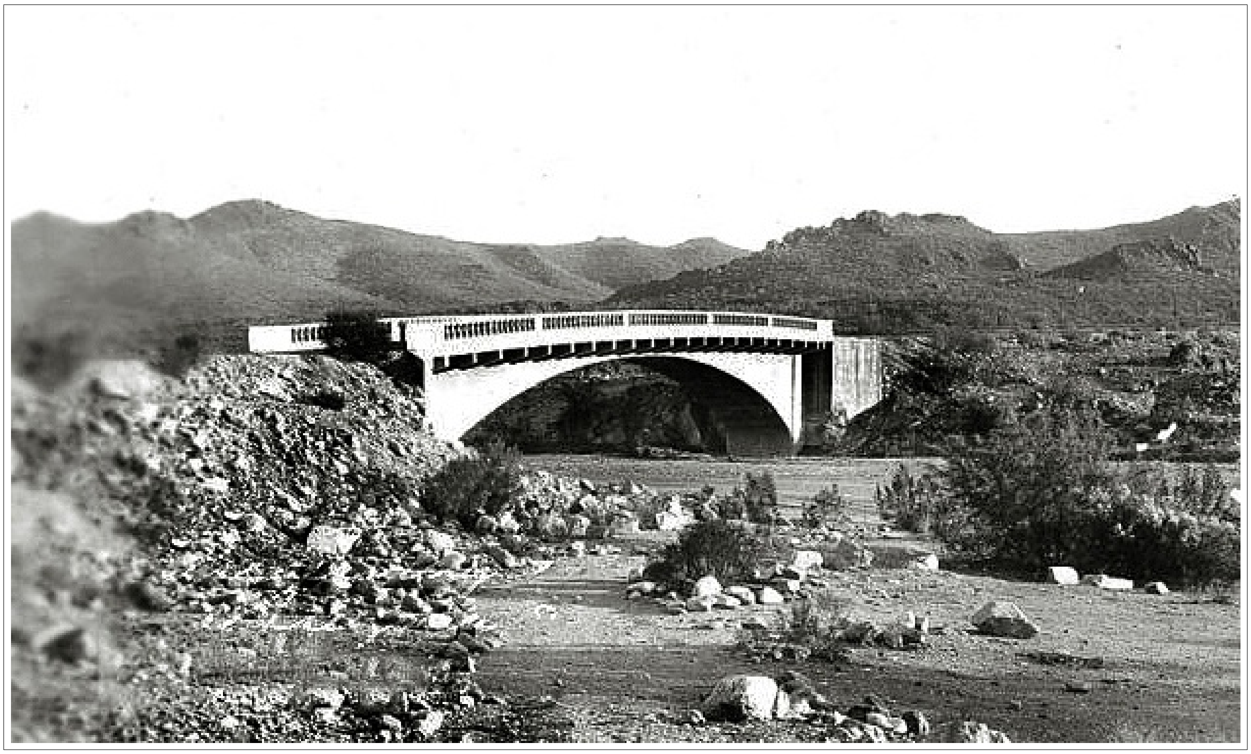

Figure 42. Queen Creek Bridge (08440), ca. 1920. Arizona State Archives.

The territorial and state engineers and the individual counties and municipalities accounted for almost all of the vehicular bridges in Arizona, but a third entity—or group of entities, actually— was active in bridge construction as well. The federal government, through the Interior Department, built several vehicular spans associated with government highway programs. Coming from a variety of bureaucratic sources and circumstances, these bridges displayed a wide range of technological expression, some of which were as esoteric as they were dramatic. The bridges themselves were remarkable enough, but what was perhaps even more remarkable was the fact that they were built at all. Virtually every major bridge built by the federal government in Arizona before 1916 required individual Congressional approval.

The federal agency most active in territorial and early state road and bridge construction was the Office of Indian Affairs [OIA, predecessor to today's Bureau of Indian Affairs] in the Department of the Interior. With thousands of square miles of land on nineteen separate reservations, the OIA was responsible for the infrastructure of a large part of Arizona. In the early 1900s the OIA made a concerted effort to improve commerce on the extensive Navajo and Hopi Reservations in northeastern Arizona Territory. Key to this

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was a proposed bridge over the Little Colorado River to link the reservations with Flagstaff. The Indian Office contracted with the Midland Bridge Company of Kansas City 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 steel suspension structure [Figure 43].

Figure 43. Cameron Suspension Bridge, n.d. Postcard. (The bridge now carries a pipeline, instead of vehicles.)

The main suspension cables were comprised of seven woven steel cables clamped together, which were tied into massive concrete deadmen at the four corners. The 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. Midland erected the Cameron Bridge in 1911. Named after U.S. Senator Ralph Cameron, the structure soon spawned a trading post and a small settlement.

The Cameron Bridge has had a profound impact on the commerce and transportation of a rugged, remote and isolated section of Arizona. Its construction marked an important contribution to the region's economy and opened the Navajo Reservation and the remainder of the region to traffic from the south. As a pivotal part of the north-south territorial highway, the bridge provided an important entrance to Grand Canyon National Park from the populated areas of Arizona. Because of their exotic nature and expensive erection costs, suspension bridges were infrequently built in Arizona and the country. The Cameron Bridge is notable as the older of the two vehicular suspension bridges remaining in the state—a significant hybrid of suspension and truss engineering.

Inducing the federal government to pay for the territory's internal improvements in the name of Indian advancement had been the idea of Ralph H. Cameron, Arizona's Territorial Delegate to Congress.[36] As his

[36]Directing funds that had been appropriated for Indian support to serve Anglo needs was hardly novel. The Office of Indian Affairs had been prey to pork barrel politics since its inception in 1824. Despite occasional efforts by reformers to clean it up, the Indian Office remained the archetype of government corruption and inefficiency through-

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namesake bridge over the Little Colorado was under construction in April 1911, Cameron introduced legislation in Congress to build two other wagon bridges on the San Carlos Indian Reservation. His bill allotted $100,000 to pay for steel or concrete structures over the San Carlos and Gila Rivers near the town of San Carlos, in southeastern Arizona.

Ostensibly, the spans would benefit the Apache Indians by providing all-weather access from the reservation to the Solomonville-San Carlos Highway, the principal route through the region. But they would also form a strategic crossing of the Gila River for Anglo travelers along the territorial east-west route. The San Carlos Bridge, as planned, would combine with the Tempe Bridge under construction over the Salt River and the proposed Antelope Hill Bridge over the Gila in western Arizona to span the route's three most problematic crossings. Moreover, it would form the only point between Florence and Duncan at which Anglo freight wagons could traverse the Gila River on their way to the booming mining district around Globe.

Cameron's bill failed, and he re-introduced it on January 29, 1912, without the appropriation. This too failed. When Arizona was admitted into the United States two weeks later, Cameron was replaced in Congress by Carl T. Hayden. Hayden almost immediately resumed his predecessor's quest for bridges. In March 1912, he introduced a bill again directing the Secretary of the Interior to examine suitable sites for the San Carlos bridges, as well as a steel span over the Colorado River at the Yuma Indian Reservation. This time, without the commitment to fund actual construction, the legislation passed. The proposed San Carlos and Yuma bridges were surveyed late in 1912; the next year Congress approved funds for their construction.

Responsibility for locating and designing the San Carlos Bridge had been delegated to the Indian Office in Washington, D.C. Rather than place the structure at San Carlos, as had been envisioned in the initial legislation, the agency proposed a location more than twenty miles upriver, at the Naches Siding of the Arizona & Eastern Railroad near Calva. OIA engineers sited the bridge over a meandering stretch of river bounded on both sides by earthen banks. The Solomonville-San Carlos Highway paralleled the river on its south side, as did the tracks of the Arizona & Eastern Railroad. As delineated by OIA in July 1913, the bridge was comprised of seven Pratt through truss spans, each extending 138 feet in eight equal-length panels, for an overall structure length of 980 feet. To fabricate and erect the San Carlos Bridge, OIA contracted with the Midland Bridge Company, contractor for the Cameron Bridge. It is unclear whether OIA engineered the trusses for the San Carlos Bridge or whether Midland was responsible for their design. Based on the generalized drawings produced by OIA, the agency probably delineated the overall layout and configuration of the bridge and left the specific truss design and detailing to the bridge company.

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out the 19th and early 20th centuries. Although bridge construction did indeed benefit Native Americans, it undoubtedly profited the commerce and transportation of Anglos far more. Several exhaustive studies of the Indian Office have been produced, including Robert M. Utley, *The Indian Frontier of the American West: 1846-1890* (Albuquerque: University of New Mexico Press, 1984); Francis Paul Pruscha, *The Great Father: The United States Government and the American Indians* (Lincoln, Nebraska: University of Nebraska Press, 1984); and Paul Stuart, *The Indian Office: Growth and Development of an American Institution, 1865-1900* (Ann Arbor, Michigan: UMI Press, 1978).

Midland riveted the members of the San Carlos Bridge in its Kansas City shops, using steel pieces rolled in the Pittsburgh mills of the Cambria Iron Works. During the fall of 1913, the firm shipped several carloads of steel to the site by rail and stored the steel components beside the construction site. Steelworkers then used a wooden traveler to erect the trusses over traditional timber falseworks. The San Carlos Bridge was reported complete by the end of the year. Building the San Carlos Bridge proved far easier than keeping it open to traffic, however, given the problematic nature of the Gila River. The Christmas flood of 1914 marked the first major test of the San Carlos Bridge since its completion. The steel structure itself withstood the high waters, but the river shifted its channel dramatically immediately upstream, cutting a 500-foot-wide swath through the south embankment. "The bridge proper was uninjured but left isolated by lack of facilities to confine the stream," AHD engineer Merrill Butler reported, "permitting the Gila to change its course and wash around the approach."[37] With the south approach destroyed, the bridge was rendered worthless, only a year after its completion.

The San Carlos Bridge was federal property. Money had been appropriated for the bridge's construction but not its maintenance and not for rectification works on the Gila. A little more than a year after the flood, Frank Olmsted, a Los Angles-based engineer under contract with the Department of the Interior, investigated the site and recommended that the riverbank be rebuilt to restore the bridge's south approach. But without funds, the Indian Office could do little to repair the structure. It thus stood abandoned, as the river cut progressively deeper into the south embankment at each flood. "The usefulness of this particular bridge has been lost to the community for a period of something over five years because of erratic stream action," Butler wrote in 1920. "Necessity for stream control is, therefore, emphasized in conjunction with bridge construction and maintenance."[38]

The proposed bridge over the Colorado River at Yuma had exactly the opposite problem than the San Carlos Bridge: it proved durable enough once completed but its construction was plagued with woe. Ostensibly to provide a crossing for the Yuma Indian Reservation across the river in California, the bridge would also carry the Ocean-to-Ocean Highway as the only bridged crossing of the Colorado for some 600 miles. The State of Arizona would contribute $25,000, as would Imperial County,

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[37] *Fourth Biennial Report of the State Engineer*, 1918-1920, p. 65.

[38] Ibid. Instead of re-channeling the river under the bridge, the Indian Office eventually opted to extend the bridge over the new channel. OIA reportedly added four 126-foot trusses to the structure's south end to reach the new embankment. The San Carlos Bridge was thus put back into service in February 1921. In the mid-1920s, it was made part of U.S. Highway 180 (later U.S. 70) and placed under the aegis of the state highway department. As traffic along the highway increased, the narrow trusses eventually formed a bottleneck. By the mid-1930s the highway department began planning a new, wider structure to replace the San Carlos Bridge. In 1935 the original bridge was replaced by the Arizona Highway Department, and four of its truss spans were moved by relief workers and re-erected in the Prescott and Tonto National Forests. The Whispering Pines Bridge in the Tonto National Forest has since been removed. The two-span Perkinsville Bridge (**09474**) and the single-span Walnut Creek Bridge (**08741**) in the Prescott National Forest continue to carry vehicular traffic.

California; OIA would fund the rest. The bridge would be located at the foot of Prison Hill, near the Arizona Territorial Penitentiary and immediately upstream from the existing ferry. As delineated, the structure would consist of a pin-connected Pennsylvania through truss, with a rigid-connected Warren deck truss approach span at one end. The trusses would be carried high over the river by concrete abutments and pier. In June 1914 the OIA contracted with the Omaha Structural Steel Works to fabricate and construct the bridge for over $72,000.

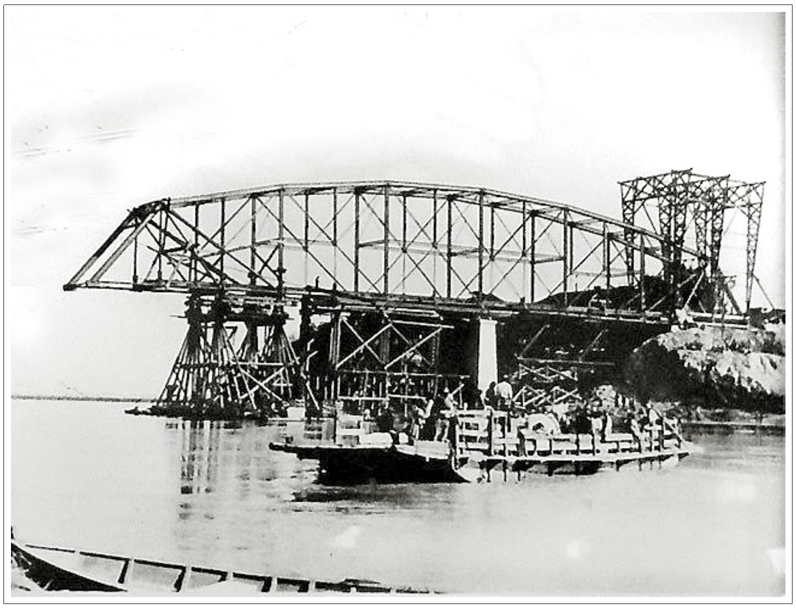

Figure 44. Ocean-to-Ocean Bridge under construction, March 1915. Arizona State Archives.

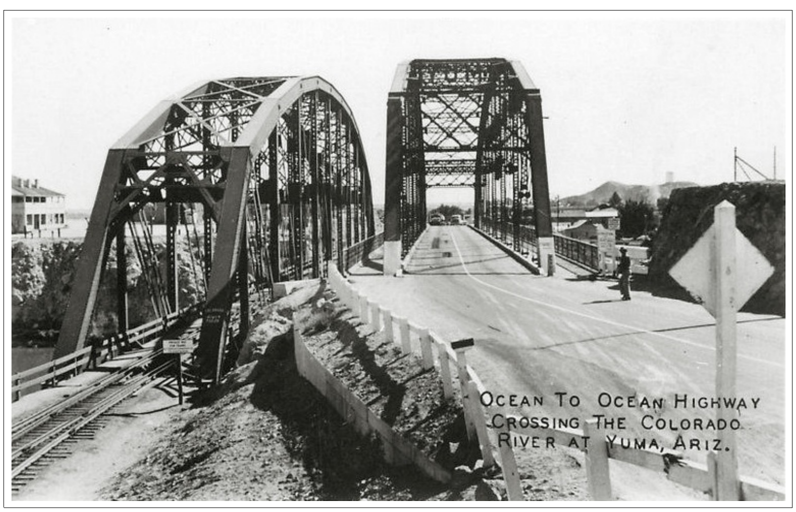

Figure 45. Ocean-to-Ocean Bridge (right), n.d. Postcard.

In a classic instance of bureaucratic bumbling, Office of Indian Affairs engineers designed the bridge in Washington, DC, without benefit of an on-site visit at Yuma. The truss was to be erected using traditional falseworks. But after the falsework washed away twice in flash floods, the contractor devised an alternate erection system. The truss was prefabricated on a barge upriver from the crossing site, floated to the site and lowered onto the abutments in one breathtaking operation. On March 3, 1915, the 336-foot-long span was swung in a carefully choreographed maneuver amidst widespread celebrating throughout the town [Figure 44]). On May 22 the Ocean-to-Ocean Bridge (**08533**) was ceremoniously opened to traffic. "This is the first highway bridge built across the Colorado River in all its length," the *Yuma Sun* stated in 1915. Although the writer neglected the dozens of bridges at the river's upper reaches in Colorado, the Ocean-to-Ocean Bridge was the first highway span over the lower Colorado [Figure 45]).

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As the contractor was struggling to build the Yuma Bridge in 1914, the Indian Office solicited help from Arizona and California to erect another major span over the Colorado River. This bridge would carry the Old Trails Highway, Arizona's other transcontinental route. Topock, Arizona—halfway between Yuma and the Utah border—was chosen as the crossing site. The new structure would be situated just south of the existing Red Rock Bridge, J.A.L. Waddell's famous cantilevered truss built for the Santa Fe Railroad in 1890. Each government entity contributed $25,000 to construction of the Topock Bridge, and San Bernardino County agreed to design the structure. County Surveyor S.A. Sourwine engineered this long-span steel arch. Whether he received consulting help or not, his design for the Topock Bridge bore more than a passing resemblance to the Bellows Falls (Vermont) Arch Bridge, completed in 1905.

In June 1915 the contract for fabrication and erection of the bridge was let to the Kansas City Structural Steel Company. Taking a cue from the difficulties experienced erecting the Ocean-to-Ocean Bridge at Yuma, engineers for Kansas City Steel erected this bridge using a novel cantilever system, in which the bridge halves were assembled on their sides on either side of the river and hoisted into place using a unique ball-and-socket center hinge. The bridge was completed on February 20, 1916. At its completion the longest arch bridge in America, the 360-ton Old Trails Bridge was also distinguished as the country's lightest and longest three-hinged arch [Figure 46]).

Figure 46. Colorado River bridges at Topock, with Red Rock Bridge (since demolished) at left and Old Trails Bridge at right, n.d.. Postcard.

5 Federal Aid and the Arizona Highway Department in the 1910s and 1920s

The pace of road and bridge construction had quickened in Arizona after statehood in 1912, but the state's efforts still fell far short of its needs. It would take a massive infusion of funds from the federal government—something well beyond the appropriations for specific bridges—for Arizona's road network to begin showing marked improvement. During the 1910s the federal government was beginning to take a more active role in road and bridge construction. Just months after Arizona became a state in 1912, Congress passed the Post Office Appropriation Act, dedicating $500,000 toward construction of rural roads to facilitate mail delivery. This legislation allocated $500,000 through the Secretary of Agriculture toward construction of rural roads to facilitate mail delivery. Seventeen states—not Arizona—took advantage of this opportunity, resulting in construction of 425 miles of improved roads. This mileage, however, represented only a small step in the right direction.

Four years later the government took a much larger step, when President Woodrow Wilson signed the Federal Aid Highway Act on July 11, 1916. This legislation ushered in a massive new level of federal commitment to road building. Part of the impetus came from the postal service, which had difficulty delivering mail in many rural areas because of the poor roads. Business leaders also promoted the legislation, citing the need for reliable roads to get farm commodities to market. The act was intended to develop an interconnected network of well-built and well-maintained roads throughout the country.

Seventy-five million dollars were initially available to states over the first five years, apportioned by a ratio based on area, population and miles of rural post roads. The states' allotments could be used only on projects approved by the U.S. Bureau of Public Roads [BPR], predecessor to today's Federal Highway Administration. Expenditures could not exceed $10,000 per mile, exclusive of bridge costs. The latter were to be paid by counties, sometimes with state assistance. Federal funds were to be used on rural roads, or on roads in communities with under 2,500 residents, but they could not be used in urban areas. And they could not be used on projects involving convict labor. Federal aid could be used on new road construction, bridge construction, reconstruction work or extraordinary repairs.[39]

The act stipulated certain organizational requirements for state highway departments. This favored states with established infrastructures and tended to place Western states at a competitive disadvantage. As one of 15 states that did not initially comply with these requirements, Arizona was compelled to restructure its highway administration. In March 1917 the Arizona State Legislature did just this. The state engineer, with approval of the State Board of Control, was empowered to enter into contracts and agreements with the federal government and administer the program on the state level. Arizona's share of the federal aid fund

[39] In its first two years, federal aid was granted exclusively toward construction of post roads. These tended to be lightly traveled secondary roads, with wooden bridges and machine-graded roadways. The 1919 iteration of the Highways Act allowed work on more heavily trafficked through routes or roads connecting urban centers. It also increased the per-mile expenditure on road construction to $20,000.

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amounted to $3.7 million, distributed over a five-year period—about two percent of the Congressional appropriation.

With the funding mechanism now in place, the state could receive federal aid grants from the Bureau of Public Roads. But World War I interceded, and shortages of funds, materials and even engineers forced the program into hiatus almost immediately. By 1919 only $500,000 of the $75 million appropriation had been spent, and only 12½ miles of road had been built. In the entire country. After the war, rising inflation, labor strikes, materials shortages and shipping problems further stymied roadwork, so that little construction was accomplished between 1916 and 1921. Meanwhile, Arizona was having its own problems. Despite the promise by the Arizona State Legislature to match all federal funds and State Engineer Thomas Maddock's vow in 1920 that "no Federal Aid has been lost or will be lost to Arizona," the highway department soon had trouble matching the increasing federal allotments.[40]

The infusion of such large amounts of money was welcome, but federal aid created a number of logistical problems for the highway department. Before the act, the agency had been organized to handle about $1 million of construction and maintenance work annually. Federal aid more than quadrupled this capacity and added new layers of bureaucracy to the construction process. The attendant paperwork increased correspondingly. Additionally, the BPR established more stringent bridge and highway guidelines and required more detailed planning, surveying and engineering for federal aid projects.

Projects were now planned and approved on both state and federal levels. Maddock found himself unable to guide the requisite surveys, plans, specifications, estimates, reviews and bid lettings through the process under the exacting deadlines established by BPR. "The requirements of the Bureau of Public Roads more than doubled the amount of work necessary in the preparation of plans and specifications," he reported to the governor in 1920, "and required so much time that it was not possible to proceed with construction as promptly and rapidly as would otherwise have been the case." To further complicate the process, the state engineer's office now had to coordinate with fourteen county boards of supervisors, thirteen county highway commissions and several city and town councils—each vying for a share of the federal allocation. "The difficulties, disadvantages and delays of this system are so obvious as to need no comment," Maddock concluded ruefully. "However, we were confronted by facts and not by theories, so we proceeded promptly to make the best of a difficult situation."[41]

Maddock was further frustrated by the $10,000 per mile limitation on highway funding maintained by BPR. Arizona's rugged terrain, especially in the mountains east of Superior where a major highway had been

[40]State of Arizona, State Engineer, *Fourth Biennial Report of the State Engineer to the Governor of the State of Arizona: 1918-1920* (Phoenix: Republican Print Shop, 1921), 21.

[41]*Ibid.*, 27.

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planned, would require far more expensive construction for road building. To help alleviate the problem, he sought cooperation from the counties in planning and funding projects. He urged them to issue bonds of indebtedness to commit money for future projects. Subsequently, twelve of Arizona's fourteen counties voted bond issues totaling $15 million (Maricopa issued $8.5 million; Graham and Gila were the holdouts).

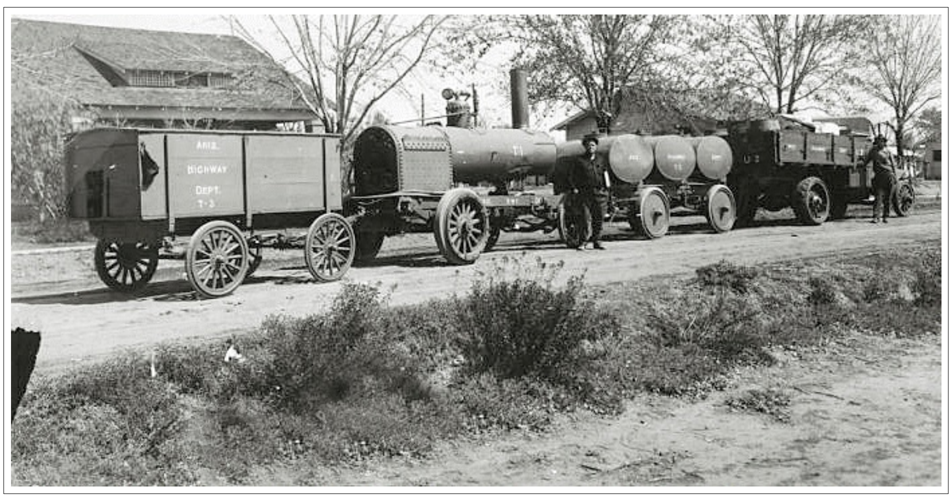

Figure 47. Arizona Highway Department equipment convoy, 1925. Arizona State Archives.

The changes brought about by federal aid transformed the state's road and bridge construction mechanism, as the state engineer's office grew into the Arizona Highway Department [AHD]. By the end of 1920, AHD employed more personnel than all other state agencies combined. The department's total allocation of funds that year exceeded the total expenditures of every state, county, city, school and road district in the state combined for 1914. AHD was the largest employer of engineers in the state. The department's maintenance and construction vehicles constituted Arizona's largest truck fleet [Figure 47]. It purchased more supplies for its various construction camps than all other state institutions combined. The department was Arizona's largest consumer of explosives. And following a change in state law in January 1919 that allowed the highway department to contract for road construction, AHD was the state's largest contracting entity.

Arizona Federal Aid Project No. 1, appropriately enough, involved construction on the Florence Bridge. Originally built in 1885 by the territory, repaired in 1905 and rebuilt in 1909, it was one of the state's most important spans and one of its most problematic. The Florence Bridge was in need of extensive repairs when the state began assigning federal aid dollars in 1917. The project entailed almost $132,000 of work, half of which was funded by the federal government. Federal Aid Project [FAP] No. 2 involved 3.86 miles of concrete paving on the Phoenix-Tempe Highway, FAP 3 involved work on the Holbrook-St. Johns Highway through the Petrified Forest. FAP 4 contemplated reconstruction of about 50 miles of road in the vicinity of the Antelope Hill Bridge but was not undertaken. FAP 5 entailed construction of roadway and drainage structures on 2.2 miles of the Kingman-Oatman Highway (a segment of the Old Trails Highway). This included construction of a two-span concrete slab bridge over Old Trails Wash in Kingman. Completed in 1917, the bridge and adjacent roadway carried mainline traffic. The Old Trails

Wash Bridge (**08594**) is today distinguished as the oldest existing bridge built using federal aid funds in Arizona [Figure 48].

Figure 48. Old Trails Wash Bridge (08594), 2018.

Many of Arizona's earliest federal aid projects involved bridge construction of one form or another, often to repair or replace faulty existing spans. FAP 10 funded the Marinette Bridge, a five-span concrete arch structure over the Agua Fria River in Maricopa County. FAP 15-C went toward repairs on the San Carlos Bridge, and FAP 25 was earmarked for bridges on the Tucson-Nogales Highway. FAP 31 funded the Wickenburg Bridge over the Hassayampa River. Built in 1914 by Maricopa County, the original Wickenburg Bridge consisted of four concrete spans. Two spans washed out in autumn 1916 and had been replaced with a steel truss. When the bridge suffered extensive further damage from floods in 1919, the highway department moved to replace it entirely with a three-span through truss, using federal highway money. Merrill Butler, faced with the prospect of another in a growing list of major bridge failures, stated, "Previous efforts to construct and maintain this bridge have cost the taxpayers of Maricopa County something over $20,000, together with a part-time loss of use. This department contemplates an additional expenditure of about $70,000, making a total of over $90,000. A properly designed bridge in the first place would have saved $60,000 and much inconvenience."[42]

Even projects not specifically earmarked for bridgework often entailed construction of small-scale drainage structures—primarily concrete culverts and slabs—as part of the adjacent roadwork. For instance, FAP 13

[42]*Fourth Biennial Report of the State Engineer*, 1918-1920, 68-69. Three spans from this structure were later moved to another site to form the Boulder Creek Bridge (**00193**) in Maricopa County.

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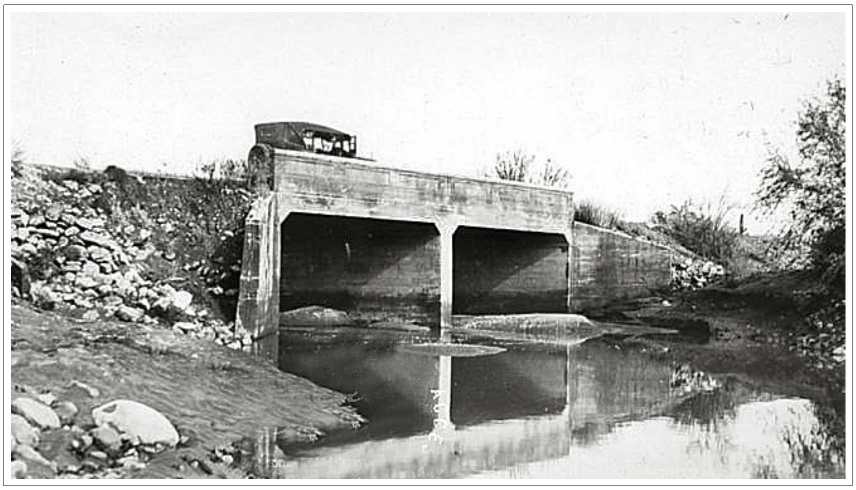

Figure 49. Small bridge on Yuma-Welton Highway, 1926. Arizona State Archives.

on the Clifton-Franklin Highway in Greenlee County included construction of a concrete bridge near Franklin and smaller bridges and fords in Ward Canyon. And FAP 26 involved construction of 18¾ miles of roadway and several drainage structures on the Yuma-Welton Highway (part of the Ocean-to-Ocean Highway) [Figure 49].

All of this construction work placed a considerable burden on the state engineer's office for bridges. To help shoulder the increased workload, the department hired R.V. Leeson as its bridge engineer on a consulting basis in July 1918. Leeson, who also functioned as assistant chief engineer for the Topeka Bridge and Iron Company, served in this role for a little more than a year. His most noteworthy commission during his tenure with the state was the Gila River Bridge (**08152**) in Greenlee County. In September 1919 Leeson was replaced by Merrill Butler, Arizona's first full-time bridge engineer. One of Leeson's principal responsibilities during the summer of 1919 was to produce a set of standard plans for small-scale concrete bridges. The state engineer's office had been using standards for small-scale concrete bridges beginning with Cobb's administration. With federal involvement, however, these needed to be redrafted and approved by BPR.

Leeson delineated plans for concrete slabs (6- to 24-foot span), concrete culverts (both box and arch) and three-beam deck girders (up to 50-foot span). These designs were to be used by the state engineer's office and promulgated to the individual counties for use on county-funded construction. During the 1918-1920 biennium, the state engineer's office planned or built some 77 slab bridges, 92 box culverts, ten girders and five arch culverts using the standard plans. In all, some 747 such standard-plan structures were planned or built during the biennium, for an aggregate cost of almost $500,000.

Additionally, Leeson and Butler designed about two dozen bridges from site-specific designs. These included concrete girder structures at Mescal Wash, Railroad Wash, Queen Creek, Continental, Sonoita River and Granite Creek (**00042** [Figure 50]); four slab bridges over canals in Maricopa County; and concrete arches at Emerald Gulch, Cottonwood, Marinette and Queen Creek. The state engineer's office also engineered a multiple-span steel truss bridge over the Hassayampa River at Wickenburg. The largest concrete bridges of the biennium were the Marinette Bridge over the Agua Fria River (since demolished) and the Luten arches over the Gila River (**08152** [Figure 40]). and Queen Creek (**08440** [Figure 42]).

see continuation sheet

Figure 50. Granite Creek Bridge (00042), 2003.

The state engineer's office continued at the same accelerated pace during the 1920-1922 biennium, steadily improving and expanding the network of state highways [Figure 51]. "The office of State Engineer has become in reality the Arizona Highway Department," Thomas Maddock stated in his report to the governor. "While certain duties still exist in regard to the irrigation of land, the highway work has so greatly increased that the Highway Department has become the largest single business in the State of Arizona."[43] With Butler as the department's bridge engineer, AHD developed more bridge standards, which it used for its own projects and distributed to the county engineers for use on county roads. Additionally, the department produced or reviewed designs for several county-built structures. "Various counties in the State have availed themselves of the services of the Department for the preparation of bridge plans and examination of sites and manufacturers' proposals," stated Butler.[44]

Most of the drainage structures built with federal aid were generated from standard designs and contracted for under the umbrella contracts of the adjacent roadwork. A few bridges, however, were of sufficient scale to warrant individual contracts, let separately from the contracts for the adjacent road grading. For these Butler engineered site-specific concrete and steel spans. Some of Arizona's more noteworthy early concrete bridges date from this formative period. These include the Devils Canyon Bridge (**abd.** [Figure 52]), a single-

[43]State of Arizona, State Engineer, *Fifth Biennial Report of the State Engineer to the Governor of the State of Arizona: 1920-1922* (Phoenix: Republican Print Shop, 1922), 7. Maddock continued:

> The Arizona Highway Department has endeavored to keep up with the changing conditions of our time and construct the thru roads in the State in such a manner that they will not only carry the present traffic, but that their location will anticipate future increased traffic. And, when this traffic is realized, hard-surfaced pavements can be laid over the present grades and drainage structures and the original investment will not be lost, as has so frequently been the case in the past.

[44]*Fifth Biennial Report of the State Engineer*, 1920-1922, 57.

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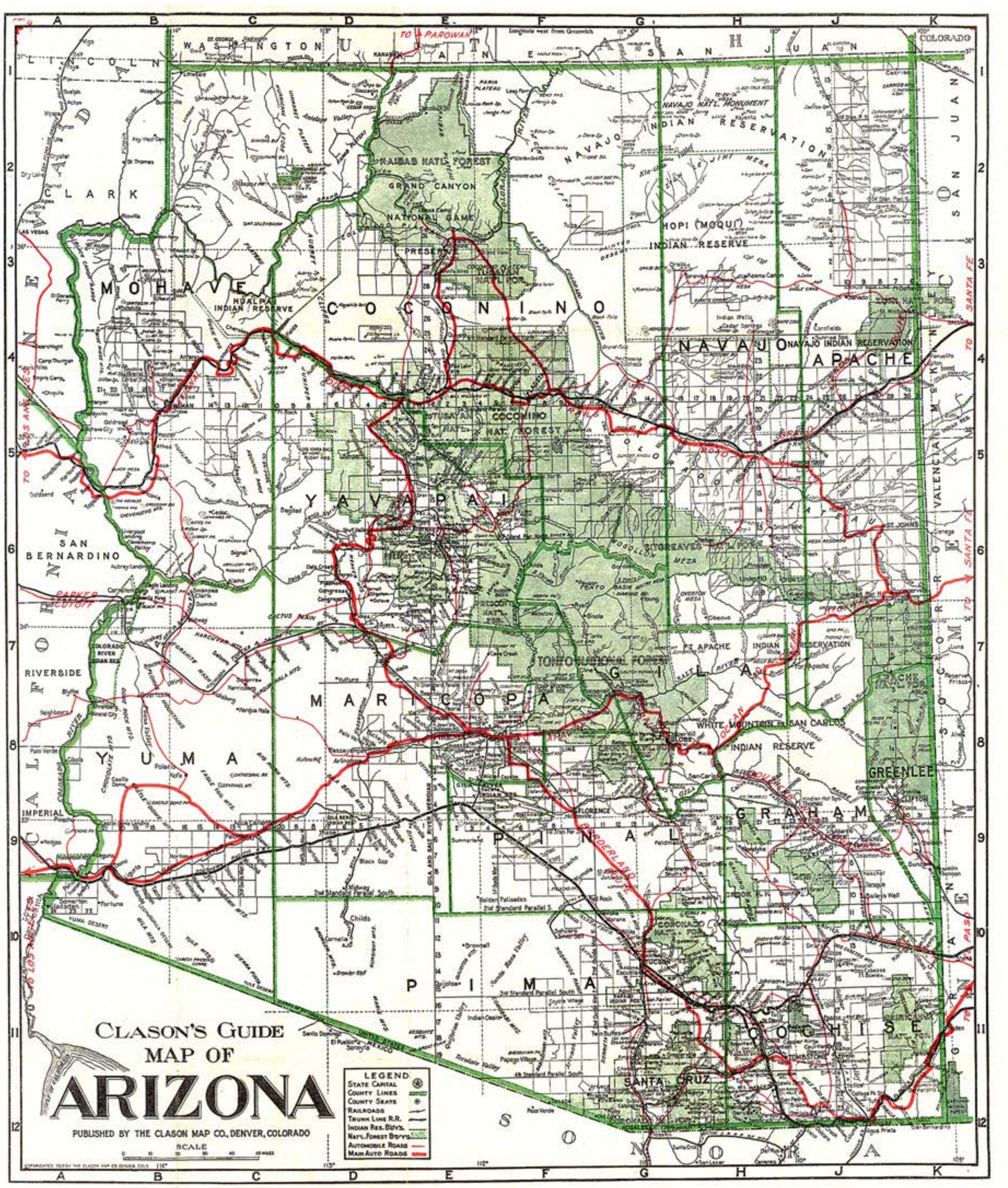

Figure 51. Clason's Guide Map of Arizona, 1917.

Figure 52. Devils Canyon Bridge, 2018. (The b ridge has been abandoned in place following a re-alignment of the highway.)

span concrete filled spandrel arch; the Queen Creek Bridge (**abd.** [Figure 53]) near Superior, a long-span concrete open spandrel arch; the Cordes Bridge (**08249** [Figure 54]), a three-beam girder; and the Concho Bridge (**08480** [Figure 55]) and the New River Bridge [Figure 56], two concrete through girders; and the Hell Canyon Bridge, a concrete deck girder (**abd.** [Figure 57]).

Figure 53. Queen Creek Bridge, 2018. (The bridge has been abandoned in place following a re-alignment of the highway.)

Figure 54. Cordes Bridge (08249), 2018. (The center-span pier has recently been added.)

None of these bridges were particularly innovative, technologically. The Concho and New River Bridges were apparently design experiments, and the three-beam girders were unusual in their configuration but noteworthy only by degree. Rather, these concrete structures—filled and open spandrel arches, deck and through girders and simple slabs— followed industry standards in their profile, reinforcing and span length.

Figure 55. Concho Bridge (08480), 2018.

Figure 56. New River Bridge. (Bridge has been demolished.)

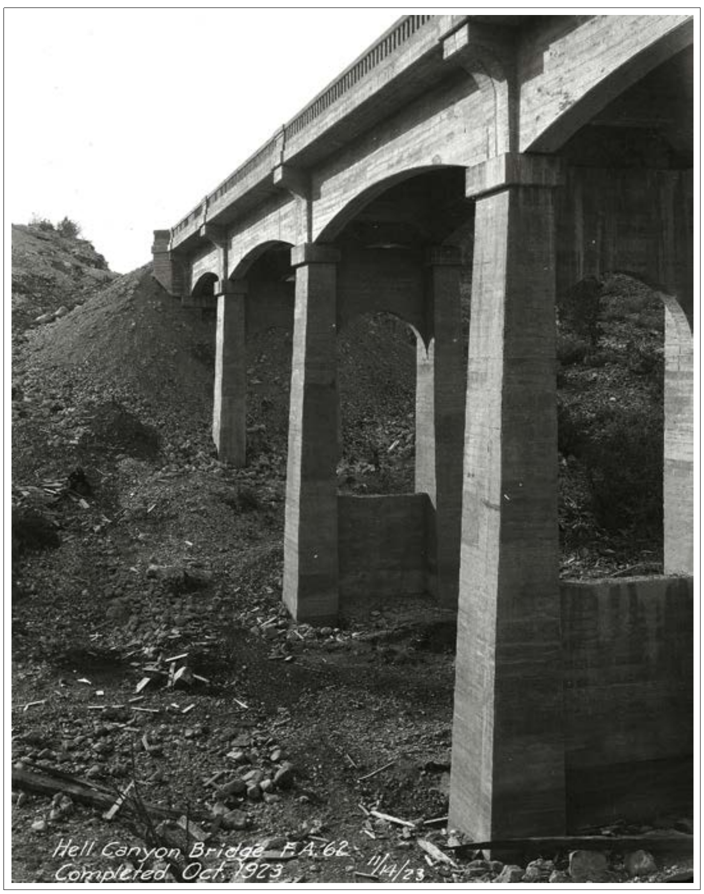

Figure 57. Hell Canyon Bridge, 1923. ADOT.

The most noteworthy of these early federal aid bridges was the structure over Cienega Creek in Pima County. With equal funding from a Pima County bond issue, the Cochise County Road Fund and Federal Aid Project 18, the Arizona Highway Department in 1920 began construction of a portion of the Borderland Highway across southern Arizona. The 28-mile-long section extended between Benson and Vail and included a major crossing of rugged Cienega Canyon near Vail. For this, Thomas Maddock designed a long-span concrete arch over the canyon with a concrete girder viaduct over the nearby railroad tracks. Extending 146 feet, the open spandrel arch was comprised of two tapered ribs that sprang from concrete foundations with spread footings. These ribs supported a series of concrete columns which in turn supported the concrete deck. The deck was bounded by concrete guardrails with square balusters and paneled bulkheads.

In 1919-1920 the AHD bridge department designed three almost identical open spandrel concrete arches for Arizona highways—the Cienega Bridge and bridges over Queen Creek [Figure 53] in Pinal County and Hell Canyon [Figure 57] in Yavapai County. The design of the Hell Canyon bridge was later changed, and the Cienega and Queen Creek structures were undertaken as originally drawn. After completing the drawings for Cienega, AHD let the contract for the Cienega Bridge to Tucson contractors English & Pierce. Using concrete and reinforcing steel provided by the highway department, the contractors completed the structure for a cost of a little more than $40,000.

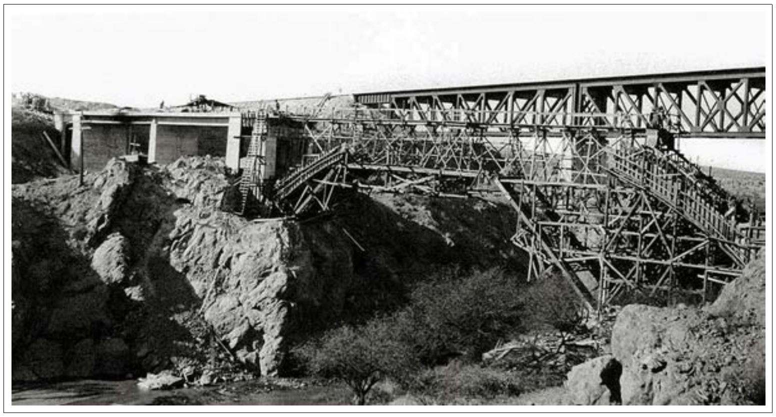

Figure 58. Cienega Bridge under construction, showing falsework before addition of the center pier. Engineering News-Record, 1922.

Of the three open spandrel arches extant in Arizona, the Cienega Bridge has the longest span. Additionally, it is the oldest of the surviving open spandrel arches in the inventory. The thing that made this bridge additionally noteworthy to engineers at the time was the method used in its erection [Figure 58]. In an article published in *Engineering News-Record*, Butler described the circumstances. "Falsework of rather extraordinary detail was designed for the Cienega Bridge recently built by the Arizona Highway Department, but the design after erection appeared to be somewhat unsafe and was therefore supported by an additional tower through the river bed." The tower steadied the falsework and prevented its collapse during the construction. The centering was dropped into the streambed after the concrete work on the bridge had been completed [Figure 59].[45]

Figure 59. Cienega Bridge, 2018.

[45] Merrill Butler, "Special Trussed Falsework for Concrete Arch." *Engineering News-Record*, Vol. 89, No. 12 (September 21, 1922) 498-499.

As America entered the 1920s, many states were experiencing an economic expansion. This industrial growth was fueled by the automobile industry, which simultaneously helped expand other related industries and expedite the entire country's growth. "The automobile industry, as a result of the assembly line and other technological advances, grew from a relatively modest size in the years before [World War I] to become one of the most important forces in the nation's economy."[46] Americans bought 1.5 million cars in 1921, 5 million in 1929. The same automobile that propelled Arizona's good roads movement had catapulted all transportation networks into the spotlight. The ascendence of the motorcar coincided with the development of a burgeoning new industry: commercial trucking. By the end of the 1920s, the number of commercial vehicles was actually growing faster than the number of passenger cars. The decline of goods transported by railroads and the corresponding expansion of commercial trucking amplified the need for well-constructed, interconnecting roads.

In November 1921 Congress passed the Federal Highway Act, which vastly expanded the 1916 legislation. The new law authorized $50 million for roadwork in 1921, $65 million in 1922 and $75 million in 1923. By the end of the decade, BPR would spend some $750 million on federal aid highways. More importantly for Arizona, the new law acknowledged the greater lengths of highways needed in the western states, the large tracts of federally owned land and the difficulties experienced in raising their 50/50 match of funds. While it did not increase the federal appropriation for highway construction appreciably, it did decrease the states' match proportionately to the amount of federal lands in the states. Using this sliding scale, Arizona's share of road and bridge funding thus fell from 50 percent to less than 30 percent.

Under the new law, federal funds would be apportioned to making improvements on 7 percent of the highways in each state. These so-called seven percent highways, designated explicitly by the state highway department in each state, thus became essentially the highway systems for the western states. The following year Arizona delineated almost 1,500 miles of roads to be included in its 7-percent network [Figure 60]. Unsurprisingly, these essentially followed the existing state highways. Before the 1921 Act, Arizona had been experiencing difficulties in matching the federal allotment for the state. "Only one-sixth of the Federal Aid appropriated to Arizona had been matched with State funds on projects which could early be completed," Maddock reported. The net result of the law was that the state would receive more federal funds for road and bridge work. Maddock was optimistic about its effect on Arizona's roads, stating:

> At the present rate of progress, it is conservatively estimated by the Arizona Highway Department that Arizona's Seven Per Cent system will be so improved within the next fifteen months that it will be possible to average thirty miles per hour in traversing any road across the State.[47]

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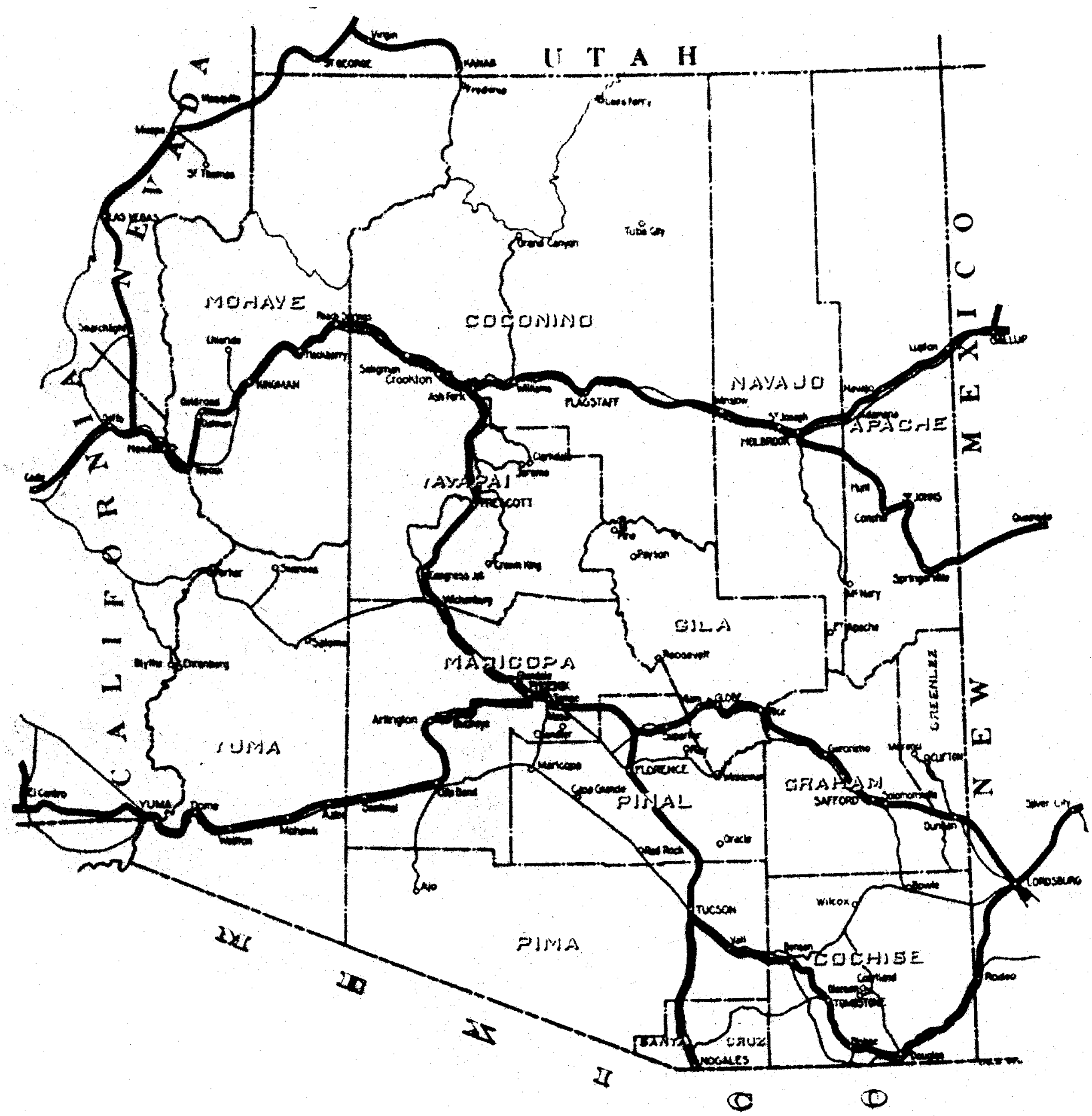
[46] Allan Brinkley, et al., *American History: A Survey* (New York: McGraw- Hill, Inc., 1991), 700.

[47] *Fifth Biennial Report of the State Engineer*, 20.



ARIZONA HIGHWAY DEPARTMENT
FEDERAL AID 7% HIGHWAY SYSTEM
SCALE

Figure 60. Federal Aid 7% Highway System, 1922. ADOT.

The establishment of the seven percent network marked the first definitive designation of Arizona's highway system. An administrative history produced by the state highway department in 1939 described the state of affairs before this designation:

> Throughout the period from 1909 to 1922 the State system was susceptible to many changes. Maps of this era indicated the highway system to be tentative or proposed. If a State engineer decided to expend funds upon a road it was considered as a part of the State highway system; likewise, if he or a successor elected to abandon any section as a State highway, the only apparent action necessary was to discontinue to expend additional State funds for betterment or maintenance, and in the course of time it lost its identity as a part of the system.[48]

By the mid-1920s, the public was becoming disaffected with the cooperative highway associations and their transcontinental roads. No fewer than 250 registered highways then vied for travelers' attention. The highway markings were often inconsistent, the guidebooks misleading and confusing, and the highways themselves often little more than dirt tracks. Moreover, they were often routed, not in the straightest line over the best roads possible, but in lengthy meanders to connect dues-paying municipalities. "The harmless tourist in his flivver doesn't know whether he is going or coming," travel writer William Ullman stated, "whether he is a hundred miles from nowhere or on the right road to a good chicken dinner and a night's lodging." When the Pikes Peak Ocean-to-Ocean Highway Association rerouted its road from San Francisco to Los Angeles, the editor of the *Reno Evening Gazette* (one of the towns abandoned by the association) complained bitterly:

> The public is learning this fact—that transcontinental highway associations, with all their clamor, controversy, recriminations and meddlesome interference, build mighty few highways . . . In nine cases out of ten these transcontinental highway associations are common nuisances and nothing else. They are more mischievous than constructive. And in many instances they are organized by clever boomers who are not interested in building roads but in obtaining salaries at the expense of an easily beguiled public.[49]

As early as 1914, the National Highway Association had formulated plans for a 51,000-mile network of highways that included three east-west and three north-south primary routes. The 1916 federal aid legislation had neglected to coordinate the road-building efforts among the states, however. The result was a crazy quilt of mismatched roads that often ended at the states' borders. This problem was national in scope, begging for a national designation of highways. In 1924 the American Association of State Highway Officials [AASHO] began working on just such a plan. The following year AASHO and the Agriculture Department formed a Joint Board on Interstate Highways to adjudicate the highway designations. Late in 1925 the Secretary of Agriculture approved the new system.

[48] Arizona Highway Department. "History of the Arizona Highway Department." Unpublished manuscript, 1939, 15.

[49] Quoted by Richard F. Weingroff, "From Names to Numbers: The Origins of the U.S. Numbered Highway System," *AASHTO Quarterly*, Spring 1997.

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As a replacement for the often confusing naming system for highways, a uniform system of numbers would be instituted. Under this scheme east-west highways would be given even-numbered designations; north-south highways, odd-numbered. Diagonal highways would receive special designations. Three-digit numbers were assigned to relatively short-distance connector routes.[50] The highways would be marked uniformly with a shield bearing the route's number, the letters "US" and the state's name in black on a white background. Despite the obvious logic behind the numerical national system, the named highways still had their advocates. "I feel that such a move will never waken a popular response," Phil Townsend Hanna wrote in *Western Highway Builder*. "The Lincoln Highway and reputable routes of like character will never lose their identity. Romance is the manna on which the Americano thrives." He concluded: "Of all the idealistic proposals yet advanced for the administration of highways, none can equal this for pure imbecility."[51]

The U.S. highways in Arizona followed predictable patterns [Figure 61]. The Ocean-to-Ocean Highway across the southern part of the state was incorporated into U.S. Highway 80, the transcontinental route between Savannah and San Diego. The National Old Trails Highway that cut across the state's northern tier became part of U.S. Highway 66 between Chicago and Los Angeles. The original territorial North-South Highway became part of U.S. Highway 89 between Provo and Phoenix. And the route that meandered across the center of the state from Springerville to Ehrenberg by way of Globe and Phoenix later became part of U.S. Highway 60, a transcontinental road that began at Norfolk, Virginia, and extended through Arizona to Los Angeles.[52]

This designation and consolidation of routes had little effect on bridge construction in Arizona other than to prioritize the work on the more heavily trafficked routes. The majority of road and bridge work under the new legislation remained under the aegis of the state engineer's office, with oversight provided by the Bureau of Public Roads. For routes in the national forests and national parks, however, this responsibility lay directly with BPR. This agency functioned much like the state in bridge administration. The minor drainage structures were developed from BPR standard designs and let for contract as parts of overall road grading and drainage contracts. Larger and more technologically ambitious bridges were designed individually by engineers in the BPR's San Francisco, Denver or Phoenix offices and contracted for on an individual basis.

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[50]The American Association of State Highway and Transportation Officials [AASHTO] maintained the connector-route designation until 1934, when it began assigning the three-digit numbers to mainline routes. At the same time AASHTO began eliminating split route designations.

[51]Quoted in Weingroff, "From Names to Numbers."

[52]W.A. Sullivan, "U.S. Highway 60" Arizona Highways IX:1 (January 1933), 3-4. Of this route Sullivan stated:

> Destined to become one of the major arterial routes of Arizona when completed, U.S. Highway 60, running through the central part of the state, virtually bisects the state from east to west, It is one of the few roads in the nation which has been given federal designation before being finished. Its importance in the transcontinental system required recognition before it was completed. Designation has been given to the entire route ([through Arizona), approximately four hundred and ten miles long, except a thirty-five mile link from Show Low to Springerville in Northeastern Arizona.

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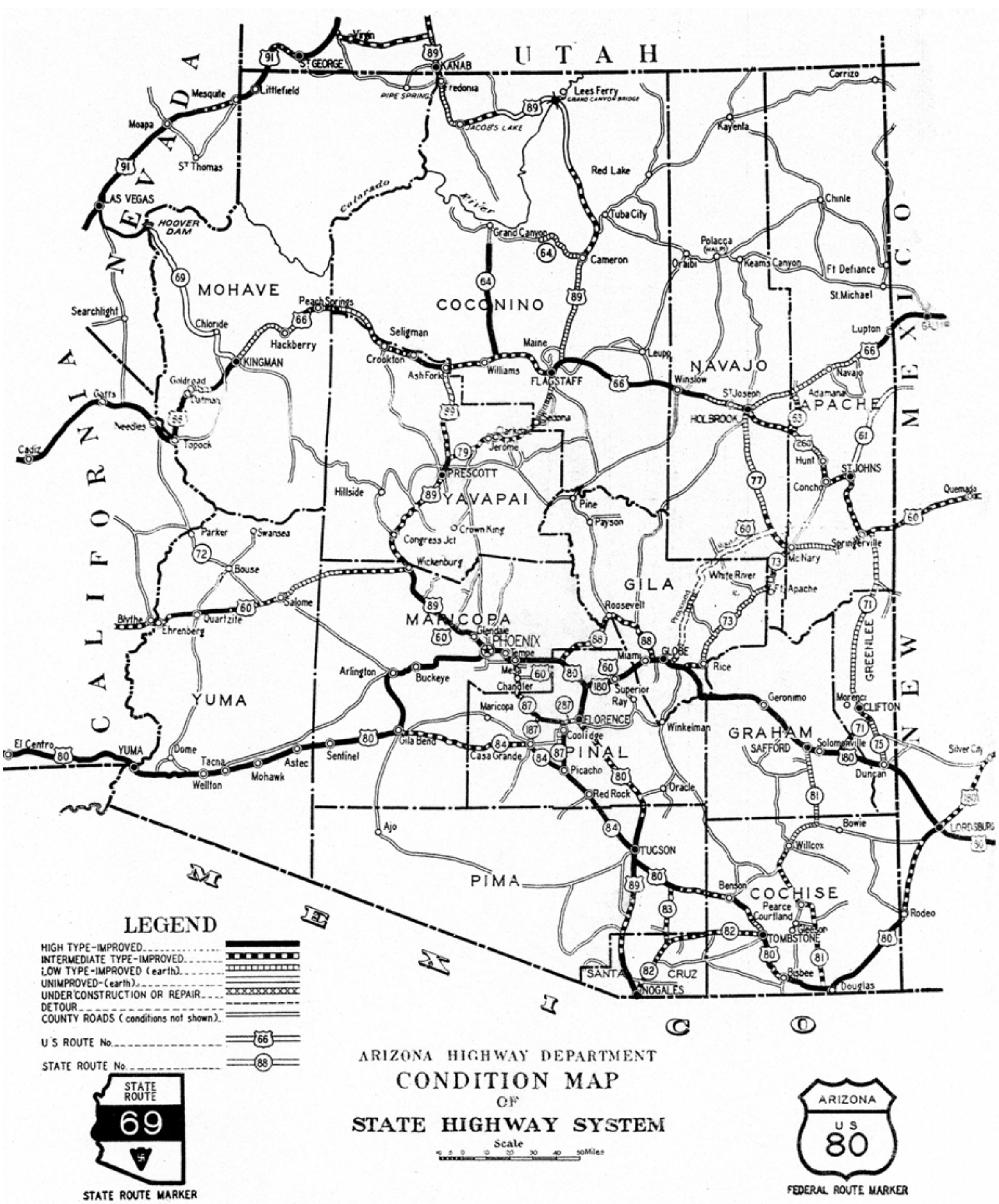

Figure 61. Arizona Highway Map, 1932.

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These engineers used much the same bridge design standards as AHD, so the repertoire for BPR structures in Arizona was similar to those designed by the state. The principal difference lay in the reliance on steel for

Figure 62. Walnut Canyon Bridge, 2018. (Bridge has been closed to vehicular traffic.)

superstructures in lieu of concrete. Several important BPR bridges have been built in Arizona: the Salt River Bridge (**00037**), a long-span steel truss built in 1919 in the Tonto and Crook National Forest; the Walnut Canyon Bridge (**09225** [Figure 62]) in the Prescott National Forest; the Parker Bridge (**00191**) over the Colorado River; the Midgley Bridge (**00232**) and Pumphouse Wash Bridge [**00079**] on the Oak Creek Canyon Road through Coconino National Forest.

The most picturesque of the BPR bridges from the period is the Dead Indian Canyon Bridge, a deck truss built in 1933-1934 on the highway to Grand Canyon National Park. When the National Park Service established the Grand Canyon National Park in 1919, no road extended westward from the Cameron Trading Post into the park. Access to the park was by way of a circuitous wagon road through the Navajo Reservation, which discouraged park visitation. During the early 1930s, to correct this problem, the Arizona Highway Department and the U.S. Bureau of Public Roads undertook an extensive road building effort that would provide automobile access from the east to Grand Canyon National Park's south rim. In the early 1930s, BPR built the Cameron-Desert View approach to the park, naming the 31-mile route the NavaHopi Highway.

About 13 miles east of Desert View, the route crossed Dead Indian Canyon, a broad, rocky chasm on the northern periphery of the Gray Mountains. For this crossing, BPR engineers delineated a rigid-connected steel deck truss supported by braced steel piers. The structure was comprised of three Warren truss spans, with built-up box beams for the upper and lower chords, a concrete deck and welded steel guardrails. In

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keeping with the Rustic Style then in use by the Park Service, the bridge featured decorative stone veneer on the concrete abutments and wingwalls. The Bureau of Public Roads awarded a contract for the bridge's construction in August 1933, to Vinson and Pringle for $45,000. The Phoenix-based contractors had completed the steel erection by January and in May had completed the structure. As an important crossing in a major access road to the park, the Dead Indian Canyon Bridge formed the final link in the route opened five years earlier by the nationally significant Navajo Bridge. Abandoned and in pristine condition, the Dead Indian Canyon Bridge is one of Arizona's more spectacular vehicular trusses (**00032** [Figure 63]).

Figure 63. Dead Indian Canyon Bridge (00032), 2018.

During the 1920s the Arizona Highway Department expanded its role in road and bridge construction incrementally. In August 1927 the state legislature discontinued the office of state engineer, in its place establishing the Arizona State Highway Department. The legislature at that time also established the Arizona State Highway Commission, a five-member board charged with oversight of the highway department. The highway department called this legislation "the first systematic highway code for the administration of all matters and affairs directly affecting the highways of the State," but in truth the state engineer's office had been calling itself the state highway department unofficially for years.[53] As a practical matter, the newly formed agency functioned much like its predecessor.

[53] "History of the Arizona Highway Department," 4.

The AHD bridge department underwent a steady expansion as well. During the 1922-1924 biennium, Merrill Butler was succeeded by Ralph Hoffman as state bridge engineer.[54] The bridge department had grown by then to include three engineers. Arizona's bridges had, to this point, been a sometimes quirky collection of structures—long-span concrete Luten and open spandrel arches, concrete rail top slabs, two-beam and three-beam girders, pin- and rigid-connected steel trusses, timber trestles, three-hinge steel arches, long suspension bridges. And as illustrated by bridges such as the Florence, Tempe and Antelope Hill structures, the engineering on these was sometimes questionable.

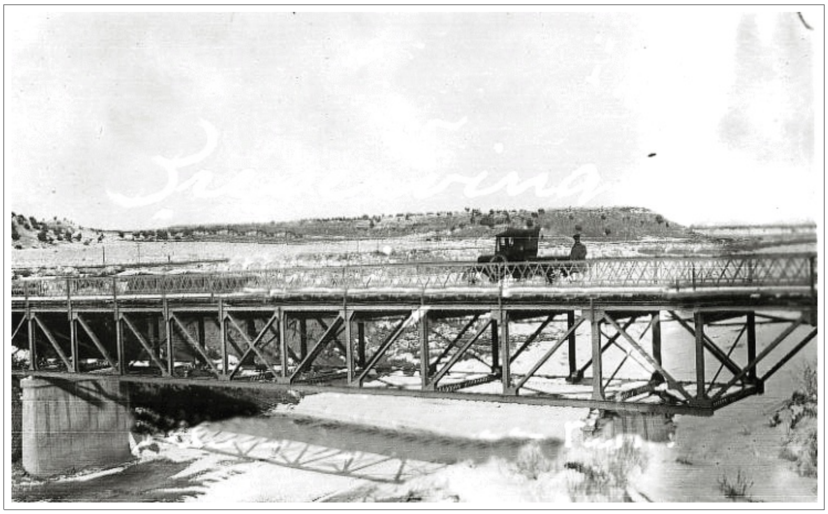

Figure 65. Allentown Bridge (03073), 1924. Arizona State Archives.

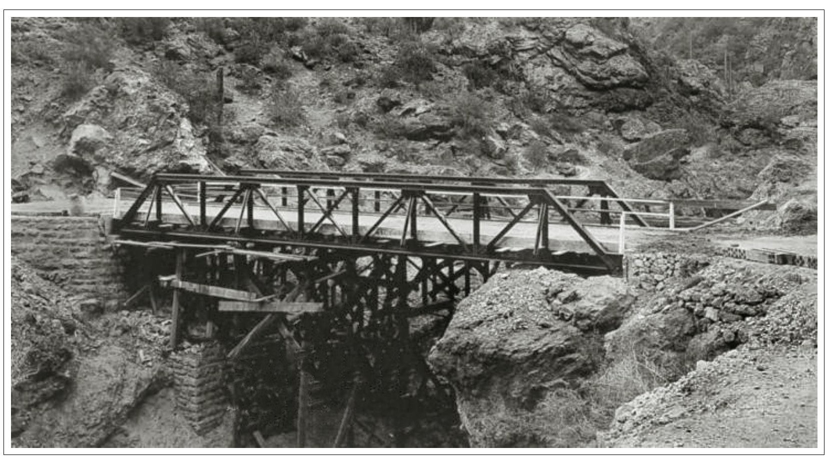

Figure 64. Fish Creek Bridge (00027) under construction, 1923. Arizona State Archives.

Hoffman's arrival marked a philosophical change in the way AHD designed and built bridges. "The aim of those connected with this department, in the past two years, has been economy in design," he stated in an annual report to the governor. "A former policy of the use of mass sections and excess materials has been discarded in favor of lighter sections with more reinforcement and less concrete, resulting in an appreciable saving."[55]

[54]Ralph A. Hoffman (1894-1967) functioned as the Arizona State Bridge Engineer between 1927 and 1955. While there he was distinguished as both prolific and innovative. After leaving AHD, Hoffman formed the private engineering firm Hoffman and Miller.

[55]State of Arizona, State Engineer. *Sixth Biennial Report of the State Engineer to the Governor of the State of Arizona: 1922-1924* (Phoenix: Manufacturing Stationers, Inc., 1924), 137-138.

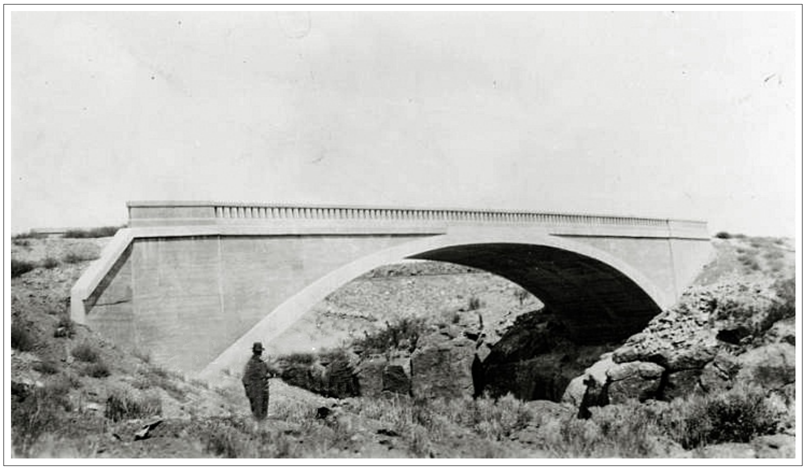

Figure 66. Verde River Bridge (08236), 1924. Arizona State Archives.

Using specifications developed by AASHO, Hoffman was able to standardize bridge design in the state to an unprecedented extent. "Structural design is governed largely by the class of road on which the bridge is located," he stated. "There are three classes of State roads in Arizona, namely the primary and secondary Highways of the Seven Per Cent Federal Aid System and the non-Federal Aid State roads. Up to the present time, however, only two types of design have been used, as no distinction has been made between the two classes of Federal Aid Highways." Hoffman proved more innovative than his predecessor, employing steel to a greater degree for superstructures than had Butler and using cantilevering for the first time in Arizona (**03073**) [Figure 64].[56]

During the biennium the AHD bridge department delineated some forty special bridge designs, including ten steel trusses, four reinforced concrete arches and twenty-six concrete girders, for an aggregate cost of over $500,000. Among these were the Fish Creek Bridge (**00027** [Figure 65]), Lewis and Pranty Creek Bridge (**00028**), and Sanders Bridge (**03074**), three steel pony trusses; the Mormon Flat Bridge (00026), a through truss; the Verde River Bridge (**08236** [Figure 66]), a concrete filled spandrel arch; and the Little Hell Canyon Bridge (**03381** [Figure 67]), a steel deck truss.

Figure 67. Little Hell Canyon Bridge (03381) under construction, 1923. Arizona State Archives.

Among the bridges built during that period, one—the Hell Canyon Bridge in Yavapai County— incorporated aesthetics in its design. In

[56]Hoffman's first cantilevered structure, the Allentown Bridge (03073) in Apache County, employed a steel deck truss, which cantilevered by two panels over the supporting piers.

the early 1920s the Arizona Highway Department undertook extensive road construction to build the 50-mile-long Prescott-Ash Fork Highway. The largest of the drainage structures along the route spanned Hell Canyon, a rugged wash near Drake, just north of the famous Santa Fe Railroad trestle. AHD bridge engineers initially designed and contracted for a 154-foot open spandrel arch similar to other bridges over Cienega Creek (**08293**)] and Queen Creek (**abd.**) then underway elsewhere in the state. Additional substructural investigation, however, revealed that the bridge's south abutment would rest on a sizeable boulder field, providing an unstable foundation condition for an arch of that scale. Late in 1922 State Engineer W.C. Lefebvre changed the bridge's design to this multiple-span concrete girder with high concrete piers. Each span featured two slightly arched girders that bore directly on the tapered concrete piers. The 20-foot-wide concrete roadway was bounded by concrete guardrails with paneled bulkheads and square balusters.

Figure 68. Hell Canyon Bridge, 1986.

Using the reinforcing steel already on-site, contractor L.C. Lashmet began construction of the Hell Canyon Bridge in January 1923. His crew completed the structure in July. "The high trestle has a very pleasant effect, with the arched girders on the high, slightly tapered piers," Lefebvre stated. "It was completed at approximately the same contract price as was the bid for the arch and compares favorably with it in every aspect."[57] Most of the concrete girder bridges built in the 1920s and 1930s, most featured designs with four or more relatively shallow girders. The earliest bridges built in the 1910s typically employed two-girder designs, and of these only three remain. The Hell Canyon Bridge [Figure 68] is a throwback to this earlier design, made

[57]*Sixth Biennial Report* , 143.

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necessary by the need to use available materials then on the ground at the site. It is distinguished by its picturesquely arched girders and handsomely proportioned piers.

The next two years marked a continuation of AHD's standardization of bridge design. With two more engineers in the bridge department, the agency sought to incorporate the new AASHO standards for steel and concrete bridges into the state's repertoire. "At present we are in more of a quandary than before the advent of these new specifications as regards to certain points of design, Hoffman stated, "such as distribution of loads, moment factors, etc. We are using parts of the two new sets of specifications for design as well as part of the old bureau requirements. This Department is now preparing a comprehensive set of formulas for use in the design of structures which will give the men working on design a ready reference on points now covered in three sets of specifications." Hoffman explained the increased work undertaken by his department:

> The old practice of using excessive curvature in the road in order to make a right angle crossing on a stream, or to fit a particular bridge site, has, for the sake of safety and future economy, been abandoned, and, whereas, it was a former practice to fit the road to the bridge, we now build the bridge to fit the road and stream regardless of the angle. (This) increases the volume of work in the office and even with the increased force the Department is barely able to keep up with the schedule.[58]

Figure 69. Pine Creek Bridge (00031), 1924. Arizona State Archives.

Hoffman and his department engineered some 205 bridges during the 1924-1926 biennium, aggregating over $750,000 in construction costs. Notable among these were a pair of filled spandrel concrete arches—the Pine Creek Bridge (**00031** [Figure 69]), a two-span arch on the Apache Trail, and the Fossil Creek Bridge (**03215**) between Gila and Yavapai Counties.

The longest bridge undertaken in the mid-1920s spanned the Gila River in Maricopa County. The Arizona Highway Department had intended from the start that the Gillespie Dam apron act as a temporary crossing, with a permanent bridge to follow. AHD engineers had begun

[58]State of Arizona, State Engineer. *Seventh Biennial Report of the State Engineer to the Governor of the State of Arizona: 1924-1926* (Phoenix: Kelly Print, 1926), 65-66.

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planning for a concrete bridge here even before the dam was completed. For this crossing, Thomas Maddock had originally envisioned a reinforced concrete girder structure, similar to other bridges the state had built at Antelope Hill, Florence and Coldwater, despite their structural shortcomings. Later department engineers seemed poised to repeat their mistakes with the Gillespie Dam Bridge, planning a series of long-span concrete girders for this crossing. For additional advice, they contacted R.V. Leeson. Leeson recommended that the highway department drop the girder design in favor of a series of long-span steel trusses. With spans of up to 200 feet in length, the truss design would reduce the number of piers by almost two-thirds from the girder configuration. Given that most of the Gila River bridge failures in Arizona had historically involved catastrophic pier scour and settlement, this reduction was significant.

With Leeson's assistance, AHD bridge engineer Ralph Hoffman designed the multiple-span structure. "The plans are designed under modern specifications for live load and heavy trucks for bridges on the Federal Aid Highway system," the highway department stated. As delineated by Hoffman in September 1925, the bridge was comprised of nine truss spans— five 200-foot trusses over the river's channel at the bridge's center, flanked by two 160-foot trusses at each end. The trusses supported a 19-foot-wide concrete roadway, with the deck carried at the trusses' lower chord level and the steel truss webs extending over the roadway on both sides. "The concrete floor and its supports being designed for two 15 ton trucks abreast on the bridge with an additional allowance of 30 per cent for impact. In this floor alone there is a total of 930 cubic yards of concrete and 75 tons of reinforcing steel, enough to build complete a fair size bridge."[59]

The most critical aspect of the bridge's design was the substructure. AHD described the piers and abutments of the Gillespie Dam Bridge:

> The deepest pier foundation is approximately 45 feet below the stream bed and rests on a compact caliche hard pan. The conditions found by drill tests are favorable to the use of steel sheet piling and open dredging. These two piers of about this same depth and contain approximately 500 cubic yards of concrete each. The other piers vary in depth below stream bed from 20 to 30 feet. All piers are of gravity type with but little reinforcing steel for dowels at the construction joints. The abutments are of the U-type with a pier for the support of the span and reinforcing wings tied by reinforced concrete ties in the earth fill, making an economical type for the height which on the east end of the bridge is approximately 35 feet from grade to the bottom of foundations.[60]

Three months after Hoffman completed the construction drawings for the Gillespie Dam Bridge, AHD moved to build the immense structure. With funding for the construction earmarked under Federal Aid Project 64-B, the highway advertised for competitive bids late in 1925. Eleven contractors submitted proposals for the project. On January 11, 1926, The highway department let the contract to the lowest bidder, the Lee Moor Construction Company of El Paso, Texas. On February 12, a Lee Moor crew began excavating for the piers. Pier Nos. 1 through 5 and and 10 were founded on solid bedrock. Pier Nos. 6 through 8 were founded on hard caliche—an unconsolidated gravel bed that floored the river's main channel. To found the shallower

[59] *Ibid.*

[60] *Ibid.*

see continuation sheet

piers, the men used Wakefield sheet piling with steel shoes. The deeper piers required either steel sheet piling or open timber crib cofferdams to protect the excavations from the river. Even with that, water was a problem at Pier Nos. 6 and 7, the deepest piers on the structure. The Lee Moor crew was forced to install 12-inch deep well pumps and 16-inch centrifugal pumps to dewater these two holes. With capacities of 3,600 and 4,500 gallons per minute, respectively, the pumps operated continuously for five weeks while the excavation and pier construction were underway.

Figure 70. Gillespie Dam Bridge under construction, 1926. Arizona State Archives.

The concrete piers had been completed, and the men were erecting the steel trusses when the Gila River flooded in February 1927. With water washing as much as six feet over the crest of the dam, the downstream apron was rendered impassable for days, stranding cars on both sides of the river. After suffering extensive losses, Lee Moor regrouped and completed the bridge superstructure later that spring [Figures 70-71]. With the trusses in place, the men poured the concrete for the monolithic deck that summer. On August 1, 1927, the Gillespie Dam Bridge was opened to vehicular traffic. The highway department opened the bridge unceremoniously, simply pulling aside the barricades shortly after sunrise and letting cars drive across the span without fanfare. "The new state bridge over the Gila river on the Phoenix-Yuma road, the longest bridge of its type in the state, was opened to traffic yesterday

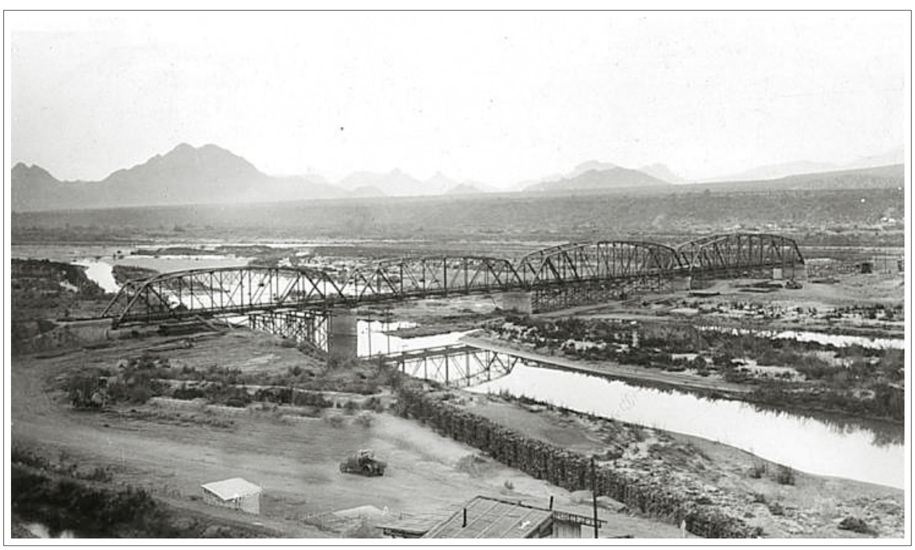

Figure 71. Gillespie Dam under construction, 1927. Arizona State Archives.

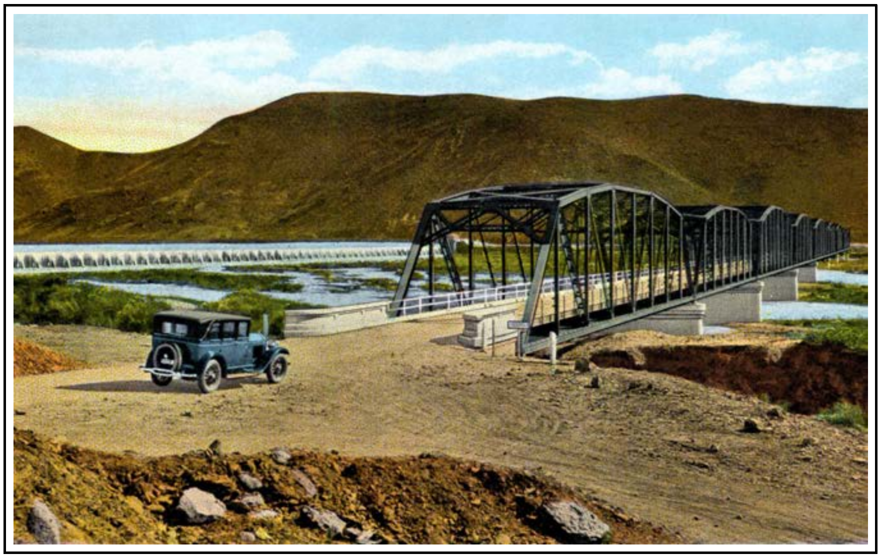

Figure 72. Gillespie Dam Bridge, ca.1928. Postcard.

morning," the *Arizona Republican* reported. "The opening of the new bridge, which required 18 months to build, will make the Phoenix-Yuma road an all-year road and will eliminate the lining up of traffic on both sides of the Gila river during flood periods in the stream as in the past [Figure 72]."[61]

Costing $320,000 to build, the Gillespie Dam Bridge was immense (**08021** [Figure 73]). The structure consumed approximately 1,200 tons of superstructural and reinforcing steel and 3,200 cubic yards of concrete. Excavation for the substructure involved moving some 5,600 cubic yards of earth. When completed, it was distinguished as Arizona's longest highway bridge and the bridge with the state's deepest foundations. A list of the five longest vehicular structures in the state at that time indicates the tremendous impact that the Gila River had on bridge construction. Four of the five spanned the Gila and the fifth—the Tempe Bridge over the Salt River—spanned a tributary of the Gila near the two rivers' confluence.

Even into the 1920s, bridges still proved to be the Achilles heel of the highway department. Despite their continued efforts, department engineers were unable to keep the major spans on the Ocean-to-Ocean Highway—or elsewhere in the state—serviceable. "At present there is not a single main route through our State which is not subject to traffic tie-ups at one or more stream crossings," Hoffman despaired in 1927. "Such conditions are distasteful to through tourists and they will seek other routes on which they are not liable to be delayed by washouts. Our State is widely known for its good roads and millions of dollars are spent within our boundaries annually by tourists who travel these roads. Why not

[61] "New Bridge at Gillespie Dam Open to Travel," *Arizona Republican*, 2 August 1927. At this time the *Arizona Gazette* reported:

> In the building of the new structure every possible care was taken to make it capable of withstanding the heaviest of floods. Each pier and the abutments for the bridge extend down through the loose sand to bed rock, some of the piers thereby being over 40 feet in length, according to the highway department. The precautions which have been taken will assure travel over the highway in every season of the year, and trips will no longer be delayed during flood periods owing to high water.

Figure 73. Gillespie Dam Bridge (08021), 2003.

make them all-weather roads by building good substantial bridges?" It was not until completion of a bridge over the Hassayampa River and replacement of the Coldwater Bridge (both demolished) in the late 1920s that the Ocean-to-Ocean Highway could rightly be considered an all-weather route. In the 1920s the engineering existed to build substantial bridges that could withstand rivers such as the Gila; the problem was money. Chronically short of funds, AHD was often forced to defer long-term planning for immediate construction and repair. Nowhere was this more apparent than at the state's bridges. The early road builders had avoided building bridges when they could, and when they could not, they often eschewed permanence for low initial construction costs. AHD engineers could not follow this strategy, however. In a 1927 *Arizona Highways* article notable for its apologetic tone, Hoffman explained the recent failures of several Arizona spans:

> The fault for (the bridge failures) cannot be laid at the door of the engineer, although he is not infallible, he can only go as far as the funds provided will permit. The State spends millions to build surfaced roads making them passable in all kinds of weather and leaves an unprotected gap here and there for the reason that the engineer is trying to make his money cover as much mileage as possible.[62]

[62]R.A. Hoffman, "Lack of Finances Held Responsible for Washing Away of Bridges in Flood Times." *Arizona Highways* III:1 (January 1927).

The Gila prompted the construction of long and problematic bridges, but it was the Colorado River that historically has formed the most formidable barrier to bridge construction in the West. The Yuma and Topock Bridges proved expensive and difficult to erect, even on relatively flat sites. This was due to the scale of the Colorado River as well as its unpredictable nature and its propensity to flood at odd times. When the highway department sought to bridge the river a third time in the 1920s, the problem of flooding on the river was eclipsed by the bridge's great height and remoteness. In 1923 AHD began planning for a bridge over the Grand Canyon near Lee's Ferry—Arizona's most challenging bridge construction to date. The Denver and Rio Grande Railroad had surveyed this site earlier for a proposed line through the region. Coconino County Engineer J.B. Wright selected a location a thousand feet from the railroad site when he conducted his own preliminary investigation for a highway bridge. Wright patterned his suspension design after the Cameron Bridge [Figure 74]. Like its predecessor, Wright's 800-foot structure featured a single span stiffened by a timber-decked through truss.

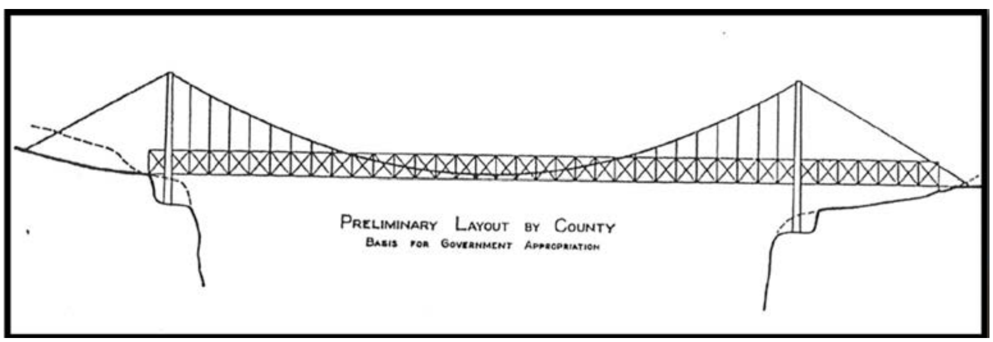

Figure 74. Preliminary design for Grand Canyon Bridge, by J.B. Wright, 1923.

Located partly on the Navajo Reservation, the proposed bridge fell under the jurisdiction of the Department of the Interior, administered by the Office of Indian Affairs. OIA used Wright's design when it requested an appropriation from Congress to fund construction of the bridge. As it has with the Yuma and Topock spans, OIA viewed the bridge as a means to promote commerce on the sparsely populated Navajo and Hopi reservations. The agency could not commit Navajo tribal money for a state highway, but it could fund construction of a bridge, through Congressional action. In December 1923 Congress allotted $100,000 of Navajo funds for the Grand Canyon bridge, to be matched by the State.

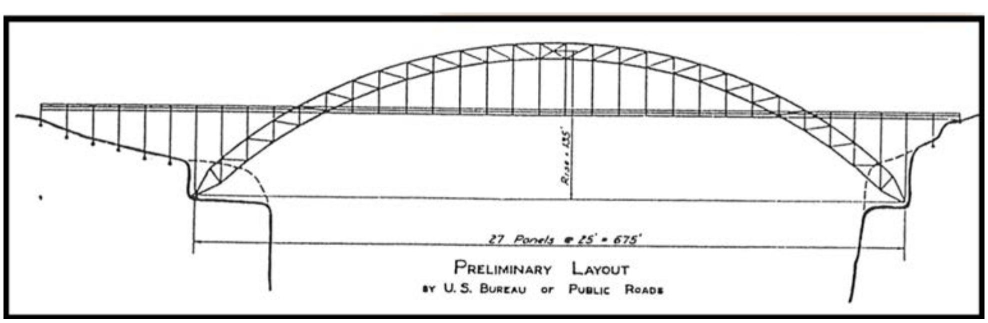

Figure 75. Preliminary design for Grand Canyon Bridge, by Bureau of Public Roads, 1924.

Interior officials turned the responsibility for the structure's planning and design over to the Bureau of Public Roads. In 1924 engineers from the bureau's Washington

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office made additional surveys of the site and soon concluded that the bridge could not be built for $200,000. They produced a series of estimates, ranging from $230,000 for a lightweight suspension structure with a wooden deck to $341,000 for a "first class steel structure with a concrete deck and a 20 foot roadway." For the latter structure, BPR engineers delineated a steel through arch patterned after the Old Trails Bridge at Topock [Figure 75]. The bureau's figures were used by the Arizona State Legislature, when a $130,000 appropriation—the lowest amount possible—was made toward the bridge's construction. This sum was increased to $185,000 by the legislature in March 1927.

AHD Bridge Engineer Ralph Hoffman had designed his own alternative to J.B. Wright's suspension bridge in 1923. But his deck-arch configuration had been used for neither the federal nor state appropriations. When the final design of the Grand Canyon bridge was turned over to the highway department in March 1927, it fell into Hoffman's lap. He wasted little time in discarding the earlier designs in favor of his own. "The Bridge Department, after a thorough study of all data available and the local conditions to be met," Hoffman stated, "arrived at the conclusion that the unit prices used in previous estimates were too low on account of the remoteness of the site, and the 130 mile haul of structural materials, and this department prepared estimates based on an entirely different type of design. This had previously been suggested by the Department as the most fitted to the location from all standpoints, using at the same time higher unit prices on structural materials."[63]

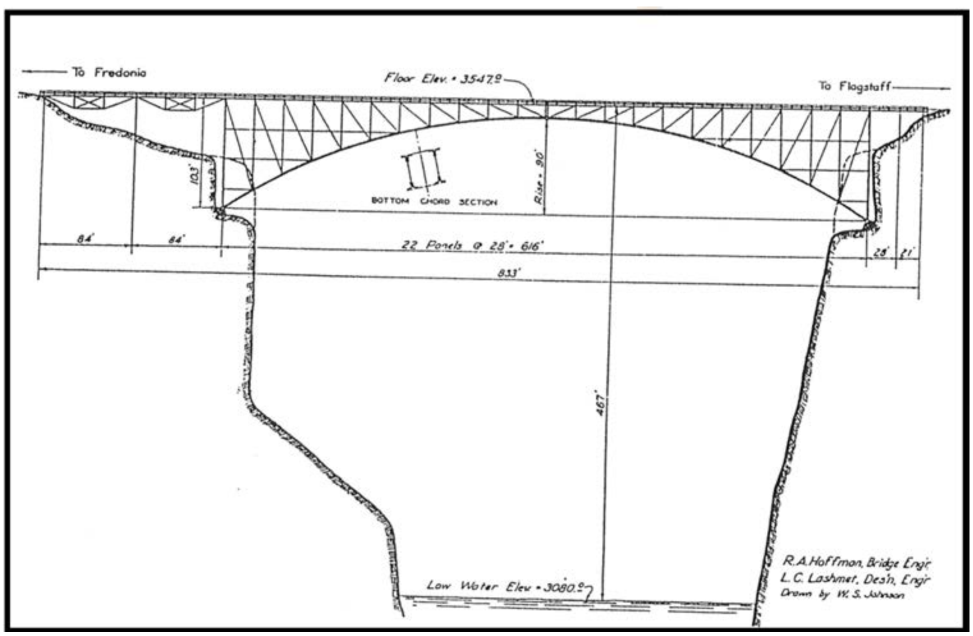

Figure 76. Final design for Grand Canyon Bridge, by Arizona Gighway Department, 1927.

Hoffman dismissed the suspension design as too costly and, with a ten-ton load limit, too flimsy. Construction of a through arch, he maintained, would have necessitated the use of heavy overhead cableways to hoist the span halves into place. With the expense of returning the cables and tower materials prohibitively high, these would be abandoned at the site, adding considerably to the cost.

[63]R.A. Hoffman, "Bridging the Grand Canyon of Arizona: The Highest Highway Bridge in the World," *Arizona Highways*, May 1929, 5-7.

"The site appeared to be ideal for the use of a deck arch and a few computations showed that this type had many advantages in erection," Hoffman concluded. "Practically all the erection material could be used in the approach spans. These spans were needed on account of maintaining a high grade line on the structure in order to get a satisfactory grade line out of the canyon on either side."[64]

The Grand Canyon Bridge was designed by Hoffman and AHD Designing Engineer L.C. Lashmet. Their plan featured a three-hinged deck arch that cantilevered from the canyon walls on both sides [Figure 76]. The spandrel-braced arch was comprised of a 22 equal panels; it featured a span length of 600 feet, a roadway width of 18 feet, an arch rise of 90 feet and an overall height of 115 feet from bearing shoe to guardrail. Including two 84-foot deck trusses on the north approach and a 49-foot approach on the south, the bridge extended a total of 833 feet. The most impressive dimension of the Grand Canyon Bridge, however, was its distance above the river level: some 467 feet from deck to water, making it the highest bridge in the world at the time of completion.[65]

With the federal appropriation about to lapse, Hoffman and Lashmet were forced to push the design in April and May, 1927. "The Department was handicapped in making extensive studies of approaches and erection schemes," Hoffman said, "as only about six weeks remained between the time of receiving orders to prepare plans and the time of the expiration of the government funds." The engineering was well under way when test excavations at the site revealed fissures in the Kaibab sandstone of the canyon's north wall. This necessitated excavating to solid rock and extending the arch's span. The bridge was completely redesigned, this time with a 616-foot span.

The structure was engineered for a uniform live load of 60 pounds per square foot on the deck, or 15,000 pounds per 28-foot panel. The loading of the floor system was calculated for one 15-ton truck or two 12½-ton trucks side-by-side on the roadway, with a 30 percent allowance made for impact loading. The wind load was taken as 60 pounds per square foot on the exposed arch webs and 30 pounds per square foot on the floor and guardrails. This was partially offset by a batter of the spandrels of one eighth inch to a foot.

Given the high costs of materials and haulage, Hoffman and Lashmet designed the bridge so that erection materials would be used in the final structure. The approach spans, for instance, were designed to re-use the materials from the construction tie-backs. During erection, each cantilevered arch half was anchored to the ground by means of an adjustable tie-back. The toggle arms for these tie-backs were to be later recycled as the vertical posts for the approach trusses. In like manner, the trusses' eyebar diagonals and lower chords, as well as the floor beams, were to be used first for the anchorages during construction. (Packing rings

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[64]R.A. Hoffman, "Bridging the Grand Canyon of Arizona: The Highest Highway Bridge in the World," *Arizona Highways*, May 1929, 5-7.

[65]R.A. Hoffman, "Closing the Arch of the Grand Canyon Bridge," *Arizona Highways*, October 1928, pages 7-8,15; "A.S. Taylor, "Bridging the Colorado Across the Marble Gorge," *Compressed Air Magazine*, Oct. 1928, pages 2547-48.

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would be inserted into the eyes to compensate for the smaller truss pins in the completed structure.) "As the bids were taken on a pound price for steel," Hoffman said, "this system resulted in a lower general price on the structural steel, than would have been obtained if erection material had not been used in the finished structure."

Comprised of built-up members similar to those of the arch, the approach trusses' upper chords were first used as the arms that tied the arch halves to their anchorages. These members were required to withstand as much as 750,000 pounds of tensile stress from the outstretched arch halves during construction. They were thus overdesigned for later use as approach truss chords. To help compensate for this, they carried the deck on floor beams similar to those of the main arch. Hoffman insisted on a concrete deck, even though it added considerably to the structure's weight and cost. A timber floor constituted an unacceptable fire hazard, he contended, given the isolated location of the bridge. Further, it would require more frequent maintenance. "Neighboring states had recently experienced the total loss of structures with timber floors in similar remote locations," he said. "It was thought advisable to prevent such a loss in this instance." Despite these attempts at structural efficiency, the Grand Canyon Bridge was immense, consuming over two million pounds of structural steel, 81,412 pounds of reinforcing steel and 503 cubic yards of concrete in the foundations and deck.[66]

A contract to build the Grand Canyon Bridge was awarded to the Kansas City Structural Steel Company [KCSS]. The cost, including engineering, would total $314,000. The first major hurdle to be overcome—indeed, the single greatest hurdle of the project—was the transportation of some 3.2 million pounds of materials, supplies and equipment over the 130 miles from the railhead at Flagstaff to the bridge site. With little improvement since the 1910s, the road north of Flagstaff was still no more than a trail in many places. And with temperatures ranging from 110° above to 16° below zero, the travel conditions varied wildly.

KCSS hired E.M. Moores and Son of Clarkdale, Arizona, to transport materiel from Flagstaff to the site, with the stipulation that 10 tons per day be delivered. To accomplish this, Moores used a 5-ton and a 12-ton truck. The loads varied greatly in size and weight, the largest steel components weighing 12 tons. This posed a serious problem at the Cameron Bridge. Rated at ten tons, the lightweight suspension bridge had to be strengthened by USIS before heavy hauling could begin. In addition to his role as teamster, Moores was responsible for road maintenance in the northernmost 80 miles of the route. When snow drifted onto the road, the trucks were scheduled so that they passed over the snow-packed stretches at night to take advantage of the freezing temperatures. Moores's drivers negotiated steep grades, sandy washes and deeply rutted roadways, taking between 13 and 20 hours for the 130-mile trip. They were able to trade off with other drivers from a road camp set up about halfway along the route. In spite of the hardships, Moores managed to ship everything to the site within a four-month period in 1927-28.[67]

[66] Ralph Hoffman, "Grand Canyon Bridge Opens New Route Across Greatest of All Natural Barriers," page 57.

[67] "Steel Arch Highway Bridge Across Colorado River," pages 646-647.

Once delivered to the site, the material was stored on the south rim. Much of the steelwork was hoisted to the opposite side by means of an overhead cableway. Vehicles and some supplies, however, were forced to use the old ferry, until it overturned during a crossing in June 1928, killing three people. The highway department then rigged a 16-foot rowboat with an outboard motor as a makeshift ferry to haul supplies. "This did not lessen but increased the danger of crossing the river," AHD engineer W.R. Hutchins said. "I have seen the boat loaded until it was invisible. This would not necessarily have been dangerous on a lake or in still water, but strange as it may seem, the Colorado at this point was at times nearly choked with large blocks of floating ice. During the summer and fall freshets the same was true of driftwood, sometimes large trees, partly submerged and incapable of being seen on the surface - a dangerous menace when one is depending on an outboard motor."[68]

Work on the bridge began on June 23, 1927. After struggling for days to haul an air compressor and other equipment to the north rim, a highway department crew began excavations for the arch foundations on the north side. The early testing had revealed fissures in the rock. This necessitated digging or blasting some 9,000 cubic yards of material to place the foundations on solid footing. Men dangled over the gorge on ropes, operating pneumatic drills and placing loads for blasting in the sheer canyon walls. Once the excavations had been roughly shaped, rope ladders were used, which were only marginally safer. "Climbing a rope ladder is no joy-ride," Hutchins commented. In this way, niches, 70 feet deep and 30 feet square, were cut into both sides of the canyon. By November the excavations were complete and work on the concrete footings had begun. Highway department laborers set forms on the ledges, using only enough concrete to build up suitably shaped footings for the massive cast steel pedestals. By the following April the foundation work on both sides was complete.

Meanwhile, in the Kansas City plant of KCSS, the components for the bridge were being fabricated from steel rolled by the Illinois Steel Company. The first erection equipment left the plant on January 5, 1928, the first structural steel two weeks later. In all, the fabricators shipped some fifty carloads of material by train to Flagstaff, where it was loaded onto Moores's two trucks. Limited by the size of the trucks and the capacity of the Cameron Bridge, the largest steel members were 53 feet long and weighed 12 tons.

In mid-March the contractor set up camp on the south side of the canyon and moved its laborers to the site. Hailing largely from Missouri, the men began work by excavating tunnels for the anchorage of the south arch half. The strategy was to complete the south arm first. When completed, it would be used as a platform from which to hoist the steel to the north side. Once the anchorage was set, the steelworkers began assembling the tie-backs, toggles and first panels of the south arm. They set the cast steel bearing shoes on the newly formed concrete pedestals in April and connected the lower chords using 15-inch pins. The workers then built the first two panels and adjusted the steelwork for line and elevation by packing grout on the bearing pedestals. An erection traveler was built to assist in handling the steel members. Made up of two pivoting 60-foot beams, this crane rolled on the upper chords of the arch. With the traveler in place to hoist and position the steelwork, erection on the arm progressed quickly.

[68]W.R. Hutchins, "Hardships Encountered in Bridging the Grand Canyon," *Arizona Highways*, May 1929, page 15.

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Figure 77. Navajo Bridge, last panel of south arm under construction, 1928. Library of Congress.

The arch half extended further over the canyon with each panel completed, until in mid-June the last panel was riveted in place [Figure 77]. At that time the 800,000-pound arm literally hung over the gorge, suspended by only the temporary tie-backs. Once the south arm was completed, a derrick was built at its end and a cableway strung across to the north rim. As steel and steelworkers rode over the gorge on the cable, the process began on the north side.

Under such extreme living and working conditions, the job took on unusual dimensions. "The men had no regular hours," stated Hutchins, "The day's work was ended when they reached camp for the night. This may have been five o'clock— the usual end of a day— or it may have been two o'clock in the morning, depending upon how fortunate they were on that day." Part of the lore of the Grand Canyon Bridge holds that the steelworkers refused to have safety nets slung beneath the outstretched arms of the arch. This was partly true. In fact, a rope net had been woven but was never installed in part because of the men's protests that it might make them careless. But a larger reason was that the net was too costly and too

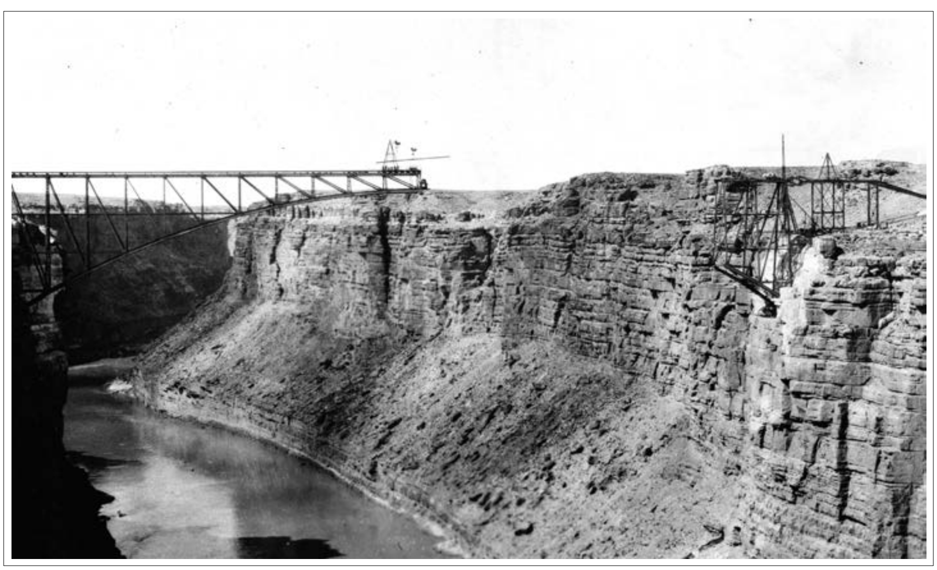

Figure 78. Navajo Bridge, south arm (left) finished, north arm (right) under construction, 1928. Library of Congress.

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dangerous to install. The steelworkers moved unfettered over the structure, apparently oblivious to the dizzying height of the bridge. All others were required to wear safety harnesses. One steelworker did slip from a beam and fall to his death. His body was never recovered from the river.

Work on the north arm progressed steadily that summer [Figure 78]. The bearing shoes were set on July 12th and grouted three weeks later with two panels of the arch in place. By the end of August the tenth panel had been assembled. The gap between the two arms was then measured for the last panel. In the KCSS shop, small adjustments in the panel members were made to compensate for erection discrepancies. The last superstructural steel was then shipped to Arizona on September 1st. On September 12, 1928, the crew was ready to lower the two arch halves and couple the center pins.

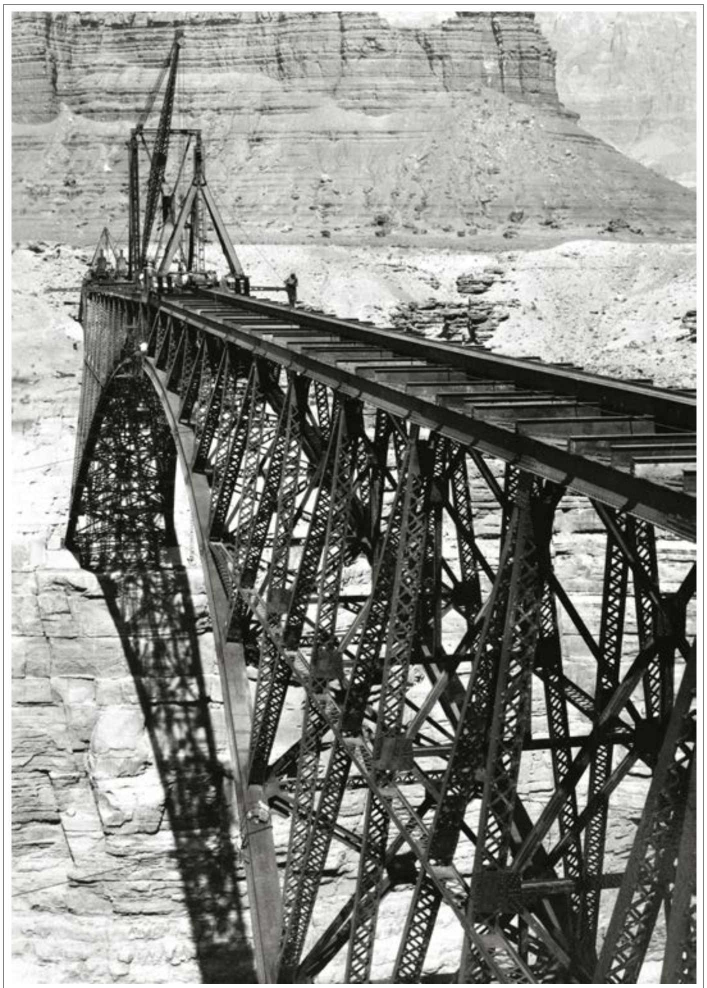

Figure 79. Navajo Bridge, insertion of center pin, 1928. Library of Congress.

The men began early that morning by aligning the two arms and inserting six-inch-diameter compression screws in the toggles. After five hours, they began lowering the south arm by adjusting the toggles. The arm was dropped nine inches before the north arm was screwed down similarly. At 5:30, the last pin was inserted. By then the temperature had begun dropping precipitously. The men screwed all four of the toggle jacks almost continuously to counteract the movements of the cooling arms, as the weight was shifted gradually from the temporary supports to the arch itself [Figure 79]. When one of the screws became lodged and could not be lowered quickly enough to keep up with the movements of the arm, it was freed entirely. By 9 o'clock that night the toggles had been loosened completely and the span completed.

The erection traveler was dismantled the next day and the tie-backs and anchorages converted to approach spans later that month. "The hazardous part was over but still much work to be done to complete the structure," Hoffman said. Their job completed, the steelworkers moved out on October 20th. By then other laborers had begun building the forms for the roadway slab. The arch had been designed so that the slab would be poured in six equal sections, distributed to prevent excessive stress on the lateral bracing. To spread the load, the forms were set and reinforcing steel placed for the entire deck before any concrete was poured. Sawdust, shipped from sawmills in Flagstaff, was spread over the slab and wetted to cure the concrete, once poured. The water for this was hauled some four miles from Navajo Springs, "which may seem peculiar to some because the river carries a great volume of water at all times," Hoffman stated. "But then it is realized that the river water was not satisfactory for concrete, carrying too high a percentage of silt, and that the water for curing would have only been developed at a lift of 475 feet from the stream to the bridge floor."

Completion of the deck on December 9th marked the last construction on the bridge itself. This left only the grading of the approaches to make the crossing accessible. The highway department had been drilling and grading in the rocky bluffs on the south side of the bridge since July. By the time the concrete had finished curing early the next year, the temporary road on this side was ready. The Grand Canyon Bridge was opened to traffic on January 12, 1929. Two days later a highway department power shovel crossed the bridge to begin work on the north approach.

The January opening was held unceremoniously, with only a few laborers and engineers present while a cold wind blew through the canyon. The gala opening would occur that summer, with the promise of better weather for the visiting dignitaries. The ceremonial dedication of the bridge took place on June 14th and 15th, as reported by the *Arizona Republican*:

> Under a typical Arizona cloudless sky, the heat tempered by a gentle south breeze, the Grand Canyon Bridge across the chasm of the mighty Colorado river was formally dedicated by four governors of neighboring states this afternoon in the presence of a crowd of more than 5,000 persons, representatives of at least 20 states. As movie and other cameras clicked and with three other chief executives of as many states standing by, Arizona Governor John C. Phillips clipped the purple and yellow ribbons which represented the breaking of an age-old barrier between the lands to the north and south of the Colorado river. Miss Elizabeth Phillips, daughter of the governor, christened the bridge by breaking a bottle of Colorado river water over the railing. Governor Phillips, who was standing at her elbow, was well sprinkled by the water, as were dozens standing near.[69]

Cars and trucks driven from Utah and Arizona clogged both sides of the bridge, as flags adorned its guardrails and an Indian band marched among the milling crowd. "Today marked the dawn of the new epoch in the history of the Southwest," Phillips declared. "Man has achieved another triumph over grim nature. By his creative genius and daring, his engineering skill, he has bridged this barrier with ribs of steel and concrete and brought into closer touch the people of two great states and has opened an avenue whereby the traffic of the west may view our scenic wonders and our people."[70] The governors shook hands

[69]"Grand Canyon Bridge Dedicated in Ceremony Led by Governors," *Arizona Republican*, 14 June 1929.

[70]*Ibid.*

at mid-span for the cameras and returned to a promontory on the north side. There they listened to speeches and bands, watched in awe as an airplane flew beneath the bridge, and held court over the symbolic "Marriage of the Southwest and Northeast". Caught up in the euphoria of the moment, the highway department congratulated itself in its house publication, *Arizona Highways*:

Figure 80. Navajo Bridge dedication, 1929. Library of Congress.

For two years the engineers of the Arizona Highway Department endured heat and cold, disappointment, discomfort, danger and responsibility almost too heavy for human shoulders; and day by day, through that time, the great bridge over the Colorado River grew under their charge. In January of this year the engineers looked upon their completed work and saw that it was good to endure when all memory of the builders perished.[71]

The ceremonies concluded that evening with a campfire program, in which the governors and highway officials passed around a peace pipe. Contemporary accounts do not record the reaction to this revelry of the Navajo and Hopi Indians encamped on the south rim [Figure 80]).

In truth, construction of the Grand Canyon Bridge <u>did</u> mark a major event in Arizona history. After the highway linking it with Flagstaff was completed two years later, it played a pivotal role in the development of a vast region that covered two states. As the only crossing of the Colorado River for some 600 miles, the bridge has had a profound impact on the commerce and transportation of a rugged and remote part of the West. Its construction opened the state from the north, providing a valuable tourist route to Grand Canyon National Park and the rest of the state. Although the Navajo Nation did not realize a long-promised economic vitalization as a result of the bridge, its role in financing the project was recognized six years later, when in January 1934 the structure's name was officially changed to Navajo Bridge.

[71] "The Bridge Builders," *Arizona Highways*, May 1929, page 30.

As Ralph Hoffman himself allowed, the design of the Navajo Bridge 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. 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 (**00051** [Figure 81]).

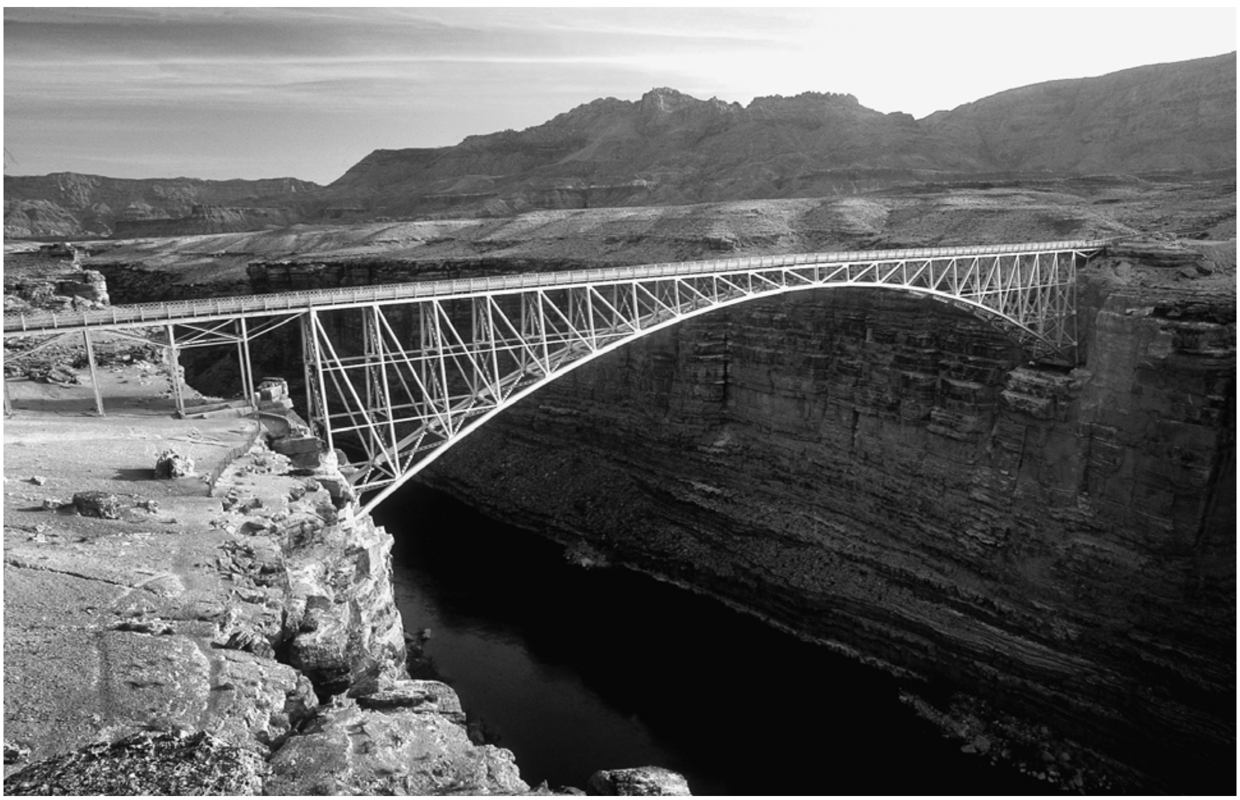

Figure 81. Navajo Bridge (00051), 1993.

Completion of the Navajo Bridge represented a culmination of sorts for highway bridge engineering in Arizona. The Arizona Highway Department would design a few other exotic but by and large the experimentation with different structural types that had marked the 1910s and 1920s had given way to design standardization. AHD undertook two other unique structures as work on the Navajo Bridge was underway.

Planning for the first of these–a long-span suspension structure over the Gila River—had actually begun some fifteen years earlier. When State Engineer Lamar Cobb first looked for a crossing location of the Gila

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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 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 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 82. Opening of McPhaul Bridge, 1929. Arizona State Archives.

In January 1928 AHD contracted with the Levy Construction Company of Denver to build the structure for more than $150,000. Although AHD engineers had outlined the bridge's location and span, Levy engineered the bridge himself with the assistance of nationally known consulting engineer Ralph Modjeski. Construction on the structure, named after Yuma County Sheriff Harry McPhaul, began in mid-1928 and was completed in December 1929 [Figure 82].

The McPhaul Bridge is significant for several reasons. First, it formed an integral link on a regionally important highway in western Arizona. Second, it was one of two bridges in the state (other: Red Rock Bridge by J.A.L. Waddell) associated with a pre-eminent American civil engineer, in this case Pennsylvania engineer Ralph Modjeski. Finally the McPhaul Bridge is technologically important as one of two vehicular suspension spans in Arizona (other: Cameron Bridge). Its rocker-type towers are rare among suspension bridges, distinguishing this structure even further among the vehicular spans in the state. Because of their exotic nature and high construction costs, suspension bridges were infrequently erected in this country, and few from the pre-Depression era have remained intact.

The McPhaul Bridge is also noteworthy for its scale. At the time of its completion, the bridge had the longest span length of any bridge in the state—79 feet—and it has the longest span among all the bridges in the inventory. Strikingly beautiful, graceful and exotic as well as historically and technologically important, the

McPhaul Bridge is one of Arizona's most important vehicular structures. its scale. At the time of its completion, the bridge had the longest span length of any bridge in the state—79 feet—and it has the longest span among all the bridges in the inventory. Strikingly beautiful, graceful and exotic as well as historically and technologically important, the McPhaul Bridge is one of Arizona's most important vehicular structures [Figure 83].

Figure 83. McPhaul Bridge, 2003.

The last major bridge of the decade was built as a replacement for the state's most important vehicular span. The original Tempe Bridge over the Salt River had functioned in place with occasional repairs since its completion in 1913, but its 18-foot roadway eventually proved to be a serious impediment to traffic at this congested crossing. In 1928 Ralph Hoffman designed its replacement—a multi-span open spandrel concrete arch along the same lines of the earlier structure. The bridge was later realigned slightly to place the footings on a granite dike that extended beneath the river. With 16 spans of 150 feet, it extended almost 1,600 feet, and its deck was double the width of the earlier structure. Its superstructure was comprised of open-spandrel concrete arches supported by solid concrete piers with bullnosed cutwaters.

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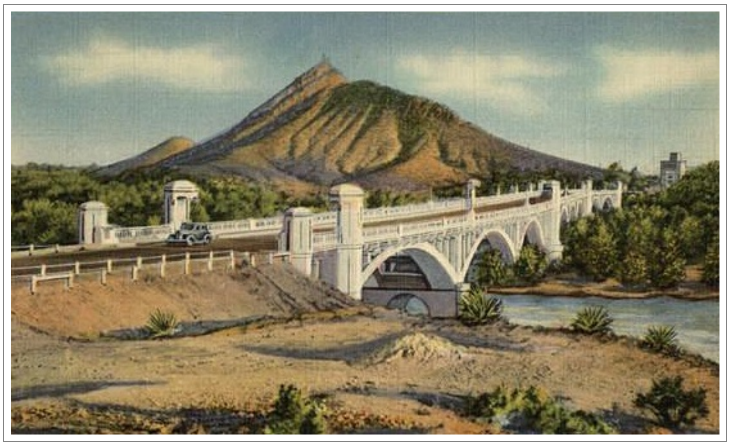

Figure 84. Mill Avenue Bridge, ca.1940. Postcard.

The highway department designated the bridge's construction as Federal Aid Project 2B and in January 1930 let a contract for almost $400,000 to the Lynch-Canon Engineering Company to build the immense structure [Figure 84]. The Los Angeles contractors began work on the abutments and piers immediately and progressed through the rest of the year. Completed in July 1931, the Mill Avenue Bridge (**09954** [Figure 85]) immediately carried heavy traffic at this pivotal crossing. The longest highway bridge in the state at the time of completion, the Mill Avenue Bridge marked the climactic end of the decade.

Figure 85. Mill Avenue Bridge (09954), 2003.

6 Depression and World War II Bridge Construction: 1933-1945

During the 1930s the Great Depression devastated the nation's economy, leaving millions jobless and homeless. By 1933 more than 13 million workers were unemployed and more than a thousand homes were being foreclosed upon each day. Government officials were quick to recognize the direct correlation between federal highway funding and employment. As early as 1930 Herbert Hoover increased federal funding for highway construction from $75 to $125 million and added an additional $80 million in future federal funds. When Franklin Roosevelt took office in 1933, nearly a third of the nation's work force was on relief, and local governments could not begin to meet the needs of the destitute. Roosevelt was immediately besieged with requests from state governors for aid. "There is no form of improvement," stated one governor, "more necessary and will better serve to relieve the acute unemployment situation than sorely needed highway construction projects on trunk roads in this state."[72]

In an effort to alleviate this financial distress, at least in part, Roosevelt established several agencies under his New Deal umbrella, whose primary purpose was to funnel billions of dollars of relief money to the destitute citizenry. Through the Works Progress Administration (WPA, later renamed the Work Projects Administration), the Public Works Administration and the Reconstruction Finance Corporation, the federal government poured hundreds of millions of dollars per year through the Bureau of Public Roads into road and bridge construction. A favored way of distributing funds to the unemployed was by means of so-called make-work projects—maintaining national forests and parks, producing artwork for public places, writing tourist guides, documenting historic properties, constructing dams, buildings, roads and bridges, etc. One of the first relief agencies

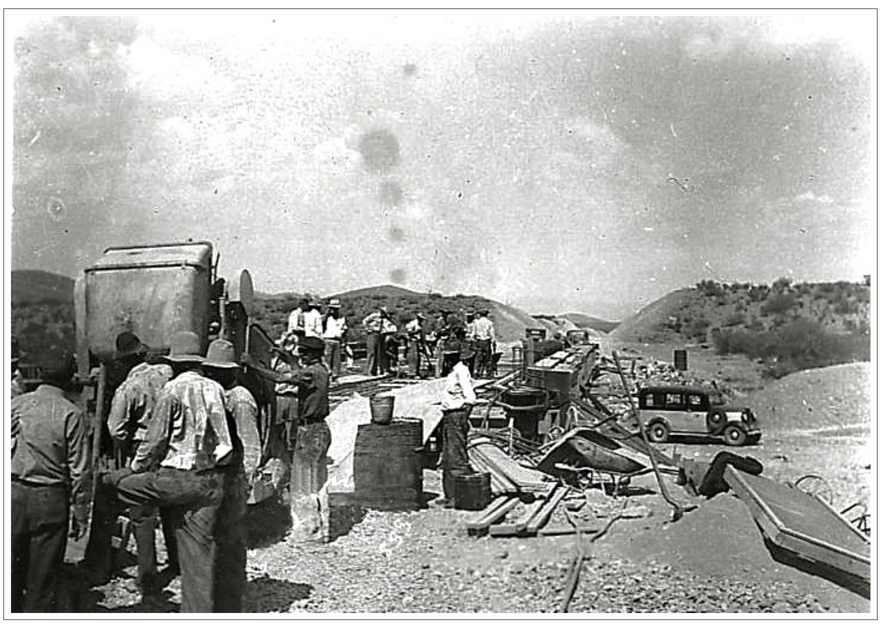

Figure 86. Bridge construction on Clifton-Duncan Highway, 1938. Arizona State Archives.

[72]Quoted in Tom Lewis, *Divided Highways: Building the Interstate Highways, Transforming American Life* (New York: Penguin Books, 1997), 22.

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established by the Roosevelt Administration was the Public Works Administration. Started in 1933 under the National Industrial Recovery Act, the PWA allocated some $400 million in funds for specific projects that were designed solely to put men to work at predetermined wage rates.

Figure 87. Civil Works Administration crew on Camelback Road in Phoenix, 1934. Arizona State Archives.

In 1933 Congress also passed the Federal Emergency Relief and Construction Act. Designated for road and bridge construction, the legislation stipulated that not more than half of the millions of dollars allotted under this program was to be used on the federal aid highway system and not less than 25 percent could be directed to extensions of the federal aid system into and through municipalities. While the act initially required states to match funds, that provision was later rescinded, setting a precedent for full federal subsidies. Cities were eligible for federal funding for the first time following passage of the Hayden-Cartwright Road Act in June 1934.[73] The act also reversed previous restrictions on the use of appropriations for urban highway construction. Not only did the cities need the improvements, but most of the unemployed were concentrated in urban areas. Subsequent legislation encouraged construction of urban grade separations, bridge widenings, and the development of a feeder road network.

Because employment was as important a goal as construction, engineers often eschewed machines for hand labor [Figures 86, 87 and 88]. Federal funds came with some unusual requirements, in effect turning the clock back to the days before many labor-saving machines were available. "Cement and reinforcing steel shall be unloaded by hand labor methods," one specification read. "Finishing of structural concrete surfaces shall be done by hand rubbing or other labor methods. Carpenter work and form work shall be

[73] A better-known provision of the Hayden-Cartwright Act was the penalty imposed upon the states for any diversions of highway revenues to non-road purposes. The reason given for this was that it was "unfair and unjust to tax motor vehicle transportation unless the proceeds of such taxation are applied to the construction, improvement, or maintenance of highways."

done by hand labor methods and the use of mechanical saws will not be permitted at the bridge site. All painting shall be done without the use of mechanical equipment." The Civil Works Administration permitted not more than 10 percent of funds be used for equipment or materials, forcing the state to supply these on most projects. By the mid-1930s the Federal Emergency Relief Administration had corrected this overzealous rule, allowing greater expenditure for materials.

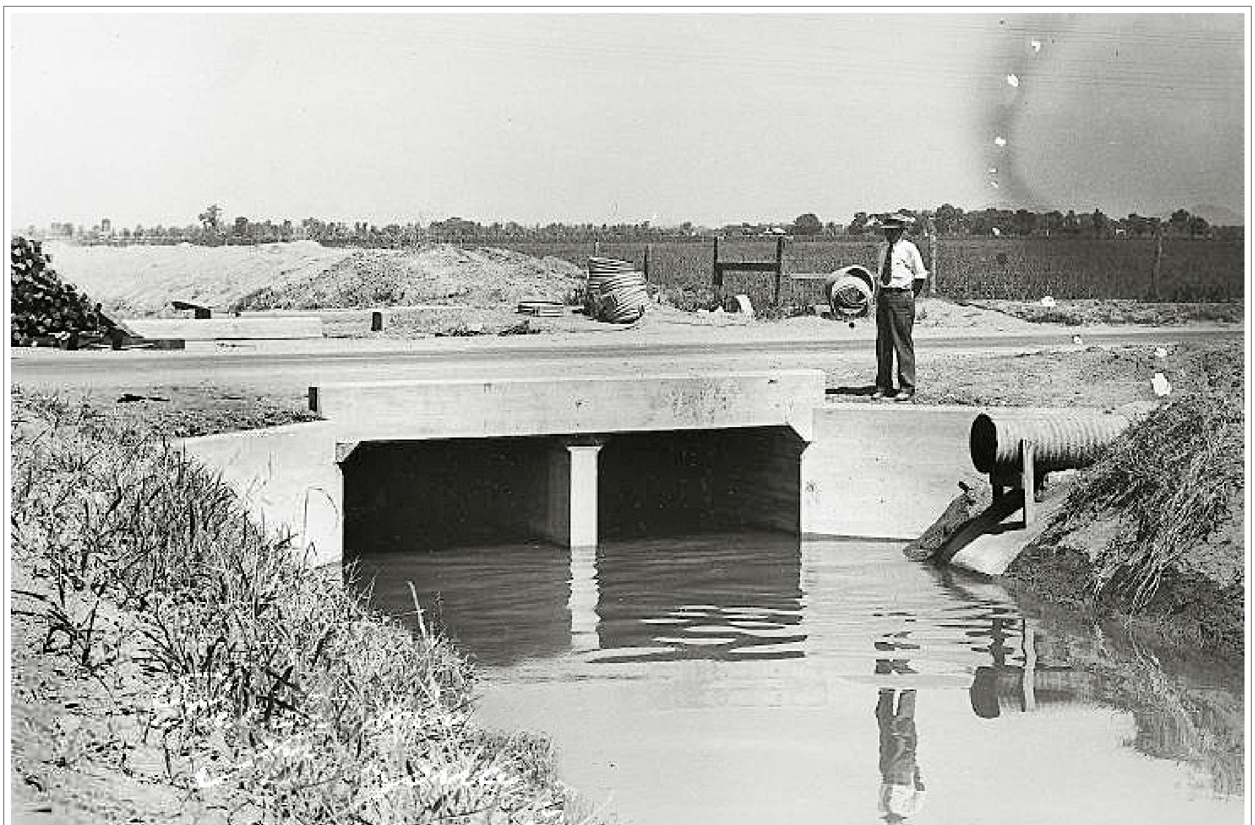

Figure 88. CWA-built culvert on Casion Road in Phoenix, 1934. Arizona State Archives.

During this time the annual federal aid grants continued to come to the states from the BPR. In 1936 alone the federal government awarded $225 million to the states for highway construction. Arizona received $2.6 million of this. In addition to the conventional federal aid for road and bridge work, which had been apportioned to the state annually since 1916, another federal program was established to help alleviate unemployment through road construction. Work under this fell under one of three categories: National Recovery Highway projects (for highways on the seven percent system), National Recovery Secondary projects (non-federal aid roads on the state highway system), and National Recovery Municipal Highway projects (highways within incorporated cities and towns). A 1933 map of the Arizona highway system indicates the extent of construction contemplated under the new program [Figure 89]. Of the $5.2 million apportioned to Arizona

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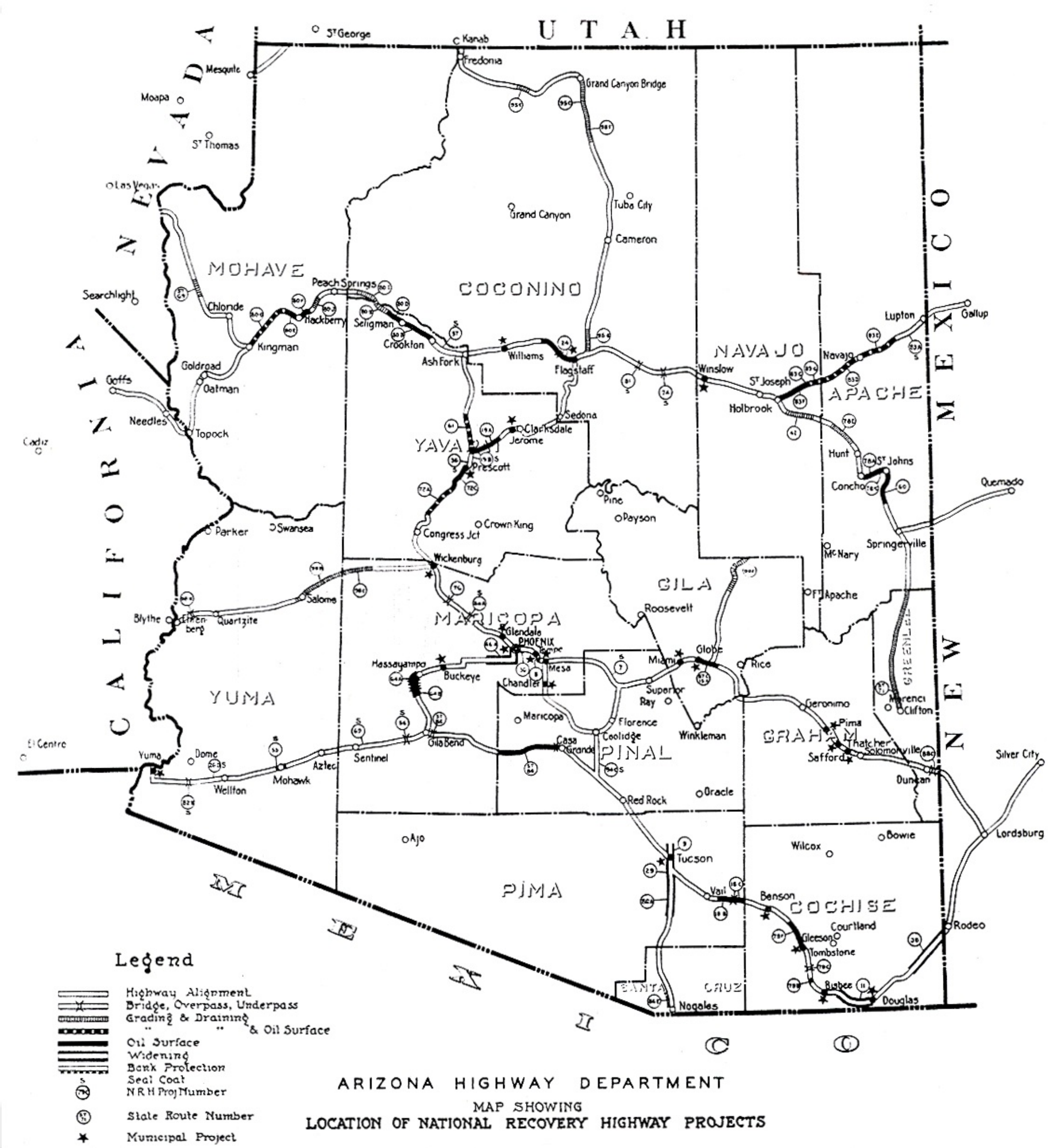

Figure 89. Arizona highway map, showing National Recovery highway projects, 1933. ADOT.

Figure 90. Tex Canyon Bridge (00059), Cochise County, 2018.

in 1934 under this program, $4.8 million went toward highway projects, $600,000 toward secondary projects and $800,000 toward municipal projects. The highway projects that year included construction of 15 bridges and two railroad grade separations. The funds were apportioned in the traditional way to federal aid projects intended for road and bridge construction. AHD engineers designed the projects, then let them out for competitive bids among private contractors. To help ensure that the construction projects would benefit the

Figure 91. Wash Bridge (01020), Pima County, 2018.

local labor pool, the contractors were required to hire locally, at stipulated hourly rates, to the extent that they could obtain local labor. Bridges were designed, as they had been in the 1920s, by highway department engineers, typically using standard plans.

These were now being built to AASHO standards, with 24-foot-wide roadways except on the more heavily trafficked highways and in population centers. Like the bridges built by AHD in the 1920s, the slab and beam structures from the 1930s typically featured standard designs. Concrete was still the preferred material for construction [Figures 90 and 91]. When culverts were called for, preference was for concrete, multiple-box configurations. Noted for utility and economy, if not elegance, concrete slabs and culverts were excellent choices for rural settings where those traits were of primary importance. Because they were labor-intensive in their construction, timber bridges experienced something of a resurgence in the state during the period [Figure 92].

Figure 92. West Carrizo Bridge (02057), Navajo County, 2018.

AHD developed two new structural types during this period. The first was the girder-ribbed steel arch. The highway department preferred this type of arch for medium-span applications, because the girders could be prefabricated using riveted steel plates in lieu of the complicated trussing of the spandrel braced arches, and then assembled on-site without the use of falsework. This allowed for more rapid construction than possible with a spandrel braced configuration like the Navajo Bridge. The girder-ribbed arch design weighed more than its spandrel-braced counterpart, but it simplified fabrication and erection considerably, saving both time and money. In locations that did not require extensive cantilevering, the girder-ribbed arch proved more economical to build. Its adoption by AHD represented an evolutionary step in bridge engineering. Completed in 1934, the Salt River Canyon Bridge (**00129** [Figure 93]) in Gila County was AHD's first girder-ribbed arch. It was followed by other similar arches: the Cedar Canyon and Corduroy Creek Bridges (**00215**), the Clear Creek Bridge (**01038**) and the Canyon Padre Bridge (**00671**).

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Figure 93. Salt River Canyon Bridge (00129), ca.1940. ADOT.

The second structural type was the concrete rigid frame. Like the girder-ribbed arch, it represented an evolutionary step toward simplification, in this case of small-scale concrete spans. AHD experimented with rigid frame bridges at rural crossings to a limited extent during the 1930s. The agency used rigid frames much more for urban grade separations, where they lent themselves to relatively short spans and could be readily overlaid with architectural ornamentation. AHD's grade separations of the 1930s typically employed conventional concrete slab or rigid frame superstructures for the overpasses and steel girders for the underpasses.

Figure 94. Winslow Underpass (00194), grand opening, 1936. ADOT.

These were treated with eith-

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er traditional (Spanish Revival or Mission Style) or contemporary (Art Deco or Art Moderne) styles. Examples of the former include the Winslow Underpass (**00194** [Figure 94]) and the Stone Avenue Underpass (**07987**) in Tucson. Examples of the latter include the Wickenburg Underpass (**00195**), the Benson Underpasses (**00262** and **00264**), the Casa Grande Underpass (**00143**) and the 17th Avenue Underpass (**07770**) in Phoenix. The highway department even began applying architectural treatments to its grade separations located in rural areas, as illustrated by the Peoria Underpass (**00160** [Figure 95]).

Figure 95. Peoria Underpass (00160), ca. 1940.

Early in its existence AHD had paid little attention to bridge aesthetics, instead concentrating on economy and functionality. Some of the more graceful structures designed by Ralph Hoffman (e.g., the Navajo Bridge (**00051**)) appear to have been motivated, at least in part, by aesthetic considerations, though he was loathe to admit it when discussing their design. "The speed with which it has been necessary to create wider and faster highways to meet the demands of traffic have left little room for thought of such fine points," he sniffed in a 1934 article.[74]

But the federal law specified that a portion of the NRH funds be earmarked for highway beautification. In response AHD began to consider the way its bridges looked in addition to the way they functioned. The answer to bridge aesthetics, according to Hoffman, lay in making the bridges as unobtrusive as possible and blending them with their natural surroundings. He believed that the superstructures should be hidden as much as possible beneath the roadway and that guardrails should be low—"as low as safety will permit"—and unnoticeable to keep from impeding the view from vehicles passing over the bridge. Hoffman reflected conventional wisdom about bridge design when he stated:

> Plain surfaces with softening curves are usually more fitting, such as are to be found in arch construction and in the development of the more recent rigid frame designs. Even with the advantages offered by these types, the straight line necessary for strength and economy do not successfully blend with nature. . . A more difficult problem presents itself in attempting to blend the bridge with the surroundings. A structure with steel trusses or other work above the deck,

[74] R.A. Hoffman, "Bridges and Beautification." *Arizona Highways* X:11 (November 1934), 3-4.

is usually the worst offender in this respect, an unfortunate occurrence.[75]

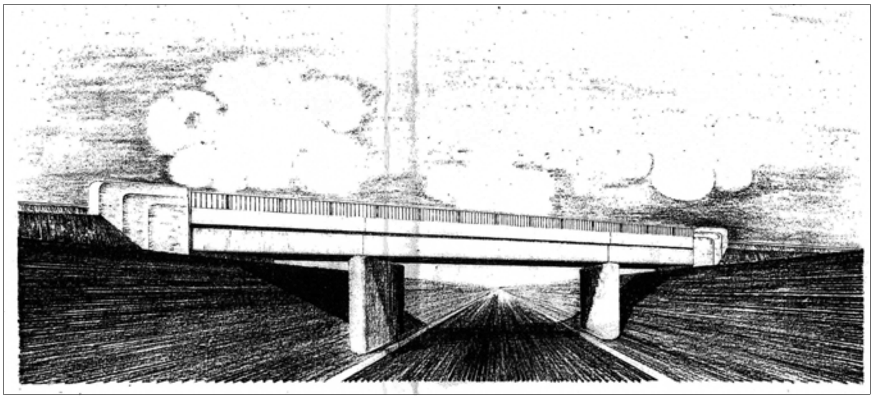

Figure 96. Ligurta Underpass rendering. ADOT.

AHD began rendering perspective views on some of its more complex rural structures to be able to judge their appearance [Figure 96]. For its structures located in urban areas, the highway department could not rely on invisibility as an aesthetic strategy, however. When AHD engineers began designing urban grade separations in the mid-1930s, they used architectural treatments to integrate the highway structures with their surroundings. The first three such structures—the Riorden , Tucson and Gila Bend Overpasses, erected simultaneously in 1933-1934—featured an Art Deco architectural treatment, "the first of their type in architectural treatment to be constructed in Arizona," according to AHD. Of these three, only the Gila Bend Overpass remains (**00118** [Figure 97]).

The most noteworthy of the bridges constructed in the 1930s are today distinguished either by their high degree of physical integrity or by their deviance from standard-plan design. These include the Salt River Canyon Bridge (**00129**), a long-span steel arch on U.S. 60; the Side Hill Viaduct (**00145**), a unique concrete slab structure on U.S. 60; the Dead Indian Canyon Bridge (**00032**), a riveted deck truss on the Grand Canyon Highway; the Midgley Bridge (**00232**) a spandrel-braced steel arch in Coconino County; the Wickenburg Bridge (**00161**), a long-span steel girder structure; and the Negro Canyon Bridge (**00267**) and Rattlesnake Canyon Bridge (**00270** [Figure 98]), two well-preserved beam structures in Greenlee County.

[75] Ibid. 4.

Figure 97. Gila Bend Overpass (00118), 2018.

In addition to programs administered through the state highway departments, the federal government undertook roadwork through one of its own agencies, the Works Progress Administration. Created under the Emergency Relief Appropriations Act in 1935, this agency was responsible for thousands of small-scale projects around the country. About 75 percent of these projects involved construction of some sort. The majority were planned and sponsored by cities, counties or other public agencies, with local match of funds that ranged from 10 to 30 percent. Despite criticism of its freewheeling spending, the WPA had a considerable impact on unemployment during the 1930s. At its peak the WPA provided relief to nearly a third of the nation's unemployed.

Figure 98. Rattlesnake Canyon Bridge (00270), 2018.

One of the favored venues of WPA work was road and bridge construction. "WPA is doing its share to cut down the tragic toll of sudden death on America's highway," *The WPA Worker* reported in July 1936. "Under the Emergency Program, workers from relief rolls have replaced thousands of narrow and dangerous bridges. They have built 11,000 new bridges in addition to repairing 17,000 others."[76] In Arizona approximately 20 percent of the WPA projects undertaken involved construction on the state's secondary roads, highways and city streets, "proposing paving, surfacing, widening, drainage and beautification over an area from Short Creek, in the northwest corner of the state, to Douglas in the southeast," according to Arizona WPA administrator W.J. Jamieson. Jamieson continued:

> With secondary roads receiving the largest percentage of funds allotted, road and highway improvement projects contemplate the expenditure of nearly $1,600,000 of federal funds. City street paving, improvement, and drainage projects propose the expenditure of more than $250,000. In Maricopa County alone, almost three-quarters of a million dollars has been allotted for projects which include the improvement of approximately 1,000 of the 3,000 miles of county roads, as well as other projects.[77]

In 1936 the WPA undertook highway projects in Arizona as diverse as improvement and beautification of US 89 between Nogales and Tucson, paving south of Bisbee and at Clifton, improvement of county roads near Douglas, construction of a highway through Papago Park in Scottsdale, construction of a bridge over Bumble Bee Creek in Yavapai County (**08221** [Figure 99]), over Short Creek in Apache County and other work in Nogales, Superior, Phoenix, Jerome, Willcox and Globe.

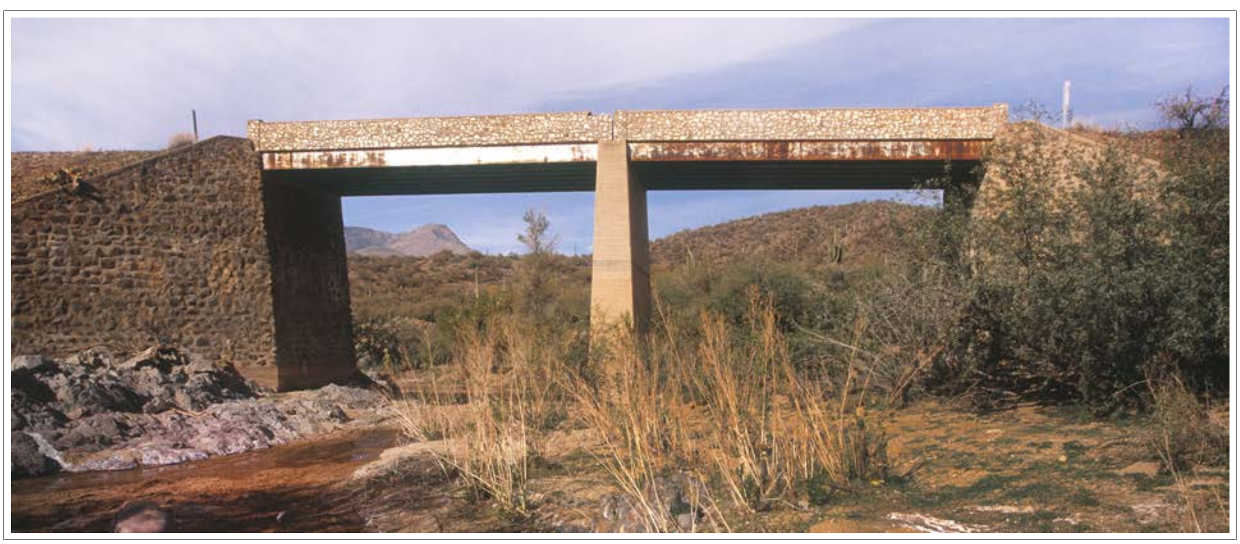

Figure 99. Bumblebee Bridge (08221), 2018.

[76]"Bridges." *The WPA Worker* 1:2 (July 1936).

[77]Lewis Allison, "WPA Building Highways." *Arizona Highways* XII: 2 (February 1936).

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The goal of the WPA was employment, with improvement of public facilities as a secondary consideration [Figure 100]. "What is more important," WPA head Harry Hopkins asked in 1935, "that the fellow who has been kicked around now for years and given a lot of relief some of it pretty miserable and uncertain, be given a job, or that some great bridge be built and he not get a job? Never forget that the objective of this whole program as laid down by the President. . . is the objective of taking 3.5 million people off relief and putting them to work, and the secondary objective is to put them to work on the best possible projects we can, but don't ever forget that first objective, and don't let me hear any of you apologizing for it because it is nothing to be ashamed of."[78] WPA administrator Ralph J. O'Rourke explained the purpose and operation of the WPA:

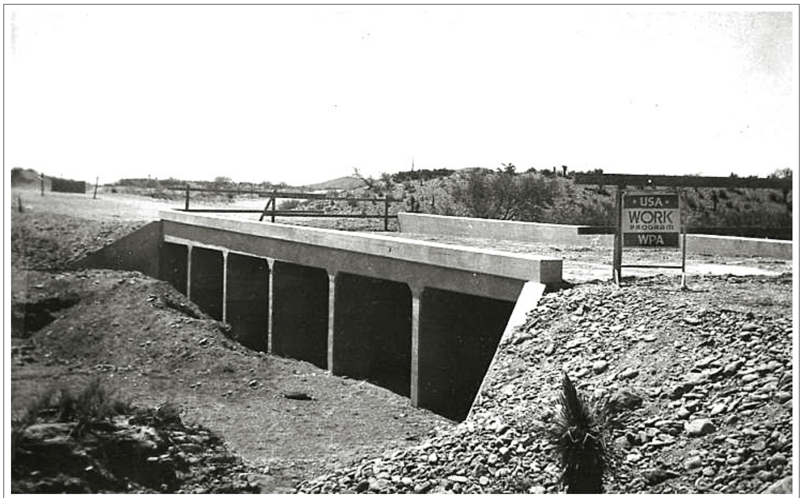

Figure 100. WPA-built culvert on Clifton-Duncan Highway, 1938. Arizona State Archives.

> It should be understood that the primary responsibility of W.P.A. projects is the employment of able bodied but destitute workers. With this responsibility in mind W.P.A. is exerting every effort to conduct projects along economical and efficient lines. Wherever possible W.P.A. has developed the type of work which will react to the benefit of the community in which the work is being performed, and it is believed that a large part of the funds expended on these projects will be returned to the community through improved conditions, elimination of dangerous roads, and the stabilization of existing highways by improved drainage facilities. Experienced personnel has been assigned to inspect the conduct and progress of the work. It is the responsibility of the sponsor of a project to provide plans and specifications for work that is to be conducted under the W.P.A.; however, W.P.A. field engineers are instructed to confer with the sponsors about changes when sound engineering principals have not been followed in the preparation of plans.[79]

The WPA program wound down as the United States entered World War II. Between 1935 and 1943, the agency had employed some 8½ million people (with over 30 million dependents), who performed nearly 19 billion hours of work for $9 billion in subsistence wages. The resulting public works projects completed by the WPA changed the physical fabric of America, if for no other reason than by their sheer numbers. In its

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[78]Quoted in Lois Craig, *The Federal Presence: Architecture, Politics, and Symbols in United States Government Building* (Cambridge, Massachusetts: MIT Press, 1978), 355.

[79]Ralph J. O'Rourke, "Works Progress Administration Highway Projects." *University of Colorado Highway Conference*, March 1936, n.p.

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eight years of service, the WPA was responsible for construction or repair of 650,000 million miles of roads and some 124,000 bridges; construction of 40,000 new public buildings and improvement to 85,000 others; construction of thousands of public parks, playgrounds, swimming pools and tennis courts; construction or improvement of thousands of municipal airports; construction of sanitation and water works, flood control systems and irrigation systems; and preservation of numerous historic buildings, including Independence Hall in Philadelphia and Faneuil Hall in Boston.

By all accounts the program was successful. "It was the most massive and comprehensive effort ever undertaken in the nation's history to ensure that every able-bodied American male—and even some able-bodied American females—would be able to earn at least the basic needs of life for themselves and their families," stated historian T.H. Watkins. "Even more than the New Deal's earlier relief programs, it was responsible for the creation of a new and immutable intimacy between the people and their government— an intimacy so thoroughly in place today that it is difficult to remember that it was once a revolutionary concept."[80]

WPA-built bridges in Arizona tended to be small-scale structures that employed standard highway department designs. They were generally indistinguishable from the concrete and steel structures being erected under traditional federal aid projects of the time. Although they were overshadowed in number and scale by federal-aid bridges, numerous structures were constructed by the WPA in Arizona during the Depression. Several of these remain in place today, including the Forman Wash Bridge (**00223** [Figure 101]), the Bumble

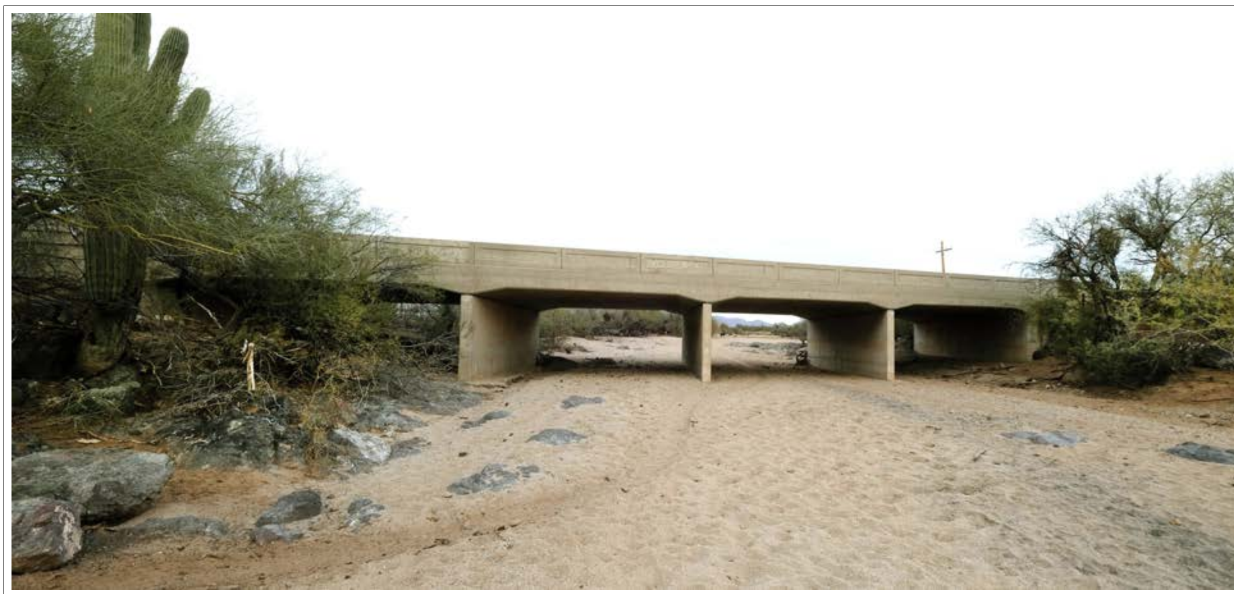

Figure 101. Forman Wash Bridge (00223), 2018.

[80]T.H. Watkins, *The Great Depression: America in the 1930s* (Boston: Little, Brown Company, 1993), 248.

Bee Bridge (**08221**), a two-span steel stringer with stone substructure and parapets; the Main Street Bridge (**09630**) in Bisbee, a steel stringer structure; the Davis Wash Bridge (**00221**), a three-span concrete slab structure on the Apache Trail; and the Willis Street Bridge (**08550**) in Prescott, a two-span concrete deck girder structure with stone masonry substructure and steel pipe guardrails on stone masonry columns.

While devastating much of the United States, the Great Depression—and Roosevelt's response to it—proved to be a boon to the nation's road system. Between 1933 and 1940 the New Deal was responsible for funneling some $1.8 billion into road and bridge construction throughout the country, funding millions of man-years of employment. During this time Arizona's state highway system grew from approximately 2,000 miles of aggregate length in 1930 to 3,624 miles eight years later [Figure 102]. Most of the construction undertaken during this period involved improvement of existing roads. A notable exception to this was construction of U.S. Highway 60 between Globe and Show Low through the Salt River Canyon. Intended to complete the last leg of the transcontinental route, the road would link Springerville, Show Low and other towns on the Mogollin Rim with the town of Globe—and, by extension, with Phoenix. Construction on U.S. 60 illustrated road and bridge work of the period.

AHD had begun planning for this route in the late 1920s. Department engineers initially considered upgrading the existing regional route, a road built in part by soldiers from Fort Apache that crossed over both the Black River Bridge (**03128**) and the White River Bridge (**03129**). But the Rice-McNary Road, as this territorial route was called, was still little more than a wagon trail, despite construction over the previous four years to improve it. Rather than upgrade the existing road further, the highway department instead surveyed an all-new route in 1930-1931. With the route design completed early in 1931, AHD divided the 130-mile road into a series of shorter sections and began letting contracts for its construction under the umbrella of Federal Aid Project 99.

Section A, the first one undertaken, included some of the route's most rugged terrain. Work on it began in mid-June of that year. Using everything from mule teams to trucks, tractors and power shovels, the contractors proceeded through summer rainstorms and sub-zero temperatures in the winter, blasting, filling and grading the road through mountainous terrain on the San Carlos Indian Reservation. After eighteen months of brutal construction, Section A was completed near the end of the year. Comprising the southernmost 10.8 miles of the route, Section B began just outside of Globe and extended through the Crook National Forest to Apache Peak. This part of the highway also ran through rugged terrain but was more accessible than Section A. Construction on it advanced more rapidly through completion in July 1932. Sections C and D, built in 1932-1933, passed through rolling woodlands before making the steep descent into the Salt River Canyon.

As construction progressed on the highway, the Depression deepened across the country; soon a premium was placed on employment for the local work force. Labor-intense hand work was used extensively in lieu of mechanized construction, and the work schedule was changed from the standard eight-hour, five-day shift to two five-hour, six-day shifts with extended furloughs to employ more workers and push construction. "Except for a few, all skilled and unskilled employees were Gila county men," reported AHD resident engineer

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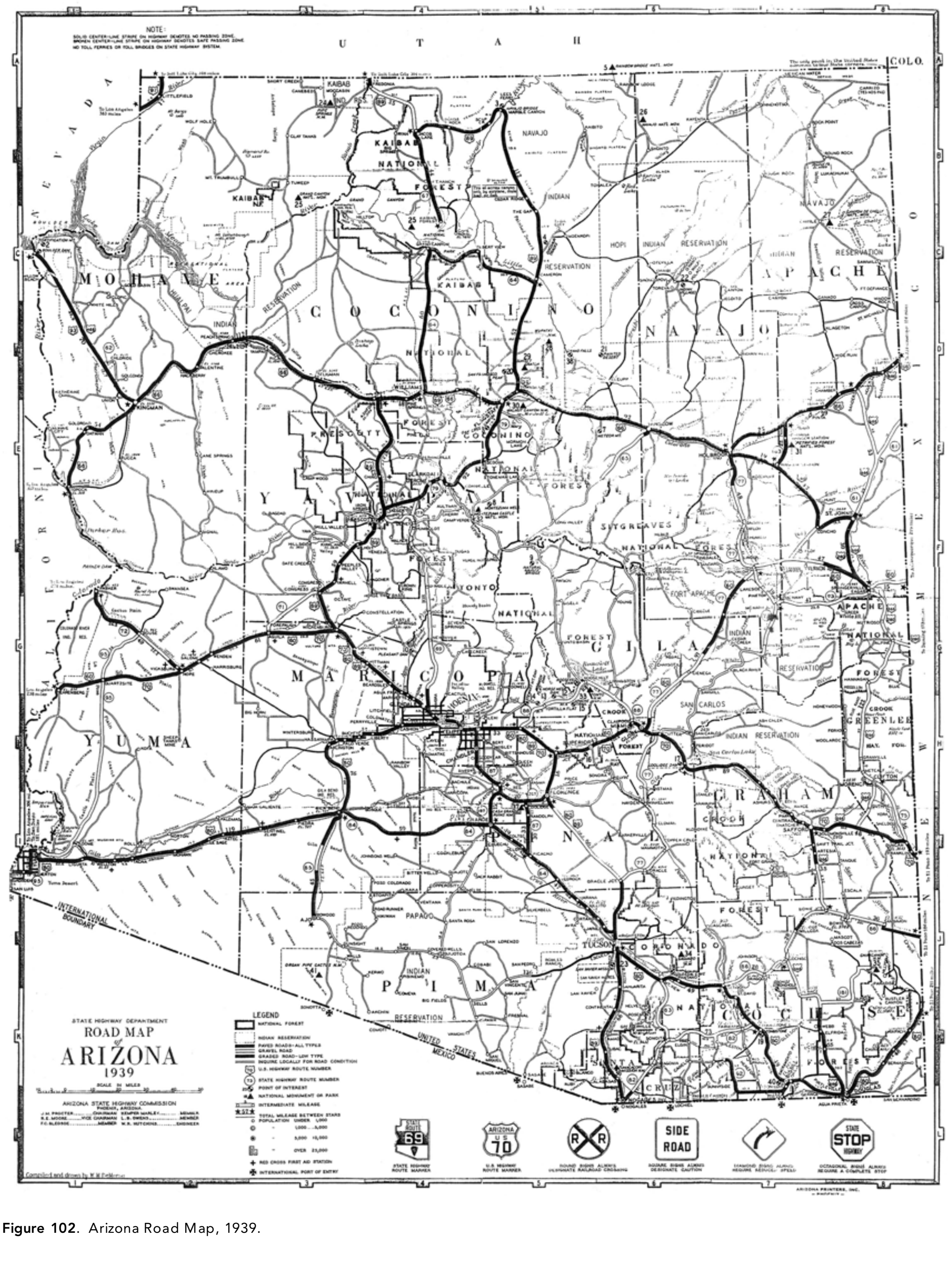

Figure 102. Arizona Road Map, 1939.

A.F. Rath, "Labor reports compiled from records show that for a period of 50 weeks the two jobs [Sections C and D] averaged 180 men per day... The benefits derived from roadwork spread over a large area, if one should care to follow it through from start to finish."[81] Using these methods, some 42 miles of highway had been graded between Globe and the Salt River Canyon by October 1933.

The steep rock walls and constricted contour of the Salt River Canyon called for a single-span bridge to carry the roadway high above the river. For this natural crossing, the AHD bridge department engineered a single-span steel arch that flexed against the canyon walls on concrete pedestals. The Salt River Canyon Bridge was an innovative structure—only the third steel arch built for Arizona's highway system. The highway department designated the bridge's construction Section E and in September 1933 contracted with the Lee Moor Construction Company of El Paso, Texas, for its fabrication and erection. The contractor began immediately on the concrete arch pedestals.

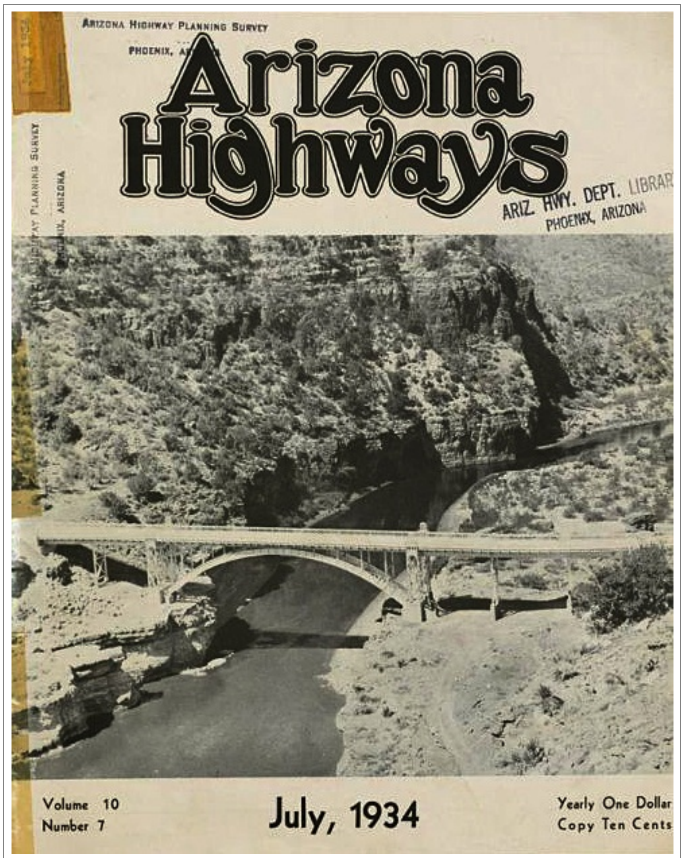

Figure 103. Salt River Bridge on cover of Arizona Highways, July 1934. ADOT.

The Salt River Canyon Bridge and its approaches presented multiple curvature problems— "more, in fact, than any bridge so far constructed in the state," according to Rath. As a result, its construction went slowly. In January 1934 work on the first pylon began. Each 18-ton arch girder was erected in five sections that spring, and in June the immense structure was completed. "From a distance and with its aluminum paint shining in the sunlight, the structure looks more like a delicate piece of filigree than a well designed and constructed highway bridge," rhapsodized Rath.[82]

Completion of the Salt River Canyon Bridge (**00129** [Figure 103]) marked the halfway point on the Globe-Springerville Highway. Although almost 90

[81] A.F. Rath, AHD Resident Engineer, "Highway 60 Moves Northward," *Arizona Highways*, July 1933, 4.

[82] A.F. Rath, "New Bridge Across Salt River and the Country Which It Will Open," Arizona Highways, September 1933, 14.

miles remained between the bridge and Springerville, once out of the canyon most of the path was relatively mild compared to the rugged construction in Sections A through D. The highway department dubbed the three-mile climb up the other side of the canyon Section F and subsequent segments Sections G through J, as construction progressed steadily northward between 1934 and 1936. Meanwhile, work had begun from the Springerville side under Federal Aid Project 105. Again, AHD divided the construction into smaller segments, the first of which extended from the outskirts of Springerville. Two of the last segments designated—F.A.P. 105-D and 105-E—involved erection of a unique multiple-span, concrete slab structure, the Side Hill Viaduct (**00145**), which skirted the side of a steep slope, and two girder-ribbed arch bridges over Cedar Canyon and Corduroy Creek (**00214** and **00215** [Figure 104]).[83] Completion of these bridges marked the last link in U.S. 60 between Globe and Springerville, and one of the last links in the national highway.

Figure 104. Cedar Canyon Bridge (00214), 2002.

The onset of World War II brought highway plans in Arizona to an abrupt halt. With fuel under tight rationing, automobile production suspended and tires and car parts in short supply, overland travel diminished precipitously. Funds and most construction materials— especially concrete, oil and steel—were diverted to the war effort. The WPA was dismantled, as the federal government shifted its focus from helping the unemployed to mobilizing for war. And many of the highway department

[83]The Side Hill Viaduct still carries traffic. The Cedar Canyon and Corduroy Creek bridges also functioned in place until 1993, when the superstructure of the Corduroy Creek Bridge was lifted, moved to the Cedar Canyon site, and installed next to the other arch as a means to widen the roadway.

engineers and laborers left their jobs to fight in the war, reducing the agency's force considerably. AHD was compelled to suspend its construction program almost entirely to concentrate its reduced resources on maintenance work. "Rationing slowed traffic almost to nothing (on Route 66)," stated merchant Bud Gunderson. "In 1943 the traffic on 66 was practically at a standstill other than military convoys."[84] No bridge construction was undertaken that was not necessary. The bridges that were built during the war used non-critical materials when possible, and some were constructed using materials salvaged from other structures.

A new form of federal grant program—Defense Access Projects—was instituted in 1941 under the Defense Highway Act. These projects were intended to build or improve roads associated with defense facilities, critical industries and sources of raw materials. Defense Access Project No. 1 in Arizona entailed construction of three timber stringer bridges, 17 concrete culverts and about five miles of road within the Fort Huachuca Military Reservation. Another such military highway improved by the WPA under this program was the 6.2-mile segment of S.R. 92 that connected Fort Huachuca with SR 82.

In actuality, Arizona's participation in the Defense Access program was limited. The state in 1944 had only 133 miles of roads on military facilities (versus 3,800 miles of state highways and 15,440 miles of county roads). The impact of the war on Arizona's roads was not so much the extent of construction on defense-related facilities as the absence of other conventional road and bridge construction. The bridge inventory includes fewer than two dozen bridges and culverts built during the three years between 1943 and 1945 (versus 34 bridges in 1942 and 36 bridges in 1946). Most were minor concrete structures, built using standard designs.

7 Post-War Construction and the Interstate Highway System: 1945-1978

As the war was winding down, Congress resumed funding the federal aid highway program, and the Arizona Highway Department continued its construction and maintenance work. After the war the state returned to its pre-war routine, with AHD planning and undertaking projects, using oversight and funding from BPR. Many of the highway department engineers and construction managers returned to the agency after the war. Others, most notably Ralph Hoffman, AHD chief bridge engineer since the early 1920s, continued with the agency through the war. Despite four years of deferred maintenance during the war, Arizona's road and bridge network remained largely intact. In 1946 an engineer from the Bureau of Public Roads gave his appraisal of the state of Arizona's highways:

> On the whole, a critical examination of the Arizona State highway system discloses a healthy condition. The Federal-aid highway system of about 2,500 miles has had almost complete first- or second-stage improvement. It shows, as it should for the average traffic, a large percentage of construction with intermediate types of bituminous surfacing. The first obligation of the State is to maintain the system (and) most of the past construction will require revamping or reconstruction in 25 or 30 years. The future healthy highway development in Arizona seems assured.[85]

[84]Quoted in Susan Kelly, *Route 66: The Highway and Its People* (Norman: University of Oklahoma Press, 1988), 79.

[85]L.I. Hewes, "Some Observations on a Modern State Highway System," *Papers Presented at the Sixth Arizona Roads and Streets Conference, April 26, 1946*, University of Arizona, 1946.

In 1944 Congress passed the Federal Aid Highway Act. Over a three-year period, the law allocated $500 million annually for construction and improvement of local and interstate roads. The total amount was divided into 45 percent ($225 million) for use on primary roads, 30 percent ($150 million) for secondary systems, and the remaining 25 percent ($125 million) for municipal roads. Beyond this, the act formally established the National System of Interstate Highways, which mandated that states build roads to connect major metropolises. The roads proposed by this legislation were minimally configured as four-lane, divided highways, expanding to six or eight lanes in urban areas. Arizona's allotted mileage under the Act included what is now Interstate 17 between Phoenix and Flagstaff; Interstate 40, which generally followed the Old Trails Highway across the northern part of the state; and Interstate 10, which generally followed the Ocean-to-Ocean Highway across the southern part of the state. The Federal Aid Act was the first step toward the establishment of a coherent federal interstate system.

In the post-war years both the American economy and its population boomed. By 1953 the population exceeded 157 million, a 20 percent increase since the beginning of the war. These people enjoyed substantial increases in their economic status and standard of living. That year visits to national parks exceeded 17 million, and Chevrolet, Ford, and Plymouth sold over 3.3 million cars. As more Americans became mobile, they logged nearly 550 billion miles on largely inferior roads. Despite the obvious need for improved highways, little headway was made over the next ten years. President Harry Truman authorized a National System of Interstate and Defense Highways in August 1947, but nothing was done to actually build these interstates. Further action—and a change of administration—was required a decade later to complete the work of the 1944 and 1947 authorizations. It would not be until the Eisenhower administration that work on the interstate system would begin.

With a background of logistical planning from his military experience, President Dwight D. Eisenhower was an outspoken advocate for an integrated system of interstate highways. As early as April 1954, Eisenhower had begun staging high-level meetings on the subject of improving federal highway programming. After lengthy debate, Congress finally passed a highway bill, the Federal Highway Act, on June 29, 1956. Acting on the President's recommendation, the legislators authorized $33.5 billion for construction of over 41,000 miles of limited-access superhighways during the next sixteen years. The federal government would pay 90 percent of the construction cost, establishing a Highway Trust Fund as a crediting mechanism within the general treasury.

The proposed network would link almost all of the cities with populations over 50,000. Built to standards heretofore unused for the nation's highways, the interstates would be engineered to accommodate speeds of up to 70 miles per hour. They would be sized to accommodate traffic volume projected to 1972, the year of the system's proposed completion. This represented by far the most ambitious road construction program in America. From 1956 through the 1970s, interstate highway construction continued at an unprecedented pace, establishing the basis for the U.S.'s current extensive highway system and transforming the urban and rural landscape through which they ran.

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The new highway numbering system resembled the 1925 practice in some ways. In the new interstate nomenclature, east-west highways descended numerically in even numbers from north to south and north-south highways descended numerically in odd numbers from east to west. Thus America's northmost east-west interstate was Interstate 94 across North Dakota, Minnesota and Wisconsin and its southernmost east-west route was Interstate 4 in Florida. The easternmost north-south route was Interstate 95 from Florida to Maine and its westernmost north-south route was Interstate 5 along the west coast. Belt routes in and around large metropolises were assigned three-digit numbers. The distinctive Interstate shield sign was adopted by AASHO in August 1957 and has been in use since.

The interstate system would rely heavily on design standards established by the American Association of State Highway Officials [AASHO].[86] Between 1938 and 1944, AASHO's Committee of Planning and Design had developed policies for highway construction based primarily on geometric design standards for high speed transportation. In 1956 AASHO revised the standards to accommodate higher speeds and heavier vehicles. AASHO's designs were intended to provide safety and efficiency for the level of military, commercial and passenger traffic that was projected to exist in 1975. The limited-access Pennsylvania Turnpike served as the model for highway and bridge design. Design standards for the interstate system were detailed by AASHO in its annual publication, *A Policy on Geometric Design of Highways and Streets*, commonly called the Green Book. AASHO outlined both minimum and desired levels for highway design, and, although the standards were ostensibly voluntary, they were adopted in whole by the Bureau of Public Roads. With the BPR funding 90 percent of the interstates' construction, the standards were in turn adopted by virtually all of the state highway departments, including Arizona's. As first conceived, the highway design differed from its eventual configuration. According to the Department of Transportation monograph for the interstate highway system:

> Under the AASHO's design standards, access to the system would be controlled as a general principal. This paramount safety measure incorporated into the new standards was not in anyway innovative, as this feature had been applied to the earliest parkway systems. It was also not originally universally applied throughout the interstate highway system at first. All railroad crossings would be eliminated throughout the system, as well as all grade crossings in urban and suburban areas. However, the standards did permit at-grade intersections in sparsely settled rural areas provided that the interstate was a two-lane highway having a design hourly volume of less than 500 vehicles; that the intersection featured an annual daily traffic of less than 50 vehicles; at-grade intersections did not exceed more than two per mile per side of highway; that additional acquisition of right-of-way at the intersection corners ensured the safety of vehicles on the Interstate; and, that prior to initial construction, the appropriate state highway department retained the authority to subsequently eliminate the intersection. The lack of a unified standard to eliminate all grade crossings, and to provide a standard system of controlled access, was seen by many highway planners at the time as a major deficiency of the AASHO's standards.[87]

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[86] By the early 1970s AASHO had renamed itself American Association of State Highway and Transportation Officials [AASHTO], but the organization's function remained unchanged.

[87] Louis Berger Group, "The Interstate Highway System in the United States," Draft Final Historic Context Report for U.S. Department of Transportation, December 2004, 29.

The standards were formulated to facilitate safe high-speed (50-70 mph) travel. Sharp curves and high grades were avoided, and the sweeping curves would take into account sight distances. Under the guidelines, directional travel on the highways would be separated, with entrances and exits limited. Traffic lanes were required to be 12 feet wide and shoulders 10 feet wide. Median strips dividing oncoming traffic in rural areas would be at least 36 feet wide; medians in urban areas 16 feet wide. Other than noted above, the highways would have no on-grade crossings with railroads and other vehicular roads, vertical clearance at underpasses would be 14 feet, and grades would not exceed 3 percent. Standardization was a character-defining feature of the interstate highway system. And standardization on such a huge scale ultimately led to ubiquity. According to historian Tom Lewis:

> The Bureau of Public Roads and the American Association of State Highway Officials issued specifications for construction that left little leeway for interpretation. Engineers simply applied the rules to the task at hand, be it Interstate 10 through Santa Monica, California, or Interstate 94 through Dickinson, North Dakota. They simply repeated the tasks in small increments of usually five, ten, twenty, or thirty miles many times over; surveying, walking the line, grading the land, laying the substrate, laying the asphalt or concrete, painting the lines, erecting the signs, holding the ribbon-cutting ceremony, and moving on.[88]

Construction of the proposed system would be a gargantuan task: 41,000 miles of divided highways built in virtually all of the states using newly minted standards over a 13-year period. Some sixteen thousand exits, 55,000 bridges and grade separations and scores of tunnels would comprise the system. Almost three-quarters of the proposed system would be built over new right-of-way, necessitating the taking of more land by eminent domain than had been taken in the entire history of road building in the U.S. Much of the route was rural, and in the West, it would traverse dauntingly rugged territory.

Planning for a freeway system in and around the Phoenix metropolitan area had already begun well before passage of the Federal Highway Act of 1956. As early as 1948, AHD, BPR, Maricopa County and the City of Phoenix had jointly sponsored a study of arterial traffic through the city. The plan that these agencies formulated involved multi-lane arterial streets—Roosevelt, Jefferson and Madison, primarily—that would carry traffic east-west through the city. Roosevelt would be reconstructed as a six-lane parkway to carry U.S. 60/70/80/89. At the west edge of Phoenix, along the alignment of 23rd Avenue, would be S.R. 69. This would collect traffic from the east-west streets and carry it northward.

The most noteworthy aspect of the plan was the configuration of S.R. 69. As delineated, it would be constructed as a limited-access freeway—Arizona's first. The freeway design remained on the drafting board through the 1950s. Within months after enactment of the Federal Highway Act, however, the system reappeared in a more detailed plan developed by the state highway department. In February 1957 AHD released the plan of an interstate system that would carry traffic from the north, south and west into Phoenix. State

[88] Tom Lewis, *Divided Highways*, 253.

Highway 69 was then programmed for construction along the earlier alignment. Newly proposed Interstate 10 would enter the city from the south immediately west of 56th Street, turn westward at Broadway and curve through town before exiting west between Southern and Broadway.

Facing complex, politically charged issues of routing, engineering, land acquisition, project funding and construction logistics, the highway planners worked slowly through the late 1950s laying out the proposed system. Finally, by May 1961 a master plan had been signed by the Arizona State Highway Commission, Maricopa County and the cities of Phoenix, Glendale, Avondale, Mesa, Buckeye and Tempe. This plan incorporated elements of the earlier schemes and combined both federal interstate highways with state primary routes, integrating limited access freeways and traditional roads into a network of arterial routes.

In this scheme, Interstate 10—tagged the Pima Freeway—would enter Phoenix from the south as it had in the 1957 design. The route became the Maricopa Freeway when it turned westward toward Yuma. The original S.R. 69 route—renamed the Black Canyon Freeway—kept its old alignment as Interstate 17. The new master plan delineated other non-interstate freeways as well: the Squaw Peak and New River freeways, which extended north-south on either side of the Black Canyon; and the Papago and Paradise freeways, which ran east-west through town.

Figure 105. 1930s culvert on U.S. 66 near Holbrook incorporated into Interstate 40, 1964. Arizona State Archives.

Elsewhere in the state, AHD engineers began conceptualizing a statewide network of freeways. The proposed new routes would follow familiar corridors. Interstate 40 in the northern tier of the state generally followed U.S. Highway 66—which itself followed the National Old Trails Highway, which followed the northern territorial road, which followed Beale's Road. With the exception of a segment between Flagstaff and Kingman, I-40 followed U.S. 66 directly over its length. In many places the older highway was upgraded directly to interstate standards [Figure 105].

A notable exception to this was in Flagstaff, the largest city along the highway's route through Arizona. Rather than follow Route 66 through the downtown's commercial district, planners in January 1959 proposed instead a bypass south of town. The Flagstaff City Council and the Coconino Board of Supervisors approved

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the proposal, but Flagstaff business owners protested vociferously that it would draw motorists away from the central business district. They formed a No By-Pass Committee, recommending that the interstate be routed through the city along the existing right-of-way for the Santa Fe Railroad. When the railroad rejected the recommendation, however, the committee drafted a city ordinance in November 1959 that banned all new commercial development along the proposed interstate route south of town. Flagstaff voters overwhelmingly rejected the ordinance, and the southern route was adopted.

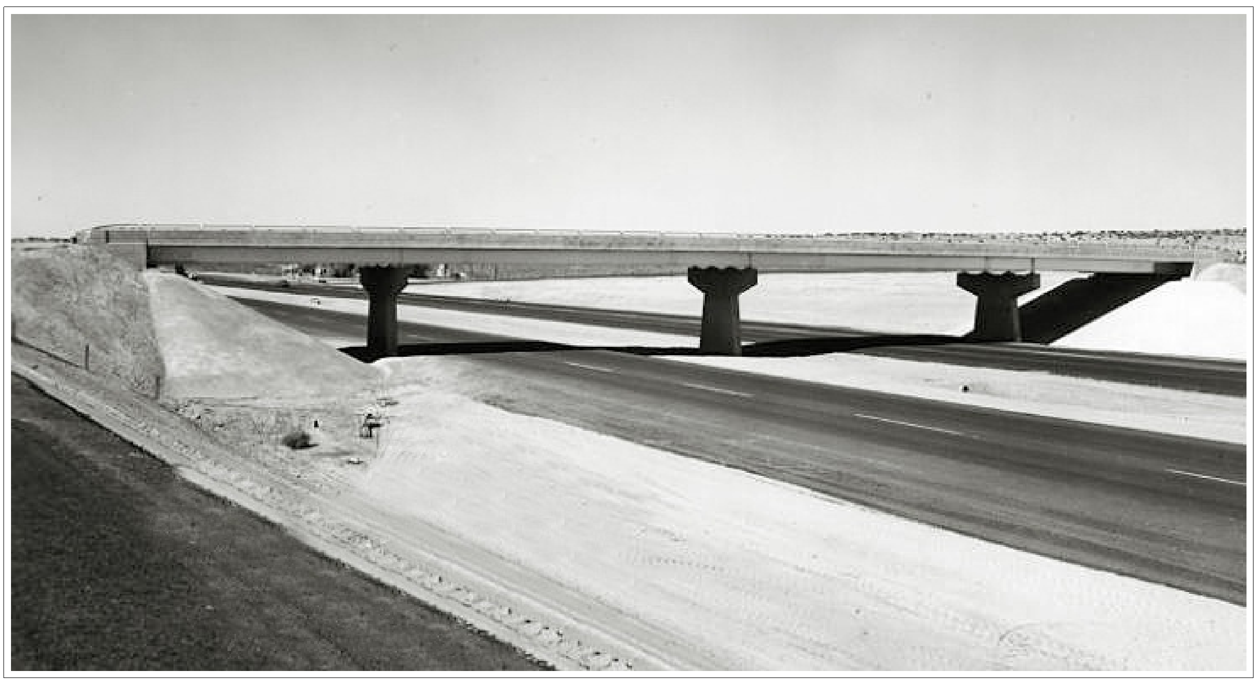

Figure 106. Interstate 40 construction in Apache County, 1964. Arizona State Archives.

Five years later, as construction work was underway on the eastern side of the state, engineers considered re-routing I-40 on the west from its planned route along U.S. 66 through Needles, California, to a route further north that connected with proposed Interstate 15 in southern Nevada. Though the revised highway would be shorter and less costly to build, merchants in Kingman and elsewhere along Route 66 protested. They enlisted the support of U.S. Senators from both Arizona and California, requesting that the Needles route be maintained; in 1966 the existing Route 66 line was kept.

Although highway engineers had hoped to complete the 360-mile-long interstate across Arizona by 1972, construction drug on into the 1980s. In 1964 the work was on schedule, with 58 miles complete and 71 miles under construction [Figure 106]. Three years later the highway was halfway complete, with 155 miles done and another 82 miles underway. In 1968 the Flagstaff bypass was complete. I-40 would veer from the route of Route 66 between Kingman and Ash Fork, following a more direct— and safer—route. This was complete in 1975; the Winslow bypass was complete the following year. And once the six-mile segment through Williams was finished in 1984, Interstate 40 through Arizona was complete.

Planning for Interstate 10 outside of the Phoenix area began in 1956. Like Interstate 40, the route followed earlier roads—U.S. Highway 80, which followed the Ocean-to-Ocean Highway, which followed the southern territorial road, which followed the Gila Trail. As the project was being planned in the 1950s, engineers had wanted a straight shot from Phoenix westward to Ehrenburg on the state line. Interests in Wickenburg, which lay on U.S. Highway 60 northeast of Phoenix, argued to be included on the line but were turned down. Construction of the freeway began on the west state line in 1960 and extended for 31 miles past Quartzite to a point called the Brenda Cutoff (so named for an old gas station on the road) [Figure 107]. There it parted ways with U.S. 60, avoided Salome, Wickenburg and Glendale, and pointed east to Buckeye and Phoenix.

Figure 107. Interstate 10, Gold Nugget Exchange (00769) at Quartzite under construction, 1963. Arizona State Archives.

Completed in 1973, the Brenda Cutoff was celebrated by travelers for its saving of time and mileage. Past Phoenix, the route extended southeast through Casa Grande and Tucson, which was rebuilt from the earlier road in 1961-1962. Southeast between Tucson and Benson, the interstate followed U.S. 80. The new route bypassed the section of the Borderland Highway (later U.S. 80) that contained the Cienega Bridge (**08293**) and two Wash Bridges (**08294** and **08306**), built in the 1920s and 1930s. From Benson, the interstate followed the Southern Pacific Railroad eastward through Wilcox to the New Mexico state line, avoiding the southward swing of U.S. 80 through Bisbee and Douglas. The bypass around Benson was opened in 1979 as one of the last segments of I-10 other than parts in Phoenix and Tucson.

Figure 108. Interstate 19, construction of grade separation near Valencia, 1962. Arizona State Archives.

The original territorial north-south road later became U.S. 89 and was eventually incorporated into Interstates 19, 10 and 17 between Nogales and Flagstaff. Beginning at the international port of entry in Nogales, Interstate 19 followed U.S. 89 for one hundred miles to its northern terminus at I-10 in Tucson. The first segments of I-19 completed were short pieces from I-10 to Valencia Road in 1962 and around Green Valley in 1963 [Figure 108]. The freeway between Nogales and Rio Rico was completed in 1974 and between Rio Rico and Green Valley in 1978. The latter marked the completion of Interstate 19.

North of Phoenix, the original territorial north-south road angled northwest toward Prescott and then cut eastward to Camp Verde and north to Flagstaff. Later, when this was incorporated into U.S. 89, the road extended north from Prescott to Ash Fork and then east to Flagstaff. In 1954 S.R. 79 was built between Phoenix and Camp Verde directly and from there to Flagstaff, eliminating Prescott in its route. Interstate 17 followed this latter route. Work began on the freeway in the late 1960s and in 1971 had been completed between Phoenix and Camp Verde. North of that point, the route followed a two-lane road, with full interstate-standard interchanges at the crossroads for several years before completion.

Interstate 15 generally followed the Old Spanish Trail as it cut across Arizona's northwest corner on its way between Spanish settlements in New Mexico and southern California. Later designated in the 1910s as the Arrowhead Trail between Los Angeles and Salt Lake City and in 1926 as U.S. Highway 91, the route angled past Littlefield and upward into Utah. As AHD engineers were planning Interstate 15 in the 1950s, they opted to cut some twelve miles from the U.S. 91 route by passing through the Virgin River Gorge east of Littlefield. The gorge route had additional advantages of lower grades for trucks and scenic views for travelers.

Construction between the Nevada state line and the gorge was undertaken first in the early 1960s, with culverts over Big Bend Wash (**05726** and **05727**) finished in 1962 and overpasses over Black Rock Road (**01115**

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and **01116**) completed three years later [Figure 109]. By that point, construction of the thirty-mile-long freeway in Arizona had been relatively mild, but the gorge proved far more difficult to manage. Standing to benefit far more than Arizona by the interstate connection with southern California, the State of Utah loaned some of its federal highway funds to assist with the construction. The money helped considerably. Terrain in the gorge was difficult to negotiate, the Virgin River required several bridged crossings, and flash flooding and quicksand caused perpetual problems, "with equipment and materials disappearing overnight." In October 1969 a helicopter performing reconnaissance in the canyon crashed, killing the pilot.

Work proceeded slowly in the late 1960s and early 1970s; in 1973 the last of the five bridges was complete. *Arizona Highways* stated at that time that the highway "enhanced rather than distracted from Nature's handiwork." The Virgin River Gorge was touted as the most scenic highway in Arizona. It was certainly the most expensive. Between the multiple bridges and rechanneling of the river, the road cost approximately $10 million per mile—the costliest rural freeway in America at the time of completion.

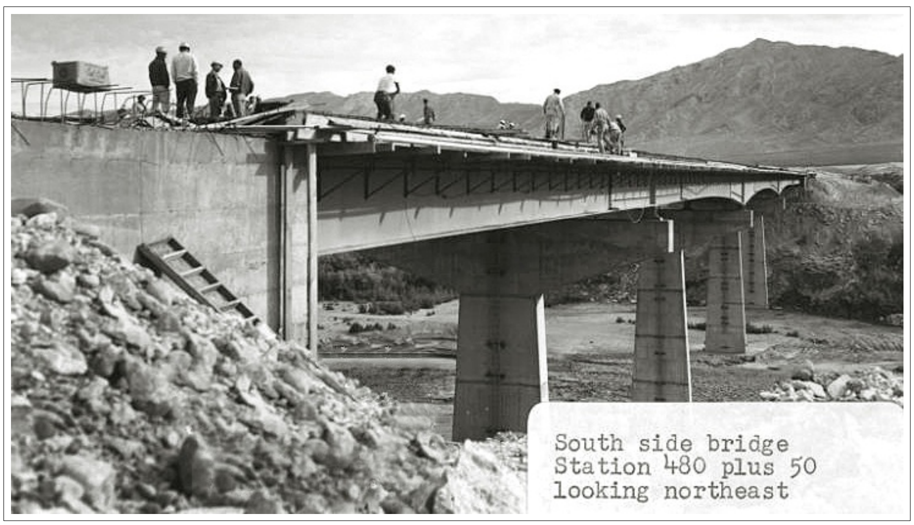

Figure 109. Construction of Virgin River Bridge on Interstate 15, 1963. Arizona State Archives.

Bridge design and construction in Arizona after World War II followed national trends, with an emphasis on small-scale concrete drainage structures. The Arizona Highway Department used AASHO standard designs for its box culverts, concrete slabs, concrete girders and rigid frame bridges. Their design changed incrementally from the 1930s, with the modifications occurring in the form of steel reinforcing, substructural design (e.g., driven concrete piles under bridge piers and abutments), roadway width and guardrail configuration. With four years' catching up to do and an entire state to cover, the focus was on rapid construction of highways with economical drainage structures. It was not a memorable period for bridgework. Of the three dozen structures identified in the inventory from 1946, the first full year after war's end, thirty-three were concrete box culverts, two were concrete slabs, and a single bridge—the Pine Creek Bridge (**00283**) in Gila County—was a modestly scaled rigid frame. With a span length of only 50 feet, it was the longest bridge of the year.

Figure 110. Pinto Creek Bridge (00351), 2003.

Over the rest of the decade, the overwhelming majority of structures—over 90 percent—were concrete box culverts or simple concrete slabs. A few simply supported steel stringer bridges were built, none of which exceeded seventy feet in span length. AHD did manage to erect at least two structurally adventurous structures during the period. Without question the most noteworthy structures in the inventory from the late 1940s were the Pinto Creek Bridge (**00351** [Figure 110]) and the Queen Creek Viaduct [**00406**] , both built on U.S. Highway 60 between Superior and Miami. Designed in 1947 by Ralph Hoffman and completed in 1949, these nearly identical, long-span structures featured two-hinge, girder-ribbed deck arch superstructures. They had been modeled after the Salt River Canyon Bridge, the state's first such structure. Both were handsomely detailed and configured and dramatically set in picturesque canyons. The Pinto Creek Bridge won an award from the American Institute of Steel Construction as the most beautiful bridge in America in its class.

The early 1950s marked a continuation of the 1940s in terms of bridge construction in Arizona, with little that was innovative or even memorable. The noteworthy exceptions to this were the Benson Bridge (**00350** [Figure 111]), a cantilevered plate deck girder bridge built in 1950 over the San Pedro River in Cochise

Figure 111. Benson Bridge (00350), 2018.

County; the Guthrie Bridge (demolished), a long-span cantilevered deck truss erected over the Gila River in 1950 in Greenlee County; the Clear Creek Bridge (**01038** [Figure 112]), a girder-ribbed steel arch built in 1951 in Navajo County; and the Hell Canyon Bridge (demolished), a cantilevered steel deck arch built in 1954 in Yavapai County. Trusses, arches, girders—all of Arizona's significant steel structures from the post-war years involved cantilevering, which had been Ralph Hoffman's trademark engineering style since the Allentown Bridge in 1923.

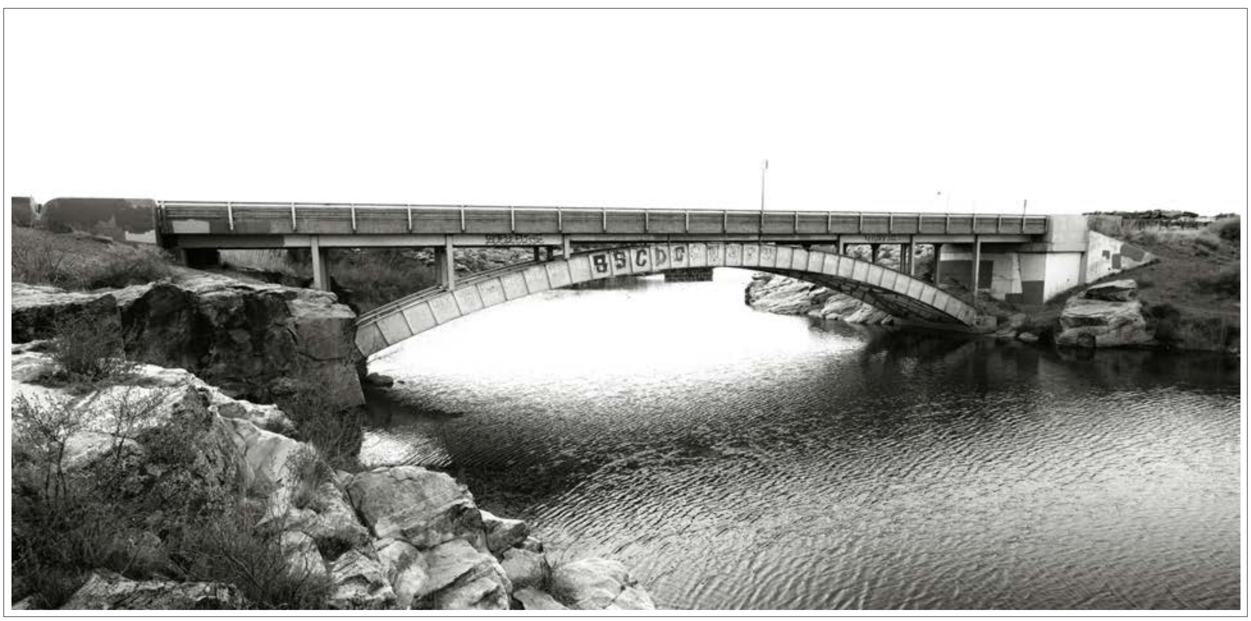

Figure 112. Clear Creek Bridge (01038), 2018.

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Figure 113. Glen Canyon Bridge (00537), 2018.

Though more structurally sophisticated than their predecessors, these recent bridges are far less graphic and have little to distinguish them technologically. The significant bridges from the late 1950s and early 1960s are all singular structures that depart from standard design trends. These include the Glen Canyon Bridge (**00537** [Figure 113)], a large-span steel arch built over the Colorado River in 1958 by the U.S. Bureau of Reclamation; the Burro Creek Bridge (**00846**), a long-span steel arch completed in 1965 on U.S. 93 in Mohave County; the Cameron Truss Bridge (demolished), a cantilevered deck arch built next to the Cameron Suspension Bridge in 1959; and long-span welded steel girder bridges over Black Canyon (**00758** [Figure 114]) and Wilbur Canyon (**00781**) in Yavapai County.

Figure 114

Construction of the interstate highway network in the state marked a watershed in bridge design, both in the number of structures built and their configurations. The interstates required construction of numerous over- and underpasses at their interchanges. For these and at other crossings in the 1940s, 1950s and 1960s the highway department employed AASHO standard designs for a new array of concrete/steel structural types—precast box beams, prestressed concrete girders and twin tees, which eventually superseded its previous structural types.

In 1945, following passage of the Federal-Aid Highway Act, AASHO had developed and distributed its first standards for freeway bridge construction. These were followed by revised subsequent editions in 1949, 1953, 1957, 1961, 1965 and 1969. "The vast amount of research and development in both steel and concrete structures practically dictates the necessity of revising the specifications every three or four years," AASHO stated in its 1957 revised edition. AASHO promulgated its specs widely among the engineering profession. "The Specifications for Highway Bridges are intended to serve as a standard or guide for the preparation of State specifications and for reference by bridge engineers," AASHO stated. "In the case of a number of States, the specifications have been adopted as basic, subject to certain supplemental specifications which embody provisions designed to meet the local needs of the State in question."[89] Arizona was among the states that employed the AASHO guidelines as its state standard.

Reflective of the limited-access highways then beginning to appear in the United States, these standards called for wider roadways, streamlined steel or concrete railing, greater horizontal and vertical clearances for grade separations and deck type superstructures. To meet these new standards, post-World War II engineers adopted alternative construction techniques, modifying existing structural types and developing new structural configurations such as prestressed concrete and welded steel girders. Continuous construction, with beams extending continuously over one or more intermediate supports, proved much more efficient structurally than simply supported beams, and it lent itself readily to long-span applications.

Engineers also began utilizing composite steel beam design, first developed in the early 1940s. In composite construction, shear connectors bond the concrete deck slab to the superstructural beams, allowing the deck to function as a structural member to carry the live loads and thus permitting more efficient superstructural design. Further, new structural materials were developed during the post-war period that would transform bridge engineering in the 1960s, 1970s and to the present. Without question, the most significant development involved prestressed concrete. First invented in the 1940s, prestressing utilized highly stressed steel

[89] American Association of State Highway Officials, *Standard Specifications for Highway Bridges* (Washington, DC: AASHO, 1957), XXIII-XXIV. The 1965 *Standard Specifications* (AASHO, *Standard Specifications for Highway Bridges* (Washington, DC: AASHO, 1956) further stated their intent:

> Primarily, the specifications set forth minimum requirements which are consistent with current practice, and certain modifications may be necessary to suit local conditions. They apply to ordinary highway bridges, and supplemental specifications may be required for unusual types and for bridges with spans longer than 500 feet.

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rods or wire to apply compressive forces into concrete to offset tensile stresses, permitting the structure to carry much greater loads more efficiently [Figure 115]. The first prestressed beam bridges appeared in Arizona in the 1950s, and by the 1960s the structural type had found relatively widespread use in the state.

Figure 115. Prestressed concrete bridge girders, Interstate 19, 1963. Arizona State Archives.

Another new structural material that found widespread acceptance during the period was welded steel. Although first developed in the 1920s, welded steel superstructures were not permitted on Federal Aid bridges prior to 1945, due to problems with the strength and durability of their welds. To accommodate the huge numbers of interstate highway bridges and grade separations underway in the 1950s and 1960s, manufacturers were prompted to develop a stronger, weldable steel and new shop-welding techniques. In Arizona relatively few welded girder bridges were built.

Similar advances occurred in concrete bridge design during the period. Concrete prestressed girders, concrete box girders and segmental concrete box girders all received early use in the 1950s and 1960s. Additionally, engineers were prompted to modify cast-in-place bridge design to address highway safety concerns. To eliminate bridge piers adjacent to highway shoulders, highway engineers were required to cut the number of spans of a typical interstate grade separation to three or four. This resulted in longer spans than had previously been used on Arizona's highways.

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 their overall design was influenced by the fact that they had to accommodate traffic both on top of the

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structure and passing underneath. The AASHO *Policy on Geometric Design of Rural Highways* describes their design:

> 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.[90]

With the exception of a handful of timber stringer structures, all of the bridges and grade separations from the 1959-1978 period are comprised of steel and/or concrete in some form or other. Among those, other than a dozen steel pipe culverts, all of the structures in this inventory employ beams, slabs or rigid frames for their superstructures. These include rolled I-beams, built-up steel girders, concrete slab-and-girders, concrete rigid frames (including box culverts) and concrete prestressed girders and box beams. All the concrete structures employ steel reinforcing bars encased within the concrete to resist tension loads. In the majority of these, called cast-in-place concrete structures, the concrete is poured around the steel bars on the site and formed into superstructural shapes (t-beams, girders, slabs, frames) created by temporary wooden or steel formworks, which are later removed after the concrete has cured (i.e., solidified). Prestressed concrete brid-

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

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ges may be similarly poured in place or they may be precast and moved onto the site. In either case, tension is applied to the steel bars at some point during the concrete curing or installation process.

Steel beams are comprised either of rolled I-beams–poured in molten state and rolled out into structural shape in steel mills and later shipped to the site for installation–or of built-up girders comprised of several parts that are riveted, bolted or welded to form the structural shapes in a fabricating plant and moved to the site for installation. Without the need for falsework construction and curing time, steel is more straightforward in its fabrication and installation than concrete, and steel beam or girder bridges are more generally rapidly assembled than reinforced concrete bridges.

Both steel and concrete superstructures from the 1950s, 1960s and 1970s invariably incorporated reinforced concrete decks to carry vehicular traffic. In the majority of bridges, the deck acts independently of the superstructural beams to allow differential expansion and contraction. If the deck is just resting on top of the superstructure and has no means of transferring longitudinal shear from primary members to the deck, then it does not assist in the resistance of bending moments induced by vehicle loading. Such decks are termed traditional or noncomposite. In a small number of bridges from the subject period, the deck is attached rigidly to the beams to contribute to the load-carrying capacity of the bridge, in what is called composite construction. Composite construction offers a more efficient use of materials since the size of the superstructural members can be reduced significantly due to the incorporation of the deck into the resisting cross-section properties. Additionally, it offers an ability to sustain greater vehicle loading and reduce live load deflection. Finally, composite construction permits greater vertical clearance by reducing stringer depth. Highway departments first incorporated composite deck construction on vehicular bridges during the 1950s; by the 1970s it had gained widespread acceptance.

All structures but the smallest box culverts featured guardrails or railings along the edges of the spans for the protection of vehicular and/or pedestrian traffic. According to AASHO: "Where the primary purpose of traffic railing is to contain the average vehicle using the structure, consideration should also be given to protection of the occupants of a vehicle in collision with the railing, the protection of other vehicles near the collision and to appearance and freedom of view from passing vehicles." The Standards continued:

> Preference should be given to providing a smooth, continuous face of rail on the traffic side with the posts set back from the face of the rail. Structural continuity in the rail members, including anchorage of ends is essential. Open joints in the railings, together with a reduced post spacing, or bolted or welded splice material in the rails, will be considered to provide the continuity. The railing system shall be able to resist the applied loads at all locations.[91]

AASHO allowed concrete, metal, timber or combinations of the three to be used for bridge rails. In Arizona, steel was the overwhelming favorite material in the historic period. Both traditional and composite decks

[91] American Association of State Highway Officials, *Standard Specifications for Highway Bridges* (Washington, DC: AASHO, 1966), 5.

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were bounded along their outer edges by concrete curbs or spandrels, to which metal (steel or aluminum) beam guardrails were attached by means of structural steel posts attached to steel anchor bolts cast into the concrete. During the late 1950s and early 1960s, these posts were bolted to the sides of the spandrel walls. By the mid-1960s, this configuration had changed, however, with the posts bolted on top of the curb. The spandrel connections have since been replaced with curb connections on the majority of the early structures, resulting in subsequent replacement of the original guardrails with Thrie beams or heavier steel beams or tubes. Similarly, concrete Jersey barrier-type guardrails have been used in recent years to replace many original guardrails, both metal and concrete.

The numerous grade separations built on Arizona's freeways in the 1950s, 1960s and 1970s generally adhered to a few functional and aesthetic 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 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.