HISTORIC HIGHWAY BRIDGES IN MARYLAND: 1631-1960:

HISTORIC CONTEXT REPORT

Prepared for:

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A Note on Quantification

Although quantification of results is anticipated to be included in the comprehensive survey of Maryland's historic bridges, this historic context report does not include detailed tabulations or numerical counts of historic bridges within the state. Such tabulations and numerical totals have not been included because any counts based upon existing sources of data would be flawed.

Existing data sources on historic bridges include the following:

- Prior historic resource survey forms, including those generated during the 1980-1981 State Highway Administration bridge survey.

- The 1993 *Bridge Inventory*, published by the State Highway Administration Office of Bridge Development, which lists all state-owned bridges in Maryland.

- The 1993 list of county-owned bridges in Maryland, a computer database located at the Office of Bridge Development of the State Highway Administration.

While each of these sources has been used in preparation of this historic context report, each source possesses serious limitations if it is to be used to provide definitive numerical data for extant historic bridges. These limitations include the following:

- Prior historic resource survey forms are not up to date regarding the existence or condition of bridges described and do not include consistently detailed bridge descriptions or photographs.

- The 1993 *Bridge Inventory* does not offer detailed or exact identification of bridge types for historic resource tabulation purposes. Metal truss bridges, metal girder bridges, and concrete arch bridges are not distinguished by type or subtype. Additionally, the *Bridge Inventory* lists only state-owned highway bridges and does not indicate how post-construction repairs may have affected the historic fabric of older bridges.

- The 1993 list of county-owned bridges in Maryland includes only county-owned spans and does not adequately distinguish the types and subtypes of historic bridges. A large number of bridges on the list are of unknown or undetermined construction date; many of those are listed simply as "1900" or "Pre-1900."

Without verification of bridge types, construction dates, and existing conditions resulting from field survey, numerical tabulations are meaningless. The cumulative result of the database limitations is to preclude reliable use of the resources to tabulate historic bridge types without results of a field survey.

A Note on Culverts

A final introductory note is necessary regarding discussion of culverts in the following report.

The 1979 Federal Highway Administration *Bridge Inspector's Training Manual* included the following definition of culvert

> A small bridge constructed entirely below the elevation of the roadway surface and having no part or portion integral therewith. Structures over 20 feet in span parallel to the roadway are usually called bridges, rather than culverts; structures less than 20 feet in span are called culverts even though they support traffic loads directly [U.S. Department of Transportation 1979:G-13].

Culverts are concisely discussed in the Concrete Bridges section and referenced in the Stone Arch Bridges section of this report. Whether culvert structures are to be included in the comprehensive survey of historic bridges in Maryland will be decided prior to such survey. The technology applicable to bridges is transferable to culverts.

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SECTION I: INTRODUCTION

Since the seventeenth century, bridge building in Maryland has proceeded in direct association with the expansion of the region's transportation network. The history of Maryland's significant bridges is in large part a narrative of successive, or sometimes concurrent, engineering solutions to the problem of effectively carrying a valued transport route (usually a road, but during the nineteenth century, often a canal or railroad) across a valley, body of water, or another transport route. In Maryland, a state characterized by varied topography ranging from the Tidewater inlets of the Eastern Shore through the hilly Piedmont terrain to the Appalachian mountains, the development of an adequate transportation system involved meeting the challenges of geography (Mitchell and Muller 1979). Consideration of Maryland's transportation history, in light of the varying topographic conditions prevalent in each region, thus aids understanding of the state's historic bridges and bridge building traditions.

Besides topography and geography, an equally important factor affecting the bridges built in Maryland has been the governmental role in transportation policy, generally constant despite many changes of government. During the early seventeenth century, the European settlement of the area was fostered by the Calvert proprietors and their appointive governors, but the earliest laws concerning transportation were passed by the General Assembly (first convened in 1635 at St. Mary's City) and put into effect by county officials. Initial administration of road work by counties occurred as early as 1642, when the legislature formed Kent County (Brugger 1988:13-14, 799). Although transportation policy goals have changed considerably from the 1630s to the twentieth century, the basic role of both the state government and local officials with regard to roadmaking and bridge building has persisted down to the present day.

A third important influence on the kinds and numbers of historic bridges seen in the state has been the extraordinary series of technological changes affecting the building of roads, canals, railroads, and their attendant structures such as bridges. With the development of cast iron, wrought iron, and finally concrete and steel, the traditional preindustrial bridge construction materials--timber and stone--came to be simply two options available to professional engineers, rather than the only possible choices in constructing durable spans. The coming of improved roads, lock canals, and long railroads in Maryland spurred the popular demand for similarly improved transportation facilities, and this demand in turn, fostered the rise of the American civil engineering profession. Many of Maryland's historic bridges display a deliberately engineered "intermodal" aspect, allowing combinations of water navigation and highway and rail traffic. Historically significant bridge engineers active in Maryland have included Theodore Burr, Lewis Wernwag, James Finlay, Benjamin H.B. Latrobe, Wendel Bollman, C. Shaler Smith, J.E. Greiner, and Daniel B. Luten.

A careful, chronological consideration of these three historic forces--the impact of topography and geography on the development of Maryland's transportation network, the shaping of that network by legislative and county actions, and the revolutionary technological and engineering advance--provides an overall background context which serves to introduce and place within history the variety of historic bridge types found in Maryland. The following narrative section of this report summarizes Maryland's transportation history, placing emphasis on major events and trends that significantly affected bridge design and construction in the state. The seven subsequent sections describe the historical development and appearance in Maryland of significant historic bridge types. Appendix A offers historical timetables relating to Maryland history and the development of bridge technology while Appendix B presents a descriptive listing of bridge builders known to have been active in the state. Appendix C presents guidelines for the identification and evaluation of Maryland's historic bridges.

SECTION II: MARYLAND TRANSPORTATION HISTORY

THE EARLY TRANSPORTATION NETWORK, 1631-1800

Geography's Influence

Maryland's distinctive physiography has greatly influenced the development of its transportation network. The is divided into Tidewater, Piedmont, and Appalachian Plateau geographic regions. The Tidewater, or Coastal Plain, area, including the Maryland portion of the so-called "Delmarva" peninsula between Chesapeake Bay and the Atlantic Ocean, as well as parts of Southern Maryland watered by tributaries of the Bay, is characterized by mostly flat or gently undulating terrain crisscrossed by partly tidal streams and rivers such as the lower Patapsco, the lower Patuxent and the Potomac, the Severn, and the Choptank and Nanticoke rivers. Between the fall line and the mountains of western Maryland lies the variegated Piedmont region; in this region the waterways feeding Chesapeake Bay have cut valleys in hilly terrain where Maryland's major building stones, including granites, sandstones, marbles, and slates are found (Maryland Geological Survey 1990). Lastly, the mountainous region of the westernmost sections of Maryland forms part of the steep Appalachian Plateau, a significant American geographic feature marking the first "continental divide" (the only one east of the Mississippi) encountered by road-builders seeking to link Maryland to the Midwest and the West (Mitchell and Muller 1979:1-2) (Figure 1).

Maryland's primarily Tidewater counties include the "Eastern Shore" counties of Worcester, Somerset, Wicomico, Dorchester, Caroline, Talbot, Queen Anne's, and Kent, and the counties of St. Mary's, Calvert, and Charles, west of the Chesapeake Bay. Parts of Cecil, Harford, Baltimore, Anne Arundel, and Howard counties below the fall line also belong to Tidewater territory. These counties also include Piedmont topography, which characterizes all of Carroll County, and nearly the whole of Montgomery County. Baltimore City, encompassing both the lower Patapsco valley (including Baltimore Harbor) and the reaches of Jones Falls and Gwynns Falls above the fall line, is also a mixed Tidewater/Piedmont area. The western counties of Washington, Allegany, and Garrett are in the Appalachian Plateau; but Frederick County straddles the Piedmont and Appalachian regions (Mitchell and Muller 1979:i, 1-2) (Figure 2).

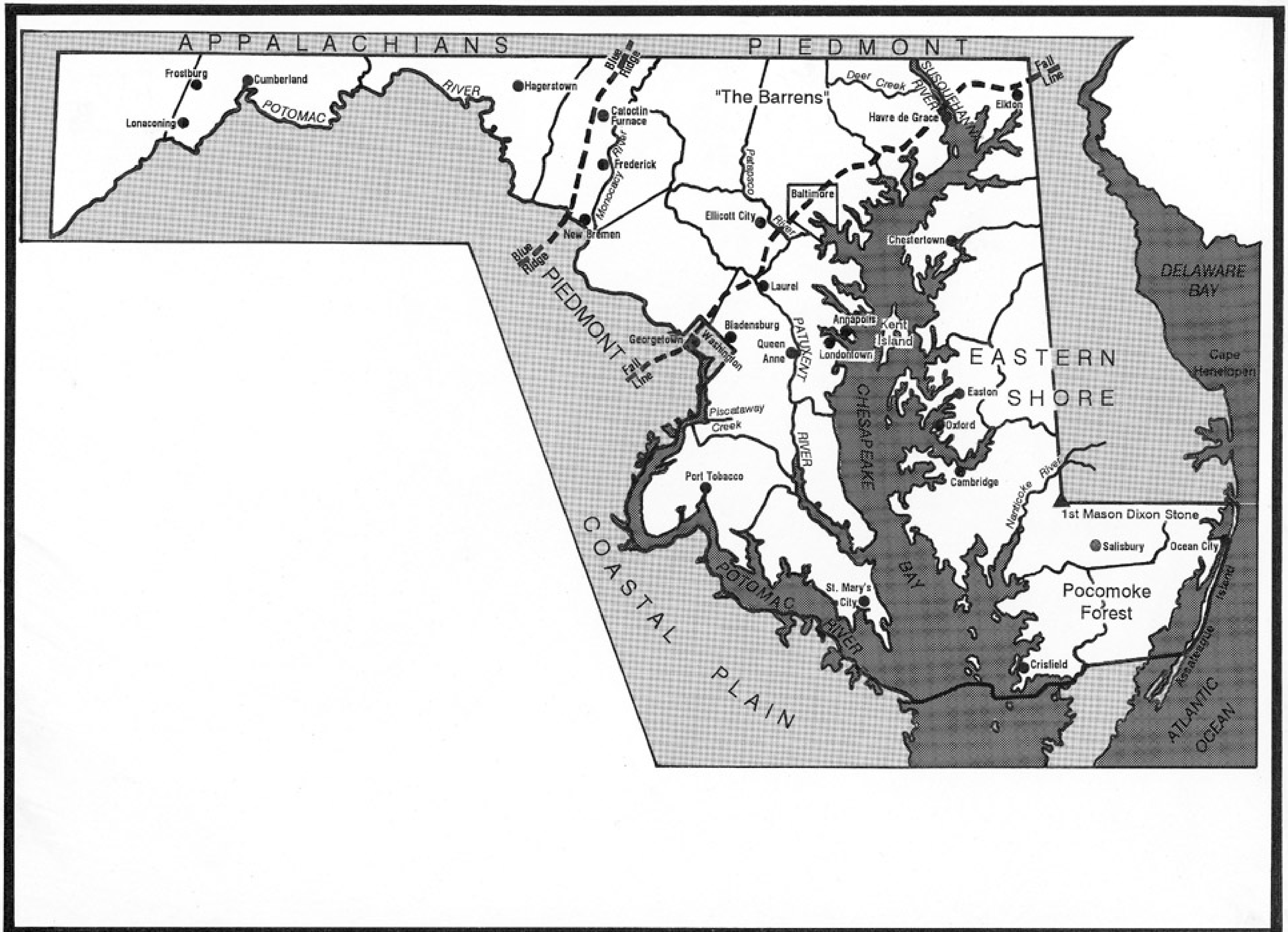

FIGURE 1: Maryland Geographic Regions

SOURCE: Mitchell and Muller 1979

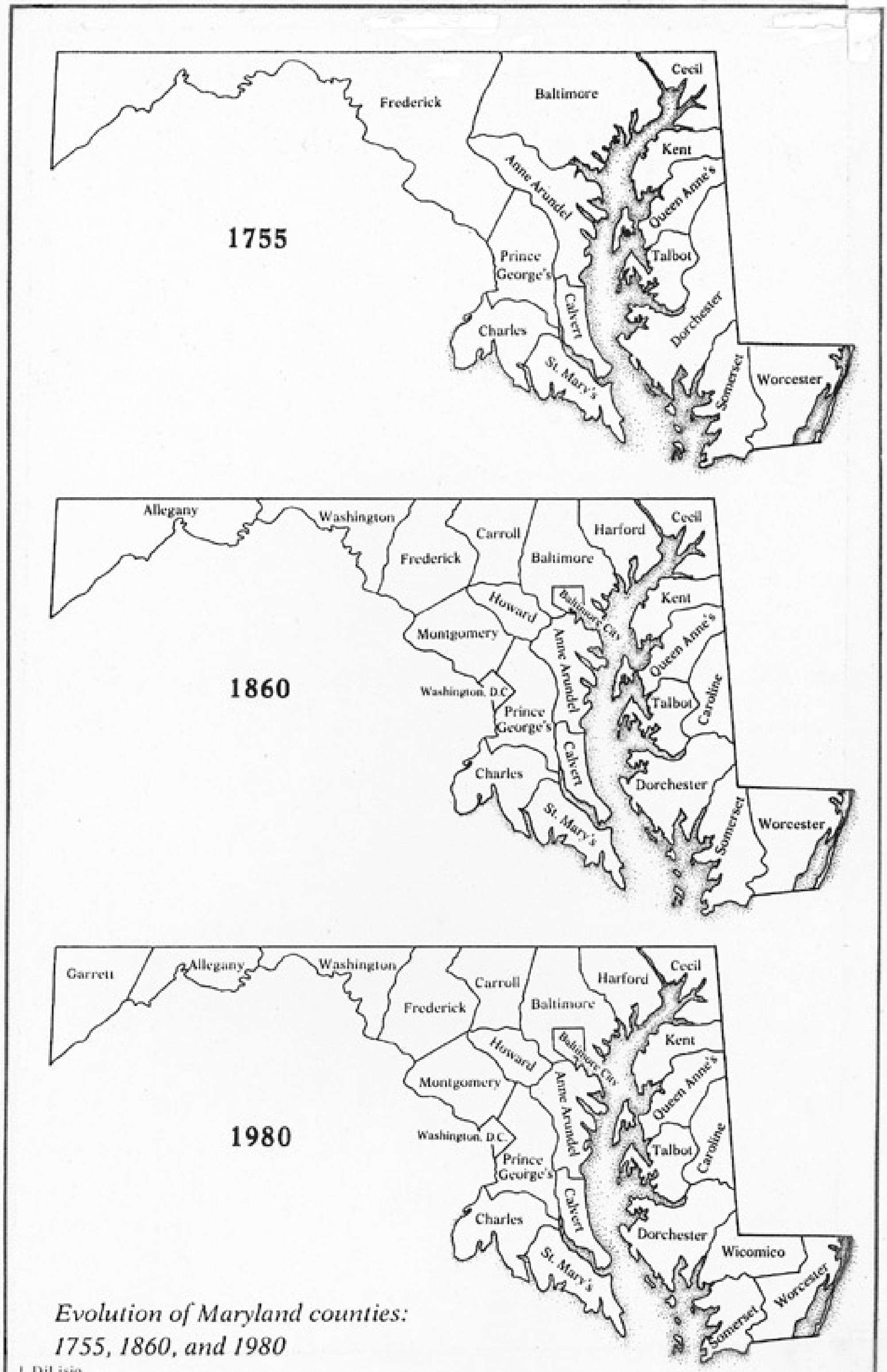

FIGURE 2: Evolution of Maryland Counties: 1755, 1860, and 1980 SOURCE: Brugger 1988

The Early and Continuing Importance of Waterways

The earliest transport routes in Maryland, followed the courses of least topographic resistance, whether overland or waterborne. The Piscataway Indians of the Algonquian group as well as their less pacific neighbors to the north, the Susquehannocks, were canoeists and trailmakers of long experience at the time of the first European settlement of Maryland by Virginia adventurer William Claiborne on Kent Island in 1631 (Brugger 1988:10-12). The many navigable rivers and streams of the Chesapeake watershed were known to the Native Americans and constituted the primary means of access into most parts of Maryland below the fall line during the settlement and early colonial eras. Early travelers' accounts, such as those written by Jesuit missionary Andrew White and Cecil County settler Augustine Herrman, all emphasize the general availability of water transport, while deploring the lack of reliable overland routes (Hall 1967:25-46, 131-135, 309-332). Some Indian trails were still in place during the colonial era; the "Seneca Trail" linking the Potomac and Susquehanna crossed the present lower Patapsco near Elkridge (Travers 1990:27) and early Baltimore and Cecil county court records and deeds refer to "old Indian roads" in those counties (Marye 1920, 1921).

Reflecting pioneers' customary reliance on navigation, no map of the Maryland colony prior to the 1755 Fry and Jefferson map of the Chesapeake area depicted roads (Quinn 1982:296-297). Despite the relative ease of waterborne travel, however, a large overland transport network, complete with some major post routes and an array of county roads, developed during the first century of European settlement (1631-1750). From an early date, the General Assembly acted to facilitate transportation among the many farms and towns founded in response to Maryland's popularity among English and (beginning in the early eighteenth century) German emigrants. A 1637 act for public ports was refused assent by Lord Baltimore, but in 1639 the legislature chartered a "ferry upon St. George's River," the main waterway into the early St. Mary's settlement (Riley 1905:8-9). In 1658, the county courts, already recognized as important Maryland transportation planners, were authorized to "establish ferries where necessary and to appoint ferrymen" (Riley 1905:31). Regular ferry service was also the subject of a 1664 law and much subsequent legislation (Riley 1905:38).

Early Roadways, 1631-1700

Although navigation persisted into the present century as an important facet of Maryland's transportation history, the continued press of settlers throughout the seventeenth and eighteenth centuries increased the need for official regulation of roadbuilding activity. In 1661, the General Assembly laid the groundwork for regular postal service with an "Act for the Conveyance of All Letters Concerning the State and Public Affairs" (Riley 1905:33). Five years later, the Assembly passed Maryland's first comprehensive general road law, for "marking and making highwayes and making the heads of Rivers, Creeks, Branches and Swamps passable for horse and foot" (Browne 1884:134-135). The 1666 act mandated that roads should be marked, indicated that crossings should be placed at the head of navigation of each body of water, and delegated roadmaking responsibilities to road overseers appointed by the counties. The law also safeguarded the right to make private access roads to farms and mills, and established a road work system that included the imposition of penalties payable in tobacco, already the marketable staple of colonial Maryland.

The basic 1666 act was periodically repassed, with amendments, throughout the seventeenth century. The 1671 version, which allowed county commissioners or "justices" to meet to lay out or amend roads any time between September 1 and October 20 of each year, was renewed in 1684 (Browne 1884:219-220, 321-322; Browne 1894:486-487). As settlement progressed toward the fall line and Native American territory was penetrated, special laws created a corps of rangers to patrol the fluid frontier. A 1696 order of the governor's council enjoined the rangers to "make and marke severall paths & that the Road which they find to be the best and nighest Road, that they double marke the same" (Browne 1900:381). Rangers such as John Oldton thereafter filed reports on their roadmaking. In 1921, historian William B. Marye traced such rough "Garrison Roads" in Baltimore County, which as late as 1755 embraced the entire area between the Patapsco and the Susquehanna (Brugger 1988:772; Marye 1921).

The 1696 order presaged a road-marking law of the same year (copies of which have not survived) and a new general road law of 1699, which set up a province-wide system of road marking and, for the first time, required "that all Publick and main roads be hereafter Cleared and well Grubbed fitt for Travelling Twenty Foot wide and good and Substantiall bridges [be] made over all heads of Rivers, Creeks, Branches and Swamps" at the discretion of county justices of the peace (Browne 1902:475-477). The road-marking system, which mandated three notches on a convenient tree for any road leading to a ferry, may have been derived from English precedent (Matthew Simons's 1635 *Directions for English Travellers* noted that directional signs were found in England, especially "in many parts where wayes be doubtful") (Lay 1992:189). Maryland's road-marking system of 1699 has been acknowledged by historians of public works as the earliest such system in the United States (Armstrong 1976:123).

The 1699 law, with its significant bridge building and roadmaking provisions, was repassed with little change in 1704 to become (with many subsequent amendments) the basic road act of colonial and early post-colonial Maryland (Kilty 1808:September 1704 Session, Chapter 21). Ample evidence exists that, by 1699, roadmaking activity in Maryland, and probably bridge building also, was well underway. Notable early roads included a 1643 (or earlier) "road by land through the forest to Virginia" from St. Mary's City (Sioussat 1899:110 note 4); this may have been incorporated into the 1650s' road leading from the early capital to settlements along the lower Patuxent River (Sioussat 1899:110-111). Between 1671 and 1684, Cecil County landowner and cartographer Augustine Herrman laid out "cart roads" linking the Delaware and Elk rivers, and leading south toward the "Great Choptank" River; Herrman's roads, and their counterparts on the western shore of the Chesapeake Bay, became the template for early post roads by 1700 (Sioussat 1899:117-118).

Concerning early bridges, a 1697 summary of roads built in Charles County noted "ye bridges over Piles his fresh branch" ("Piles" apparently being a reference to a landowner rather than a substructure erected on piles) and "ye bridges over Zachyah Swamp," a perennial source of travel problems over which the legislature mandated an unspecified "crossing" as early as 1674 (Sioussat 1899:122). The 1697 Charles County roads summary, and a 1694 Baltimore County court proceeding recommending "good and sufficient bridges for man and horse to pass over," are the earliest known documents referencing the construction of bridges in Maryland (Sioussat 1899:117, 122).

Colonial and Early National Transportation, 1700-1800

By the first decades of the eighteenth century, Maryland's transportation system consisted of numerous navigable waterways (Augustine Herrman's great 1683 map gave depth soundings for many of them), and a rapidly growing network of roads (Gould 1915; Quinn 1982:290-293) (Figure 3). Attesting to the influence of the General Assembly's 1699 and 1704 road-signing provisions, "three notch'd roads" (leading first to ferries, then in some cases to bridges) are known to have existed in Prince George's County, Baltimore County, and St. Mary's County (Sioussat 1899:120-121). The "good and substantial" bridges desired were also being built; although evidence is scanty concerning their construction, these structures were evidently of timber. As the tobacco-boom economy moderated somewhat and Maryland agriculture diversified, eighteenth century Maryland witnessed further official efforts to improve roads and bridges, as well as aid the counties in their continuing administration of transportation policy and road work (Gould 1915:123-169). In the General Assembly, these efforts culminated in enactment of the first Maryland turnpike legislation, a new general road law, and the earliest recorded state law mandating a movable-span bridge at a commercially strategic site.

The importance of road overseers and road and bridge maintenance was fully recognized by the legislature, which in 1715 exempted "overseers of highways" from jury duty (Kilty 1808:April 1715 Session, Chapter 37). Strong evidence concerning the prevalence of simple timber beam bridges in early eighteenth century Maryland comes from a 1724 law which gave overseers the right to confiscate for bridge repair any suitable trees on adjacent lands, provided that such trees "be such as are not fit to make clapboards, or cooper's timber, nor for the building or repairing any bridges that are built and maintained at a public or county charge" (Gould 1915:136). The 1724 act also noted that "the several bridges that have been heretofore over the heads of rivers, creeks, branches, swamps, and other low and miry places, are very much broken and out of repair, and several new bridges are still wanting" (Gould 1915:136). The 1724 law was renewed in 1751: not until 1795 did the state grant compensation to the owners of timber confiscated for use in repair or erection of bridges (Gould 1915:136).

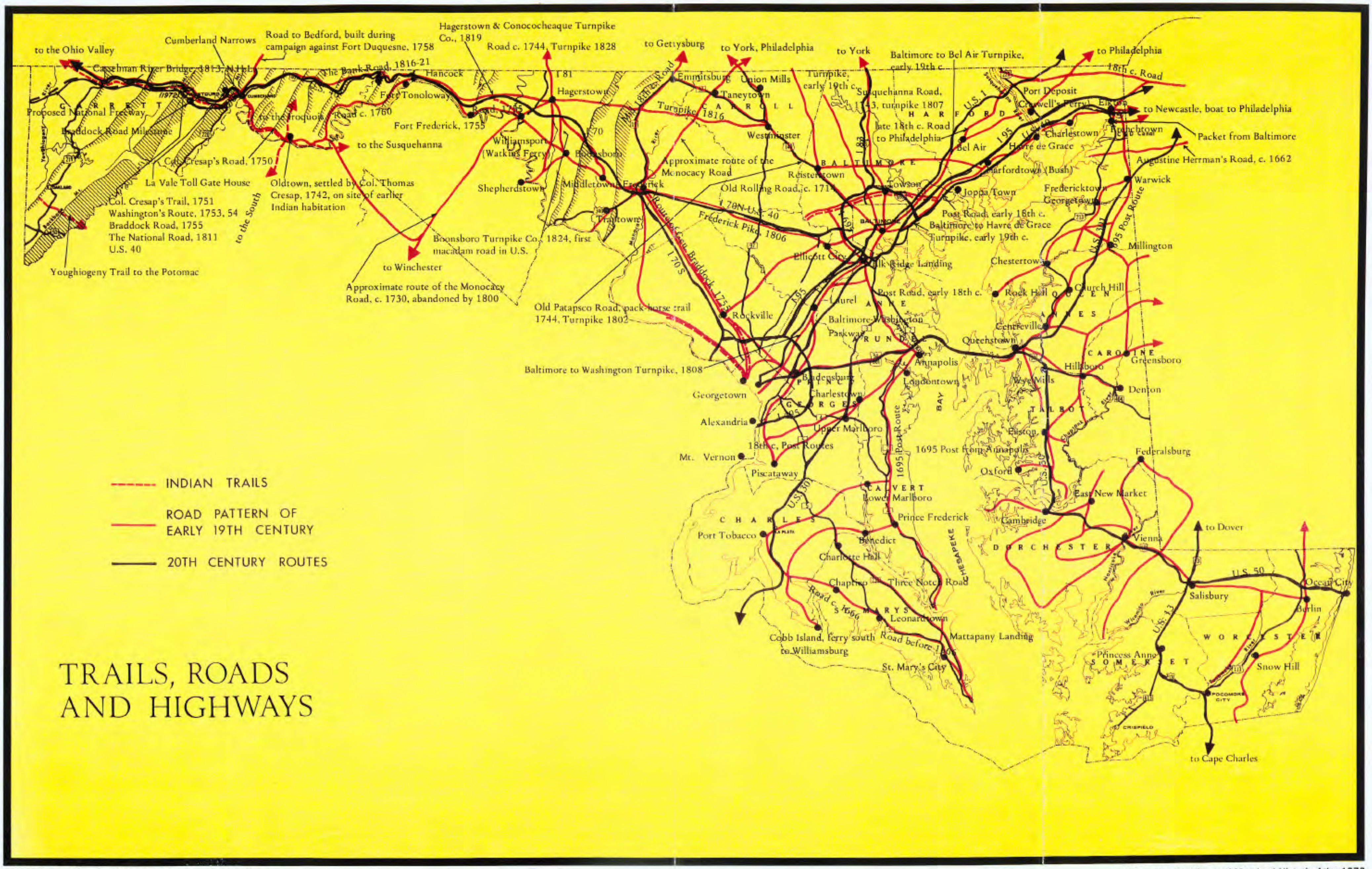

FIGURE 3: Maryland Trails, Roads, and Highways

SOURCE: *The State of Maryland Historic Atlas* 1973

The major roads built during the 1700-1800 period were almost exclusively county or privately built and maintained farm roads, but the counties, like the General Assembly, responded to economic pressures and developing patterns of emigration, settlement, and trade (Sioussat 1899:119-125). The principle of least geographic resistance demanded that the earliest major north-south routes pass through Maryland on either side of the Chesapeake Bay. Probably in existence by 1720, these north-south roads served as early overland links between Philadelphia and Virginia and were described by transportation historian Clarence Gould:

> One branch ran down the Eastern Shore, crossed the Elk River at Bohemia Manor, thence to Frederick and Georgetown on the Sassafras River, thence to Chestertown on the Chester River, thence either to Rock Hall or east neck island on the bay side of Kent County and by boat to Annapolis, or across the river at Chestertown and down through Queen Anne's County to Kent Island, where a boat was taken for Annapolis. The other branch of the road [from Philadelphia] reached Annapolis around the head of the bay, running past the head of Elk River to North East, to Susquehanna ferry near Port Deposit, to Joppa, to Baltimore, thence either across the Patapsco at Ferry Bar or around by Elk Ridge, and to Annapolis. A little way from Annapolis, the road again divided, one branch crossing the Patuxent at Queen Anne Town and leading to Upper Marlboro and Addison's ferry opposite Alexandria, and the other crossing the Patuxent at Nottingham and passing through Piscataway to the main ferry across the Potomac near the mouth of Pope's Creek [Gould 1915:125].

As Maryland colonial settlement progressed westward, the "Great Wagon Road" and its offshoots were gradually extended by the 1730s from the key port of entry at Philadelphia into the Maryland hinterland between Frederick and Hagerstown (Rouse 1973). Numerous settlers, especially the so-called "Pennsylvania Germans" of German or Swiss heritage, utilized these routes into the rich farm valleys of western Maryland. Meanwhile, Prince George's County by 1739 had a network of more than fifty roads and had authorized a road up the Potomac Valley to the mouth of the Monocacy River (Pearl et al. 1990). The latter location, from an early date the site of a large grain mill as well as an important ford of the Potomac, was linked to Baltimore by the 1750s. Roads which today bear names such as "Monocacy Road" and "West Old Baltimore Road" in Montgomery and Frederick counties are legacies of this trade pattern involving carriage of goods from Virginia through "Mouth of Monocacy" to Baltimore Town, founded in 1729 but greatly boosted by this western overland connection (Lubar 1991:19-26).

In the far western portion of Maryland, military action during the French and Indian War occasioned the building of Braddock's Road in 1755, linking Fort Cumberland, near present-day Cumberland, with the Pittsburgh region through what are now Allegany and Garrett counties. Braddock's road remained a rough route west until it was superseded in the early nineteenth century by the largely parallel National Road, the first federally built road in the United States. The Cumberland vicinity was also linked during the 1750s by a military road to Fort Bedford (at modern Bedford, Pennsylvania), where British troops mustered for the 1758 attack on the French Fort Duquesne (at present Pittsburgh) (Leviness 1958:13-17).

The Tidewater and lower Piedmont regions, by contrast, were characterized by the tobacco-related "rolling roads." There were also overland portage routes at locations in Cecil County and Talbot County where the navigational heads of Delaware River tributaries and Chesapeake Bay feeders were only a few miles apart (Gould 1915:127-128, 142-144). Large casks of tobacco were rolled by main force, or pulled by draft horses, along rolling roads that connected plantations with river landings. By the mid-eighteenth century, although county courts and the General Assembly had long recognized the damaging and cheapening effects such transportation over many miles had on the packed tobacco, laws were passed to regulate but not prohibit the system of rolling roads. These Eastern Shore portages remained economically useful into the nineteenth and twentieth centuries, when they became the routes of improved roads, turnpikes, railroads, and the Chesapeake and Delaware Canal (Gould 1915:127-130, 142-143).

A larger transportation network, however, did not necessarily bring better road conditions. Eighteenth century travelers repeatedly noted that even the major post roads to Annapolis were enclosed by dark forests; planters and farmers kept the through road back from the edge of their property in order to maximize cultivated acreage (Gould 1915:131-132). The eighteenth century growth of Baltimore as a market city, the expansion of wheat growing in Maryland, and early industrialization in the form of gristmills and iron furnaces also kept the General Assembly's attention focused on the sometimes alarming gap between the ideal and the real on Maryland's roads (Olson 1980:5-9). Laws of 1753 and 1756, noting that in icy weather travel to Annapolis was often interrupted, took steps to guarantee that millers preserve existing bridges and build new ones over millraces and tailraces (Kilty 1808:October 1753 Session, Chapter 16, and October 1756 Session, Chapter 12). The latter requirement held force well into the nineteenth century in many of Maryland's Tidewater counties (Kilty 1808:October 1753 Session, Chapter 16, note).

Military supply difficulties during the Revolution (1775-1783) highlighted the sorry condition of Maryland's overland transportation system (Leviness 1958:17). During the early national period (1783-1800), the newly independent state began to adopt a more activist role in the proper development of dependable roads and bridges. Taking initial shape through legislation enacted in the late 1780s and early 1790s, the Internal Improvements movement in Maryland was characterized from the first by a reliance on public-private partnerships, in which the balance of official action and entrepreneurial incentive often varied (Livingood 1947:7-20; Rubin 1961:63-72). Both turnpike and canal projects, however, incorporated provisions for bridges.

Baltimore interests, seeking to keep the trade of western Maryland and the Susquehanna Valley away from Philadelphia, demanded better roads; a petition submitted prior to the 1787 turnpike legislation depicted conditions as they were:

> The public roads leading from Baltimore-town to the western parts of this state, by means of the great number of wagons that use the same, are rendered almost impassable during the winter season, and the ordinary method of repairing said roads is not only insufficient, but exceedingly burdensome; and the establishment of several turnpike roads in the said county would greatly reduce the price of land-carriage of produce and merchandise, and raise the value of the land in the said county, and considerably increase the commerce of the state [Hollifield 1978:2].

The 1787 act responding to this appeal authorized three major turnpikes to be built and administered by Baltimore County as toll roads. A turnpike from Baltimore to Reisterstown would diverge at the latter community to reach both Westminster and Hanover, Pennsylvania. A road from Baltimore to Frederick would also be built, along with a turnpike linking Baltimore and York, Pennsylvania (Sioussat 1899:144-145). By 1805, the plan for county administration having failed, none of the three turnpikes was completed, and there is no evidence that any of the sections finished utilized improved technology (Hollifield 1978:2). Nonetheless, with private financial backing later in the nineteenth century, all three roads would eventually be placed in operation, as the precursors to present-day Reisterstown Road (with Westminster and Hanover pike extensions), Frederick Road, and York Road (Hollifield 1978).

In 1794, the General Assembly revised the general road law of the state, leaving most road work in the hands of the counties but setting up a system of Levy Courts to govern road and bridge construction (Kilty 1808:November 1794 Session, Chapters 52 and 54). Bridge repair specifically was to be performed by laborers hired by the courts, except in cases involving "framed or arched bridges exceeding fifteen feet in length" (Kilty 1808:November 1794 Session, Chapter 52). This was an early recognition that construction and maintenance of such bridges might involve special expertise not possessed by the average laborer. A county's levy court justices were also permitted to raise through taxes as much as 30 pounds annually for repair of a single bridge and as much as 100 pounds for construction of any new bridge (Kilty 1808:November 1794 Session, Chapter

54). Significantly, the 1794 law required cooperation between adjoining counties in building or repairing bridges over county lines. Such bridges were to be contracted out to workmen through a process of bidding and receipt of proposals (Kilty 1808:November 1794 Session, Chapter 54).

Like previous general road laws, the 1794 enactments were an attempt to systematize and control the burgeoning road network of Maryland in the early period of agricultural consolidation and waterpowered industrialization. The 1780s and 1790s also saw legislative chartering of bridge companies and canals. Associated persons were authorized to build an unspecified span over the Potomac, and in 1795 a drawbridge was specified for the Eastern Branch of the Potomac (or Anacostia River), where both the port of Bladensburg and the nation's capital (founded 1791) were located (Kilty 1808:November 1791 Session, Chapter 81, and November 1795 Session, Chapter 62). Legislation setting up the Susquehanna and Tidewater Canal and the Chesapeake and Delaware Canal included provisions requiring each canal company to erect bridges over its waterway wherever such crossings were necessary or customary (Kilty 1808:November 1799 Session, Chapter 16).

These early Assembly charters for private firms to build transport routes and associated structures anticipated the phenomenal build-up of Maryland's transportation network during the nineteenth century, a growth largely planned by corporations working in tandem with state, local, and federal officials. The canal laws of the 1780-1800 period, as well as the turnpike legislation and the general road law mandating a proposal and bid system for intercounty bridges, signified that economic and technological change was on its way, reflecting the impact of the Industrial Revolution on Maryland's time-honored roadmaking and bridge building traditions.

MARYLAND TRANSPORTATION TRANSFORMED, 1800-1900

During the nineteenth century, Maryland's transportation network experienced tremendous change (Figure 4). The primary themes in the transformation of travel in the state, including the development of private toll roads or turnpikes, the construction of the National Road, the Chesapeake and Ohio Canal, the Chesapeake and Delaware Canal, and the Baltimore and Ohio Railroad, and the ultimate demand for better county roads, have been well covered by numerous historians, including St. George Leakin Sioussat, Joseph Durrenberger, Charles Leviness, Sherry Olson, Ralph Gray, Herbert Harwood, and William Hollifield (Durrenberger 1931; Gray 1985; Harwood 1979; Hollifield 1978; Leviness 1958; Olson 1980; Sioussat 1899). The following discussion is a concise summary of such themes and their relation to events and trends which affected or shaped bridge building in Maryland.

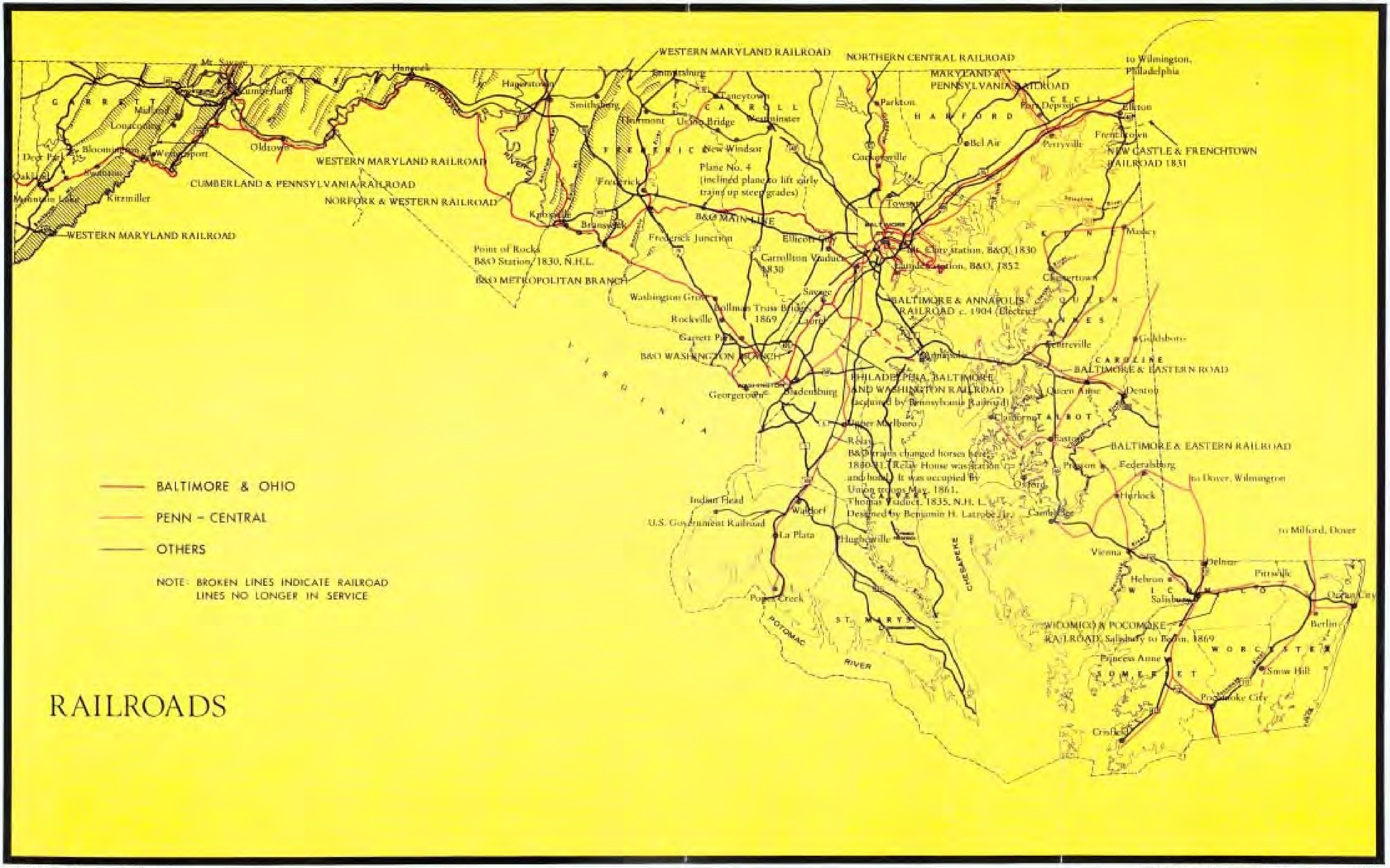

FIGURE 4: Maryland Railroads

SOURCE: *The State of Maryland Historic Atlas* 1973

Turnpikes and Turnpike Bridges

The 1787 legislation allowing Baltimore County to build improved roads, or turnpikes, to York, Frederick, Reisterstown, Westminster, and Hanover failed to produce complete highways to those destinations. Baltimore County nevertheless spent considerable sums improving portions of the old routes and was ultimately reimbursed by the General Assembly, which sought ways to attract private capital to the projects (Hollifield 1978:2). Turnpiking a road in the early national era meant straightening, rebedding, and resurfacing an old dirt route with various combinations of broken stone or gravel, or laying out by exact survey an entirely new route to take advantage of the terrain. With the scientific innovations in methods of stone surfacing and road drainage developed by British engineers Thomas Telford and James McAdam coming into American use during the first three decades of the nineteenth century, state boards of public works and private turnpike companies increasingly hired trained civil engineers to survey roads and build bridges along them (Lay 1992:110-111).

Between 1796 and 1801, five separate turnpike companies were chartered, none of which successfully completed a road (Sioussat 1899:145). During the legislative session of 1804-1805, however, the Assembly created three highly important turnpike companies: the Baltimore and Frederick Town Turnpike Company, which built the first improved link to the West (Frederick Road) through Ellicott City, New Market, Frederick, Middletown, and Boonsboro; the Baltimore and Reisterstown Turnpike Company, which with its two northern branches tapped the rich farm country of south-central Pennsylvania; and the Baltimore and York Town Turnpike Company, which connected Pennsylvania roads crossing the Susquehanna (Durrenberger 1931:66).

These companies overcame numerous challenges of topography and construction in order to build their roads. Reaching toward western Maryland, the Frederick Turnpike was gradually extended (in part, via roads financed and built by the state's banks under agreement with the General Assembly) to meet the National Road at Cumberland. Another branch of the pike led to Harper's Ferry and the Shenandoah Valley of Virginia. Treasury Secretary Albert Gallatin's famous 1808 study on internal improvements, and Governor Goldsborough's 1818 "Executive Communication on the Subject of Turnpike Roads" offered progress reports on the various turnpikes chartered by the Maryland legislature (Gallatin 1968:60-67; Goldsborough 1818). By 1807, the Baltimore and Reisterstown pike had been surveyed and was completed for ten miles of its length at a cost of $10,000 per mile. The Baltimore and Frederick Turnpike had built some 37 miles of its 62-mile total, while a restrictive clause delayed construction of the turnpike to York until after 1807 (Durrenberger 1931:66-67).

Goldsborough's 1818 report was based on questionnaires sent to each turnpike company (Goldsborough 1818). By that year, having witnessed the advantages of private capitalization of improved roads, the Maryland legislature had authorized a number of other turnpikes, including the Falls Pike (Falls Road), the first improved Baltimore and Washington Turnpike (chartered 1813 to follow approximately the route of today's Baltimore-Washington Boulevard or Route 1 through the old port of Bladensburg to Washington), the Baltimore and Havre de Grace Turnpike (an 1813 precursor to present Old Philadelphia Road), and the New Castle and Frenchtown Turnpike (also chartered 1813 to carry goods over one of the old portage routes between the Chesapeake Bay and the Delaware River) (Durrenberger 1931; Holmes 1962). Other private toll roads, such as the Westminster, Taneytown and Emmitsburg Turnpike, and the Belair Turnpike (predecessor of Belair Road), were deliberately laid out to draw the commerce of the Susquehanna Valley away from Philadelphia and toward Baltimore (Durrenberger 1931).

The Goldsborough report documented use of both simple timber beam and stone arch bridges on the early turnpikes of Maryland. On the Baltimore and Reisterstown Turnpike, completed on January 8, 1810, with twelve tollgates, "many bridges" had been built by the company "of solid materials, at a very great expense," but no special bridge tolls were charged. The Baltimore and York Turnpike, finished in 1811, included five one-span stone arch bridges and two two-span stone arch bridges, on which a total of over $15,000 had been spent. On the Frederick pike "four considerable bridges" had been erected (over Gwynns Falls, the Patapsco, the Monocacy, and Catoctin Creek). The turnpike company's $56,000 four-span Monocacy Bridge (the so-called "Jug Bridge," a stone structure southeast of Frederick which stood until 1942) was built in the expectation that the company would defray the cost by tolls. When this was not authorized, no more money was available for turnpiking or improving the old Frederick road (Goldsborough 1818).

In the early nineteenth century, the companies' clear preference for stone arch bridges at important Piedmont and Appalachian Plateau crossings reflected a growing popular demand in those areas for sturdy structures able to withstand the pressures of frequent wagon traffic as well as the force of water, ice, and flood debris along streams and rivers with moderate or high slopes. The bridges' general durability has been demonstrated; the oldest known bridges extant in Maryland are the Parkton Stone Arch Bridge over the Little Gunpowder, built in 1809 in northern Baltimore County along a piked route (Meyer 1981:5-6), and Washington County's notable collection of stone arches, all probably erected between 1819 and 1863 although some undated examples may possibly predate the Parkton arch (Mish and Cottingham 1977). Numerous stonemasons in Maryland developed skill in the layout and building of such spans, and noted engineers such as the Shrivers and Latrobes worked for the turnpike firms (Durrenberger 1931).

In the Tidewater or Coastal Plain region, where drops in elevation were not so large, few stone bridges appear to have been constructed (no major turnpikes except the New Castle and Frenchtown pike were built in the Delmarva peninsula) (Holmes 1962). On major rivers like the Susquehanna and Potomac, however, the earliest substantial spans were often long covered wooden bridges, supported on only a few piers in order to avoid obstructing heavy water flow (American Society of Civil Engineers 1976:7-14). A lengthy obstacle to the nation's earliest east-west turnpikes, the Susquehanna especially challenged the talents of the country's foremost timber bridge builders. In Maryland between 1815 and 1825, both Theodore Burr, inventor of the Burr arch type of covered bridge, and Lewis Wernwag, expert bridge constructor and designer of the famous "Colossus" bridge over the Schuylkill at Philadelphia, built long-span covered bridges at Conowingo and Port Deposit (Maryland Historical Trust 1970-1993). No longer extant, these bridges nevertheless mark the period of craftsman tradition in Maryland bridge building, as do the many stone arches erected by masons James Lloyd, Silas Harry, and John Weaver in western Maryland (Mish and Cottingham 1977).

Baltimore's preeminence as a destination of turnpikes built between 1810 and 1840 attested to that city's extraordinary growth after the Revolution. By about 1825, Baltimore was the third largest city in the United States and the terminus of seven turnpikes (Durrenberger 1931:69). Within the city, a variety of wooden bridges built under the City Commissioners' aegis (including an early drawbridge at Light Street) provided the beginnings of an urban infrastructure for the transport of freight and goods (Olson 1980). Even so, competition with such expanding port cities as Philadelphia, New York, Pittsburgh, and New Orleans kept Baltimore entrepreneurs alert to the possibility of new connections with the Midwest, where farms were rapidly replacing the old trans-Appalachian wilderness of the colonial era. Four major nineteenth century engineering projects in Maryland—the National Road, the Chesapeake and Ohio Canal, the Chesapeake and Delaware Canal, and the Baltimore and Ohio Railroad—emerged from the public effort to strengthen Baltimore's marketing position in the years prior to the Civil War (Livingood 1947; Rubin 1961). Each project directly affected the bridge building history of the state in the period before the introduction of automobiles and trucks.

The National Road

Some of Maryland's most significant bridges are located along the route of the National Road, a nationally significant improved turnpike constructed in the early nineteenth century from Cumberland to Uniontown, Pennsylvania, as the first federally built highway in the United States. In 1806, Congress authorized construction of a road "from Cumberland or a point on the northern bank of the river Potomac, in the State of Maryland, between Cumberland and the place where the main road leading from Gwynn's to Winchester, in Virginia, crosses the river, to the State of Ohio" (Sioussat 1899:183). By statute, Maryland, Pennsylvania, and Virginia granted permission for the so-called "U.S. Road" (also to be known as the Cumberland Road as well as National Road), and between 1811 and 1818 the road was built under the supervision of topographical engineers from the U.S. Army (Kanarek 1976; Sioussat 1899:184-185).

From 1818 to the early 1830s, linked to central and eastern Maryland via turnpikes from Cumberland through Hagerstown and Frederick, the National Road was maintained under Federal administration (Kanarek 1976:11-17). The unprecedented nature of the road's sixty-foot right-of-way was a perennial problem for nearby residents who built fences and even houses on the land allotted for the road. Repair of the National Road was a still worse challenge, as narrow iron wagon wheel rims and dragged sawlogs tore up the roadway surface. In 1823, U.S. Army engineer David Shriver, Jr., observed that "the road has suffered so much, that its original form is lost, and the sum in hand is not sufficient to stop the progress of ruin on it" (Kanarek 1976:13). Between 1832 and 1835, the U.S. War Department expended over $900,000 on National Road repairs, which included laying a new McAdam (or macadam) surface on the road (Kanarek 1976:14-17).

Semicircular stone masonry arches and culverts were the preferred bridges constructed along the route of the National Road. Where streams and rivers were encountered at an angle to the roadway, the so-called "S-bridges" were built, with a shape that allowed the bridge to be erected perpendicular to the bank (Ierley 1990:105). A significant, extant Maryland stone arch bridge, the Casselman River Bridge at Little Crossings, was built in 1813 by contractors Kerns and Bryson to a design by David Shriver to carry the National Road over the Casselman River near Grantsville, Garrett County (Little Crossings Historical Committee 1964). At least one original National Road stone arch culvert has also been located in the same area (Ware 1991:234).

Indicating the faith Maryland authorities placed in stone arch turnpike bridges, an 1834 dispute between Maryland and the U.S. Army engineers concerning the proper type of bridge for the National Road crossing of Will's Creek near Cumberland was resolved in favor of a stone span, over the objections of Captain Richard Delafield, who wanted a less expensive wooden superstructure on stone abutments and wingwalls. Bridge and culvert maintenance on the road remained a regular, indeed chronic concern after the Maryland part of the National Road was taken over by the state in 1835 (Kanarek 1976:11-17).

By 1878, when the General Assembly turned over ownership of the National Road to Allegany and Garrett counties (Maryland General Assembly 1878:256-258), competition from the Baltimore and Ohio and other railroads had reduced commercial through traffic on the decayed road to a trickle. The Maryland Geological Survey's 1899 report on highways sadly noted that the National Road through Maryland was too narrow, muddy, and virtually impassable at points, and that bridge parapets on the Casselman River arch were disintegrating (Johnson 1899:214-215, 234-235). Renewal of the road as U.S. 40 awaited the coming of auto and truck traffic during the twentieth century (Allen 1991:38-43).

Maryland's Canals: C&O and C&D

Like the National Road, the earliest professionally engineered lock canals in Maryland represented public attempts to capture western and southern trade. Canal construction involved creating artificial, commercial water routes, often alongside a major river which would provide a water supply for operation of locks and basins. Existing roads had to be carried over or under canals, which themselves were sometimes required to cross roads or rivers on aqueducts. Bridge building, particularly stone masonry, was given impetus by the chartering of canal companies in Maryland.

Between 1824 and 1850, the Chesapeake and Ohio (C&O) Canal was constructed from the vicinity of Georgetown, near Washington, D.C., to Cumberland, Maryland, although its promoters hoped to extend it over the mountains to Ohio. Though economically outranked by the Baltimore and Ohio (B&O) Railroad, the canal operated well into the second decade of the twentieth century as a means of transporting goods and crops from western Maryland to the coastal and Atlantic trade. The Chesapeake and Delaware (C&D) Canal, completed in 1829 to link the Chesapeake and Delaware bays and widened to become a "ship canal" in the early twentieth century, currently remains in operation (Gray 1985).

Both canals necessitated bridges, but the types built evidently varied considerably. On the line of the C&O, from Georgetown west through the vicinity of Cumberland, the canal was spanned by dressed stone masonry arch bridges, and was occasionally carried (as at Monocacy River) by stone aqueducts (Sanderlin 1964) (Surviving examples of such structures, sometimes built of distinctive red Seneca sandstone, as well as various small bridges associated with lock complexes, have been documented and recorded by an ongoing project of the Historic American Engineering Record of the National Park Service [Sanderlin 1964]). The C&D, by contrast, was spanned by several covered timber bridges and also included several early movable bridges (pivot or swing type). The fairly low profile of the C&D Canal obviated the need for major aqueducts. During the twentieth century, however, vertical lift bridges would be erected over the C&O at Williamsport (a railroad span) and over the C&D at Chesapeake City (to carry a highway) (Gray 1985).

The B&O Railroad and Maryland's Bridges

The C&O Canal's great rival during the nineteenth century was the Baltimore and Ohio Railroad. The B&O line transformed the Maryland landscape between 1830 and 1900 and ushered in momentous changes in bridge building technology (see Figure 4). The B&O made stone viaducts and then metal truss bridges acceptable to the general public by demonstrating that they would work if properly engineered. As the acknowledged innovator among early American railroad companies, the B&O was likewise a training ground for American civil engineers; such distinguished engineers as Benjamin H. Latrobe, Jonathan Knight, William G. McNeill, Caspar Weaver, Stephen H. Long, Wendel Bollman, and John E. Greiner began as railroad engineers and played significant roles in Maryland's bridge history. Although the spans built by the B&O and other railroads in the state generally were not intended for highway travel, the heavy loads they regularly carried proved the viability of such bridge types as the high masonry arch, the Long truss, the Bollman truss, the plate girder, and the timber trestle (Harwood 1979).

The history of the Baltimore and Ohio Railroad has been chronicled in detail by Herbert H. Harwood, Jr., in his *Impossible Challenge* (Harwood 1979). Technological historian Robert Vogel summarized the "firsts" of the B&O: "first practical railroad in America; the first to use an American locomotive; the first to cross the Alleghenies" (Vogel 1964:84). The B&O main line as fully articulated between 1829 and 1860 ran west from Mount Clare Station in Baltimore along the Patapsco valley through Ellicott City and Sykesville to Point of Rocks, Brunswick, and Harper's Ferry, and along the Potomac Valley to reach Cumberland and points beyond (Harwood 1979:14-34). Its success assured from an early date, the B&O throughout the nineteenth century built spur lines and access tracks to prominent mills, factories, mines and quarries, and lumber stands in the Piedmont and Appalachian Plateau counties of Maryland (Harwood 1979:206-396).

The initial stretch (the old main line) of the railroad west of Baltimore became the location of several imposing stone arch bridges, after the directors and engineers led by Jonathan Knight determined that most of the first bridges immediately west of the city should be of masonry (Harwood 1979:15-16). (Colonel Stephen H. Long entered a dissent to this decision, and later constructed the only major timber bridge—the Jackson Bridge, a covered wooden "Long truss" of his design—on the first division of the B&O, to carry the Washington and

Baltimore pike over the tracks [Harwood 1979:15-16]). Notable among these stone arch bridges is the nationally significant, extant Carrollton Viaduct, a two-span granite structure 312 feet long and including an 80-foot main arch over Gwynns Falls. Built in 1829-1830, the Carrollton Viaduct is the oldest surviving railroad bridge in the United States (Schodek 1987:77-78). Other extant or partially extant stone arches on the B&O's first division include some small spans near Baltimore, the remains of the Patterson Viaduct, at Ilchester on the Patapsco, and part of the Oliver Viaduct at Ellicott City (Harwood 1979:398).

Between 1833 and 1835, as the B&O constructed its Washington Branch south of the old main line, the well-known Thomas Viaduct was erected over the Patapsco near Elkridge. This structure, like the Carrollton Viaduct a major engineering landmark, is the oldest multiple arch railroad viaduct in the United States and possibly the best-known historic bridge in Maryland. Designed by Benjamin H. Latrobe and built in 1835, the Thomas Viaduct is 612 feet in length and consists of eight 58-foot arches built on a curvature that was itself revolutionary for its time (Harwood 1979:206-207). Still in service, "Latrobe's Folly" stands today as a physical legacy of the rise of the civil engineering profession in bridge building, as reflected in early nineteenth century Maryland railroading practice.

The Baltimore and Ohio Railroad prior to 1900 was carried on a variety of technologically innovative bridge structures in addition to the solid stone arches and imposing viaducts of its first division. Between 1840 and 1850, at Elysville (later Daniels) on the Patapsco and Harper's Ferry, covered wooden truss bridges of Latrobe's design, in which some cast iron was utilized in joints and wrought iron for certain tensile members, marked the key transitional phase from wood to iron in bridge building (Harwood 1979:48). Lewis Wernwag, who had built long-span timber bridges over the Susquehanna, was brought in by Latrobe to construct spans at Harper's Ferry. By 1849, when Latrobe's annual chief engineer's report noted that new bridges with "a superstructure of iron upon stone abutments" would be erected at Savage and Bladensburg, the railroad was following the lead of prominent bridge engineer Squire Whipple, designer of a series of small iron truss bridges over the Erie Canal in the early 1840s. Latrobe's "new bridges" of 1849 were of another new design, the Bollman truss, pioneered by the B&O's own master of road Wendel Bollman of Baltimore, who had formerly served the railroad as foreman of bridges (Vogel 1964).

The Bollman truss, discussed in further detail below in the section entitled "Metal Truss Bridges," was structurally a combination truss and suspension bridge, in which a system of lines of trussing carried individual panel loads to the ends of the frame by members acting independently of one another. Patented in 1851, with a renewal of rights in 1866, Bollman's design was utilized extensively along the B&O line (as a through truss in some cases and a deck truss in others) and was marketed throughout the United States and South America by Bollman's Baltimore-based bridge companies, W. Bollman and Company and the Patapsco

Bridge Company, between 1855 and the 1870s. Appropriately, Savage, Maryland, where one of the first two Bollman truss bridges was built in 1850, is the location of the last known surviving Bollman truss. Although not the original span at the site, the bridge has been restored by Howard County and designated a National Civil Engineering Landmark and a National Historic Landmark (Vogel 1964).

The Bollman trusses on the B&O heralded the widespread use of metal truss bridges in Maryland for highways as well as railroads. As technology progressed and mathematical understanding of truss analysis became more refined, Bollman's unusual design was largely superseded by less complex, easier to market Pratt and Warren metal truss bridges (see "Metal Truss Bridges," below). On the B&O and many other Maryland railroads, the late nineteenth century witnessed adoption of Pratt and Warren designs as well as use of highly adaptable, simple structure types such as the metal plate girder (the earliest known example of this type in the United States was a 54-foot prefabricated single-track deck girder erected by the Baltimore and Susquehanna Railroad at Bolton Station in 1847), and the wooden timber trestle, although reliable masonry arch bridges and viaducts were still being built throughout the century (DeLony 1993:43; Harwood 1979; Tyrrell 1911:195). Trusses as well as timber beam bridges supported on timber piles were used by railroads active on the Eastern Shore between 1860 and 1900 (Hayman 1979).

Bollman's companies were among the earliest to actively market truss bridges as easy to erect; the historic span at Savage still bears numerical imprints intended to guide work crews in the proper placement of the members. After the Civil War, however, a full complement of prominent metal truss bridge building firms became interested in selling trusses to railroads and county commissioners. Baltimore-based companies known to have built trusses in Maryland included Bollman's two firms, the Baltimore Bridge Company, led by Charles and Benjamin Latrobe and Charles Shaler Smith, and the H.A. Ramsay firm (Howard 1873:216-218). Firms located outside of the state but marketing in Maryland between 1865 and 1900 were the King Bridge Company and the Wrought Iron Bridge Company, both of Canton, Ohio; the Pittsburg Bridge Company; the Penn Iron Bridge Company; Nelson and Buchanan (who also acted as agents for Pittsburg Bridge Company); the Roanoke Iron and Bridge Company; and the York Bridge Company (primarily active after 1900) (Maryland Historical Trust 1970-1993).

Pioneered by the Baltimore and Ohio, railroad construction in Maryland during the nineteenth century included many important freight and passenger lines, such as the Northern Central and the Western Maryland Railway (Gunnarson 1990). An array of railroads also served the Delmarva peninsula, connecting Tidewater farms and towns and linking them to markets in Baltimore and Philadelphia (Hayman 1979).

The Road Network and the 1899 Report on Highways

Although major improved turnpikes, canals, and railroads dominated Maryland's commercial and industrial transportation in the nineteenth century, a highway network was also gradually developing. The state's basic system of county roads, and private roads built to access farms or factory sites, slowly expanded during the 1800-1900 period, under the patronage of the General Assembly and county officials. After the pioneering private toll road legislation of 1804-1805, many other turnpike laws were enacted, most of which resulted in actual construction of pikes. Historian Joseph Durrenberger observed that Maryland, to a greater degree than Pennsylvania, New York, or New Jersey, did not summarily abandon its turnpikes to decay, and in 1899 had a greater proportion of turnpike mileage in actual operation than did the other Mid-Atlantic states (Durrenberger 1931:161).

In 1818, the county courts were authorized to regularly appoint three-person panels of viewers to inspect potential or proposed road and bridge locations and "examine whether the public convenience requires it" (Sioussat 1899:154). The 1818 law was expanded in greater detail in the 1853 code, which, with subsequent revisions and amendments of 1856, 1860, 1874, and 1888, governed county administration of public roads and bridges until the end of the century (Sioussat 1899:154). The legislature also maintained its protective interest in the encouragement of private access roads; the right to construct such roads was specifically extended to quarry operators and mine owners (1833) and to millers, factory owners, limekiln operators, and distillery owners seeking railroad access (1836) (Maryland General Assembly 1836:n.p., Chapter 255). By an 1835 law, plans for private roads had to be submitted to the county levy courts (Maryland General Assembly 1835:n.p., Chapter 253).

State maps and county atlases published in Maryland between 1865 and 1900 depicted a full road network, with numerous overland routes clearly shown even in remote or mountainous regions (Hopkins 1877, 1878a, 1878b, 1878c, 1879). While a well-interlaced array of roads certainly existed near Baltimore and in the western Tidewater counties, unfortunately, many of the roads so depicted were largely unimproved dirt routes, dusty in dry weather, impassable due to mud in rainy times, and either neglected or filled with deep wagon wheel ruts from too much travel (Johnson 1899). By the 1890s, however, with bicycling a popular pastime and automotive traffic on the horizon, voices were raised for road reform. The 1894 statement of the Maryland Road League offered a pragmatic analysis of the counties' predicament:

> The Commissioners are already authorized by statute, in their discretion, to commit the roads and bridges to experts, but unanimously refuse to do so, probably for the reason, among others, that they do not feel warranted in incurring the resulting expense. It

> is likewise not worth while to recommend that they should be compelled to employ engineers (they probably would not consent to it in the first place); while, if such a law were forced upon them, lack of funds would probably compel them to employ inefficient men, and no good would be attained [Maryland Road League 1894:8-9].

The league recommended that the state create an "engineering department" and place its services at the command of each county, which they hoped would eventually set up a county engineer's office of its own. Although many counties were slow to professionalize their road and bridge functions, these recommendations gathered force during the 1890s and finally took shape in the Maryland Geological Survey's supervision of state road-building (1899-1908), the 1901 founding of the Baltimore County engineer's office, and the creation of the Maryland State Roads Commission in 1908 (Maryland Road League 1894). It is noteworthy that Baltimore City had employed professional civil engineers as early as 1880 and had begun a separate roads engineer office by 1898 (Olson 1980).

Fittingly, the nineteenth century era in Maryland transportation history closed with publication and widespread discussion of the 1899 *Report on the Highways of Maryland*, issued by the Maryland Geological Survey under authority of an 1898 act of the General Assembly. The report included a full survey of Maryland's roads by county, and for the first time in Maryland history scientifically analyzed the relation of topography, climate, and geology to road making in the state. Traditional roadway surfacing practices, whether they involved use of gravel, broken stone, or oyster shells (available in abundance in the Tidewater counties), were generally criticized (Johnson 1899; Sioussat 1899).

The report also found most Maryland bridges under 30 feet in length to be of simple timber beam, or king-post or queen-post form, although these spans were rapidly being replaced with short iron bridges, "some of which are of a flimsy construction" (Johnson 1899:206). The Maryland highway geologists recommended for short spans "a combination of masonry and I-beams, between which are transverse arches of brick, the whole covered with concrete, over which is laid the roadway." Reflecting the development of structural concrete, a technological advance of the nineteenth century of significance equal to the introduction of structural steel, this recommendation constituted the first official Maryland endorsement of concrete in bridge building. No extant examples of the unreinforced concrete, composite arch-and-beam bridge recommended by the 1899 report are known, although concrete culverts were being constructed in the state prior to 1903, when the first reinforced concrete highway bridge in Maryland was built (Johnson 1899:206-208, 1903:169).

The roadway reforms urged by the Maryland Road League and the Maryland Geological Survey capped a century of strain on the transportation network, resulting from the great growth of commerce and industry in the state. During the latter half of the nineteenth century, construction of railroads in

Maryland peaked, and the rail network partially eclipsed the overland roadway system as the primary conveyor of freight and crops. The twentieth century, however, would bring a dramatic reversal of this temporary eclipse, under the pervasive influence of yet another technological advance that profoundly affected Maryland road and bridge building: automobile and truck traffic.

MODERN TRANSPORTATION IN MARYLAND, 1900-1960

The twentieth century continued the transformation of Maryland's transportation network by the forces of industrialization. While railroads such as the B&O and Northern Central were connecting more and more of the state to markets and supply centers, their major modern rivals, automobiles and trucks, effected a near-total, dramatic improvement of Maryland's highways and county roads. Under the aegis of the Maryland Geological Survey and the State Roads Commission, old roads were upgraded, numerous new roads and bridges were built, and scientific standardization of design and construction was no longer the province of the railroads only. From a technological perspective, the state agencies, and increasingly throughout the century, professional county engineering departments, introduced and popularized the building of modern bridge types such as reinforced concrete spans and steel truss bridges. By 1960, through arterial planning studies, beltway and expressway construction, statewide road surveys, and major special programs such as the 1938-1952 Primary Bridge Program, the state possessed a highway system able to convey freight from the Eastern Shore to western Maryland in little more than half a day.

State Aid and Creation of the State Roads Commission

The rapid development and spread of automobiles and trucks in the United States during the first decades of the twentieth century presented Maryland's road planners with the imperative necessity of upgrading the 13,118 miles of dirt roads in the state as of 1900. Only 1,365 miles of the road mileage total of 14,483 were already "improved" in any way; improved roads included 890 miles of stone-surfaced roads, 225 miles surfaced with gravel, and 250 miles of oyster shell roads. The stone-surfaced total encompassed 497 miles of operating turnpikes or toll roads, but 130 miles of former turnpikes had been abandoned by 1900. The remainder of 263 miles of stone roads constituted the state's entire total of route mileage surfaced with stone by the counties and Baltimore City (Leviness 1958:39).

As in the case of the B&O and other railroads, the strong scientific influence of professional engineering served to modernize Maryland's roads, with periodic legislative assistance from the General Assembly. Between 1898 and 1905, the Highway Division of the Maryland Geological Survey was headed by Arthur N. Johnson, later dean of the University of Maryland School of Engineering. Although it had fallen into considerable disrepair, Johnson lauded the old National Road for its carefully planned engineered avoidance of grades steeper than eight percent. The Geological Survey recommended passage of a state aid road law and creation of a professionally staffed state roads commission, a goal supported by many farmers who had seen demonstrations and models of properly surfaced stone roads. The initial response to these concerns was the State Aid Act of 1904 (or Shoemaker Act). This act offered $200,000 annually in state money for macadamizing county roads provided the counties gave matching funds and permitted state supervision of the work (Leviness 1958:46-47).

In 1908, Governor Austin Crothers, leader of the Good Roads movement in Maryland, persuaded the legislature to take the next significant step. Five million dollars was appropriated for state-sponsored improvement and construction of roads. A new State Roads Commission was formed, headed by former Baltimore County Chief Engineer Walter W. Crosby (Leviness 1958:55). Maryland's roadway modernizing efforts reflected the nationwide pattern; in 1905, only 14 states had highway departments (5 of these were founded in either 1904 or 1905), but by December 1914, when the American Association of State Highway Officials (AASHO) was founded, 33 states had set up highway commissions or divisions (Armstrong 1976:74-75). A strong incentive for formation of state highway agencies was soon provided by the landmark 1916 Federal Aid Road Act, which released United States government funds for state road construction and anticipated the growth of an interstate highway system (American Association of State Highway Officials 1953a:112).

In 1912, the State Roads Commission under prominent transportation engineer Henry G. Shirley instituted district engineer offices throughout Maryland (Leviness 1958). Another key move toward greater organizational efficiency within the Maryland State Roads Commission was taken between 1916 and 1919, when the state was divided into seven subdivisions, or "residencies of from two to six counties each, with a Resident Engineer living at a central point in each residency, responsible for all work therein" (Maryland State Roads Commission 1920b:15). The residencies were Cumberland, Frederick, Hyattsville, Baltimore City, Baltimore County, Chestertown, and Salisbury (Maryland State Roads Commission 1920b:15-16).

Road Improvements, 1900-1960

The Maryland State Roads Commission in its early years continued on the progressive path set by the Highway Division of the Maryland Geological Survey under Johnson, offering road design review services, state aid, and promotion of proper concrete bridge construction. Selection of a "state roads system," composed of about 1,300 miles of existing roads due for direct improvement by the state, was completed in 1909. By the end of 1911, starting with a one-mile section of road from Federalsburg to the Dorchester County line, the commission had built 168 miles of road, and an additional 176 miles was under construction (Leviness 1958:56). Between 1906 and 1915, the geological survey and the roads commission also completed the Baltimore-Washington Boulevard (Route 1), reconstructing and paving 30 miles of the old turnpike between the two cities. The boulevard was later widened and further improved to handle heavy World War I and World War II traffic to such installations as Fort Meade (Leviness 1958).

Highway development in Maryland after the World War I era was characterized by increasing growth of the state-owned and state-aided systems, and highlighted by construction of notable through roads, parkways, and expressways by state or federal authorities. All private toll roads or turnpikes in the state were purchased by 1915 (Hollifield 1978), and the passage of the Federal Aid law in 1916 greatly benefited Maryland. Limited access, high-speed expressways in the United States were to a great extent pioneered by the Pennsylvania Turnpike, built in 1939-1940 as the first such route designed to carry a high volume of automotive and heavy trailer truck traffic (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:5).

The Maryland State Roads Commission, and eventually individual counties led by the professionally staffed Baltimore County Roads Department, reacted to the 1930s advent of tractor-trailers by increasing the emphasis on proper, standardized design and construction of right-of-way structures including bridges and culverts. The following major highway projects were completed by the State Roads Commission, or by federal authorities, in cooperation with local officials, between 1910 and 1960 (lists compiled from all available sources):

Baltimore-Washington Boulevard (1906-1915; 1918-1919 rebuilding with concrete, including first American use of concrete shoulders; 1928-1930 widening and straightening).

Crain Highway, later U.S. 301 (1922-1927; first major new road constructed on entirely new location by the State Roads Commission).
State Route 416, Upper Marlboro to Sunderland (1920s; connected Washington with resorts in Calvert County).

Salisbury-Snow Hill Road, or State Route 12 (1920s).

Westminster-Mt. Airy Road, or State Route 27 (1920s).

Defense Highway, or U.S. 50, between Washington and Annapolis (1920-1926).

"Eastern Shore Boulevard," or parts of U.S. 50 and State Route 404 (linking ferry slip on bay at Mattapeake with Queenstown, Wye Mills, Hillsboro, and Denton; 1930s-1940s).

U.S. 40, or "new" Philadelphia Road (major 1930s project, Baltimore to Aberdeen, opened as Pulaski Highway).

U.S. 40 west of Baltimore to Frederick (1935-1940; dual lanes added 1955).

Annapolis Boulevard, or Ritchie Highway (1934-1938).

Access roads to wartime facilities (1940-1945; including Martin Boulevard, State Route 235 to Patuxent Naval Air Test Center, and numerous others).

John Hanson Highway, U.S. 50, Washington-Annapolis (1955 highway replacing Defense Highway of 1926).

Federally sponsored road construction in Maryland during the 1910-1960 period included a series of parkways notable for their significant design, and during the 1950s several important expressways and "beltways" around Washington and Baltimore, a recognition of the advancing suburbanization spurred by the family car near the area's biggest cities. In addition to wartime access routes, major federal highway or parkway projects of the early and middle twentieth century were the following (lists compiled from all available sources):

Rock Creek and Potomac Parkway (1920s-1935; first parkway system in Maryland directly influenced by Bronx River Parkway of 1923, pioneering parkway in the United States).

George Washington Memorial Parkway (1930s-1950s).

Suitland Parkway (partially opened 1942, primarily as wartime access route to communities in vicinity of Camp Springs (later Andrews) airfield.

Baltimore-Washington Parkway (opened 1954; section from near Jessup to Baltimore constructed by State Roads Commission).

I-70, Baltimore-Frederick (1956; extended and improved U.S. 40 as first project of Interstate Highway Act in Maryland).

I-270, Washington-Frederick (1957).

Baltimore Harbor Tunnel and approach routes (1957).

I-83, Baltimore-Harrisburg (1959; linked to Jones Falls Expressway in 1962).

Baltimore Beltway (1950s-1962).

I-95, John F. Kennedy Memorial Highway (1950s-1963).

Washington or Capital Beltway (1950s-1964).

These diverse twentieth century roadway improvements authorized by state and federal authorities were accompanied by the simultaneous professionalization of county roads and bridge administration in Maryland. Baltimore County's engineer, first appointed in 1901, pioneered in this respect, introducing the first reinforced concrete bridge built in Maryland (a 1903 structure carrying York Road over a stream near Cockeysville) and generally promoting construction of concrete bridges and scientifically designed roads (Johnson 1903:169). The 1929 annual report of the Baltimore County engineer proudly noted that no less than 742 "concrete bridges and culverts" had been built by the county since 1902, exclusive of a number of structures built with state aid during the period. How many of the 742 were replacements of earlier concrete spans is unknown (Baltimore County Roads Engineer 1929:68).

Metal truss bridges were still constructed in Maryland well into the twentieth century by the counties and the state (and by the still successful railroads), but reinforced concrete represented the leading edge of ordinary bridge design, and was incorporated into small spans as well as longer, sometimes movable, bridges over the rivers of the Eastern Shore (Maryland State Roads Commission 1912-1960). The trend toward standardization affected much twentieth century bridge building in the state during the 1900-1960 period, but consulting engineers were also often employed. Notable Maryland bridges designed by outside consultants and reported in annual reports of the State Roads Commission included important movable bridges (such as the 1916 Hanover Street Bridge) and the three monumental structures built to cross Maryland's major water bodies between 1940 and 1952. These high, imposing spans—the Thomas J. Hatem Memorial Bridge over the Susquehanna at Havre de Grace (1940), the Governor Harry W. Nice Memorial Bridge carrying U.S. 301 over the Potomac (1940), and the first Chesapeake Bay Bridge (1949-1952)—required consulting engineering design and construction management and rank as significant historic, though fairly recent, bridges in Maryland (J.E. Greiner Company 1938).

Bridge Standardization and Roadway Planning Studies

Two additional characteristic aspects of the growth of Maryland's modern transportation system in the twentieth century have been the development of standardized bridge plans for commonly needed reinforced concrete structures, and the reliance on roadway planning studies, often performed by government agencies or prominent outside consultants. A concise discussion of these two trends, as seen in Maryland between 1900 and 1960, provides greater understanding of the abundance of small, twentieth century concrete bridges found on Maryland's highways.

In the United States, the use of standard plans for structures such as bridges was pioneered by the railroads during the nineteenth century. By 1900, bridge engineers like Henry G. Tyrrell and J.A.L. Waddell realized that the Good Roads movement and the concurrent automotive revolution would require construction or reconstruction of a large number of ordinary highway bridges. Tyrrell, Waddell, and such writers as Milo S. Ketchum included such plans in their textbooks (Ketchum 1908, 1920; Tyrrell 1911; Waddell 1916), while the U.S. Bureau of Public Roads, the American Association of State Highway Officials (AASHO), and the American Society of Civil Engineers (ASCE) promoted standardization as a cost-saving alternative for county and municipal engineering departments (American Association of State Highway Officials 1953a:103-106; Armstrong 1976:71-85).

The Baltimore County engineer's office, which in 1901 began to construct concrete bridges and culverts, may have led Maryland in joining the movement toward standardization. The earliest standardized bridge plans drafted by the State Roads Commission date to 1909, and offer designs and specifications for a variety of reinforced concrete beam, slab, and girder bridges. In 1912, 1919, 1920, 1924, 1930, and 1933, the State Roads Commission prepared a full series of standard plans and specifications for concrete culverts and bridges ranging from a mere 6 feet in length to 42 feet (Maryland State Roads Commission, Standard Plans 1909, 1912b, 1919, 1920b, 1930b, 1933).

Such plans, used in conjunction with other standardized handbooks such as the June 1931 *Specifications and Contracts for Highway Bridges and Incidental Structures* and the 1932 *Field Manual for Bridge Inspectors* (both issued by the State Roads Commission), offered much guidance to the state's road and bridge builders in the modern era (Maryland State Roads Commission 1932, 1934). Although standardization was encouraged for straightforward crossings without special circumstances, many non-standardized bridges continued to be built. These included the state-built movable bridges on the Eastern Shore and the high concrete ribbed arches erected in Baltimore City between 1910 and 1930. Additionally, certain bridge building firms specialized in reinforced concrete construction, and offered patented designs of their own. This twentieth century trend is illustrated by an array of graceful concrete arch county bridges designed by Daniel B. Luten's significant bridge building company.

Luten's arches, as well as major concrete arch spans in Baltimore City (Clifton Avenue Bridge and Edmondson Avenue Bridge, for example), were greatly influenced by the City Beautiful movement of the early twentieth century, led by civic planners and architects who advocated construction of aesthetically pleasing public structures such as playgrounds, parks, and railroad stations. City Beautiful planners designed municipal plans featuring wide avenues or boulevards, with broad vistas and an expansive or monumental feel. Open spandrel ribbed arches and simply ornamented concrete bridges were typically chosen for crossings on such boulevards (33rd Street and Loch Raven Boulevard are Baltimore City examples).

Standardization went hand in hand with the rise of roadway planning in Maryland, which also affected patterns of bridge building in the state between 1900 and 1960. The Olmsted Brothers studied park roads for Baltimore and Washington, D.C., between 1900 and 1920 (Olmsted Brothers 1904). Long-range highway survey and planning was aided during the Depression by President Franklin D. Roosevelt's Department of Agriculture, where the Bureau of Public Roads provided funding and personnel for statewide surveys of roads and right-of-way structures (Armstrong 1976:84-85). Reacting to a half century of fatal accidents, federal legislation of 1934 mandated a complete nationwide study of all railroad grade crossings where railroad tracks intersected roads directly at grade. Maryland responded with the January 1935 report *Railroad Grade Crossings in the State of Maryland*, which found a total of 921 such crossings and recommended their elimination via construction of overpasses or underpasses (Maryland State Roads Commission 1935:12). Many such grade crossing elimination structures remain in service on Maryland's roads and railroads.

Other significant state planning studies of the 1930s included the 1935 *Ten-Year Highway Construction Program* report prepared by the Maryland State Planning Commission; the 1937 *Report of the Highway Advisory Committee* (which recommended sweeping additions to the main arterial system of Maryland); the 1938 *Preliminary Report of the Statewide Highway Planning Survey* (the most comprehensive and accurate survey undertaken since the 1899 Maryland Geological Survey report on Maryland highways); and the 1938 detailed Greiner report on Maryland's "Primary Bridge Program," which laid out plans for construction of the Bay Bridge and the long-span Susquehanna and Potomac bridges, and summarized debate (bridge versus tunnel) over what became the Greiner-built Baltimore Harbor Tunnel in 1957 (J.E. Greiner Company 1938; Maryland State Highway Advisory Committee 1937; Maryland State Planning Commission 1935; Maryland State Roads Commission 1938).

Congenial to transportation management and financial goals, the planning approach continued to affect Maryland road and bridge building between 1940 and 1960, with the 1950s witnessing a plethora of long-range forecasts, feasibility studies, and engineering evaluations by prominent consultants including many by Baltimore-based J.E. Greiner Company. Among the more significant planning studies and surveys, constituting benchmarks in the twentieth century development of Maryland's road system, were the 1940 projection study *Maryland Highway Needs, 1941-1960*, which recommended a 26-foot width or more for all rural bridges (but underestimated the coming impact of suburbanization on highway design before 1960); the 1944 Robert Moses study of Baltimore City's arterial routes; the 1952 *Proposed Twelve-Year Program for Road Construction and Reconstruction, 1954-1965* and the Public Administration Service's 1952

Maryland's Highways: A Report on an Administrative Survey (Maryland State Roads Commission 1940a, 1952a; Public Service Administration Service 1952).

The twentieth century spread of standardized designs, and especially the issuance of highway planning studies, marked the practical end of Maryland's traditional system of individual road and bridge petitions and "viewing" of bridge sites by citizens appointed by the county commissioners or courts. Gradually, during the period between the 1930s and the 1950s, the planning concept was built into county and municipal road construction. The old nineteenth century railroads and canals were succeeded by a vastly improved highway network, although the economically useful B&O Railroad and C&D Canal persisted with improvements beyond 1960 (Callcott 1985:39-40, 66-68).

SECTION III: TIMBER BRIDGES

HISTORICAL DEVELOPMENT

The earliest bridges built in North America were timber bridges. According to one account, European settlers at first utilized the bridges constructed by the Native American populations, which consisted of tied timbers laid across upturned forked tree trunks (American Association of State Highway Officials 1953a:19). This design was adopted by the settlers, who then modified the design by hewing the upper portions of the timbers to provide a flat surface and by adding a handrail to one side (American Society of Civil Engineers 1976:143). Where crossings exceeded the length of the available timber, short spans were joined and supported on wood piles or on timber cribs filled with earth or stone. In fact, the earliest recorded timber bridge-like structure built by European settlers in America was most likely this type of design. Constructed in 1611 on James Towne Island, Virginia, this timber bridge extended approximately 200 feet into the water and provided docking facilities in the 12-foot-deep channel (American Association of State Highway Officials 1953a:19).

These early techniques of timber beam bridge building were utilized extensively in the seventeenth and eighteenth centuries, with varying degrees of sophistication. In 1662, a timber crib-type bridge, known as the "Great Bridge," was constructed over the Charles River between Old Cambridge and Brighton, Massachusetts. In 1761, a 270-foot-long timber bridge was constructed over the York River in York, Maine by Major Samuel Sewall. It was supported by thirteen bents consisting of four piles each and had a center draw span that "provided a sufficient way for sloops to pass and repass through the bridge" (American Society of Civil Engineers 1976:149). One of the largest early bridges constructed with a draw span was the Boston-Charlestown bridge over the Charles River. It was 1,503 feet long and 42 feet wide, resting on 75 pile-type piers. The bridge had a six-foot-wide railed-in pedestrian walkway and was illuminated by forty "elegant" lamps (American Society of Civil Engineers 1976:150).

These examples illustrate the pinnacle of this simple, timber beam bridge construction in America. Needing to increase the length of individual spans, master carpenters and builders soon began to experiment with new bridge designs that utilized timber arch and truss forms, as well as combinations of the two, with varying degrees of success (Figures 5 and 6; Plates 1 and 2).

Timothy Palmer (1751-1821), a carpenter from New England, was one of the earliest American pioneers of timber arch building. In 1794, he designed the Piscataqua Bridge,

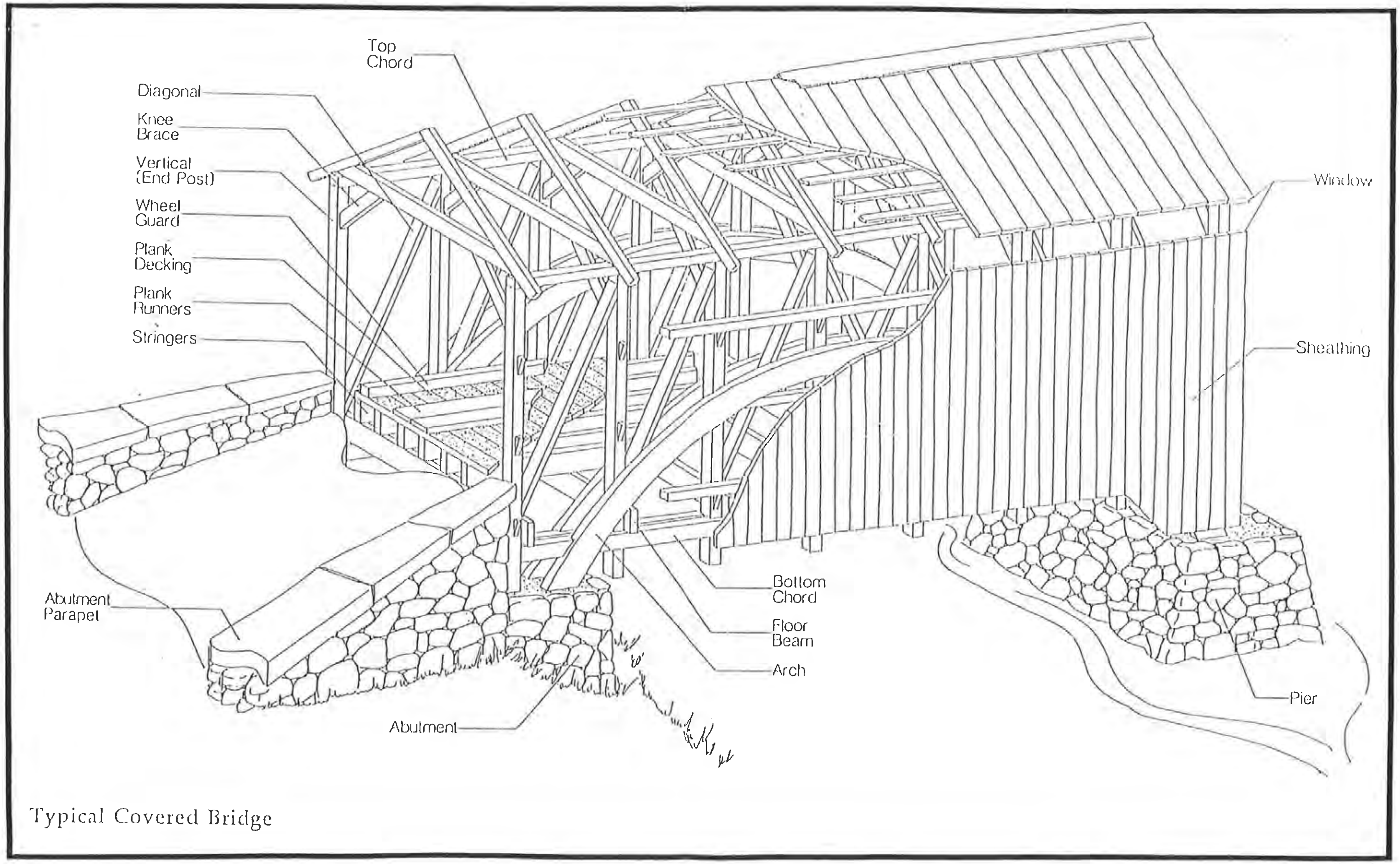

FIGURE 5: Typical Covered Bridge

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986

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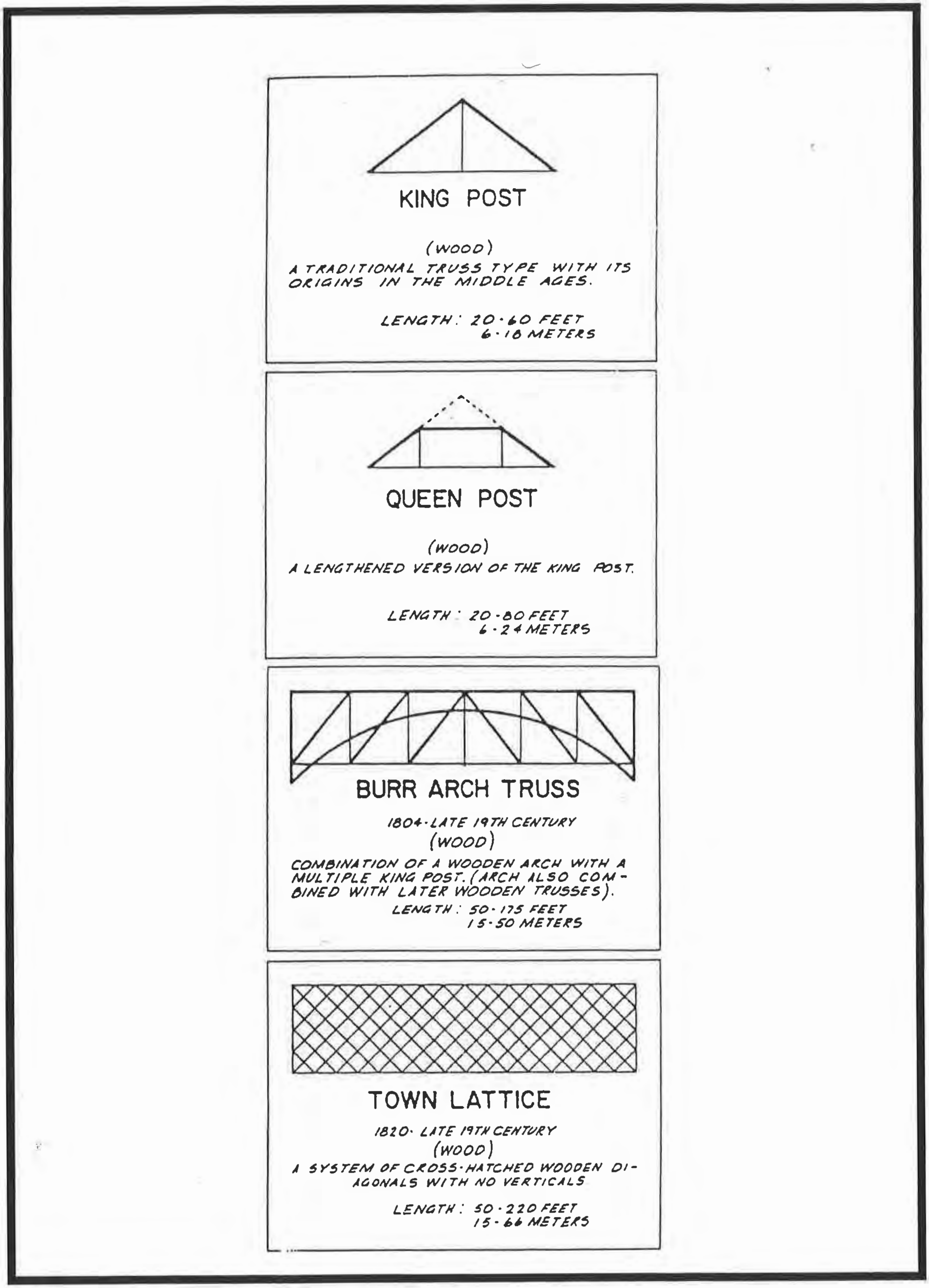


FIGURE 6: Wood Truss Types SOURCE: Allen and Jackson 1975

PLATE 1: **Typical Timber Covered Bridge: Bridge at Hickory** SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1926)

PLATE 2: Typical Timber Multiple-Span Beam Bridge: Bridge at Friendsville

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1932)

an arch bridge over the Piscataqua River near Portsmouth, New Hampshire. Known locally as the "Great Arch," the arch-truss section of the 2,362-foot bridge, which spanned the navigable channel of the river, had a vertically curved floor system supported by three concentric ribs. Palmer modified the floor system of his later bridges to give them only a moderate rise, reducing the risk to life and limb (American Society of Civil Engineers 1976:152).

In the early nineteenth century, Theodore Burr (1771-1822) developed a truss-arch combination, which he patented as the Burr truss in 1817. By combining the arch with the truss form, Burr was able to increase the length of the individual spans; the arch reduced the longitudinal sag of the road surface which had constrained the span-length of the earlier beam bridges (Lay 1992:278). Burr truss bridges were constructed over many significant crossings including the crossing over the Hudson River at Waterford, New York and the Susquehanna River crossing at McCall's Ferry, Pennsylvania.

Ithiel Town (1784-1844) is credited with having designed the first true truss in America. In 1820, he designed the Town lattice truss. This truss is composed of a stiff web of closely spaced diagonal timbers. The Town truss was exceptionally strong and easy to construct, and competed well with the Burr truss. Although Town lattice truss bridges were almost exclusively made of wood, the truss became the prototype for later wood and metal truss forms.

One early successor to the lattice truss was the Long truss. Patented by Colonel Stephen Long in 1829, the Long truss was a lattice truss that was refined to its essential elements. Long calculated the stresses in each of the individual members and sized them according to the load that they would carry (Lay 1992:279).

Because the wood members of these bridge types were subject to deterioration, the majority of the timber bridges were covered with roofs and wood siding to protect against the elements. Thus the "covered bridge" became a particularly versatile early American bridge form. When properly maintained, these wood bridges could have a long service life. The most frequent causes of covered bridge failures resulted from the lack of maintenance, fires, or floods (Armstrong 1976:109).

The railroads had a significant impact on the construction as well as on the continuing popularity of the timber bridge. During the 1830s, the Baltimore and Ohio Railroad employed bridge builders such as Lewis Wernwag to construct bridges over its major crossings. Burr, Town, and Long trusses were all extensively employed and became standard for railroad-bridge construction (Waddell 1916:21).

Another type, the timber trestle bridge, also was used extensively by the railroads. The first timber trestle was built by the Philadelphia and Reading Railroad in 1840 (Waddell 1916:22). With timber in abundant supply, the railroads used this functional design as an inexpensive and practical bridge option for its lines, particularly in remote locations of the country (Plate 3).

The popularity of the timber bridge continued into the 1880s even with the ascension of iron and steel as bridge materials. The combination of timber with other materials began with the invention of the Howe truss in 1840. William Howe patented a truss which utilized iron verticals as tension members and wood diagonals as compression members. The Howe truss became a standard of railroad bridge design. By the 1860s, the problem of wood deterioration was under better control with the invention of pressure creosote treatments, which extended the life of the wood members. Timber pile bent structures remained popular, in particular in tidal areas, into the twentieth century. These were most often used in combination with concrete.

Timber bridges continued to be constructed in the United States during the twentieth century. A significant technological development of the 1930s permitted construction of timber-concrete composite structures, featuring decks utilizing both timber and reinforced concrete. The 1975 American Society of Civil Engineers *Design Guide and Commentary on Wood Structures* offered the following description of composite decks of timber and concrete:

> Composite timber-concrete decks are commonly used in bridge construction. Construction is such that timber carries most of the tension forces. Composite construction is of two basic types, T-beams and slab decks. . . .Composite T-beam sections consist of timber stringers, which form the stem, and concrete slab for the flange area. Notches are cut into the top edge of the stringers to resist horizontal shear and mechanical fasteners are driven into the top to prevent vertical separation so that the two components perform integrally. Stresses due to temperature changes must be considered in the concrete section.
>
> Composite slabs consist of nominal 2-inch lumber, usually nailed-laminated with the wide faces vertical, and a concrete section cast monolithically in place. Grooves are formed by using alternate laminations that differ in width by 2 inches or by fabricating panels with a 2-inch offset between laminations. Horizontal shear is resisted by grooves cut into the projecting laminations or by metal shear plates. Transverse joints in the timber portion are made by dapping or cutting alternate laminations to a different length to provide finger joints. The concrete slab should be reinforced for temperature stress and for negative bending stresses when the deck is continuous over a support. No falsework or extensive forming is necessary with this construction [American Society of Civil Engineers 1975:372-73].

The timber-concrete composite slab type of bridge construction was pioneered in the United States by James F. Seiler and the American Wood-Preservers Association between 1932 and 1935. The latter organization's 1935 patent for "composite wood and concrete construction" became the basis for such technology.

PLATE 3: **Typical Timber Trestle: Bridge Crossing Gwynns Falls in Baltimore** SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, early 1930s)

TIMBER BRIDGES IN MARYLAND

Because of the availability of lumber in the state, the timber bridge was a functionally popular bridge type in Maryland from the European settlement era to the twentieth century. The numerous small streams that cross the state as well as the larger rivers such as the Susquehanna were often spanned by timber bridges during the eighteenth and nineteenth centuries.

In 1724, the Maryland General Assembly acted to clarify the rights of the counties to create and maintain bridges. The Assembly empowered county officials,

> as often as need shall require, for the repairing and making of bridges over the heads of rivers, creeks, branches, swamps, or other low and miry places, to cut down, or cause to be cut down, any tree or trees growing on any of the next adjacent land to such bridges necessary to be made or repaired, and the same trees to maul, or caused to be mauled, and carried from off such adjacent lands, and applied to the making and necessary repairs of such bridges as aforesaid [Kilty 1808:November 1724 Session, Chapter 14].

Although the type of timber bridge is not specifically stated in the 1724 law, these bridges were most likely simple beam-type bridges, and king and queen post truss types, which could be constructed rapidly and cheaply over Maryland's small streams and rivers (a 1795 supplement to the 1724 act granted compensation to the owners of the trees taken by the county to construct these small bridges) (Kilty 1808:November 1795 Session, Chapter 37).

In the early nineteenth century, Maryland took advantage of the evolving bridge truss technology. The state's major river crossings attracted significant bridge builders to Maryland. In 1817-1818, Theodore Burr constructed the Rock Run Bridge, an eighteen-span, 4,170-foot, covered Burr arch truss bridge over the Susquehanna at Port Deposit. The bridge burned in 1823 and was rebuilt in 1824 by Louis Wernwag, a native of Germany who became a prominent bridge builder in the United States after his immigration in the late 1700s. Wernwag also constructed the Conowingo Bridge over the Susquehanna River at Conowingo, Maryland, in 1818. This was a seven-span, 1,334-foot, covered, highway bridge that served the local community until 1847 when it was destroyed in a spring freshet.

These bridges represent the most impressive of the covered bridges built in the state. More common, however, were the smaller covered timber bridges, such as the Roddy Road Covered Bridge over Owens Creek in Frederick County, Maryland. Constructed by an anonymous builder, this is a single-span, king-post truss bridge that has stood in its current location since circa 1850. A 1937 survey of the state's covered bridges detailed 52 covered bridges, 35 of which were extant at the time of the survey, including Burr, bowstring, queen-post and king-post truss-type bridges.

Storms, fire, development, and vandalism have reduced this number to seven known covered bridges extant in Maryland today.

Apart from covered bridges, Maryland had an abundance of small uncovered timber bridges of the timber beam and king-post and queen-post truss varieties. An 1899 statewide survey of highway bridges conducted by the Maryland Geological Survey indicated that:

> a majority of the small bridges with spans up to 30 feet, culverts, and drains are of wood. The shortest spans are a simple beam to which is nailed the flooring and rails. For spans from 10 to 30 feet, a simple triangular frame with a central tension rod or post forms the supporting truss [Johnson 1899:205-206].

Many of these small bridges were replaced with metal truss and later with concrete spans, necessary for the growing traffic demands of the industrializing state.

Timber trestle-type railroad bridges were also constructed in Maryland. While constructing the more ornate and complex bridges in urban areas, the Baltimore and Ohio Railroad built the purely functional timber trestle bridges over crossings in its more rural locations. One such example is the B&O bridge over Antietam Creek constructed in about 1867. This timber trestle bridge, which is nearly 400 feet in length, was originally constructed to serve the Washington County Branch of the B&O Railroad and is believed to be the longest timber trestle built by the railroad company.

Despite the rise of use of metal and concrete in bridge building, timber bridges continued to be constructed in Maryland in the twentieth century. Many of these later timber bridges were timber and concrete composite structures favored in the flat terrain of the Tidewater region. Such timber-and-concrete composite structures were evidently introduced in Maryland by the State Roads Commission engineers, who kept abreast of early twentieth century trends in composite bridge design. In the 1937-1938 *Report of the State Roads Commission*, Bridge Division Chief Engineer Walter C. Hopkins acknowledged professional interest in such structures:

> The bridges constructed have been varied, with miscellaneous types and of different materials. Bridges have been built of concrete, steel, timber, or stone, or combinations thereof. Careful study is given the employment of those materials most satisfactorily adapted to the structure in question. Balance, proportion and treatment that will result in simplicity, gracefulness and pleasing appearance are always considered and sought by the designer [Maryland State Roads Commission 1938:71].

The Bridge Division's earliest timber-and-concrete composite bridges were built in 1937-1938 in Tidewater Maryland. Three such bridges were constructed in Wicomico County, and one each in Calvert, St. Mary's, Queen Anne's, Kent, and

Caroline counties. Pictured in the 1937-1938 State Roads Commission report, the longest such bridge was "a timber and concrete composite bridge of twelve 20-foot spans, providing a clear roadway of 26 feet, and two 3-foot, 1-inch sidewalks, over Tony Tank Pond, on the road from Salisbury to Princess Anne near Salisbury, Wicomico County" (Maryland State Roads Commission 1938:83).

Subsequent State Roads Commission reports refer to additional timber-concrete composite bridges constructed under state authority between 1939 and 1960, primarily at Tidewater (Coastal Plain) sites on the Eastern Shore and in Southern Maryland (Maryland State Roads Commission 1939a:71, 1943:45). In 1947, Bridge Division engineers observed that "the development of the composite use of timber and concrete has permitted the design of economical structures with the general appearance from the roadway of a much more costly bridge" (Maryland State Roads Commission 1947:53).

Conclusion

The following summary statements regarding structural characteristics for timber bridges, key periods of significance for timber bridges in Maryland, and the earliest known documented examples of timber bridges in the state are based solely on documentary research.

Timber beam bridges (see Plate 2) consist of timber beams supported by a timber or masonry structure. Intermediate supports may be timber pile bents, and abutments may be timber, masonry, or concrete. Railings and floor system are usually wood (as in Plate 2).

Timber trestle bridges (see Plate 3) consist of timber beams supported by a system of high timber piers or pile bents. High timber trestles were frequently utilized as railroad bridges.

Timber covered bridges (see Figures 5 and 6 and Plate 1) consist of a structural timber truss covered by timber roofing and siding which serves to protect the structural components from the weather. A variety of truss types were used, including king-post, queen-post, Town, and Burr. The truss systems include vertical and diagonal elements, between horizontal upper and lower elements called top and bottom chords. In the Burr arch-truss variant, a timber arch is added to provide further structural support (see Figure 6). In the Town truss variant, also called a lattice truss, the truss consists of timber members crossing at 45- to -60-degree angles, connected with wooden pins or trunnels. Timber covered bridges often feature wood plank decking supported on a system of timber stringers and floorbeams; wheel guards and plank runners are sometimes installed on the decking. Typically, timber covered bridges are supported on masonry abutments and (if more than one span) piers.

Timber-and-concrete composite bridges include a superstructure consisting of a composite timber and concrete slab. The timber and concrete materials work integrally to carry the deck loads. These composite decks are typically supported on timber piers or piles. Railings may be of wood or concrete.

Key periods of significance for timber bridges in Maryland, as indicated by documentary research include *1724 to ca. 1900*, during which simple wooden beam bridges continued to be constructed by local and county authorities, in single-span and multiple-span variants; *ca. 1800 to ca. 1900*, the heyday of covered bridge construction in the state, including major long-span river crossings by significant bridge builders Theodore Burr and Lewis Wernwag, as well as a large number of smaller timber covered bridges built with different truss configurations (simple king-post and Burr arch-truss are known to have been utilized); *ca. 1840 to 1900*, the period when large timber trestles for railroad use predominated; and *ca. 1935 to*

1960, the era of development and use of timber-concrete composite bridges by the State Roads Commission in the Tidewater or Coastal Plains region of Maryland.

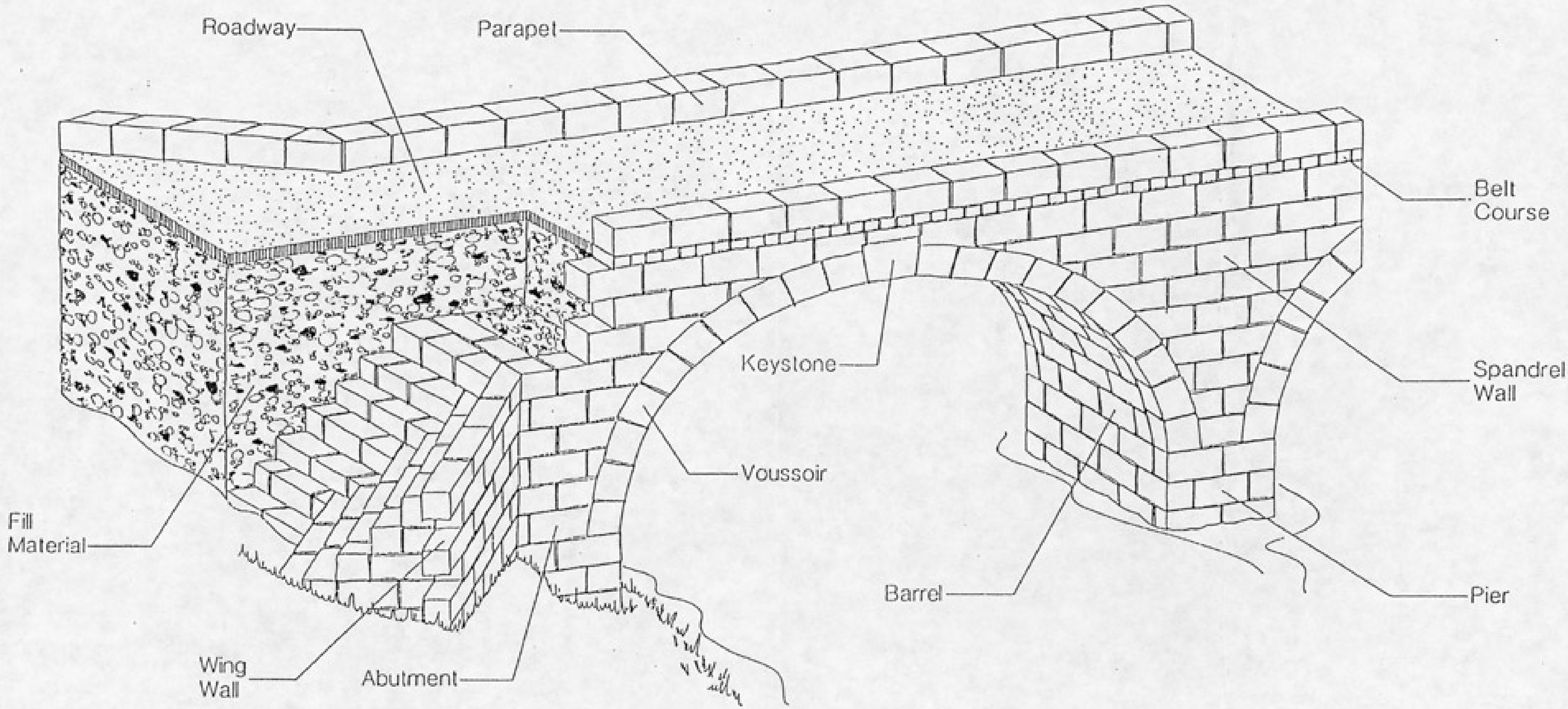
The earliest known documented examples of timber bridges in Maryland are those referenced in the 1724 Act of the General Assembly concerning the cutting of timber for bridge construction. The earliest known documented covered timber bridges built in Maryland are the Susquehanna River long-span covered bridges constructed in 1818 by significant bridge builders Theodore Burr and Lewis Wernwag. Dating of the earliest timber trestles built in the state cannot be exactly stated, but documentary sources indicate that during the 1840s Maryland railroads such as the Baltimore and Ohio and the Northern Central erected trestles. The earliest known documented timber-and-concrete composite bridges in the state were eight such structures erected by the State Roads Commission in Tidewater (Coastal Plain) locations in 1937-1938. (According to the 1993 State Highway *Bridge Inventory*, seven of these structures are extant.

HISTORICAL DEVELOPMENT

The stone arch bridge represents one of the earliest recorded advances in bridge building, illustrating the movement from simple beam spans to use of the structural arch form to better support loads. Engineering historians have traced the first functional precursors of stone arch bridges to the so-called corbelled arch, utilized in ancient cultures. The corbelled arch consists of masonry blocks built over a wall opening by uniformly advancing courses from each side until they meet at a midpoint. No actual arch action is produced by this design, also often called a false arch (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:A-5).

Since a true arch cannot support itself until the keystone is properly in place, the construction of stone arches required temporary support of the entire structure on falsework, usually composed of a scaffolded timber framework. Stone arch construction utilizing circular arches with keystones, and falsework during construction, was perfected by the ancient Romans, and the basic, necessary technology thereafter remained largely unchanged for two thousand years. Improvements between Roman times and the seventeenth century primarily consisted of efforts to achieve a greater span-to-rise ratio (that of the typical circular Roman arch was 2:1); for nearly 400 years after its 1345 construction, Florence's Ponte Vecchio with its "flat" (high span-to-rise ratio) trio of arches held the record for highest span-to-rise ratio (Lay 1992:267-268).

Coming from a tradition of craftsman design, the stone arch bridge owed its remarkable historical persistence to its load-carrying strength, its relatively simple construction technique, and its long life (Figure 7). The stones utilized in a stone arch bridge may consist of rubble masonry (rough unfinished and untooled stones), squared masonry (stones which have been tooled to a rectangular shape and roughly finished), and ashlar masonry (squared stones given a further tooling to a more refined finish). Construction of the substructure (piers and abutments from which the arch is said to "spring") was first accomplished, followed by the initial building of the "arch ring" (the basic ring composed of adjacent, usually wedge-shaped stones, or voussoirs, arranged in a radiating circle or ellipse) on the temporary system of wood falsework. With the arch rings in place across the intended width of a span (the rings together comprising the arch "barrel"), the remainder of the structure, including spandrel walls built on the arch at its outermost edges, could then be erected. Fill composed of dry earth or ballast was usually consolidated on top of the arch barrel for stability and was contained within the solid spandrel walls (P.A.C. Spero & Company 1991:13-14).



Typical Stone Arch Bridge

FIGURE 7: Typical Stone Arch Bridge

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986

Arch bridges constructed of stone have included small bridges and culverts, as well as larger and longer multiple-span viaducts and aqueducts. Perhaps because the technology of arch construction was received rather than invented in the United States, bridge historian J.A.L. Waddell noted in his 1916 *Bridge Engineering* that "stone arch bridges have played a very small part in bridge evolution in America" (Waddell 1916:28). More recently, Carl Condit found that arch bridges of stone were "extremely rare" in the American colonies and that hardly any evidence of seventeenth century stone arch bridges existed (P.A.C. Spero & Company 1991:13). Legislation of the colonial period has survived indicating that colonial authorities (including Maryland's General Assembly of 1699) encouraged "good and substantial" bridges, but these may well have generally been of timber, a more readily available and less costly material than building stone in many parts of colonial America. The earliest extant datable examples of stone arch bridges in the United States are the Frankford Avenue Bridge, a three-span bridge constructed in 1697 on the King's Highway over Pennypack Creek near Philadelphia, and the Choate Bridge, a two-span structure built in 1764 at Ipswich, Massachusetts (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:43; DeLony 1993:5).

Beginning in the late eighteenth century and continuing through much of the nineteenth century, the construction of stone arch bridges in the United States was given impetus by the internal improvements movement that spawned such ambitious engineering projects as turnpikes, canals, railroads, and water supply systems for rapidly growing cities. Turnpiking an existing road or properly building a new turnpike included plans for reliable stream and river crossings and a durable road surface of stone or gravel. Thus, the wealth of turnpikes built in the eastern United States between 1790 and 1840 often included improved bridges of stone to replace ferries or earlier simple wooden spans.

Canals required a variety of bridge structures, including short spans to carry the towpath from one side to the other at tight places, and culverts and aqueducts to take the canal itself over rivers and roads running transverse to its right-of-way. Lastly, the development and remarkable success of railroads in the nineteenth and early twentieth centuries inspired professional engineering interest in the design and erection of masonry structures that could effectively withstand the unprecedented heavy moving loads of locomotives and freight trains. Early large stone arch bridges constructed for railroad use, including Maryland's historic Carrollton and Thomas viaducts, dramatically illustrated the great strength inherent in the arch form. So, too, did the humbler stone culverts, often constructed to standard plans by railroads in the late nineteenth century.

The majority of surviving stone arch bridges and culverts in the United States are thus, historically linked to a turnpike, canal, or railroad of the 1800-1900 period (Plate 4). Private turnpike companies expended considerable capital building masonry arch bridges under the direction of experienced masons, but regular maintenance was not always adequately provided, and problems developed ranging from deterioration of parapet walls to bulging of spandrel walls due to accumulating moisture in the earth fill. Generally, the arches built for canal and railroad bridges were more likely than turnpike bridges to be designed by trained engineers. Stone masonry arch construction, frequently involving use of dressed masonry, was popular for railroads such as the B&O and the Pennsylvania Railroad even after the versatility of the metal truss bridge had been demonstrated in the latter half of the nineteenth century. Older turnpike bridges, however, attracted engineers' attention after the coming of the automobile and truck forced county, state, and municipal officials to provide for the heavy traffic demands of the twentieth century. Many such bridges were destroyed or seriously altered, but others continued in use or were bypassed and remained standing.

Though one of the most ancient bridge types, the stone arch bridge made a distinctly modern contribution to the development of concrete bridge technology. The stone masonry arch provided the precedent for arches constructed first in plain or unreinforced concrete, then later in concrete reinforced with metal sections, rods, or bars which resisted the tensile forces. Although few stone arches were built after the first several decades of the twentieth century, the persistence of the arch as built in the more plastic material, concrete, was due in large measure to the demonstrated advantages of stone masonry construction, as shown in numerous turnpike bridges and railroad spans.

STONE ARCH BRIDGES IN MARYLAND

Although no datable seventeenth or eighteenth century stone arch bridges in Maryland are known, the 1699 Act of the General Assembly requiring "good and substantiall" bridges over all heads of creeks and rivers may have occasioned construction of stone bridges as well as timber bridges, since the basic technology of stone arches was well known by that time (Browne 1902:475-476). The earliest legislative reference to arch bridges was the 1794 law which specified that common laborers hired by the county courts should not be permitted to supervise construction of "framed or arched" bridges over 15 feet in length (Kilty 1808:November 1794 Session, Chapter 52). This law, however, clearly indicated that the stone arch bridge was a familiar and important bridge type in early national, and probably colonial, Maryland.

The advent of turnpikes in the state, pursuant to an 1804-1805 law incorporating Maryland's first private toll road companies, spurred construction of stone arch bridges for important crossings where simple timber beam structures might be likely to wash out or deteriorate under heavy wagon traffic. A questionnaire sent out to major Maryland turnpike officers in 1818 under authority of the General Assembly and Governor Charles Goldsborough elicited evidence that the Baltimore and Reisterstown Turnpike Company had built many bridges "of solid materials," while the Baltimore and Frederick Turnpike Company had by that time expended over $56,000 on constructing the four-span stone bridge over the Monocacy just southeast of Frederick (this 1808 bridge, known as the "Jug Bridge," stood until 1942). The Baltimore and York Turnpike Company had built five one-span and two-span stone arch bridges on its improved "York Road," including the oldest extant datable stone arch bridge in Maryland, the Parkton Stone Arch (Goldsborough 1818). The Lloyd family of Chambersburg, Pennsylvania, and their various associated masons, dominated construction of the early nineteenth century stone arch highway bridges of Washington County; James Lloyd also is recorded as builder of the B&O's pioneering Carrollton Viaduct of 1829 (Mish and Cottingham 1977; Schodek 1987:77-78).

PLATE 4: **Typical Multiple-Span Stone Arch Bridge: Wilson's Bridge Crossing Conococheague Creek on the National Pike**

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, circa 1930)

Between 1811 and 1825, the federally built National Road also was constructed through Maryland between Cumberland and Uniontown, Pennsylvania. This landmark early federal public works project involved design and construction of numerous small-span arch culverts and a number of significant large bridges, such as the 1813 Casselman River Arch. Simultaneously, the Maryland legislature sponsored numerous extensions to the Baltimore and Frederick Turnpike with the object of connecting eastern and central Maryland to the National Road at Cumberland. The 1818 Wilson's Bridge and other early structures among the approximately 30 significant stone arch bridges known to have been built in Washington County were erected on these turnpikes linking Baltimore and Frederick with Cumberland and points west (Mish and Cottingham 1977).

Major canal projects, such as the Chesapeake and Ohio Canal (1828-1924) and the Chesapeake and Delaware Canal (begun 1824), also inspired construction of stone arch culverts and several large aqueducts to carry the canals over intervening streams and rivers. Perhaps the greatest impetus to stone arch bridge construction in Maryland, however, occurred with the founding and expansion of the Baltimore and Ohio Railroad during the 1820s and 1830s. During that period under the guidance of such distinguished engineers as Benjamin H. Latrobe, Jr., and Jonathan Knight, the B&O first erected near Baltimore its nationally significant Carrollton Viaduct (earliest stone arch railroad bridge in the nation), followed this with construction of other early stone arch railway spans at Ilchester and Ellicott City (Patterson and Oliver Viaducts, each now only partially extant), and climaxed its initial expansion toward Washington with the design and erection of the extant Thomas Viaduct in 1835, an imposing eight-span Roman arch structure that was the first multiple-span railroad viaduct and the first to be built on a horizontal curve (Harwood 1979).

The initial B&O building campaign also involved construction of numerous, less prominent stone arch culverts. A second major building campaign, between the late 1890s and 1910 under former Pennsylvania Railroad Chief Engineer Leonor Loree, resulted in the erection of a second generation of stone arch culverts and viaducts, many of which appear to be extant based on historical research and prior Maryland Historical Trust historic resource survey forms prepared by county historic preservation officers in the counties through which the B&O passed. During the nineteenth century and the early twentieth century, the growing city of Baltimore also engaged in construction of many stone arch spans for culverts and bridges. In 1866, the City Commissioner suggested construction of a stone bridge to carry Madison Street and three years later, reported erection of a "substantial" 40-foot stone bridge on Wilkens Avenue over Gwynns Run (City of Baltimore, City Commissioner 1866:250; 1869:376). In 1901-1902, the city built the present Boston Street Bridge, a masonry arch constructed of brick, to carry heavily traveled Boston Street and a railroad from the industrial district of Canton (Baltimore City Chief Engineer 1902).

The Good Roads movement of the late nineteenth and early twentieth centuries in Maryland fostered renewed interest in the preservation of the older stone arch highway bridges of the state, many of which had fallen into disrepair. The 1899 comprehensive report of the Highway Division of the Maryland Geological Survey noted how stone arch deterioration had been caused by "the weather and in part by willful destruction." Moisture penetrating the bridges often froze, causing "with the frost, a perceptible bulging and cracking of the walls." The 1899 report noted the four-arch "Jug Bridge" over the Monocacy as an example of such bulging problems, and observed that the parapet walls of the Casselman River Arch and the Cabin John Aqueduct Bridge were both in decayed condition (Johnson 1899:206-207). After purchasing nearly 190 miles of old turnpike right-of-way in 1910 and 1911, the State Roads Commission implemented a program to begin "the saving of the old stone arches and similar structures existing on these former turnpikes," noting that many of the bridges were "important and valuable both physically and historically" (Maryland State Roads Commission 1912b:80). Between 1908 and 1911, the State Roads Commission acted to save those bridges "most likely to fail and to permit probably the saving of all the rest" (Maryland State Roads Commission 1912b:80).

Maryland's historic stone arch bridges include a range of outstanding extant examples, reflecting primarily the early nineteenth century emphasis on the development of turnpikes, canals, and railroads for the state. Among the bridges are a number that are nationally significant, such as the 1813 Casselman River stone arch on the National Road, the 1829 Carrollton Viaduct on the old main line of the Baltimore and Ohio Railroad, and the 1835 Thomas Viaduct on the Washington Branch of the same railroad. A large number of stone arch turnpike bridges, both single-span and multiple-span, have also survived. Many original stone arch bridges and aqueducts likewise exist along the right-of-way of the Chesapeake and Ohio Canal, and there is also a historic resource of national importance in the Cabin John Aqueduct (or Union Bridge), a Roman arch built in the 1857-1864 period by the federal government for the Washington water supply system in the midst of the Civil War. A concise description of the major types of significant stone arch bridges found in Maryland, with some discussion of specific examples, serves to document the state's remarkable built heritage in this bridge form.

Stone Arch Roadway and Turnpike Bridges

Historical research has located no evidence of any extant, or non-extant but documented, stone arch bridges built in Maryland during the seventeenth and eighteenth centuries. Maryland's surviving nineteenth century stone arch highway or turnpike bridges include a group of some 24 (as of 1977) significant bridges in Washington County (out of an estimated 30 actually constructed between 1818 and 1863). The concentration of such bridges in Washington County (in the group is the famous Burnside Bridge, a key, famous point in the Civil War Battle of Antietam) has inspired considerable historical study, including Helen Ashe Hays's 1910 regional classic *The Antietam and Its Bridges* and a 1965 photo exhibit at the courthouse in Hagerstown (Hays 1910; Mish and Cottingham 1977). Significant stone arch turnpike bridges also were built in other Maryland counties. The oldest documented stone arch bridge in Maryland is the Parkton stone arch, a two-span masonry bridge over the Little Gunpowder Falls, built in 1809 for the Baltimore and York Turnpike. The state's second-oldest stone arch turnpike bridge that has been securely dated is the Casselman River Arch, erected in 1813 on the National Road near Grantsville (Little Crossings Historical Committee 1964).

The design characteristics of Maryland's extant historic stone arch bridges vary in number of spans, shape of piers and parapets, rise-to-span ratio, type of stone employed (brick was also utilized in some cases), and in the treatment of the masonry (coursed rubble, squared, or ashlar). Based on historical research and prior survey forms, the following are descriptions of some representative known stone arch bridges built for turnpikes, the National Road, and private or municipal roads in Maryland:

Parkton Stone Arch: Maryland Route 463 (old Baltimore and York Turnpike) over Little Gunpowder Falls, Baltimore County (MHT-BA-593). Built in 1809 and the oldest surviving, dated stone arch bridge in Maryland. Two arch spans, each 18 feet long. Central pier 6 feet thick and abutments 8 feet thick. Built in 1809 for the Baltimore and York Turnpike, one of the first group of turnpikes chartered by the state. Attributed to John Davis (1770-1864), clerk of Philadelphia Waterworks and first superintendent of Baltimore Water Company.

Casselman River Arch: Old Route 40 (National Road) over Casselman River, near Grantsville, Garrett County (MHT-G-II-C-023). Built in 1813 for the National Road, the first improved turnpike built by the federal government. 354-foot-long bridge built of uncoursed masonry, with single arch span. At time of construction, the largest single-span arch bridge in the United States. The distinctive "humpbacked" shape of the bridge provided better drainage for the roadway. Repaired in 1911 with six steel supporting columns; remained in service until 1933. Recognized as National Historic Landmark (1964).

National Road Stone Arch Bridge at Stanton's Mill: Old Route 40 (National Road) over stream near Grantsville, Garrett County (MHT-G-II-C-016). In contrast to the imposing Casselman River Arch, this bridge is representative of the smaller spans constructed by the Army topographical engineers who laid out the National Road. Built in 1817, the bridge is a single-span 30 feet in length and constructed of cut sandstone blocks. Later altered somewhat by addition of concrete parapet coping and concrete on underside of the arch.

Wilson's Bridge: Originally carried Hagerstown and Conococheague Turnpike, a Maryland-sponsored link to the National Road, over Conococheague Creek seven miles west of Hagerstown, near Wilson, Washington County (MHT-WA-V-001; HAER No. MD-41). Built in 1819 and the earliest dated stone arch bridge among the group of such arch bridges located in Washington County. Built by Silas Harry, of Chambersburg, Pennsylvania, a mason known to have built at least three other turnpike or roadway bridges in Washington County. Constructed of coursed local limestone, Wilson's Bridge is a structure of five segmental arches, symmetrical about the largest, central arch. Cut voussoirs comprise the exterior arch rings, and the bridge is supported by piers with conical projections. After partial collapse, the bridge was rehabilitated and since 1984 has been a pedestrian bridge in a county park (see Plate 4).

Funkstown Turnpike Bridge: Alternate Route 40 over Antietam Creek at Funkstown, Washington County (MHT-WA-I-029). Built in 1823 by the Lloyds of Pennsylvania for the turnpike leading to the National Road, this three-arch bridge of smoothly dressed limestone is the earliest dated, extant stone arch bridge over Antietam Creek in Washington County, where a sizable number of stone arch bridges were constructed between 1823 and 1863. The bridge features segmental arches with carefully cut voussoirs. The Lloyds and their various associate masons constructed the majority of Washington County's significant stone arch roadway bridges of the early nineteenth century. The arches of the Funkstown Turnpike Bridge were widened with concrete during the early twentieth century, and the original stone parapets were replaced with concrete parapets.

Devil's Backbone Bridge: State Route 68 over Beaver Creek, Devil's Backbone near Booth's Mill, Washington County (MHT-WA-II-017). Built in 1824 of coursed limestone with one large segmental arch lined with cut stone. A good, early example of the "humpbacked" variety of stone arch bridge, in which the spandrel walls rise to a peak above the crown of the arch. Only known span built by local stone mason Jabez Kenney.

Burnside Bridge or Lower Bridge: Burnside Bridge Road (old Sharpsburg-Rohrersville Road) over Antietam Creek one mile south of Sharpsburg, Washington County, within Antietam National Battlefield Park (MHT-WA-II-132). This bridge, thanks to its significant association with the Civil War Battle of Antietam, is possibly the best-known stone arch roadway bridge in Maryland. Built in 1836 of coursed locally quarried limestone by John Weaver, the bridge includes three arches springing from piers which are characterized by rounded or conical projections. Significant for its historic commercial associations like the other stone arch turnpike bridges in Maryland, the Burnside Bridge was the scene of fierce fighting during the September 17, 1862, Battle of Antietam, and has been preserved by the National Park Service.

LeGore Bridge: LeGore Bridge Road over the Monocacy River, near Woodsboro, Frederick County (MHT-F-8-49). A fine example of a privately constructed stone arch roadway bridge of the late nineteenth century, built to provide better access to a significant industrial operation. Built in the 1890s by James William LeGore utilizing limestone from his LeGore Combination Lime Company quarries, the 50-foot-high, five-span LeGore Bridge aided the industrial commerce of Frederick County and has carried modern auto and truck traffic throughout the twentieth century.

Boston Street Bridge: Boston Street over the Harris Creek Sewer, Baltimore City. As this span and others in Maryland demonstrate, masonry arches could also be constructed in brick. This bridge, built in 1901-1902 to finally solve a chronic metal bridge deterioration problem at the site due to powerful sewer gases, was constructed in brick. It employed all the techniques of stone arch construction and exemplifies municipal masonry arch engineering practice in early twentieth century Baltimore, which was then engaged in upgrading the professionalism of its engineering and public works functions.

Stone Arch Railroad Bridges

Equivalent to turnpike bridges in their historic engineering importance, stone arch railroad bridges constitute a second category of significant stone masonry structures built in Maryland during the nineteenth and early twentieth centuries. The Baltimore and Ohio Railroad, the first railroad in the United States to cross the Appalachian range, pioneered the design and construction of many important stone arch bridges, including the early Carrollton and Thomas Viaducts, both recognized as nationally significant civil engineering landmarks. The B&O's promotion of well-engineered stone arch spans extended to smaller bridges as well, such as culverts to cross the many streams intersecting the state's railroads and roads. Throughout the nineteenth century, under such prominent B&O chief engineers as Benjamin H. Latrobe, Jr., and Leonor Loree, the Baltimore and Ohio Railroad constructed stone arch bridges at sites where the piers and abutments necessary for such spans did not block water flow or interfere with traffic beneath the bridge (Harwood 1979).

Historical research was not undertaken into the surviving operating and engineering records of Maryland's railroads; thus, no estimate is possible concerning the approximate number of stone arch railroad bridges, underpasses, and overpasses constructed in the state until such research is performed. Based on investigation of prior Maryland Historical Trust historic resource survey forms, Historic American Engineering Record (HAER) documentation, and secondary sources, the following are concise descriptions of some outstanding or representative examples of stone arch bridges built in connection with the Baltimore and Ohio and other railroads in Maryland:

Carrollton Viaduct: Old B&O Main Line over Gwynn's Falls, Baltimore City (HAER No. MD-9). This historic structure was the earliest stone masonry bridge built for railroad use in the United States. Designed by B&O engineer Caspar Weaver and built in 1828-1829 by James Lloyd (of the Lloyd family of Chambersburg, Pennsylvania, prominent masons who were responsible for many of Washington County's stone arch highway bridges), the Carrollton Viaduct is a 312-foot-long bridge consisting of a full-centered arch with clear span length of 80 feet above the stream. An arched passageway, or underpass, was also included in the structure in one of the masonry-walled approaches. Heavy granite blocks utilized in the bridge were brought from quarries near Ellicott City and Port Deposit, then erected and dressed on the site. The falsework supported over 1,500 tons of such granite, a remarkable engineering accomplishment. The Carrollton Viaduct, a National Historic Landmark and National Civil Engineering Landmark, remains in service after 164 years.

Thomas Viaduct: Washington Branch (now main line) of the B&O over Patapsco River near Relay, between Baltimore and Howard counties (HAER No. MD-3). Built in 1835 as part of the construction of the Washington Branch of the B&O Railroad, this monumental structure was the first multiple-span masonry railroad bridge in the United States and the earliest to be built on a curving alignment. Named for railroad president Philip Thomas, the bridge was designed by B&O Chief Engineer Benjamin H. Latrobe, Jr., and was built by John McCartney, an Ohio master mason, under the supervision of Latrobe and the B&O chief of construction, Caspar Weaver. The Thomas Viaduct includes eight Roman arches built on a 4-degree curve, which was accomplished by laying out the lateral pier faces on radial lines, thus creating wedge-shaped piers. Due to the construction on the curve, there are variations in span and pier width between the two sides of the bridge. The viaduct is constructed of roughly dressed Maryland granite ashlar, quarried along the Patapsco River. Essentially unaltered except for repairs to the masonry and drainage system in 1937-1938, the Thomas Viaduct is a National Historic Landmark and a National Civil Engineering Landmark.

Waring Viaduct: B&O Metropolitan Branch over Big Seneca Creek, near Germantown, Montgomery County (HAER No. MD-22). The Waring Viaduct, a 274-foot-long, 74-foot-high stone viaduct with three 65-foot arches, is a good representative of the early twentieth century masonry arch viaducts built under the B&O leadership of Leonor Loree, a prominent civil engineer formerly employed by the Pennsylvania Railroad who was brought in to repair and upgrade the B&O rail network in Maryland. Loree utilized stone viaducts as well as plate girders to replace the various metal trusses, including some Bollman trusses, on the Metropolitan Branch. The Waring Viaduct was erected in 1905-1906, and attests to the continued construction of stone arch bridges, well into the twentieth century.

Small Stone Arches: Various locations, along the old B&O Railroad Main Line and Washington and Metropolitan Branches in Maryland. A group of representative examples of stone arch bridges and culverts constructed by the B&O were extant at the time of the 1979 publication of historian Herbert Harwood's *Impossible Challenge: The Baltimore and Ohio Railroad*. Like the railroad viaducts along the B&O lines, these smaller spans date from two distinct building campaigns: the initial construction and expansion of the railroad under Latrobe (1830-1850), and the later upgrading of the whole line under Pennsylvania Railroad veteran engineer Leonor Loree (first decade of twentieth century). On the oldest route, or Main Line, of the B&O, Harwood noted over 10 stone bridges dating to 1830-1850 (several may have had later additions or may have undergone reconstruction) and at least one structure (a twin arch southeast of Mt. Airy) dating to 1901. One other 1835 bridge (the Bascom Creek Bridge) was noted by Harwood on the Washington Branch of the B&O (Harwood 1979).

Other Significant Stone Arch Bridges

Other known stone arch bridges constructed in Maryland include a variety of structures built for the Chesapeake and Ohio Canal during the nineteenth century, and a singularly significant Roman arch, the Cabin John Aqueduct (Union Bridge), built between 1857 and 1864 by the federal government for the Washington, D.C., water system. In different ways, these structures display the traditional characteristics of stone arch bridge construction, adapted to meet the challenge of a large, engineered public works project.

To carry streams under the canal bed, more than 200 stone arch culverts were built along the right-of-way of the C&O Canal, between 1828 and its 1924 closing. While most such culverts were at right angles to the canal, a minority of such culverts were constructed at a skew angle to the canal bed, which required an innovative rifled construction of the arch rings comprising the barrel of the arch. Built in 1832, Culvert 65, documented as HAER No. MD-32, is an example of the skewed construction of C&O canal culverts. The canal also required larger aqueducts at river and major creek crossings; these, too, were arch structures supporting the canal itself above the river or stream (Sanderlin 1964). In Washington County alone, C&O engineers built five notable aqueducts between 1832 and 1840 (Mish and Cottingham 1977). Two of the most notable were the Conococheague Aqueduct at Williamsport, a three-span arch structure with piers on rounded footings and crowned at the parapet with decorative capitals, and the Licking Creek Aqueduct, featuring only one arch but with a total structure length of over 120 feet. Since the creation of the Chesapeake and Ohio Canal National Park in the 1950s, extant and partially demolished C&O canal culverts and aqueducts have been in the care of the National Park Service. Similar culverts were constructed on the lower-lying Chesapeake and Delaware canal, but these were destroyed during the twentieth century transformation of that canal into a ship canal (Gray 1985).

Another stone arch bridge of national historic engineering significance in Maryland is the Cabin John Aqueduct or Bridge, also known as the Union Arch or Bridge. This remarkable Roman arch was built between 1857 and 1864 under the direction of Army engineer Montgomery C. Meigs, also responsible for the U.S. Capitol dome. After surveys authorized by Congress, Meigs in 1853 recommended a water supply plan for growing Washington which involved moving water from the Potomac River above Great Falls in Maryland. Meigs persuaded officials to fund construction of a massive conduit capable of supplying the city with over four times the water furnished at the time to Paris. To avoid loss of head in the pipe as it crossed the valley of the Cabin John Branch, a Potomac tributary, Meigs designed and built an arch bridge 450 feet long to carry it, with a single flat arch span of 220 feet and a 57.25-foot rise. Running between its solid spandrel walls, the bridge contained a brick conduit 9 feet in diameter. The structure has a bottom arch of radially layered, cut and dressed granite, and inner rings of radially layered sandstone, the material utilized on the remainder of the bridge. Hidden behind the solid sandstone side walls, the actual, structural spandrel walls of the bridge consist of arches (five on the west end, four on the east), which reduce the dead-load weight of the structure on the haunches (Schodek 1987:112-114).

The Cabin John Bridge or Aqueduct continues to furnish water to the District of Columbia, and also carries MacArthur Boulevard over Cabin John Branch and the twentieth century George Washington Memorial Parkway. The structure also once carried a railway (Trautwine 1872:343). The bridge is a National Historic Landmark and a National Civil Engineering Landmark designated by the American Society of Civil Engineers (Schodek 1987:112-114).

Conclusion

The following summary statements regarding structural characteristics for stone arch bridges, key periods of significance for stone arch bridges in Maryland, and the earliest known documented examples of stone arch bridges in the state are based solely on documentary research.

Stone arch bridges (see Figure 7 and Plate 4) consist of a masonry arch barrel or ring, on the outermost edges of which are built spandrel walls which serve as retaining walls to contain the fill material (rubble, large rocks, or dry soil) deposited over the arch. The arch, which is in compression, carries the loads transmitted by the deck and spandrel walls. The spandrel walls typically extend above the roadway deck level to form the parapet walls of the bridge; a belt course, flush with or projecting from the spandrel wall, may give greater definition to the parapet. The arch ring is frequently articulated by voussoirs, or wedge-shaped cut stones (the center voussoir, called the keystone, is often given greater architectural treatment). Stone arch bridges may also include a date stone placed within the parapet. Typical substructural supports include masonry abutments and wingwalls, and masonry piers (if the bridge is a multiple-span structure). Numerous stylistic variations are possible in form and treatment of materials.

Key periods of significance for stone arch bridges in Maryland, as indicated by documentary research, include *1790-1830*, the era in which stone arch turnpike and National Road bridges were first built in the state; *1825-1850*, the period when the B&O Railroad and other Maryland railroads initially utilized stone arches, including the B&O's nationally significant Carrollton Viaduct (1829) and Thomas Viaduct (1835); and *1850-1910*, during which railroads continued their use of stone arch spans, and such bridges enjoyed expanded use on the roads of the Piedmont and Appalachian Plateau regions of Maryland. Between *1828 and 1924*, stone arch canal bridges and aqueducts were also constructed for the C&O Canal.

The earliest known documented examples of stone arch bridges in Maryland are the 1809 Parkton Stone Arch (Bridge #3105), the 1813 Casselman River Arch on the National Road, and the 1818-1819 Wilson's Bridge over Conococheague Creek. A known significant grouping of turnpike-related stone arch bridges has been identified in Washington County; these bridges (including Wilson's Bridge) comprise a group built between 1818 and 1860. (Burnside's Bridge on the Antietam, built 1836, also is nationally significant for its association with the 1862 Battle of Antietam.) Other historically significant extant stone arch bridges in Maryland include the 1829 Carrollton Viaduct, the 1835 Thomas Viaduct, and the Cabin John Aqueduct, or Union Bridge, built 1857-1864.

SECTION V: METAL TRUSS BRIDGES

HISTORICAL DEVELOPMENT

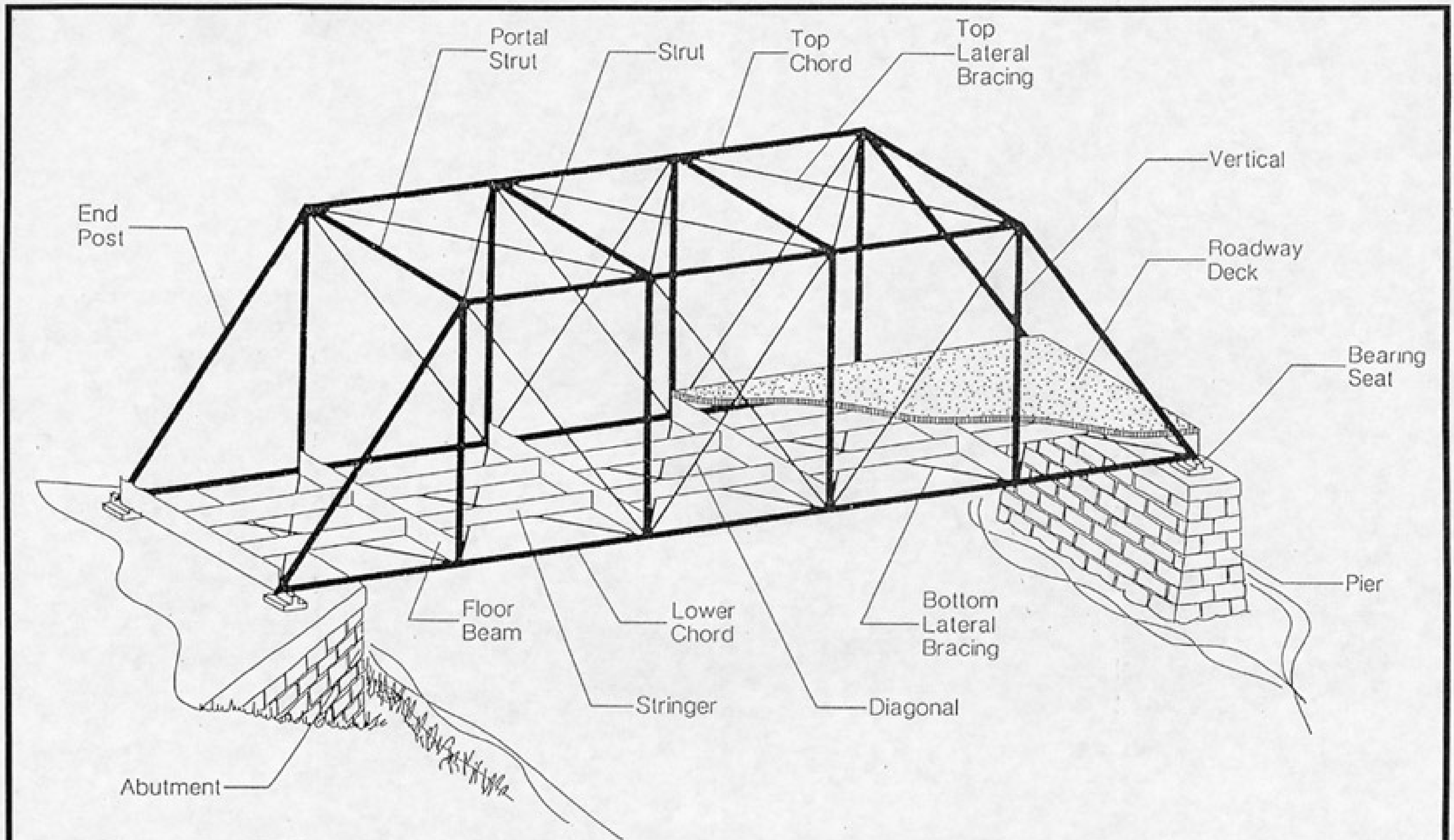
Truss bridges built in either iron or steel constitute a large number of Maryland's known historic bridges. These bridges, designed and constructed in a wide variety of types during the nineteenth and twentieth centuries, are among the most familiar historic bridges in the state. The type is widely recognized, taking second place only to timber-covered bridges and stone arch spans in their attractiveness to feature writers for newspapers and magazines. Metal truss bridges possess a significant technological history directly reflecting the evolution of Maryland's transportation network.

Prominent American highway and bridge engineer Milo S. Ketchum in his 1908 work *The Design of Highway Bridges and the Calculation of Stresses in Bridge Trusses* offered the following, succinct definition of a truss bridge:

> A truss is a framework composed of individual members so fastened together that loads applied at the joints produce only direct tension or compression. The triangle is the only geometrical figure in which the form is changed only by changing the lengths of the sides. In its simplest form every truss is a triangle or a combination of triangles. The members of the truss are either fastened together with pins, pin-connected, or with plates and rivets, riveted [Ketchum 1908:1].

Whereas a simply supported beam bridge spanning between abutments is subject to direct bending, with one structural member carrying both compressive and tensile stresses, the members of a truss individually carry only tensile or compressive stresses. The distribution of tensile (pulling a member apart) and compressive (pushing a member together) forces varies with the many types of trusses (Figures 8 through 11; Plate 5).

As presented in the Timber Bridges section of this report, construction of truss bridges in the United States originally began in the late eighteenth century utilizing timber as the basic building material. Renaissance architect Andrea Palladio's pioneering discussion of trusses was translated and circulated here as early as the 1740s, while in Europe during the late 1700s such innovative builders as the Grubenmanns erected covered wooden truss bridges in mountainous areas (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:109-126).



Typical Metal Truss Bridge

FIGURE 8: Typical Metal Truss Bridge

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986

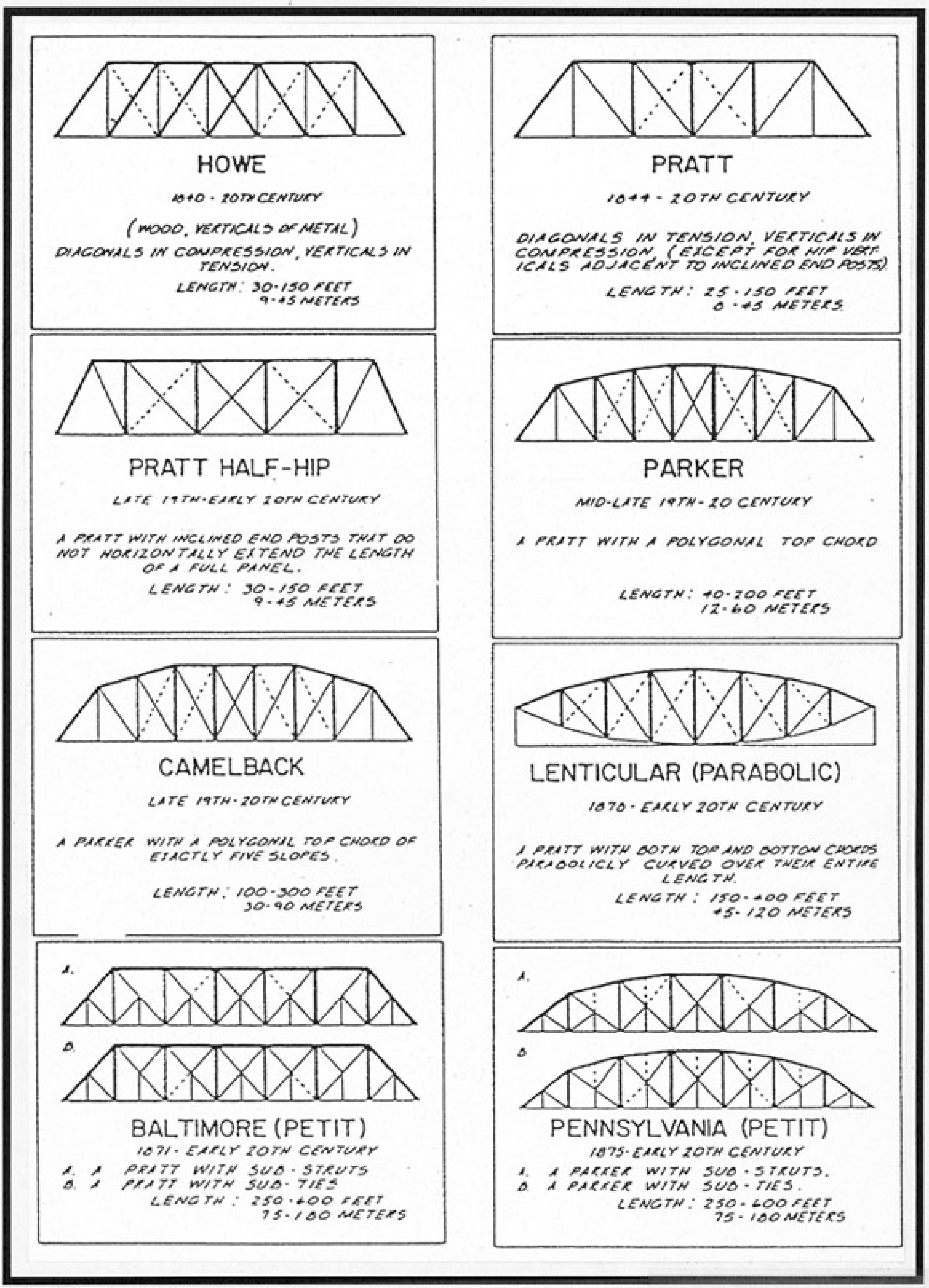


FIGURE 9: Metal Truss Types

SOURCE: Allen and Jackson 1975

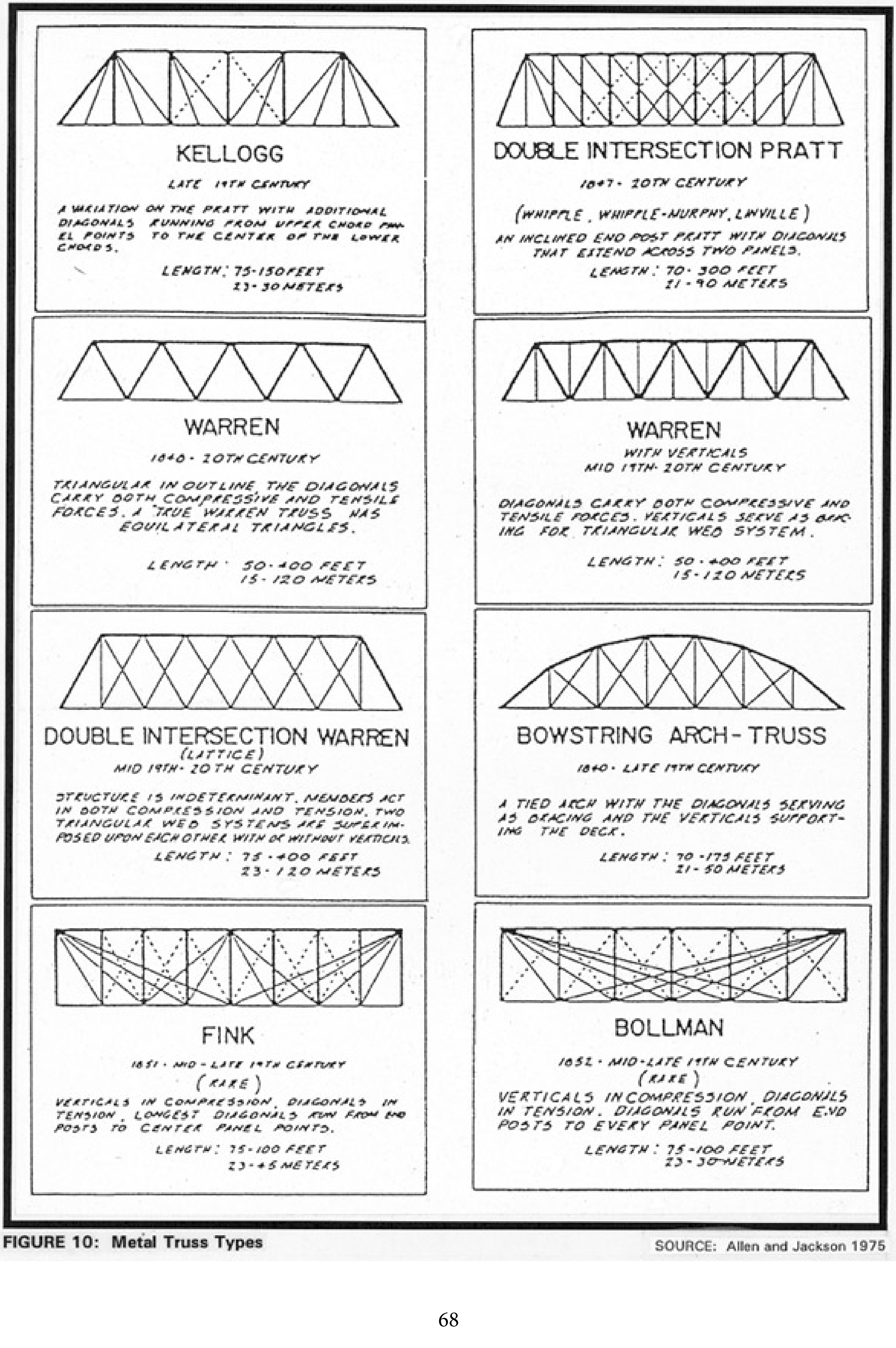


FIGURE 10: Metal Truss Types

SOURCE: Allen and Jackson 1975

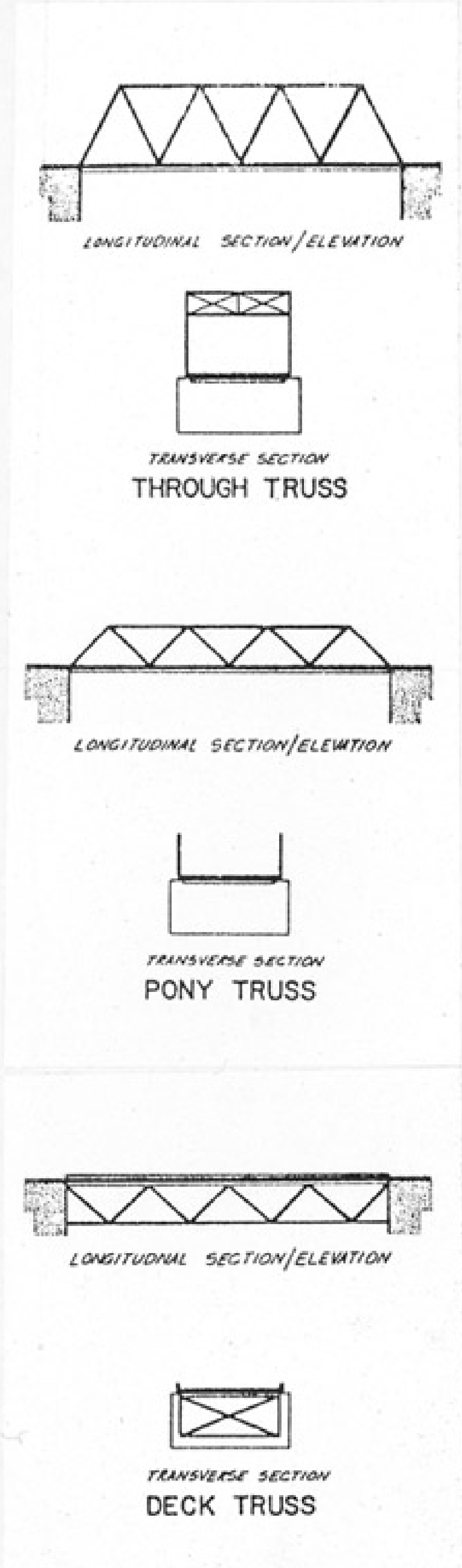


FIGURE 11: Types of Metal Truss Bridges SOURCE: Allen and Jackson 1975

PLATE 5: **Typical Metal Pratt Through Truss Bridge: Bridge Crossing the South Branch of the Patapsco River at Henryton**

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, circa 1930)

Truss bridges of all forms typically include vertical members and diagonal members located between two horizontal components called chords (upper and lower, or top and bottom). Both wooden and metal truss bridges are categorized by their specific design, which varies considerably according to the shape of members and whether they are placed in compression or tension. Trusses may also be grouped according to the relation of the deck, or roadway floor, to the rest of the superstructure. If a truss bridge carries its deck level with its bottom chord, it is a through truss, and usually has overhead bracing including portal braces between its two sides. A pony truss is a type of through truss where there are no lateral braces connecting the top chords of the superstructure. By contrast, a deck truss carries traffic on a level with the top chord, with the truss positioned below the deck (Figure 12; Plates 6 and 7).

In the United States, timber bridges built between 1800 and 1900 incorporated various wooden truss designs including the simple king-post, the queen-post (lengthened version of the king-post), the Burr arch truss (where a wooden arch combined with a multiple king-post or other wooden truss forms to produce great strength), and the Town lattice (a dense system of intersecting wooden diagonals with no vertical members). In 1840, seeking to market his design to the emerging American railroads, including Maryland's Baltimore and Ohio, William Howe patented a truss bridge that was a key transitional form between the exclusive use of wood and the iron and steel trusses of the late nineteenth and early twentieth centuries. Howe's technological advance was to employ iron rods as verticals in tension, but the Howe truss retained the older usage of wooden diagonals in compression. The 1830-1840 period also witnessed construction of composite, timber and iron trusses on the B&O under Benjamin Latrobe and Army engineer Stephen H. Long, whose Long truss was patented in 1830 (Vogel 1964; DeLony 1993:42-43).

In his 1847 *Work on Bridge Building*, Squire Whipple moved truss technology a step further toward all-metal construction by his understanding of the structural properties of cast and wrought iron (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:111). Cast iron was typically formed in a blast furnace where it was difficult to reduce a high carbon graphite level that induced brittleness. Wrought iron, however, was iron run through an additional "finery," or hearth, and with its reduced carbon content could be forged and would bend cold without cracking (Chard 1986:4-7). Whipple, who had built some of the earliest all-iron small bridges over the Erie Canal in the 1840s, suggested that cast iron, which fractures on impact and cannot carry tensile loads, be utilized for compression members in trusses, while the ductile wrought iron be reserved for tension members (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:111). Herman Haupt's 1851 treatise *A General Theory of Bridge Construction* also promoted metal truss bridges as practical, durable alternatives when properly engineered (Tyrrell 1911:166).

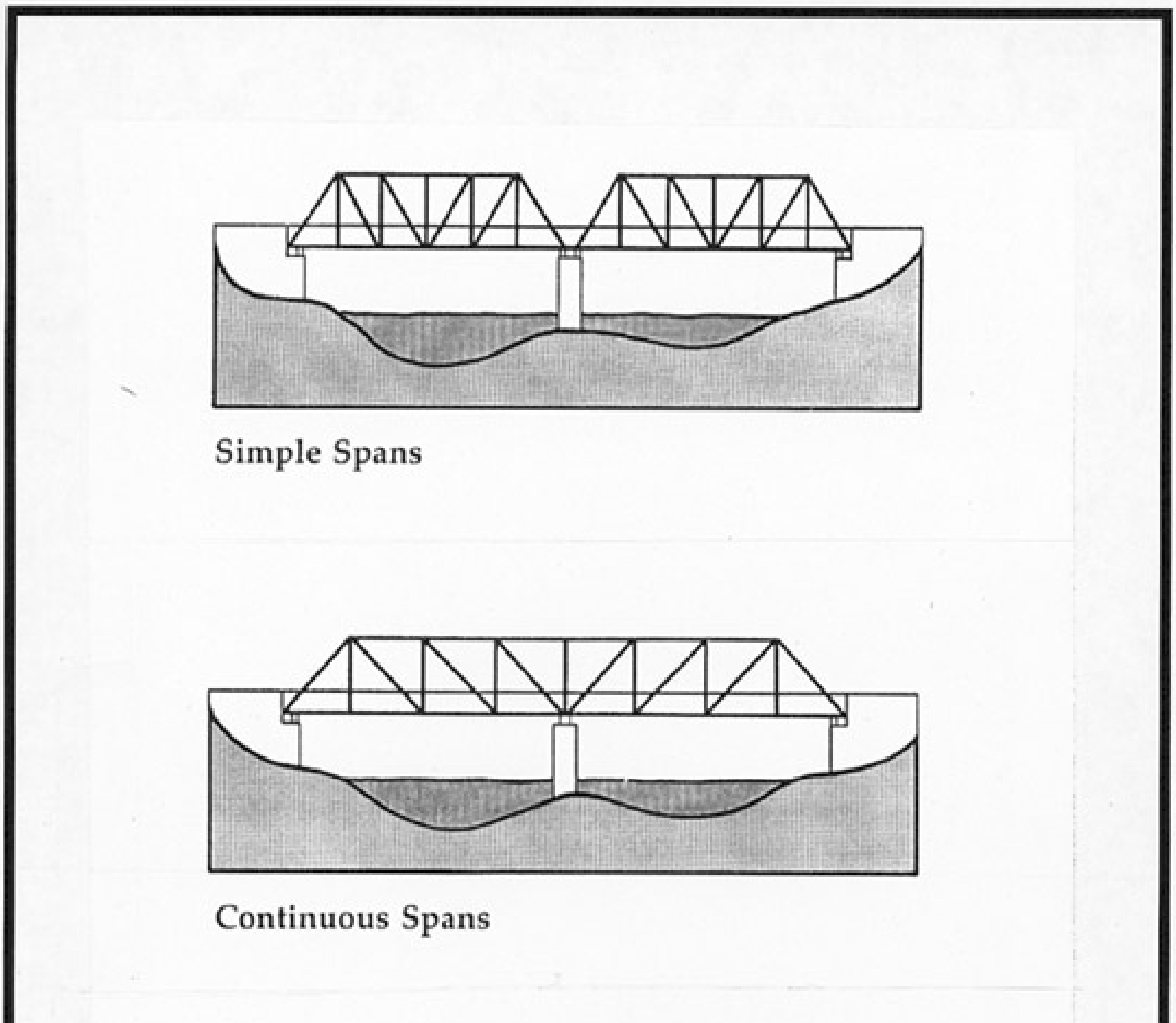


FIGURE 12: Types of Metal Truss Spans

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986

PLATE 6: Typical Metal Multiple-Span Pratt Pony Truss Bridge: Bridge Crossing Winter's Run at Edgewood

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, circa 1940)

PLATE 7: **Typical Metal Double-Intersection Pratt Truss Bridge: Bridge at Havre de Grace** SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1927)

Under the initial impetus of the expansion of American railroads, the period between 1840 and the Civil War saw the patenting and introduction of the majority of the earliest metal truss forms seen in the United States, including the popular Pratt (1844) and Warren (1848) types as well as Squire Whipple's bowstring truss (1841), his modified, "double intersection" Pratt (1847), Albert Fink's distinctive truss with long diagonals (1851), and the combination Burr arch and Pratt truss patented by Herman Haupt (1851) (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:109-126). An event of signal importance in Maryland's bridge building history was Wendel Bollman's patenting of the Bollman truss in 1852; Bollman's truss, as described below, was utilized extensively on railroads and roads in the state, although the Bollman truss bridge at Savage Mill in Howard County is the only known surviving example in the world (Vogel 1964).

Bollman also evidently suggested the design for what became the popular Phoenix column, a cylindrical vertical member manufactured and marketed extensively by the Phoenix Bridge Company of Phoenixville, Pennsylvania. Based in Baltimore, Bollman's Patapsco Bridge Company and its rival, the Baltimore Bridge Company, run by distinguished engineers Benjamin and Charles Latrobe and Charles Shaler Smith, were significant early bridge building firms selling to railroads and local governments in Maryland and elsewhere (Vogel 1964).

The latter four decades of the nineteenth century brought improvements in metal truss technology to a peak, as an increasing number of "bridge works" and "iron works" in the eastern United States were able to fabricate built-up truss bridge members in the shop then ship them by rail to prospective bridge sites by prior arrangement with local officials, who in many cases had filled out order forms describing the type, size, and location of the desired spans (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986). Historical research and previous historic resource surveys of Maryland bridges have identified some twenty-five to thirty bridge companies that built, or may have built, truss bridges in the state between 1850 and 1920. (See below, under "Metal Truss Bridges in Maryland," for further discussion of these companies and bridges they are known to have built in Maryland.)

Refinement of mathematical analysis of truss design, as well as empirical observation of the bridges in the field, led to a large variety of modifications to the basic early metal truss types during the late nineteenth and early twentieth centuries. Significant modified varieties included the Baltimore truss, a Pratt with added strength derived from sub-struts or sub-ties that was used extensively on the B&O Railroad. Cantilevered truss construction methods, in which sections of a truss bridge were built out from piers with sometimes complex anchorage systems holding back the upper parts of the unfinished span, were also pioneered in the late nineteenth century, by a significant Baltimore-based engineer. Charles Shaler Smith, founding partner of Smith, Latrobe & Company and its successor the Baltimore Bridge Company during the 1870s, designed and built the world's first high cantilevered truss, carrying the Southern railway over the Kentucky River in 1876-1877 (Schodek 1987:362). In 1939-1940, cantilevered truss construction methods were employed by the J.E. Greiner Company to build the Governor Harry W. Nice Memorial Bridge carrying U.S. 301 over the Potomac River (J.E. Greiner Company 1938:98-101).

The following short descriptions summarize the most important metal truss types developed during the nineteenth and early twentieth centuries in the United States, including transitional, modified, and some "hybrid" forms. Brief references are given to known structures in Maryland exemplifying each type (general sources for truss type information are Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986 and P.A.C. Spero & Company 1991). No early transitional truss structures constructed of wood and iron appear to have survived in Maryland judging from research and previous survey information. Further discussion of significant Maryland metal truss bridges, their approximate numbers and distribution, and highlights of their history may be found below in the subsection entitled "Metal Truss Bridges in Maryland."

The Pratt Truss

The Pratt truss was first developed in 1844 under patent of Thomas and Caleb Pratt. Prevalent from the 1840s through the early twentieth century, the Pratt has diagonals in tension, verticals in compression, except for the hip verticals immediately adjacent to the inclined end posts of the bridge. Pratt trusses were initially built as a combination wood and iron truss, but were soon constructed in iron only. The Pratt type successfully survived the transition to iron construction as well as the second transition to steel usage. The Pratt truss inspired a large number of variations and modified subtypes during the nineteenth and early twentieth centuries.

The majority of Maryland's surviving metal truss bridges are Pratt through and pony trusses, including both pin-connected and riveted examples. Known early examples described in existing Maryland Historical Trust historic resource survey forms include the Four Points Bridge over Tom's Creek in Frederick County (MHT F-6-9; pin-connected through truss built 1876 by Wrought Iron Bridge Company of Canton, Ohio) and the Gapland Road Bridge in the same county (MHT F-2-3; pin-connected pony truss built 1879).

Major subtypes of the Pratt design included:

Double Intersection Pratt Truss (Whipple, Whipple-Murphy, or Linville)

This subtype was patented in 1847 by Squire Whipple and modified in 1863 through addition of crossed diagonals by Lehigh Valley Railroad Chief Engineer John W. Murphy. Prevalent through late nineteenth and early twentieth century. The Double Intersection Pratt bridge is characterized by additional diagonals extending across two panels of the basic Pratt truss. This subtype was widely used for long-span railroad bridges. The only known previously surveyed Maryland example of a Double Intersection Pratt is the Poffenberger Road Bridge (MHT F-2-5 and HAER No. MD-35) in Frederick County, a pin-connected version.

Pratt Half-Hip Truss

The Pratt Half-Hip subtype was developed during the latter part of the nineteenth century. Characterized by inclined end posts that do not extend the length of a full panel, this subtype became popular in the United States from the 1890s into the early twentieth century. Research has uncovered one previously identified Maryland example, a half-hipped, pin-connected pony truss built at an undetermined, early twentieth century date by the Smith Bridge Company to carry Newcomer Road over Beaver Creek in Washington County (MHT-WA-II-475).

Parker Truss

The Parker truss was developed by C.H. Parker in a series of patents he filed between 1868 and 1871. Characterized by Pratt design but with an inclined top chord, the Parker truss was popular for longer spans well into the twentieth century. Maryland examples located through research include the Bullfrog Road Bridge over the Monocacy in Frederick County (MHT-F-6-8, a riveted through bridge built 1908 by York Bridge Company) and several spans constructed by the State Roads Commission during the 1930s.

Baltimore (Petit) Truss

Developed in 1871 by engineers of the Baltimore and Ohio and Pennsylvania Railroad, the Baltimore (Petit) truss subtype was popular into the early twentieth century. The Baltimore (Petit) truss was characterized by Pratt design featuring additional, auxiliary sub-struts or sub-ties linking the chords and the diagonal and vertical members. Maryland examples located through research include Bridge 1679, a steel bridge taking the Western Maryland Railroad over the National Road at Cumberland (MHT-AL-V-B-151, built 1912) and the Old Post Road Bridge near Havre de Grace (MHT-H-12073, built of steel in 1905 by American Bridge Company).

Pennsylvania (Petit) Truss

The Pennsylvania (Petit) truss was introduced during the mid-1870s as a variant of the Parker truss. Like the Baltimore (Petit) design, the Pennsylvania (Petit) was characterized by the addition of sub-struts (to resist stresses) or sub-ties (to transmit stresses) to a demonstrably useful form (the Parker). Pennsylvania (Petit) trusses were erected well into the twentieth century. A known, significant Maryland example is the 1924 Glendale Road Bridge in Garrett County, comprising two spans built by McClintic-Marshall during the construction of Deep Creek Lake (HAER No. MD-88).

Camelback Truss

Also a variation on the Parker truss design, the Camelback truss was characterized by its distinctive polygonal top chord consisting of exactly five slopes. The Camelback truss was popular for through spans primarily from its inception in the late nineteenth century through the mid-twentieth century. Maryland examples discovered through research may include a group of bridges built in the 1920s and early 1930s under the aegis of the State Roads Commission.

The Warren Truss

Patented in 1846 by British engineers James Warren and Willoughby Monzoni, the Warren truss and its variants constitute a commonly built metal truss bridge type of the nineteenth and early twentieth centuries. The original form of the Warren was purely a series of equilateral triangles in which the diagonals carried both compressive and tensile loads. Later, verticals were added but served only as bracing for the entire triangular web system between parallel top and bottom chords. Like the Pratt truss, the Warren truss was widely built throughout the United States from the middle of the nineteenth century well into the twentieth century, and spawned many variants, including a double intersection, or lattice, subtype in which two triangular truss systems are superimposed with or without verticals.

Research located Maryland Historical Trust historic resource survey forms for two Warren steel trusses in Maryland: the 1907 Carter Farm Bridge on Deer Creek in Harford County (MHT-HA-799; this bridge was evidently moved from another site, as were many other highly adaptable short span trusses in the United States) and the 1910 Reel's Mill Road Bridge over Bush Creek in Frederick County (MHT-F-5-8). Both bridges were riveted pony trusses built by the prolific York Bridge Company of York, Pennsylvania.

The Bowstring Arch-Truss

A highly significant type including an arched upper chord (tied, or rigidly fixed at the abutments) with diagonals serving as bracing and supporting the roadway, the bowstring arch-truss's development dates from Squire Whipple's patent of 1841. Although Whipple and bridge engineers such as Thomas Moseley patented proprietary forms of the bowstring arch, the arch-truss in the bowstring configuration (with Pratt or Warren trusses) was not frequently built until the late nineteenth century, primarily for lightly traveled rural roads requiring relatively small spans. The development of metal bowstring arch structures is discussed in greater detail in the section of this report entitled "Metal Suspension, Arch, and Cantilever Bridges." Research uncovered previous Maryland Historical Trust survey forms or HAER recordations for one bowstring arch-through truss bridge (HAER No. MD-83; the Waverly Street Bridge at Williamsport) and three pin-connected pony trusses on rural roads (MHT-F-2-5, the Crum Road Bridge over Israel Creek in Frederick County, built circa 1875 by the King Iron Bridge Company; MHT-F-2-2, the Bennies Hill Road Bridge over Catoctin Creek, also a King product built circa 1880 in Frederick County; and MHT-HA-1237, Bridge 51 in the Whitakers Mill Historic District, Harford County, a bowstring arch-truss bridge of undetermined date featuring a Warren truss configuration).

The Bollman Truss

Once widespread but now reduced to a single known extant example in the world, located over the Little Patuxent River at Savage Mill in Howard County, Maryland, the Bollman truss type is perhaps Maryland's most significant contribution to metal truss design, if not American civil engineering itself. Wendel Bollman's national significance as an early, innovative bridge engineer has been chronicled by technological historian Robert Vogel (Vogel 1964) and is discussed in more detail below in the subsection "Metal Truss Bridges in Maryland." Patented in 1852 and utilized extensively on the Baltimore and Ohio Railroad, for which Bollman worked as master of road, the Bollman truss featured vertical members in tension, with diagonals also in tension and running from the top corner of each truss endpost to every panel point (joint where verticals met the lower chord) on the truss. Vogel has shown that Bollman's truss was, as Bollman originally maintained, a composite suspension-and-truss bridge, with a non-structurally functional lower chord and diagonals performing much like the suspenders or hangers on a suspension bridge (Vogel 1964).

Like the similar truss developed by Albert Fink for the B&O and other railroads, Bollman's truss represents the key transitional stage in American bridge engineering between empirical, rule-of-thumb design and the mathematical analysis of truss loading promoted by such engineers as Squire Whipple and Herman Haupt. Although his Patapsco Bridge Company offered Pratt trusses as well as his own patented truss for railroads and highways, the Baltimore-born Bollman stands as one of the most important engineering figures of the industrializing nineteenth century. Bollman bridges were built so often by the B&O between 1850 and 1880 that the railroad has accurately been spoken of as being "Bollmanized," but such structures were also located on roads in Baltimore City and County as well as western Maryland (Harwood 1979; Vogel 1964).

The Wichert Truss

During the late nineteenth and early twentieth centuries, many variants of the Pratt and Warren truss designs were developed and put into service on United States roads and railroads. An additional significant twentieth century truss type which deserves mention is the Wichert truss, which was utilized in several important bridges built in Maryland.

The Wichert truss is a significant type of continuous truss. Continuous trusses have a chord and web configuration that continues uninterrupted over one or more intermediate supports, compared with simply supported trusses which are supported only at each end. Due to concerns over potential stresses caused by intermediate pier settlement, continuous trusses were not generally employed until the early twentieth century. In 1930, E.M. Wichert of Pittsburgh addressed the problem with his Wichert truss, a continuous truss in which hinged quadrilateral sections were included over the intermediate piers. Wichert's first major truss bridge constructed to this design was the 1937 Homestead High Level Bridge over the Monongahela River at Pittsburgh.

Maryland State Roads Commission engineers, noting the usefulness of the Wichert design for long river spans, built an early example of the Wichert truss between 1937 and 1939, in cooperation with the West Virginia State Roads Commission. A high-level crossing of the Potomac connecting Shepherdstown, West Virginia, with Washington County, Maryland, this extant 1,020-foot-long structure includes six spans of Wichert continuous deck trusses with a 24-foot clear roadway (Maryland State Roads Commission 1939a:80; Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:124). In 1939-1940, J.E. Greiner Company and the Maryland State Roads Commission incorporated Wichert-type deck trusses in the Governor Harry Nice Memorial Bridge over the Potomac and the Thomas Hatem Memorial Bridge crossing the Susquehanna at Havre de Grace (J.E. Greiner Company 1938). Continuous deck trusses were also utilized in portions of the first Chesapeake Bay Bridge, built between 1949 and 1952 by Greiner under state contract (Brown 1952:17).

Post-1900 Patterns in Truss Fabrication and Use

The Good Roads movement of the 1880-1900 period prompted calls for improvement of ordinary bridge structures as well, and in numerous jurisdictions official policy called for replacement of older wooden bridges with metal trusses. The development of the Bessemer and open hearth processes permitted the manufacture of low-carbon structural steel, which became generally available for truss bridge construction during the 1890s (Chard 1986). Other late nineteenth and early twentieth century technological improvements, such as the invention of the portable pneumatic riveter, allowed great flexibility in truss construction. By 1920, built-up truss members could be shop-riveted and the bridge connections riveted on site.

Engineering handbooks of the 1890-1920 period accurately reflected the remarkable versatility and usefulness of the metal truss bridge, whether pin-connected or riveted, built in iron or steel, or utilized for fixed or movable spans. Milo Ketchum's 1908 text *The Design of Highway Bridges* noted American Bridge Company standards recommending pin-connected or riveted Pratt through trusses for highway bridges of 80 to 168 feet, quadrangular Warren riveted trusses for 80- to 152-foot spans, Camelback trusses (Pratts with polygonal top chords, usually having five slopes) for 168- to 220-foot crossings, and pin-connected Petit trusses for spans longer than 220 feet (Ketchum 1908:213).

In 1924, the American Society of Civil Engineers' Special Committee on Specifications for Bridge Design and Construction issued a final report on "specifications for design and construction of steel highway bridge superstructure." The committee, which included prominent Baltimore engineer J.E. Greiner, recommended rolled beam bridges up to 40 feet long, plate girders or lattice trusses from 30 to 100 feet, riveted half-through (or pony) trusses between 50 and 100 feet, riveted trusses at 90 feet and over, and riveted or pin-connected trusses at 150 feet and over (American Society of Civil Engineers Special Committee on Specifications for Bridge Design and Construction 1924:267).

In 1933, Victor Brown and Carleton Conner in their *Low Cost Roads and Bridges* noted several changing patterns in modern roadway truss usage. While "truss spans for low cost bridges" were "commonly of structural steel" and ranged from 60 feet to 250 feet, Brown and Conner found that "near the lower limits and up to 100 feet, the rolled steel I-beam is replacing the pony and short span steel truss." With the development of heavy trucks, which featured high cabs and trailers, deck trusses of steel were gradually replacing through trusses whose portals and overhead bracing limited vertical clearance. Brown and Conner recommended a variety of efficient inexpensive crossings, including combinations of through trusses or pony trusses with reinforced concrete and steel girder approach spans (Brown and Conner 1933:510-516).

METAL TRUSS BRIDGES IN MARYLAND

The development of the metal truss bridge in Maryland resulted from the early growth of railroads in the state. Although Squire Whipple in the early 1840s had designed a number of small iron truss bridges over the Erie Canal in New York State, Maryland soon thereafter became a laboratory for experimentation in adapting iron to railroad bridge design. It was necessity that caused the railroads to pioneer the construction of metal truss bridges: the railroads' heavy locomotives and rolling stock required bridges far stronger and more reliable than those yet built for highway use.

The earliest attempts to adapt truss designs to metal construction were characterized by "an intuitive sense of proportion, stress, and the general 'fitness of things'" that lacked exact science (Vogel 1964:80). Such vagueness had sufficed when constructing timber bridges for the relatively light loads to which highway bridges of the time were subjected, but the results were frequently uncertain when this approach was applied to new materials and new uses. Perhaps the first metal truss bridge in the state was an iron Howe truss that was erected in 1846 at Monument Street in Baltimore to accommodate the Baltimore and Susquehanna Railroad. It appears that the City of Baltimore appropriated $6,000 to J.R. Trimble to erect the bridge; it is not known how successful the enterprise was. Another bridge built at about the same time was a metal truss using cast iron compression members and wrought iron in tension. Unfortunately, it is not known what truss design was used, but the design, materials, or workmanship proved defective; the bridge suffered "absolute collapse" in 1848 "without any warning and in the absence of any unusual loading" (Hilton 1913).

It was under the aegis of the Baltimore and Ohio Railroad in the 1850s that the idea of the metal truss was brought to successful fruition. In his 1849 Chief Engineer's report, Benjamin H. Latrobe announced that "reconstruction of the large Bridges at Little Patuxent and at Bladensburg. . .will be executed in a few months. . . . It is proposed to erect a superstructure of Iron upon stone abutments, at each place -with increased span, for greater security against future floods" (Vogel 1964:88).

The design that was subsequently to be known as the Bollman truss was what Latrobe had in mind. The design, which owed some debt to Latrobe's own work with radiating struts, was the creation of B&O's master of road, Wendel Bollman. One year later, in 1850, the first manifestation of Bollman's design was erected over the Little Patuxent River at Savage Factory. The 76-foot-long Savage Bridge and its sister bridge at Bladensburg gave "much satisfaction" and caused Latrobe in his 1850 report to express great confidence in the future of iron bridge construction. Soon thereafter, Bollman truss replacements were erected by the B&O over the Patapsco River at Elysville and over the Potomac River at Harpers Ferry, followed by numerous B&O Bollman trusses in Maryland and other states.

Bollman was a transitional figure between intuitive and exact engineering. Although he made use of mathematical analysis, he also relied upon empirical methods to test his designs. He would frequently build models of his designs and then load them until they collapsed in order to discover weaknesses (Vogel 1964:83). Bollman applied for a patent on his truss design in 1851 and received it in 1852. No later than 1855, one of Bollman's former B&O assistants, John H. Tegmeyer (subsequently Baltimore City Commissioner), formed a company in Baltimore that advertised "Wendel Bollman's Patent Iron Suspension Railroad Bridge" in several railway journals (Vogel 1964:87, 91).

Although the design was marketed to railroads, it appears that Allegany County Commissioners and the Cumberland City Council took notice of the Bollman truss in 1854. Will's Creek in Cumberland had been the site of at least six ill-fated bridges since 1755, including an iron suspension bridge that lasted from 1816 to 1838. The suspension bridge's timber replacement was in complete disrepair by 1854 when the County Commissioners and the City Council agreed to split the cost of replacing it. According to an 1878 account, "a contract was made with a Baltimore firm for the erection of an iron bridge of the Bollman pattern," and the bridge was completed by the end of the year (Lowdermilk 1971:371). Although it is unclear if this Cumberland bridge was the first metal truss highway bridge in Maryland, it was certainly one of the first, and appears to be the first direct translation of railroad-developed metal truss technology to highway use in the state. The Will's Creek Bridge had lasted 38 years when it was replaced in 1892, far longer than any of its predecessors at the site.

As a nexus for railways and the accompanying concentration of engineering talent, Baltimore rapidly became an early center of bridge building activity. Not only were there railroad bridges to construct in the city and its environs, but Baltimore had need of a great number of metal highway bridges as the earlier timber bridges proved unequal to the traffic demands placed on them by the growing city.

In 1858, Bollman left the employ of the B&O and joined John Tegmeyer and John Clark in Baltimore to found W. Bollman and Company, apparently the first company in the nation to design, fabricate, and erect bridges (Vogel 1964:91). Advertising designs for roofs, engine houses, and machine shops as well as Bollman truss bridges, the company ceased operations in the early 1860s because of the Civil War. Before its close, W. Bollman and Company obtained considerable B&O work (Olson 1980:107). After the conclusion of the Civil War, in 1865, Bollman (John Tegmeyer having become City Commissioner of Baltimore) organized the Patapsco Bridge and Iron Works, which built railroad and highway bridges (including other proprietary types as well as Bollman trusses) not only in Maryland, but also in North Carolina, Cuba, and Mexico until the company was dissolved upon Bollman's death in 1884. One of Bollman's last projects was the replacement of the movable bridge at the mouth of the Jones Falls (giving entry to the City Dock) with a truss swing span that opened for travel in 1880 (Baltimore City, Jones' Falls Commission 1882:695). This project was conducted under the aegis of the Commission for the Improvement of Jones' Falls, formed in response to the flooding of 1868 and the drought of 1872 (Olson 1980:163).

Bollman's chief Baltimore competitor was Smith, Latrobe and Company, organized by Charles Shaler Smith, Benjamin H. Latrobe, and C.H. Latrobe in 1866, and reorganized as the Baltimore Bridge Company in 1869. Before its dissolution in 1880, this company constructed major bridges across the Mississippi, Missouri, and Kentucky rivers (built in 1876, the Kentucky River Bridge was the first major cantilever bridge in the nation).

H.A. Ramsay & Co. was another bridge firm operating in Baltimore in the 1870s and 1880s. This firm was responsible for at least three of the bridges built by the Jones' Falls Commission in the 1880s. The first, a replacement at Pratt Street, was a heavy wrought-iron bridge of 106 feet, including three 20-foot-long through trusses. The second was at Chase Street, crossing both Jones Falls and the tracks of the Northern Central Railroad; it consisted of two spans "of the triangular type." The third bridge built over the Jones Falls was a heavy three-span though truss. All three of these bridges were built by Ramsay in 1881 (Baltimore City, Jones' Falls Commission 1882:697-699).

Other bridge-building firms operating in Baltimore in the nineteenth century were Campbell and Zell Company (1896-1899); J.G. Clarke and Company, subsequently Clarke Bridge Company (1879-1883); A. and W. Denmead and Sons (1850s); and Murray and Hazelhurst (building bridges 1857-1869).

Baltimore's flurry of metal truss bridge activity from the 1850s through the 1880s, along with the 1854 Bollman truss bridge over Will's Creek in Allegany county, proved the usefulness of metal truss bridge design to highway applications. County Commissioners in the Piedmont and Appalachian Plateau counties soon took notice of Baltimore's experience. They undoubtedly noticed, too, that the metal trusses the railroads were erecting in their counties were withstanding prodigious loadings and were not being washed away by every spring freshet. The typical timber beam bridge so prevalent in the counties was notorious for its inability to deal with either challenge. In addition, the timber bridge, covered or uncovered, was subject to decay and required a considerable amount of maintenance. The proven ability of metal truss bridges to bear great loads and to remain standing through flood and time must have impressed county commissioners considerably.

However, erecting metal truss bridges was a proposition qualitatively different from the way counties had hitherto built bridges. With timber or stone arch bridges, a local artisan was contracted to build the structure and be responsible for its upkeep (Thomas and Williams 1969:271). With metal truss bridges, not only was the engineering talent needed to design them usually unavailable locally, but the metal members of the truss could be produced only at major foundries. The advent of the metal truss required the importation of expertise and materials from urban areas.

The formation of Bollman's companies in their various manifestations (starting with John Tegmeyer's enterprise) provided the means by which counties could import both the necessary design expertise and the actual spans into their locales at a reasonable cost. In the early years of Bollman's companies and subsequent rival companies, it was probably necessary for a firm is representative to visit the site of the proposed bridge and return to the company's fabrication plant with the necessary data. Soon, however, the process was streamlined; the fabricating companies provided local officials with all the information necessary to determine which truss type was suitable for a given site. The local officials would then complete and return to the fabricating company an order form that provided all the data necessary to the fabrication of the desired bridge. The bridge company would then fabricate the truss members and ship them to the site, along with detailed instructions (and imprints or matchmarks on the members) for the erection of the bridge. Finally, the local officials would have the truss erected on abutments made by local masons.

Numerous companies across the nation were formed to provide metal truss bridges to cities, towns, and counties. The Baltimore companies described above conducted a degree of business in Maryland, but the Patapsco Bridge and Baltimore Bridge companies by the 1870s had begun to expand to other states and countries. The bridge building business became extremely competitive, with companies from other states also expanding into Maryland. Information gathered from previous Maryland Historical Trust historic resource survey forms on metal truss bridges in Maryland indicates that a number of bridge companies provided metal truss bridges in the late nineteenth and early twentieth centuries, including the following firms:

Wrought Iron Bridge Company, Canton, Ohio - built Pratt through truss bridges in Maryland from 1870s through 1890s;

King Iron Bridge Company, Cleveland, Ohio - built Pratt and bowstring trusses in Maryland from 1880 through 1892;

Patapsco Bridge and Iron Works, Baltimore - in addition to its work in Baltimore, built a Pratt pony truss in 1879;

Baltimore Bridge Company - in addition to its work in Baltimore, built a Pratt pony truss in 1885;

Pittsburg Bridge Company, Pittsburgh, Pennsylvania - built a Pratt through truss in 1882;

Smith Bridge Company, Toledo, Ohio - built Pratt and Pratt half-hipped trusses from 1889 through 1890;

Groton Bridge and Manufacturing Company, Groton, New York - built Pratt pony trusses in the last years of the nineteenth century;

York Bridge Company, York, Pennsylvania - built Pratt, Warren, and Parker trusses in the first quarter of the twentieth century;

Vincennes Bridge Company, Vincennes, Indiana - built a Pratt through truss in the first quarter of the twentieth century;

John Stauver McIlvane, Philadelphia, Pennsylvania - built a modified Pratt pony truss in 1909.

Not surprisingly, given its close proximity to Baltimore City, Baltimore County appears to have taken the lead among Maryland counties in erecting metal truss bridges at an early date, not always with the happiest of results. By 1868 the county apparently had erected an iron truss bridge in Phoenix, a bridge that met the same fate as so many in 1868, being washed away by the floods of November (McGrain n.d.). The loss of this bridge may have caused some second thoughts about the invincibility of metal trusses, for in 1874 the county solicited sealed proposals "for building an open wooden truss bridge, on the Burr Truss plan, over the Gunpowder Falls" (McGrain n.d.).

Despite this regression, there is a great deal of evidence that metal truss bridges were totally back in favor by the 1880s. As an example, in 1884 H.A. Nagle, Superintendent of Bridges for Baltimore County, advertised for sealed proposals for "a wrought iron Pratt truss bridge over the Big Gunpowder Falls." Nagle was very specific about what type of bridge the county wanted, stipulating that "parties tendering must furnish a clearly made out strain sheet of their design" for a "through bridge, consisting of one span 86 feet between masonry" with a roadway "12 feet wide in the clear and not less that 13 feet high in the clear" (McGrain n.d.).

Such advertisements attracted a healthy response; one such advertisement for yet another bridge over Gunpowder Falls received bids from nine bridge companies, including The Penn Bridge Company, H.A. Ramsay and Sons, Pittsburg Bridge Company, the Wrought Iron Bridge Company, and the King Bridge Company (McGrain n.d.). Clearly, the Superintendent of Bridges was able to satisfy his requirements for metal truss bridges in Baltimore County.

Judging from available information, the distribution of metal trusses in Maryland encompasses few in the Tidewater, but a number of examples, with fairly equal distribution, in the Piedmont and Appalachian Plateau. One exception is Frederick County, where the York Bridge Company in the early twentieth century built a great number of metal trusses, primarily Pratt but also Warren and Parker trusses. In the same county, King Iron Bridge Manufacturing Company erected several bowstring pony truss bridges. It is possible that there are inaccuracies in these estimates of preliminary distribution trends owing to the variation in the level of available documentation throughout the counties.

By the turn of the century, reinforced concrete technology had made great strides and local officials thus had another option from which to choose. In some counties, such as Baltimore County, reinforced concrete bridge technology was eagerly embraced at an early date. Just as Baltimore County had been in the forefront among counties in the adoption of the metal truss in the third quarter of the nineteenth century, it was also the first county to build a reinforced concrete bridge in the first quarter of the twentieth. In fact, the 25-foot reinforced concrete beam bridge near Sherwood Station was the first of its kind in the state, and in the words of its creators "shows the progressive character of the work that the County Roads Engineer is inaugurating" (Johnson 1903:169).

As evidenced by Baltimore County Reports in subsequent years, this bridge was the harbinger of the future; reinforced concrete structures were rapidly to gain ascendancy over the metal truss in the county. The announcement of the Sherwood Bridge provides the rationale: "Steel rods are imbedded in the concrete beams to enable them to withstand heavy loads; but no steel surface is exposed to the air, so that there is practically no cost for maintenance of a bridge of this character" (Johnson 1903:169).

Although other counties were not quite so quick to embrace the new technology, reinforced concrete bridges began to compete with truss bridges for the small to moderate spans across rivers and creeks. The State Roads Commission committed itself at the end of the first decade to developing standard plans for reinforced concrete bridges and intensified its efforts in the 1920s.

Metal truss bridges were still being erected throughout the state, but in significantly declining numbers. The older metal bridge fabricators were disappearing, or had already disappeared, by this time. A new, and less numerous, generation of metal truss fabricators (many comprising large companies which absorbed smaller competitors) met the needs of this declining market:

> Bethlehem Steel, Bethlehem, Pennsylvania - built at least one camelback through truss in the 1920s;
>
> American Bridge Company, Ambridge, Pennsylvania - built Pratt and camelback trusses in 1920s and 1930s;

McClintic-Marshall, Pittsburgh, Pennsylvania - built Pratt, Parker, and Camelback trusses beginning in the teens through the early 1930s;

Roanoke Iron and Bridge Company, Roanoke, Virginia - built Pratt and Camelback trusses in the 1920s and 1930s.

Besides the decline in numbers, the character of truss bridges was changing; the lighter and more delicate appearance of nineteenth century trusses was giving way to more solid forms that addressed the heavier load requirements necessitated by the dramatically increasing loads, volumes, and speeds of automobile and truck traffic on Maryland roads.

Although reinforced concrete designs dominated the spanning of small to moderate crossings by the 1930s, the metal truss assumed renewed prominence as the means by which monumental bridges spanning major rivers were built in the late 1930s and 1940s. The bridges over the Susquehanna River at Havre de Grace and over the Potomac at Ludlows Ferry, and the Wichert truss bridge over the Potomac at Washington County heralded a new era in truss bridge building. These bridges exemplified the adaptability of the form as it continued to evolve in response to the need to span longer distances and carry heavier loads.

Conclusion

The following summary statements regarding structural characteristics for metal truss bridges, key periods of significance for metal truss bridges in Maryland, and the earliest known documented examples of metal truss bridges in the state are based solely on documentary research.

Metal truss bridges (see Figures 8 through 12 and Plates 5 through 7) comprise two parallel trusses and a floor system supported on a concrete or masonry substructure. Each metal truss consists of individual components connected in a series of triangles. The particular type of metal truss bridge is defined by the arrangement of individual members, and the way in which those members are stressed (compression or tension); a wide variety of configurations is possible, many of which were proprietary, or patented variants, such as the commonly known Pratt and Warren types.

Individual members form the horizontal portions of the truss, called top and bottom chords, and the vertical and diagonal web members. The verticals and diagonals are connected to the top and bottom chords at joints (pin connections or rivet connections are possible). Minor web components may include sub-struts or sub-ties. Members may be in tension or compression, depending on the variety of truss (see Figures 9 through 12).

Other basic components include the portal, stringers, floorbeams, and deck. Portal bracing provides lateral bracing for the two parallel trusses at the top of the end posts. Stringers are longitudinal members which transmit loads to the floorbeams, which in turn transmit loads to the trusses at each panel point (joint connection) where the floor beams, the chord, and the verticals and diagonals are connected.

In addition to proprietary types, metal truss bridges are categorized by the relationship of the roadway to the truss. Simply stated, if the truss system rises above the roadway or deck level but does not include overhead portal bracing, the bridge is termed a pony, or half-through truss. If portal bracing connects the trusses, the span is a through truss. If the truss system is located entirely beneath the deck, the bridge is called a deck truss.

Key periods of significance for metal truss bridges in Maryland, as indicated by documentary research, include *1840-1860*, the transitional period from timber trusses through iron-and-timber structures to all-metal trusses during which early metal truss designs (Pratt, Howe and others) were patented and B&O bridge builders Benjamin Latrobe and Wendell Bollman introduced the Bollman truss (1851); *1860-1900*, the era of metal truss bridge popularization for railroad and highway use, and the movement toward all-steel trusses rather than iron bridges; and *1900-1960*, the period in which metal truss spans for highway use were increasingly standardized under the impetus of organizations such as the American Society of Civil Engineers, and also the era when the modern metal girder bridge, which could be readily widened, gradually replaced the metal truss bridge for all but monumental spans and their approaches (the 1940 Governor Harry Nice Bridge over the Potomac River, the 1940 Thomas Hatem Bridge over the Susquehanna, the 1952 Chesapeake Bay Bridge, and several western Maryland bridges featuring Wichert truss systems employed combinations of deck trusses and through metal trusses).

The earliest known documented examples of metal truss bridges in Maryland are the nationally significant Bollman Truss Bridge in Savage (1869; moved 1887) and iron bowstring trusses and Pratt trusses in Frederick County dating to the 1870s. Documentation exists that metal truss bridges were employed on the B&O Railroad, Northern Central Railroad, and in Baltimore City during the 1850s and 1860s. As thorough surveys of existing truss bridges in all Maryland counties have not been performed, information about early construction dates for this type of bridge is greatly skewed toward those counties where prior surveys have taken place.

Based solely on prior survey information and research, it appears that the unique Bollman Truss at Savage is the earliest extant metal truss bridge in Maryland and the only surviving example of its type in the United States. Prior survey information similarly indicates that metal truss "firsts" in Maryland may include the Poffenberger Road Bridge over Catoctin Creek, a Double-Intersection Pratt Truss built circa 1878 (MHT F-2-5); the Crum Road Bridge over Israel Creek, a bowstring pony truss built circa 1875 (MHT F-8-2); and the Four Points Bridge over Tom's Creek (MHT F-6-7), a Pratt through truss built in 1876. These conclusions, however, as well as a securely dated chronology of extant early metal truss bridges in Maryland, must necessarily be verified through field survey.

Judging from documentary research, twentieth century developments in metal truss fabrication and use, such as employment of riveted connections rather than pin-connection, are well represented in Maryland. The earliest Wichert trusses known to have been built in Maryland were incorporated into a 1,020-foot-long bridge between Washington County, Maryland, and Shepherdstown, West Virginia, in 1937-1939 by the Maryland State Roads Commission in cooperation with West Virginia authorities.

SECTION VI: MOVABLE BRIDGES

HISTORICAL DEVELOPMENT

As mentioned in the discussion of Maryland transportation history earlier in this report, rivers and creeks were the primary means of transportation for early residents of Maryland. The gradual construction of roads in the colony encountered rivers as obstacles that had to be crossed, but when those rivers served as the primary avenues of transportation, it was not sufficient simply to build a bridge over the river. When those rivers were navigable, some means had to be found to cross the river and at the same time permit the river's navigation. In order to allow vessels to navigate a bridged waterway, one must build either a high, fixed bridge with adequate clearance or a movable bridge with a span that moves out of the way when a vessel approaches. As building a high bridge usually required extensive approach work and very high grades, movable bridges became the predominant technological solution to the problem of how to bridge navigable waters.

In a 1907 paper intended to open discussion and establish specifications for movable bridges, C.C. Schneider, past president of the American Society of Civil Engineers, classified movable spans by the following categories (Schneider 1908:258-259):

1. Swing bridges, which turn about a vertical axis;

2. Bascule bridges, which turn about a horizontal axis or roll back on a circular segment;

3. Lift bridges, which lift vertically;

4. Traversing or retractile bridges;

5. Transporter or ferry bridges;

6. Pontoon or floating swing bridges.

Brief descriptions of these categories were provided in 1926 by Otis Hovey, Assistant Chief Engineer of the American Bridge Company, in his text *Movable Bridges*:

> A swing bridge consists of a superstructure arranged to turn about the vertical axis of a pivot anchored to the center pier. In ordinary cases the

pivot is at the center of a span of two equal arms, which balance each other when the bridge is open, thus providing two equal openings for navigation. It is sometimes necessary to place the pivot near one end. The shorter arm must then be counterweighted to balance the longer arm when the bridge is open.

Bascule bridges are, strictly speaking, those in which one end rises as the other falls, but the term is commonly applied to any type moving about a horizontal axis, either fixed or moving, as well as to those that roll back on a circular segment [rolling lift bascule spans]. They may consist of a single leaf spanning the channel [single leaf] or of two symmetrical leaves [double leaf] meeting at the center.

Lift bridges moving vertically consist of simple spans resting on piers when closed. In most cases the weight of the lifting span is counterweighted by means of ropes, or chains, attached to the ends of the span and the counterweights, which pass up and over sheaves on top of towers at the ends of the bridge.

Retractile, or traversing, bridges [move] horizontally. When closed they form simple spans across the channels. Some telescope inside of the adjoining spans; others recede above the approaches, the rear end being tilted upward and the free end downward. In some cases the approach span is first moved aside, transversely, to permit the draw span to recede in its place.

Transporter, or ferry, bridges are rarely used. A fixed span across the channel is supported on shore towers at a sufficient height to clear navigation. A platform, or a car, is suspended under the span and arranged to travel across the channel from shore to shore.

Pontoon bridges are. . .adapted for use when local conditions prevent the construction of more stable structures when a temporary crossing must be quickly made, as in military operations. They may consist of small boats, or pontoons, lashed together for temporary use, or more elaborate and stable pontoons in permanent structures [Hovey 1926:17-19].

With the exception of transporter or ferry bridges, there is at least one historical example of each of the above categories of movable bridges over the navigable waters of Maryland; for the swing, bascule, and retractile categories, there are numerous examples (Figure 13; Plates 8 and 9). As examples of the type, Maryland's bridges represent a movable bridge technology with historical precedents dating to ancient times. Movable bridges were described by ancient historians, developed in the

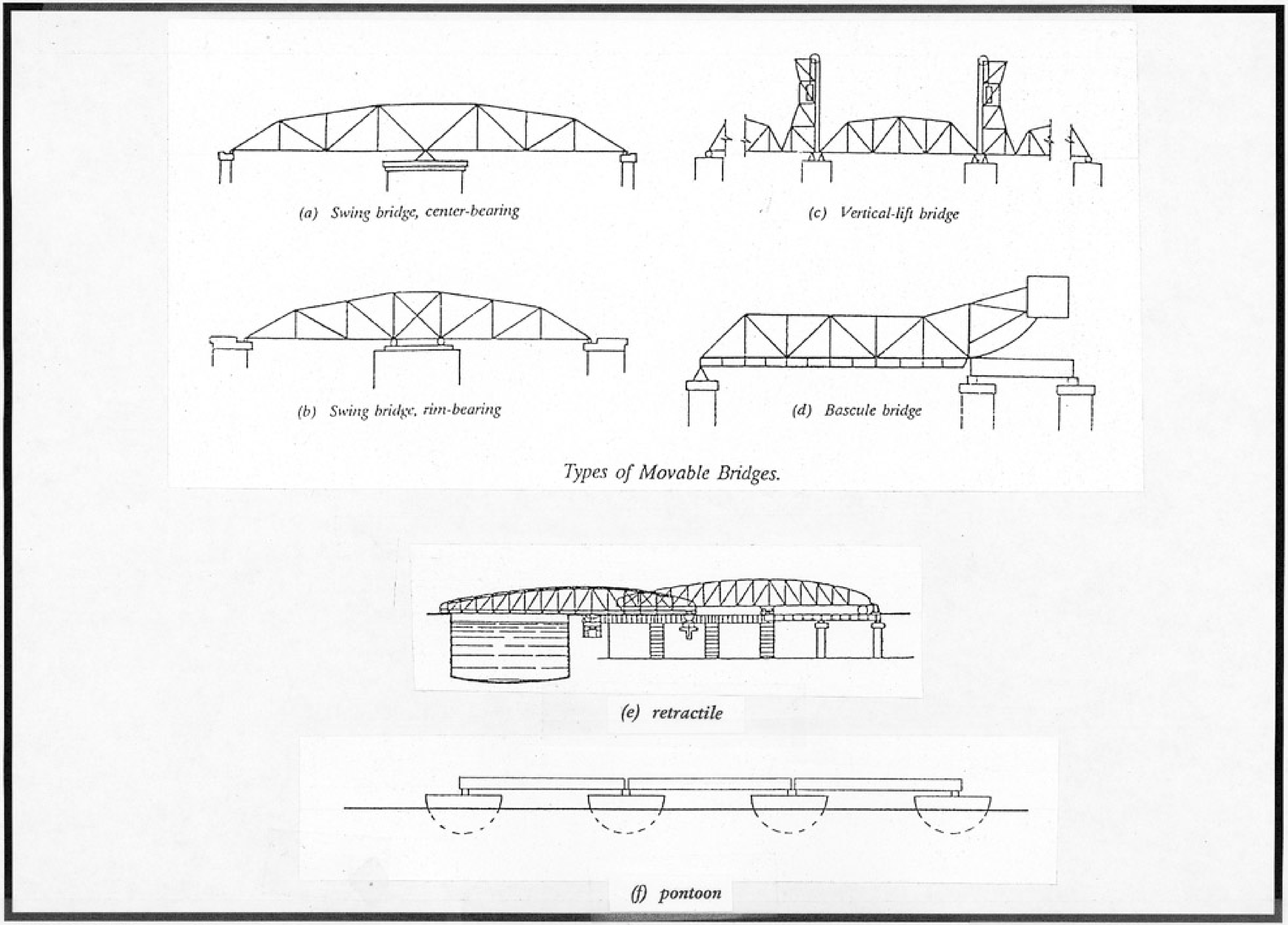


FIGURE 13: Types of Movable Bridges

SOURCE: P.A.C. Spero & Company 1991

PLATE 8: **Typical Single-Leaf Bascule Movable Bridge: Bridge at Kent Narrows** SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, date unknown)

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PLATE 9: **Rare Retractile Movable Bridge: Bridge Crossing Knapps Narrows at Tilghman Island**

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, circa 1926)

Renaissance, and flourished in the late nineteenth and early twentieth centuries. Today,as high bridges increasingly replace older movable bridges, the type has significantly declined as a bridge building option for navigable waters.

The operation of movable bridges in the United States is regulated by the U.S. Army Corps of Engineers, which was given authority over navigable waters by Congress in 1894 (U.S Army Corps of Engineers 1933:123). Listings of all bridges over navigable waters (U.S. Army Corps of Engineers 1926) and regulations governing the operation of each bridge (U.S. Army Corps of Engineers 1939) have been published periodically based on the navigation needs of the waterways. These regulations must be posted on upstream and downstream sides of the bridge. Some movable bridges had 24-hour service because the operator lived near the bridge and was able to respond to a boat whistle or horn blast; others required notice ranging from 4 to 24 hours. Some spans included operators' houses for the convenience of the tenders.

The following subsections summarize the development of each of the movable bridge categories which have been built in Maryland.

Swing Bridges

Although bascule bridges appear to have been much more common than swing spans in the middle ages, swing-span technology is documented during the Renaissance. In about 1500, Leonardo da Vinci made a sketch of an unequal-armed, or bob-tailed, center-bearing swing bridge which was swung by means of hand winches. By the early seventeenth century, the essentials of the center-bearing pivot as used in late nineteenth and early twentieth century swing spans had already been worked out. In 1625, the French "Royal Engineer-in-Chief," Salomen de Caux, designed a double-swing bridge for the large lock at Cherbourg. It consisted of two spans, each with two unequal arms, the longer arms (27 feet each) of both meeting at the center of the bridge. Each swing span revolved on a central iron bearing and was supported by balance wheels rolling on a circular track in order to steady the span as it spun to the open and closed positions (Hovey 1926:I, 12, 13).

The advent of metal structural members in the very late eighteenth century had a particularly beneficial impact on the development of movable spans. The first known metal bridge was the cast-iron arch bridge at Coalbrookdale, England, a non-movable bridge. But by 1805, iron was used in the construction of movable bridges at the London Docks. Soon thereafter, in 1818, a double swing span of iron was built at St. Katherine's Docks, near the Tower of London (Hovey 1926:I,13,14).

As in Europe, the first movable spans in America were constructed of wood. It is unclear when the first all-iron movable bridge was built in the United States, but the Rush Street swing-span bridge erected in 1856 over the Chicago River appears to be one of the first examples of a large all-iron movable bridge in the nation (Hovey 1926:I,14,15). The Chicago River bridge was swung on a mechanism referred to as a rim-bearing pivot, in which the span's weight is supported by a series of wheels or bearings running on a circular track or drum on the top of the pier that bears the swing span. Developed in the early nineteenth century by English engineers, rim-bearing pivots were commonly thought to be necessary to bear the great weight of large swing spans. In the 1870s, American engineers began to build swing spans supported on center-bearing pivots (Hovey 1926:I, 36), returning to the simpler design pioneered in 1500 by Leonardo and utilized on all swing spans before the development of the rim-bearing pivot in the early nineteenth century.

Due to their simplicity, reliability, and comparative economy, the center-bearing design gradually prevailed over the more complex rim-bearing design. By the third decade of the twentieth century, the center-bearing type had nearly superseded the rim-bearing type for all but the widest city highway bridges. By that time, many engineers had come to appreciate the advantages of the swing span over rival forms of movable bridges. As Otis Hovey stated in 1926, "when there are no restricting circumstances, a swing bridge is the simplest, best, and most economical type in first cost and maintenance" (Hovey 1926:20). Disadvantages of swing bridges include slowness of operation, interference with the channel during operation, and obstruction of navigation when there is a series of swing spans in close proximity (Hool and Kinne 1943:1-3).

The jack-knife bridge is a special type of swing bridge used only for railway bridges, consisting of a deck girder under each rail, one or more needle beams under the free end, and a gallows frame over the pivots. The action of the bridge is quite similar to the old-fashioned parallel ruler. In 1926 Hovey dismissed the type as "nearly obsolete and will not receive further consideration" (Hovey 1926:18).

Bascule Bridges

Not all engineers agreed with Hovey's assessment of the superiority of the swing span; the bascule span had many adherents throughout its long history. In the twentieth century George Hool, Professor of Structural Engineering at the University of Wisconsin, strenuously advocated the benefits of the bascule in both his 1924 and 1943 editions of *Movable and Long-Span Bridges*. Hool's preference for the bascule was largely based on the rapidity with which a vessel could pass through the navigation channel of a bascule as compared a swing span channel, but he also adduced a number of other benefits including economy of operation (Hool and Kinne 1943:1-8). Although favoring swing-span bridges, Hovey acknowledged that the bascule was preferable when numerous parallel bridges had to be erected over a river or when a city had a narrow waterway, as in Chicago (Hovey 1926:22).

Of the numerous examples of movable bridges built in the Middle Ages, the vast majority seem to have been bascules, in which the movable span swings upward as it opens to let vessels through. Drawbridges over moats are illustrative examples of this type of construction in its simplest form, as was probably the original London Bridge, completed in 1209. Bascule bridges may consist of one movable span ("single leaf") or two movable spans ("double leaf"); the double leaf is typically used when more navigational clearance is needed. Most of the early bascules were operated by an "out-haul line attached to the free end and running upward and inward to the source of power" (Hool and Kinne 1943:1). Although the majority of these bascules did not have counterweights, thereby increasing the effort to operate them, counterweighted bascules designed by military engineers began to appear on European artificial waterways in the eighteenth century (Hovey 1926:7). In 1839 a bascule railway bridge was constructed at Selby, England, and others were to appear in Copenhagen in 1867, Rotterdam in 1878, and Koenigsberg in 1880 (Hardesty et al. 1975:515).

The earliest construction of the modern bascule span is attributed to the 1894 construction of the Tower Bridge in London and the Van Buren Bridge in Chicago. (Hardesty et al. 1975:516). During this and subsequent decades numerous patented bascule designs were developed by bridge engineers in the United States (Hool and Kinne 1943:28, 29). The bascule design attracted engineers of ingenuity and genius; bridge engineer J.A.L. Waddell commented, "they [the designs] are scientific, and they represent, probably, the best and most profound thought that has ever been devoted to bridge engineering" (Waddell 1916). Waddell, himself, had patented a bascule design.

Two bascule types predominated in this period: the trunnion bascule, in which the movable span swings upward around a fixed-axis trunnion or pivot at the center of rotation which coincides with the center of gravity; and the rolling lift bascule span, where the center of rotation (and gravity) moves away from the opening as the span swings upward. The trunnion bascule, in its simpler forms, evolved from the medieval drawbridge and its development by European military engineers in the early eighteenth century. In his 1916 *Bridge Engineering*, Waddell stated that the first important bascule bridge in the United States (1897) was the Michigan Avenue Bridge in Buffalo, New York, a trunnion type in which the free end of the span was connected by cables running to pulleys atop a tower and then down to large cast-iron wheel counterweights running in semicircular tracks. The trunnion bascule evolved in the late nineteenth and early twentieth centuries with the development of the simple trunnion or "Chicago" type and the multiple trunnion or Strauss type. The simple trunnion, patented by the Chicago Bascule Bridge Company, was essentially a refinement of the time-tested bascule mechanism with an integral counterweight. The multiple trunnion design was far more complex, featuring three subsidiary trunnions in addition to the main trunnion, all connected by struts that form a rectangle when the span is closed and a parallelogram when the span is open.

The rolling lift bascule shared with its ancestors the fundamental upward-swinging motion of the movable span, but it added an additional movement--the span retreated from the opening as it was swung up, thus providing even more clearance for navigation. This additional movement was accomplished by attaching the span to a segmental girder, which simultaneously tilted the span upwards as it rolled back on its track. Two early nineteenth century French bridges "were the forerunners of the modern rolling lift bascule": one was a 40-foot track girder bridge built at Havre before 1824; the other, rotating on a wheel, was built at Bregere (Hardesty et al. 1975:514).

At the end of the nineteenth century, two variants on the rolling lift bridge were patented--the Scherzer and the Rall. Developed in 1893 by William Scherzer, who was granted twelve patents for variations between that date and 1921, the Scherzer Rolling Lift Bridge Company's bascule became the most popular of all bascule types by 1916. The first Scherzer rolling lift bascule bridge was the Van Buren Street Bridge in Chicago, the plans for which were completed in 1893 (Hool and Kinne 1943:1; Hardesty et al. 1975:516). A Scherzer rolling-lift bascule is characterized by its large, concrete counterweight and segmental circular moving girder. The span's movement occurs as it rotates on a short circular segment along a horizontal track girder. The rectangular counterweight is attached to this short, shoreward section of the moving leaf. In the main pier, below the counterweight, is a pit that receives the counterweight when the bridge is open. For a simple, single-leaf, Scherzer rolling-lift bridge three piers are necessary: the main pit pier, the rest pier for the free end of the leaf, and a shoreward pier for the approach span.

The Rall design, as constructed by the Strobel Steel Construction Company, utilized a roller of much smaller diameter. As the span is opened, the span first revolves about a pin until the main roller comes into bearing with the track girder; the span then rolls along this track, the swing strut tilting the span as the roller causes it to recede from the opening (Hool and Kinne 1943:16, 17).

Vertical Lift Bridges

In the 1500s, Leonardo da Vinci designed a vertical lift bridge in which the movable span maintained its horizontal orientation as it was lifted and lowered vertically (Hovey 1926:4). The first recorded vertical lift bridge actually constructed was a seventeenth century 30-foot span with a lift of 6.5 feet that was part of a wood trestle at Vienna over the Danube River (Hardesty et al. 1975:513). In 1872, Squire Whipple, one of the pioneers of American bridge design, began to build small lift spans over canals in New York State; subsequently a number of small spans were erected over canals in other eastern states (Hool and Kinne 1943:158).

The first large vertical lift bridge was designed by Waddell in 1892 and erected on South Halstead Street in Chicago with a movable span of 130 feet and a maximum vertical clearance of 155 feet (Hool and Kinne 1943:158). There was little progress made in the building of vertical lift bridges until 1908 when there was a surge in interest in the design; in the following two decades approximately 70 vertical lift bridges were erected in the nation, one engineering firm erecting about 40 of these bridges (Hardesty et al. 1975:513; Hool and Kinne 1943:158). Hool cited the following advantages for the vertical lift: economy, simplicity, rigidity, reliability, and ease of operation (Hool and Kinne 1943:158-160).

Retractile Bridges

The nineteenth century French architectural historian Viollet-le-Duc provided evidence that retractile bridges were commonly built in southern France and Italy at an early date (Hovey 1926:I, 4-4). In this type of movable bridge, the movable span is typically drawn up and over the approach span, although other arrangements were also built. It was not a very efficient design; the force required to operate such a span exceeded that of any other type of movable bridge (Hovey 1926:I, 18). Quite common in southern Europe in the Middle Ages, the retractile design also found application in the United States on smaller bridges where the effort required was not prohibitive. However, it seems that the retractile span remained a vernacular design to which no noted engineer addressed himself. In 1926 Hovey dismissed the type as "nearly obsolete" (Hovey 1926:18) and in 1943 Hool did not even list the retractile as a movable bridge option.

Pontoon Bridges

Herodotus stated that the Persians constructed a pontoon bridge of 673 boats in the early fifth century B.C. over which thousands of soldiers marched to wage war with Greece. At three places the boats were lashed together in such a way that they could be swung aside to let vessels through--certainly the earliest, albeit rudimentary, attested version of the swing span (Hovey 1926:I, 2). Much later, da Vinci designed a pontoon swing span, at about the same time that he designed his swing and vertical lift bridges (Hovey 1926:I, 4). Pontoon bridges have been, and continue to be, used in military operations when a river must be spanned quickly and temporarily, but they have also been used where more expensive permanent bridges were not warranted (Hovey 1926:19).

MOVABLE BRIDGES IN MARYLAND

In November 1795 the Maryland General Assembly passed an act to authorize the Eastern Branch Bridge Company to construct a bridge over the Eastern Branch of the Potomac River. What is noteworthy about this act is that it was the first time that the Maryland Assembly stipulated the construction of a movable bridge. The act required the company to build a bridge with a draw "at least thirty feet wide" and "to keep a sufficient number of hands at all times ready for the purpose of raising the said draw, in order to admit vessels to pass without delay through the said bridge, for which no price or reward shall be demanded by the said company, or their agents." The act also provided for dereliction of duty on the part of the company: "and in case of neglect, the directors for the time being may be indicted, and fined therefor as for a public nuisance in Prince George's county court" (Kilty 1808:November 1795 Session, Chapter 62).

Although the Eastern Branch bridge was the first legislated movable bridge project, it is not known whether this was the first movable bridge constructed in Maryland. Augustine Herrman's map of 1670 illustrates that Maryland in its earliest days was indeed "a fringe of scattered settlements, strung along the bayside and along the banks of the navigable rivers, with not a trace of connecting highways" (Sioussat 1899:109). Navigation of the waterways of Maryland by sloop and pinnaces was the norm; roads served to augment, not replace, the transportation network of rivers. Too many families, planters, and towns of the Tidewater area were dependent upon the navigation of the rivers to permit the new roads and their ferries, and later bridges, to interfere with the primary mode of transportation.

The critical importance of navigation for early Tidewater Marylanders suggests that bridges built prior to the 1795 act could have been movable bridges. Given the critical importance of navigation to Tidewater residents, it is highly likely that the earliest bridges across the navigable portions of Tidewater rivers and creeks were movable. Although there is no documentation to indicate the nature of the Tidewater's earliest bridges, it can be conjectured that if a later bridge at a particular site is known to have been a movable one, the earliest bridge at that site is also likely to have been a movable structure.

The first movable bridges in Maryland were in all likelihood either simple bascule or retractile types. The 1795 act's reference to "raising the draw" of the Eastern Branch bridge indicates that this bridge was a simple bascule. Likewise, the first bridge at Denton on the Choptank River, authorized in 1808 but probably not completed until around 1820, appears to have been a simple bascule, if "drawbridge" is to be understood in its specific rather than generic sense. Retractile bridges were probably also built during this early period, although documentation of the type does not occur until 1858, when the first bridge at Miles River Neck was constructed as a retractile with a navigation clearance of 30 feet. Due to the excessive force needed to operate retractile spans, subsequent use of the design was to remain minimal, although one was built at Knapp Narrows at the late date of 1926 by the State Roads Commission for Talbot County (U.S. Army Corps of Engineers 1926).

The one recorded non-military instance of a pontoon bridge in Maryland occurred in the late eighteenth or early nineteenth century. In the 1770s ferry service across the Patapsco River was initiated at Elkridge Landing; it was called the Patapsco Upper Ferry. Several years later William Hammond began a ferry service below the landing. When the Upper Ferry was put out of business by the construction of a nearby bridge, Hammond built a pontoon bridge that featured a movable section (essentially a floating swing span) that allowed vessels to navigate to and from Elkridge Landing (Travers 1990:57).

Although stone abutments were stipulated for the 1795 Eastern Branch bridge, most movable bridges of the Tidewater would have been of timber construction, if they were typical of movable spans in early nineteenth century Tidewater Maryland. Both the Denton and Miles River Neck nineteenth century bridges were of timber construction; the Miles River bridge used white pine for the superstructure, hemlock for the flooring, and white oak for the piers. The fixed spans of these and other early movable bridges in the Tidewater area probably featured simple-span beam superstructures supported by timber bents. The nineteenth century movable bridges consisted of multiple small spans, which were short (around 20-25 feet) and numerous; it was not unusual to find bridges that had over 100 spans. The reason for the small, multiple spans was twofold: first, timber beam spans were limited by the physical properties of the material; second, the riverbeds of many Tidewater rivers and creeks consisted of soft mud which could not distribute the greater loads of longer spans. By designing a structure with numerous and relatively short spans, the load could be distributed more equally over the substructure and soil, and thus ensure more structural stability, a true necessity for the secure alignment of movable spans. Due to the state of Tidewater riverbeds, short and numerous spans continued to characterize many Tidewater movable bridges even after reinforced concrete piers had begun to replace timber bents in the early twentieth century ("Design and Construction of the Bush and Gunpowder River Bridges, Consisting of a Series of Reinforced Concrete Slab Spans" 1914:195).

It is not clear when swing bridges were first built in Maryland, but records indicate two early Baltimore swing spans. The first candidate is the Light Street Bridge, built in 1856 across the Middle Branch of the Patapsco River (Hilton 1913:10). When the bridge was rebuilt in 1891, the City Commissioner reported that the old configuration of end-bearing piers was retained when the actual swing span was replaced by an iron structure manufactured by the King Iron and Manufacturing Company of Cleveland, Ohio (Baltimore City Commissioner 1891:826). The fixed spans of the bridge were supported on timber bents similar to those found on Tidewater bridges.

The other early swing bridge was a short span located near the city docks. An 1869 bird's-eye view of Baltimore depicting the mouth of the Jones Falls and the harbor shows a movable bridge on Block Street crossing the waterway between the harbor and the mouth of the Jones Falls, where the city docks were located (Olson 1980:164). The view clearly illustrates details of the span, such as the fenders which protect the central pier. In the 1867 *Report of the City Commissioner* the condition of this bridge was described as poor, and the commissioner proposed "at some future time to submit a comparative estimate between a thorough repair of this bridge, which it now demands, and the construction of a new one upon a better principle" (Baltimore City Commissioner 1868:79). A movable bridge had been located at the site since the construction of the City Docks around 1816. A plat map of 1823 showed the Block Street movable bridge at the location, but unfortunately provides no clue as to what sort of movable span was used. However, in 1880 the noted bridge engineer, Wendel Bollman, erected a truss, swing-span replacement for the Block Street bridge.

The first fully documented swing bridge in Maryland was a massive one at Havre de Grace over the Susquehanna River. Construction of this bridge reflected the growing confidence that professional engineers had in large swing spans as a due to the success of the Chicago River bridge of 1856. The Susquehanna bridge was built in 1866 to carry the tracks of the Philadelphia, Baltimore, and Wilmington Railroad over the Susquehanna River. The bridge was truly an ambitious structure; its total length was 3,273 feet and it featured a swing span with a 174-foot 9-inch navigational clearance. Although its construction had been delayed since the 1840s because of Port Deposit residents' fears that the bridge would interfere with navigation, by 1866 the huge granite piers and abutments were in place and the superstructure, consisting of 12 timber spans (Haupt trusses), was completed by July of that year. The project was under the direction of Engineer George A. Parker. The bridge's superstructure was replaced sometime between 1870 and 1880 with an iron truss and swing bridge; it is this version of the bridge that was converted to highway use in 1907 by the Havre de Grace-Perryville Bridge Company and transformed into a double-decker bridge by the State Highways Commission in 1927. The double-decker swing bridge remained in operation until 1940 when it was replaced by a high fixed-truss bridge.

Also indicative of professional engineers' interest in the use of the swing span for major bridges was the presentation of a paper by Charles Shaler Smith, co-founder of the Baltimore Bridge Company, to the American Society of Civil Engineers in 1874 in which he discussed the loading of rim- and center-bearing pivots in swing spans. The paper reflected the renewed attention that American engineers were giving to the center-bearing pivot.

Perhaps as a result of the success of the swing span over the Susquehanna, numerous swing bridges were constructed in the Tidewater and in and around Baltimore during the last quarter of the nineteenth century and the first decades of the twentieth century. Some of these bridges remain in operation today. In 1925, the first year in which the U.S. Army Corps of Engineers drew up a list of the bridges over the navigable waters of the nation, there were 41 movable highway bridges in Maryland, of which 24 (60%) were swing spans. Today there are four known, extant swing bridges in the state.

As noted earlier, it appears that simple bascule spans were among the earliest movable bridges in Maryland. However, by the mid-nineteenth century, swing spans were built more frequently; this trend appears to have continued through the end of the century. By the first decade of the twentieth century, the bascule design received a great deal of attention by Maryland State Roads Commission engineers. Between 1904 and 1939 the State Roads Commission constructed at least 17 bascule bridges over the navigable waters of the state including the Chester, Choptank, Miles, Patapsco, Sassafras, Severn, Nanticoke, and Bohemia rivers. Today, 20 of the 24 movable bridges in Maryland feature bascule spans, some of which were built in the last decade.

The renewed interest in the bascule bridge coincided with the development of standardized reinforced concrete bridges during the same period; very few bascule spans were integrated into the old timber bent substructure designs. Although the State Roads Commission never developed a standard plan for movable bridges as such, a standard plan was developed in 1919 for a two-story reinforced concrete operator's house that was used on those movable bridges that warranted a full-time operator (Maryland State Roads Commission 1919).

In the relatively few cases where specific information about the type of bascule built is available, the Scherzer rolling lift predominates. However, the Hanover Street Bridge over the Middle Branch of the Patapsco River, completed in 1916, featured a Rall rolling lift provided by the Strobel Steel Construction Company of Chicago (Maryland State Roads Commission 1916:62). This bridge was designed by John Edwin Greiner, then a consulting engineer; Greiner had formerly been employed by the B&O Railroad, Keystone Bridge Works, and Gustav Lindenthal (the prominent civil engineer who had developed a notable expertise in movable bridges of all types) (Spero 1983:6, 7). Costing $1,200,000 and measuring 1.62 miles in length, the bridge was a massive undertaking for the State Roads Commission. As expressed by the Commission, "this is the largest piece of work the commission has undertaken since its creation and when completed will be the largest reinforced concrete bridge in the State and one of the most difficult pieces of bridge engineering construction in the country" (Maryland State Roads Commission 1916:62).

There are records of only a few vertical lift bridges in Maryland. A four-span vertical lift bridge was constructed by the State Roads Commission between 1910 and 1919 over the Pocomoke River in Pocomoke City (Army Corps of Engineers 1926). At least two were constructed over canals: one over the Chesapeake and Ohio Canal at Williamsport (HAER No. MD-23) and another over the Chesapeake and Delaware Canal at Chesapeake City, built around 1927. In a paper presented to the American Society of Civil Engineers, U.S. Army engineer Earl I. Brown described the reasons for the selection of the vertical lift design at Chesapeake City:

> The vertical lift type of bridge was selected for all locations on the basis of lower first cost and maintenance expense. Furthermore, fireproof doors could thus be provided economically, and most of the vessels would require the bridge to be only partly open, thus reducing further the operating expenses and delays to land traffic [Brown 1930:317].

In summary, movable bridges in a variety of forms have protected the navigability of Maryland's rivers and creeks from the earliest period of Maryland history to the present. Although current design trends emphasize the use of the high span to accomplish the same task, there remain over 20 movable bridges in Maryland that continue to mediate between the conflicting demands of vehicular and navigational traffic (Maryland Department of Transportation 1993a).

Conclusion

The following summary statements regarding structural characteristics for movable bridges, key periods of significance for movable bridges in Maryland, and the earliest known documented examples of timber bridges in the state are based solely on documentary research.

Movable bridges (see Figure 13 and Plates 8 and 9) are characterized by their ability to change position in order to permit unimpeded navigation on the waterway which they span. They may consist of a single moving span or multiple moving spans with fixed approach spans. Their structural configuration varies, as described below, but they generally consist of a metal superstructure supported on concrete or masonry substructure.

Movable bridge types are defined by the particular way in which the span is made to move. Swing bridges turn about a vertical axis which is usually located on a center pier; swing spans may bear centrally on this pier (center-bearing) or may bear on the rim of a track located on the pier (rim-bearing). Bascule bridges rotate about a horizontal axis and feature decks that may be raised to a vertical or inclined position by various mechanical means. A trunnion bascule bridge moves about a fixed center of rotation located at the center of gravity of the rotating part. A roller-bearing bascule bridge also moves about a fixed center of rotation that coincides with the center of gravity, but the trunnion is eliminated and the load is carried by a segmental circular bearing on rollers in a circular track. A rolling lift bascule continually changes its center of rotation and shifts its load application points as the center of gravity moves in a horizontal line. Bascule bridges may be single-leaf (one movable deck section) or double-leaf (two movable deck sections). A final movable bridge variant, the vertical lift bridge moves out of the way through machinery that lifts both ends of the movable span horizontally to a raised position above the ordinary roadway deck level.

Key periods of significance for movable bridges in Maryland, as indicated by documentary research, include *1790-1850*, when early bascule (draw) bridges and swing spans were built of timber in the state; *1850-1900*, the era in which technological improvements in movable bridge design, such as the employment of iron and steel in movable spans, and the development of new variants of bascule rolling lift bridges (Scherzer) and swing and vertical lift bridges influenced movable bridge construction in Maryland; and *1900-1940*, the period during which major, significant modern movable bridges including the 1916 Hanover Street Bridge Viaduct (Rall type) and a group of movable spans erected in Tidewater (Coastal Plain) locations between 1910 and 1940 were built in Maryland under the auspices of the State Roads Commission.

The earliest known documented movable bridge spans built in Maryland were likely erected as a consequence of 1795 and 1808 Acts of the General Assembly permitting drawbridges over the Eastern Branch of the Potomac and the Choptank River near Denton. Historical research alone has located no surviving Maryland movable bridges dating to the eighteenth or nineteenth centuries. Significant extant early twentieth century movable spans include a number of structures built under authority of the State Roads Commission; among these are the Hanover Street Viaduct (1916; Rall-type drawbridge); Bridge #23004, the Pocomoke River Bridge carrying State Route 675 (1920; double-leaf bascule); and the Old Severn River-Annapolis Bridge (Bridge #20270; built 1924, double-leaf bascule). The 1993 State Highway Administration *Bridge Inventory* lists 20 working movable bridges on the state highway system; however, other bridges are listed as including movable spans and may no longer be operative, as field survey may reveal. Further research and survey may also identify extant movable bridges that are significant but not on the state highway system.

SECTION VII: METAL GIRDER BRIDGES

HISTORICAL DEVELOPMENT

Metal girder, or beam, bridges exemplify the modern application of traditional bridge technology. For many centuries, since ancient times, simply-supported beam bridges were constructed of wood, the most readily available material. Structurally, a beam carries its loads by bending, with upper fibers in compression and lower fibers in tension; determinants for span length include strength of materials and depth of cross section. The metal girder bridge is essentially a structure in which a floor system and roadway (made of timber or concrete) are supported by girders, generally consisting of rolled sections of metal (of various shapes, including "I" and "W") which are plain or encased in concrete. Girders are the members which span between the main supports of a structure. In bridge floor systems, the transverse members are floor beams and the smaller structural members parallel to the movement of traffic are called stringers (Merritt 1976:6-12, 6-13).

The use of metal for beam bridges followed its use for other metal structure types, such as the metal truss, metal arch, and suspension bridges. During the early nineteenth century, refinement processes such as the Bessemer process significantly reduced the carbon content of cast iron and wrought iron, thereby also reducing the tendency of the material to crack or become brittle (Chard 1986). By 1861, major bridge components were manufactured of rolled iron, and by 1870 techniques of mass production were applied to the making of a variety of iron structural shapes, including beams or girders (P.A.C. Spero & Company 1991:146-147). The general design and manufacture of such iron components between 1860 and 1890 led to the construction of many iron girder spans throughout the United States, particularly on railroads. By 1895, however, wrought iron structural shapes were rapidly becoming unavailable as steel took its dominant place in girder bridge construction (P.A.C. Spero & Company 1991:146-147).

Like their metal truss counterparts, the types of both iron and steel girder bridges developed in the nineteenth century may usefully be categorized by the relationship of the roadway, or deck, to the position of the girder or girders (Figure 14). There are deck girder, through girder, and half-through girder bridges. Plate girder spans are bridges in which the girders consist of built-up riveted sections with a deeper "web" between the top and bottom flanges of the girder. The plate girders may be placed beneath the bridge deck, in a deck girder configuration, or may rise above the level of the roadway, as in the half-through variant (P.A.C. Spero & Company 1991:146-147).

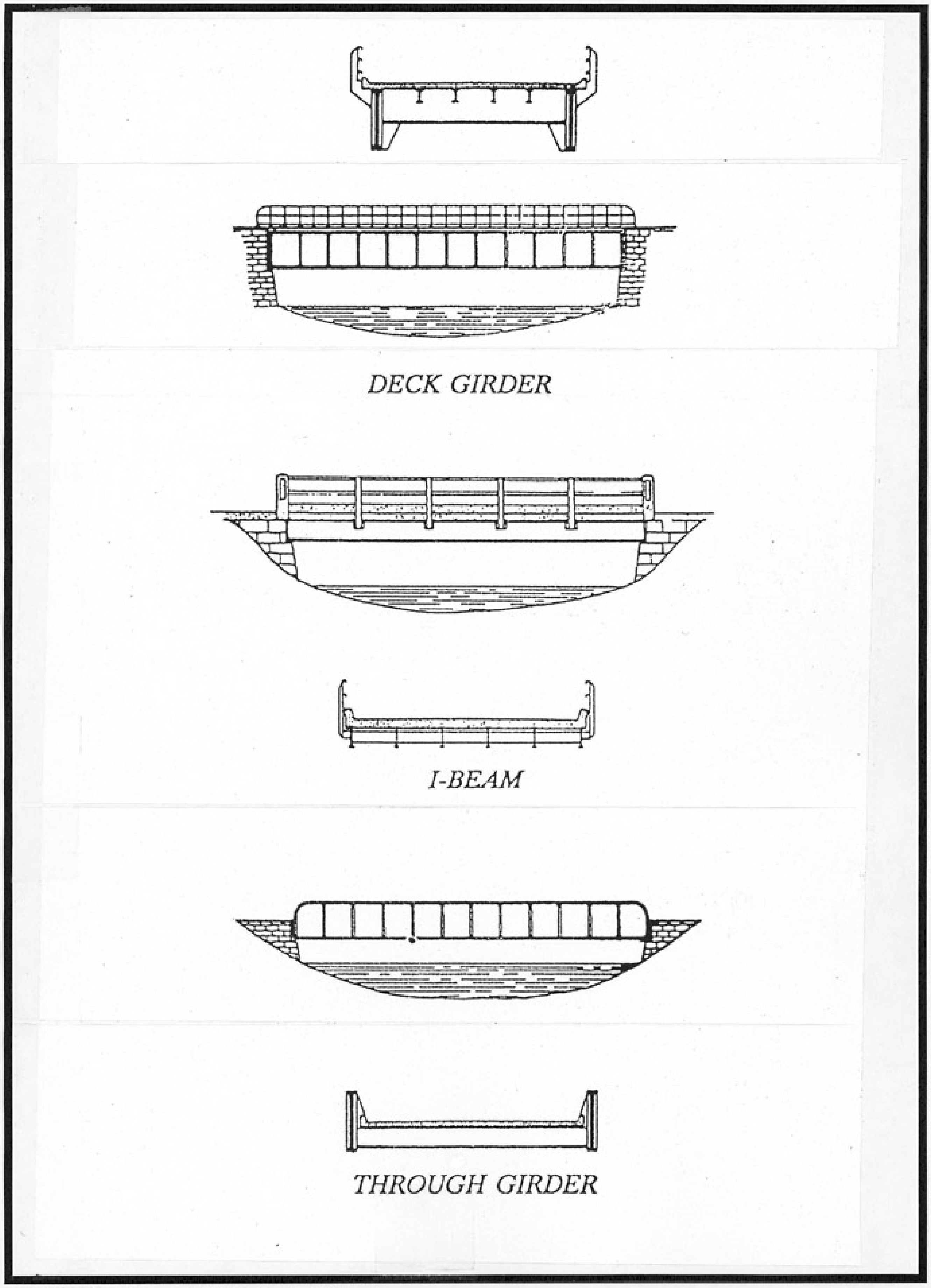


FIGURE 14: Types of Metal Girder Bridges

SOURCE: P.A.C. Spero & Company 1991

Metal girder bridges constructed of iron began to be constructed during the middle of the nineteenth century in response to industrial and manufacturing advances. Bridge engineering historian Henry Grattan Tyrrell in 1911 stated that the earliest wrought iron girder bridge in the world, a 31.5-foot-long structure with six parallel lines of supporting beams, was built by A. Thompson in 1841 to carry a highway over the Pollack and Govan Railroad near Glasgow, Scotland. Tyrrell also noted that in 1846, both William Fairbairn in England and James Milholland in the United States had constructed the earliest plate girder bridges. Milholland's span, a 50-foot iron plate girder with top flange reinforced by wood, was constructed for the Baltimore and Susquehanna Railroad (precursor of the Northern Central) near Bolton station or depot in the City of Baltimore, Maryland (Tyrrell 1911:195). Historian and prominent engineer J.A.L. Waddell in 1916 seconded Tyrrell's findings, adding that important plate girders were built for the Pennsylvania Railroad in 1853 and the Boston and Albany Railroad in 1860 (Waddell 1916:22-23).

Under the impetus of the railroads, metal girder bridge design and construction reached full development during the last quarter of the nineteenth century. Prominent bridge engineer Theodore Cooper, a key proponent of empirical bridge design and standardization, observed in 1889 that plate girders were "generally used for spans up to 65 feet and give excellent satisfaction" when riveted at the bridge fabrication shop (P.A.C. Spero & Company 1991:147-148). Crediting the "great advance in the science of detailing and proportioning" for the increasingly scientific approach to design of rolled I-beam spans and plate girders, Waddell dated popular recognition of the "great value of plate-girders for short spans" to the 1880s. By 1905, standard design plans and specifications for all types of girder bridges were available through such organizations as the American Railway Engineering Association, and the American Society of Civil Engineers, and such prominent private bridge building firms as the American Bridge Company.

With the automotive revolution bringing heavy traffic loads to ordinary highway bridges, the early twentieth century witnessed further standardization of design for girders erected on roads as well as railroads. Highway engineer Milo S. Ketchum in a 1908 handbook noted that "for spans of, say, 30 feet and under rolled beams are often used to carry the roadway, while for spans from about 30 to 100 feet plate girders are used" (Ketchum 1908:11). Waddell in 1916 observed that "the ordinary limit of plate girder spans is about one hundred (100) feet, but that limit has often been surpassed by twenty-five (25) or thirty (30) per cent for simple spans and by much more for swing spans" (Waddell 1916:409).

Plate girder bridges were typically riveted in the shop and shipped by rail to the intended sites (Figure 15; Plates 10 and 11). As in the case of metal trusses, the introduction of the portable pneumatic riveter allowed some early twentieth century plate girders to be riveted in the field, but as Waddell observed in 1916, there were many important shipment and construction considerations:

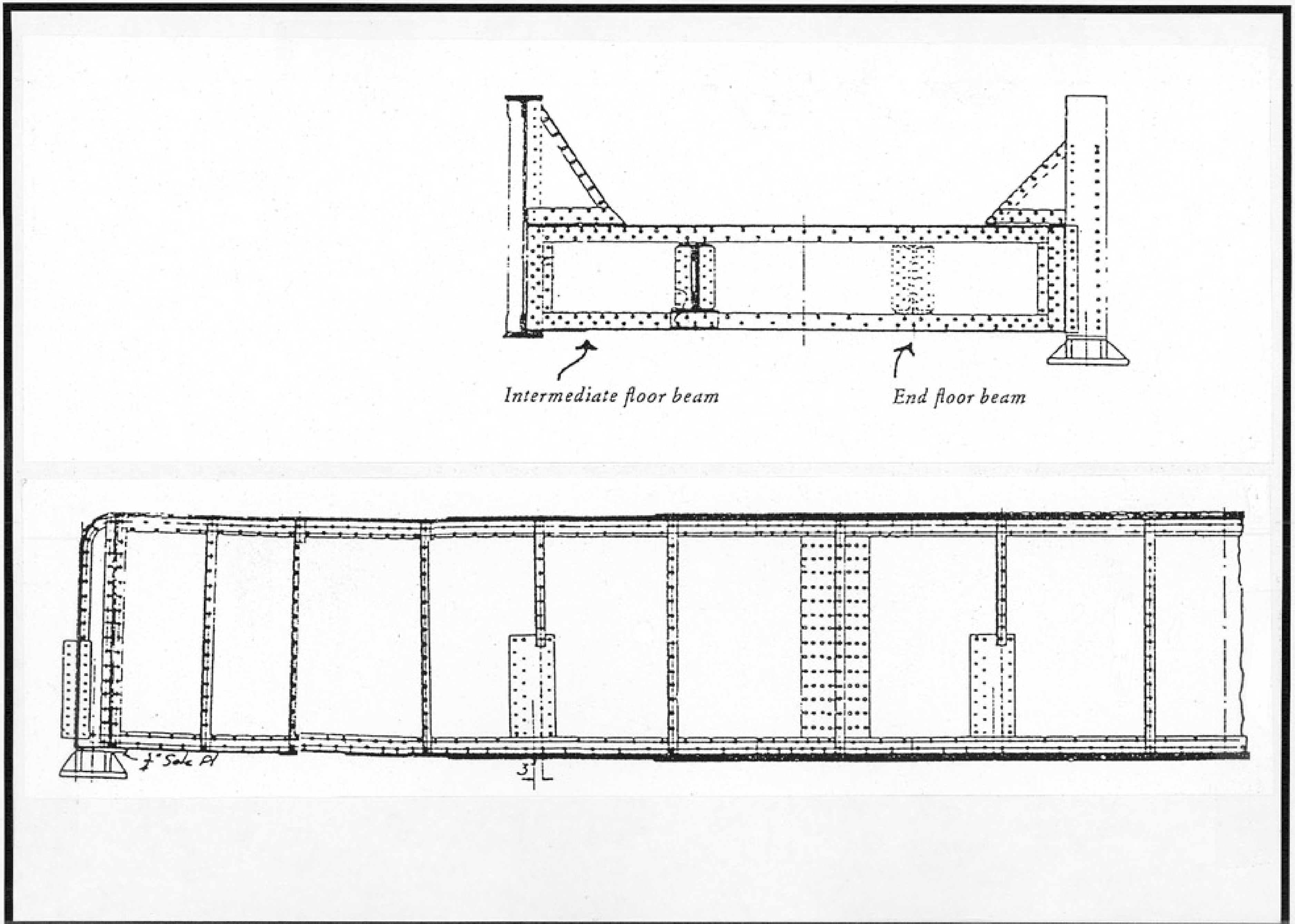


FIGURE 15: Detail, Typical Metal Plate Girder Bridge

SOURCE: Weitzman 1980

PLATE 10: : Typical Metal Plate Girder (Through) Bridge: Crossing Railroad Tracks at Severn

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1932)

PLATE 11: Typical Metal Plate Girder (Deck) Bridge: Bridge on Baker Street in Baltimore SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1931)

Usually it is the difficulty of shipping very long plate-girders from bridge shop to site that determines the superior limit of such spans. The loading of long girders on cars for shipment is quite an art, and it should be entrusted only to men experienced in such loadings; for, otherwise, the metal is liable to be injured in transit or the cars break down. . . . About as long a plate-girder as has ever been shipped in one piece was one of one hundred and thirty-two (132) feet. It required four flat cars to transport it. Longer plate-girder spans than this have been built, notably tubular bridges and swing spans, but they were shipped in parts and assembled at site. This expedient for simple spans is really permissible only in case of bridges to be sent to foreign countries, and it is to be avoided if possible even then, because it is sometimes difficult to obtain a satisfactory job of field-riveting when making the splices, although the use of pneumatic riveters tends to reduce materially the force of this objection [Waddell 1916:409].

Further development in girder bridge technology between 1900 and 1930 was marked primarily by the spread of concrete-encased rolled I-beam structures, and by the introduction of the familiar mid-to-late twentieth century highway bridge in which deep steel beams support a deck of reinforced concrete. Victor Brown and Carleton Conner in their 1933 handbook *Low Cost Roads and Bridges* remarked on the adaptability and economy of the latter type of girder bridge:

> With the introduction of the deep beam sections (30, 33, and 36 inches deep) now available, it has been possible to greatly simplify details of steel construction, particularly in the shorter span bridges. Spans of 60 to 100 ft. can be worked out, using available beam sections which will show considerable savings when compared with the older type low truss construction. . . .Where a concrete floor slab is used the beams are well protected from weather exposure and painting cost will be greatly reduced. . . .The beam spans have the further advantage that they can be widened or sidewalks added if this becomes necessary, whereas the pony truss spans cannot be widened [Brown and Conner 1933:506-507].

After the World War II hiatus on non-defense-related bridge construction ended in 1945, economical highway girder bridges such as those described by Brown and Conner were readily built by county and municipal officials across the United States.
Technological advances in use of non-traditional metals, such as aluminum, also characterized some metal girder bridge design and construction after World War II. Although ALCOA in 1933 had designed a lightweight aluminum deck for the 1882 Smithfield Street Bridge in Pittsburgh, the earliest aluminum bridge in the United States was a 100-foot-long railroad plate girder span designed by ALCOA and built in 1946 to replace an existing bridge over the Grasse River, near Massena, New York (Trinidad 1984:1). Prior to this bridge, only a bascule bridge at Sunderland, England, and a Scottish footbridge had been made of aluminum (Alison 1984).

The Massena, New York, bridge and a 1950 long-span aluminum highway bridge at Arvida, Quebec, served to demonstrate the capabilities of aluminum as a structural material. Maryland's only known aluminum bridge is a girder bridge (Bridge # 13046) designed and built in 1963 by the State Highway Administration and International Aluminum Structures, Inc., to carry State Route 32 over the South Branch of the Patapsco River near Sykesville (Alison 1984; Suffness 1992a).

METAL GIRDER BRIDGES IN MARYLAND

Metal girder bridges were most likely introduced and first popularized in Maryland by the state's major railroads of the nineteenth century, including the Baltimore and Susquehanna, its successor the Northern Central, and the Baltimore and Ohio Railroad. As discussed, bridge engineering historians have documented the fact that James Milholland (or Mulholland) erected the earliest plate girder span in the United States on the Baltimore and Susquehanna Railroad in 1846 at Bolton Station, near present-day Mount Royal Station. The sides (web) and bottom flange of Milholland's 54-foot-long span were wholly of wrought iron and included a top flange reinforced with a 12x12-inch timber. Plates employed in the bridge were 6 feet deep and 38 inches wide, giving the entire bridge a total weight of some 14 tons. Milholland's pioneering plate girder cost $2,200 (Tyrrell 1911:195). By December 31, 1861, the Northern Central Railroad, which succeeded the Baltimore and Susquehanna, maintained an operating inventory in Maryland of 50 or more bridges described simply as "girder" spans, in addition to a number of Howe trusses. Most of these were probably iron girder bridges; the longest were the 117-foot, double-span bridge over Jones Falls and the 106-foot double-span girder bridge at Pierce's Mill (Gunnarson 1990:179-180).

Perhaps because girder bridge construction technology was not difficult and became readily standardized, few descriptions of nineteenth century deck girder or plate girder construction in Maryland have been located. One such account, however, serves to illustrate how plate girder bridges, initially employed on railroads, became useful to Baltimore City engineers by the 1890s. In 1892, Frederick H. Smith, the prominent Baltimore Bridge Company partner then serving as a consulting engineer to the city, reported that the Campbell & Zell firm had been retained to build a new Lexington-Douglas Street bridge, which was to be "a deck bridge consisting of fourteen plate girders 78 feet long, reaching from wall to wall, and having curved tops upon which are riveted heavy floor plates carrying a granite block roadway 42 feet wide, and two granolithic sidewalks, each 14 feet wide, with heavy steel handrailings along their outer sides and granolithic gutter kerbing along their inner sides." Smith noted with some embarrassment that 13 of the 14 girders were in place, but the "scow with the one remaining girder is stranded in the mud a short distance below the bridge where she has been now for more than a week awaiting the tides" (Baltimore City Commissioner 1892:489).

Girder bridge construction on the Baltimore and Ohio Railroad received a boost between 1901 and 1908, when former Pennsylvania Railroad Chief Engineer Leonor Loree took charge of a major rebuilding of the B&O main and branch lines. Aiming to refit the railroad so that it could safely run 2,500-ton coal trains behind heavy locomotives, Loree ordered construction of a combination deck girder and through truss bridge at the Ilchester tunnel, a seven-span deck plate girder bridge over the Monocacy River, a girder replacement for the old Bollman truss over Tuscarora Creek, and steel plate girder center spans for several trestles along the

B&O's Georgetown Branch in Montgomery County (Harwood 1979). Loree and his immediate predecessors also constructed many girder spans during the rebuilding of the Washington County Branch leading to Hagerstown) between 1890 and 1908 (Harwood 1979:375).

As in the nation, girder bridge technology in Maryland was quickly adapted to cope with the increasingly heavy traffic demands of the twentieth century caused by automobile and truck traffic. The 1899 Maryland Geological Survey report on highways noted that "there are comparatively few I-beam bridges, one of the cheapest and best forms for spans less than 25 or 30 feet" (Johnson 1899:206). Interestingly, the report also urged construction of a composite metal, brick, and concrete bridge, noting that "no method of construction is more durable than the combination of masonry and I-beams, between which are transverse arches of brick, the whole covered with concrete, over which is laid the roadway" (Johnson 1899:206). Whether any such bridges (transitional structures between I-beams and reinforced concrete spans) were built is unknown.

Official state and county highway reports--issued between 1900 and the early 1920s through the Highway Division of the Maryland Geological Survey, and its successor, the State Roads Commission--generally do not reference or describe girder construction. An analysis of the current statewide listing of county and municipal bridges (a listing maintained by the State Highway Administration) reveals that 48 county bridges, out of the total of 141 approximately dated to "1900" by county engineers, were listed as steel girder, steel stringer, or variants of such terms. (It should be noted that the "1900" date is often given when no exact date is pinpointed for a bridge that is clearly old). A grand total of 200 bridges (including "steel culverts"), out of 550 bridges dated on the county list between 1901 and 1930, were described as steel beam, steel girder, or steel stringer and girder varieties. The total suggests that metal girder bridges in Maryland between 1900 and 1930 were only less popular than reinforced concrete bridges among the various highway bridge types built in the early twentieth century. However, these numbers must be interpreted with caution, as they do not necessarily include all county and municipal bridges.

Analysis of the more detailed 1993 Maryland State Highway Administration Bridge Inventory offers a portrait of historical patterns for the state's extant metal girder bridges built between 1900 and 1940. The earliest steel girder bridge listed on the state bridge inventory is the U.S. 11 bridge, a 308-foot-long, three-span structure built in 1909 to carry the road over the Potomac River and the Western Maryland Railway. Only one steel girder or beam structure, Bridge 3092 on State Route 147 over Long Green Creek, is dated between 1910 and 1920 (it is a single span of 37 feet built in 1915 and reconstructed or altered in unspecified fashion in 1969). Between 1921 and 1930, however, 13 bridges now extant were built as steel girders or beams, or incorporated such spans. The latter category consisted of two significant movable bridges constructed under state contracts (the 1924 Severn River

Bridge on State Route 450, featuring a double-leaf bascule along with steel beam spans, and the 1929 Bridge 2081 carrying State Route 436 over Weems Creek, a swing bridge with thirteen 20-foot steel beam spans). By 1921, most girder bridges erected by the State Roads Commission included reinforced concrete decks; as the inventory also clearly indicates, many girder bridges were structures built to eliminate dangerous railroad grade crossings (Maryland Department of Transportation 1993a).

The 1930s saw continuation of these trends in girder construction. More than 40 steel girder or steel beam structures are listed on the state inventory as dating from the 1931-1940 period. Railroad grade crossing elimination continued to prompt the use of deck girder and half-through plate girder spans (the elimination program itself was given a welcome boost by New Deal planning surveys sponsored in 1935-1940 by the U.S. Bureau of Public Roads). Improvement of such older roads as U.S. 1 (the Baltimore-Washington Boulevard) and construction of the new Pulaski Highway (U.S. 40) from Baltimore to Perryville spurred construction of many steel girder highway spans. A singularly ornamented steel girder highway bridge in Maryland, extant as of 1980-1981 (MHT-CE-998), is the U.S. 40 bridge over AMTRAK near Elkton, a four-span steel girder bridge, which appears to be concrete encased. The bridge parapets are highly ornamented with Art Moderne details. Until the World War II interruption of major bridge building, steel girder spans continued to be built in Maryland, under county, municipal, and state auspices.

A postwar trend in design of metal girder bridges, reflected in the 1963 construction of a significant Maryland example, was the development of aluminum girder bridges. Based on research alone, it appears that the 1963 Bridge #13046, a three-span structure built by the State Roads Commission and International Aluminum Structures, Inc., is the only example of an aluminum bridge in Maryland and one of seven built in North America (Canada and United States) between 1948 and 1963. Bridge #13046 includes riveted triangular box stiffened sheet girders supporting a light-weight concrete slab with a bituminous wearing surface (Alison 1984).

Conclusion

The following summary statements regarding structural characteristics for metal girder bridges, key periods of significance for metal girder bridges in Maryland, and the earliest known documented examples of metal girder bridges in the state are based solely on documentary research.

Metal girder bridges (see Figures 14 and 15 and Plates 10 and 11) are structures in which a floor system and roadway are supported by parallel metal beams or girders, which are carried by concrete, masonry, or metal supports (abutments or piers). The beams or girders are typically rolled sections, which may be plain or encased in concrete. The shape of the cross section of an individual girder may define the girder as an I-beam, or a wide flange beam. Plate girders are characterized as girders built up of riveted sections, rather than a single rolled section. Components of the girder are the flanges (horizontal portions) and the webs (vertical portions).

Girder bridges where the girders are located below the deck or roadway are termed deck girder bridges. Girder bridges in which the girders extend above the roadway level are through girders.

Key periods of significance for the metal girder bridge in Maryland, as indicated by documentary research, include *1846-1870*, when this type of bridge was introduced and popularized by the railroads as an economical and versatile expedient; *1870-1920*, when metal girder (especially plate girder) bridge design and construction was standardized and increasingly employed for highway bridges; and *1920-1965*, when the State Roads Commission utilized metal I-beams and metal plate girders (many concrete encased) heavily in construction for grade crossing elimination structures, as well as ordinary highway bridges.

The earliest known documented example of a metal girder bridge in Maryland was the 1846 plate girder erected by James Milholland on the Baltimore and Susquehanna Railroad, a span credited as the earliest bridge of this type built in the United States. The earliest metal girder bridge known to be extant in Maryland is the U.S. 11 Bridge over the Potomac River (Bridge #21001), built in 1909 by the State Roads Commission. Other significant examples of metal girder bridges constructed in the state include Bridge #3092 on State Route 147 over Long Green Creek (single-span, 1915); the U.S. 40 bridge over AMTRAK near Elkton (four-span, with singularly ornamented Art Moderne detailing); and Bridge #13046, a three-span aluminum girder bridge built in 1963 on State Route 32 near Sykesville by the State Roads Commission and International Aluminum Structures, Inc. (this bridge is the only known aluminum bridge in Maryland).

SECTION VIII: METAL SUSPENSION, ARCH, AND CANTILEVER BRIDGES

Based on historical research and review of Maryland Historical Trust historic resource survey forms, it appears that few metal suspension, metal arch, and metal cantilever bridges are extant in Maryland. Structures exemplifying the development of these three bridge types, however, were built in the state from the beginning of the nineteenth century. Although there are few surviving nineteenth century suspension, metal arch, or cantilever bridges in the state, these structural types are well represented by important Maryland bridges built between 1940 and 1955. For this reason, each of these types deserves some discussion in any context for the evaluation of historic bridges in Maryland.

HISTORICAL DEVELOPMENT: METAL SUSPENSION BRIDGES

Many technological historians have asserted that the suspension bridge is one of the oldest bridge types in the world. There is documentation that such bridges were utilized in a range of non-Western ancient societies, notably in the Far East (Tibet, China) and South America (Peru and Bolivia, areas in the former Inca Empire). Such early bridges utilized the basic principle of suspension bridges--the hanging, or suspension, of a walkway or roadway from a rope or bundle of vines anchored at both ends. A major technological advance, attributed to Tibetan bridge builders, occurred when the walkway or roadway, previously laid directly on the rope or cable, was attached instead to hangers, or suspenders, between the rope or cable and the deck. Although this innovation meant that the anchor points had to be higher in order to bring the deck level with the proper grade of an existing approach roadway, the use of suspenders opened technology to possibilities for stiffening the deck, thereby decreasing the tendency of the bridge to swing or twist under loads or wind-generated force (Lay 1992).

As suspension bridge technology became more refined, a range of cable systems was developed (Figure 16). Chain links, wire ropes, and twisted strand cables (bundled and wrapped) were employed. Besides the cables, the roadway deck, and the suspenders, the basic components of a modern suspension bridge include towers, over which are draped the cables (held in place there by saddles or cradles), and heavy masonry abutments (or anchorages) where the cables descending from the tower tops are securely anchored. This typical design configuration results in division of the bridge into a main span and two side, or anchor, spans, with approach spans often of other structural types. Suspenders on the bridges (consisting of eyebars, rods, or steel ropes) are usually spaced at equal intervals and are vertical. On twentieth century structures,

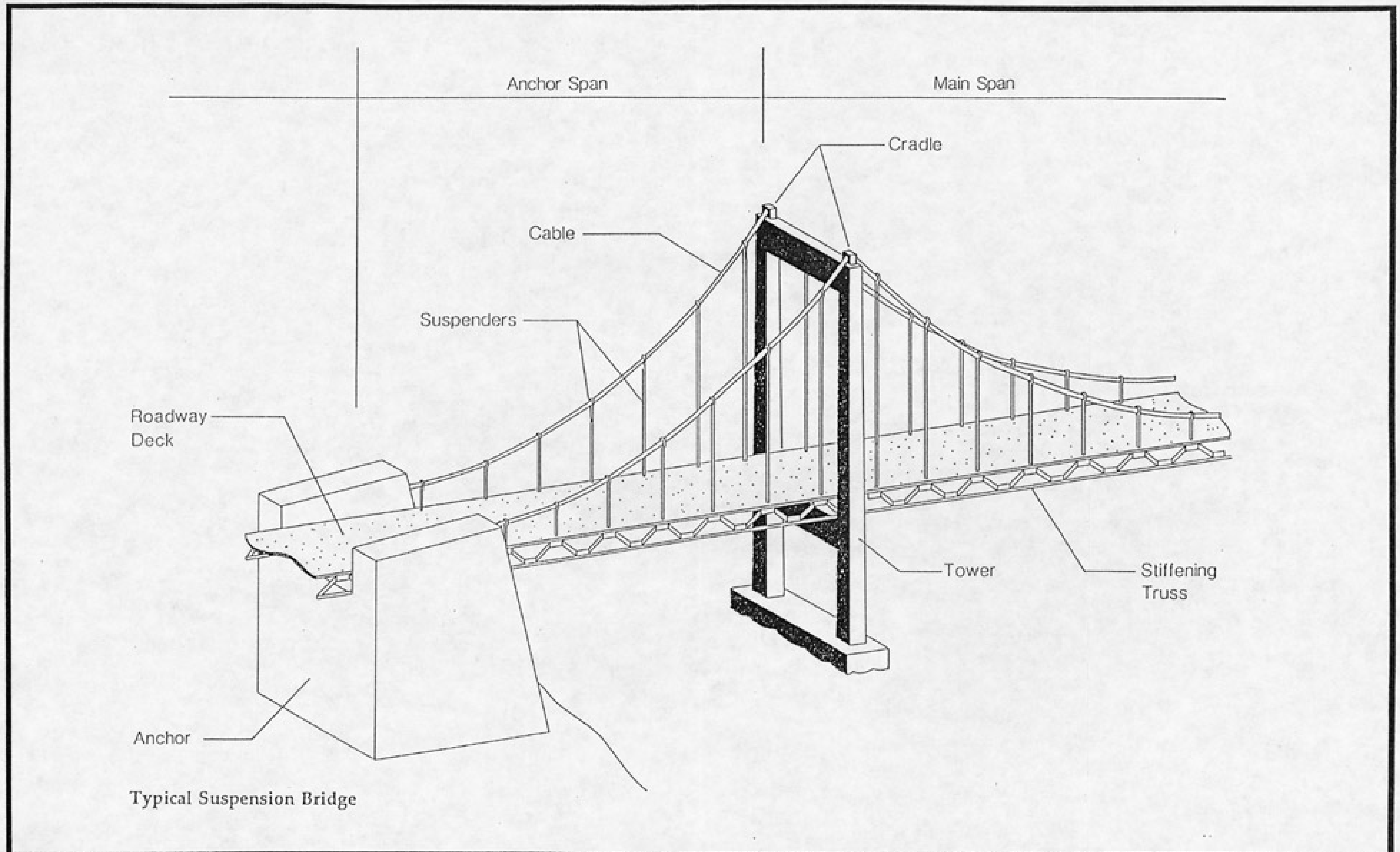


FIGURE 16: Typical Suspension Bridge

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986

the suspenders usually connect to the cables by means of bolted bands. The tendency of suspension bridge cables to deflect (swing or twist under the application of loading) is typically counteracted by the stiffening of the deck with a truss system beneath it, although this system was preceded by use of long floor joists extending across several beams (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:77).

Suspension bridges are highly significant in the history of American bridge technology because they were the earliest all-iron bridges constructed in the United States. Modern suspension bridge technology was largely pioneered by three distinguished suspension bridge builders active in the early nineteenth century, James Finley, Charles Ellet, and John A. Roebling. Finley, a judge and self-trained bridge constructor from Fayette County, Pennsylvania designed and built the first known suspension bridge in the United States over Jacob's Creek, at Uniontown, Pennsylvania, in 1801. Thereafter, some 40 Finley suspension spans were built. Finley's so-called "chain" bridges incorporated for the first time in the Western Hemisphere the use of suspenders to carry the deck at a level with the approaching roadway (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:76-79).

The Finley spans were "chain" bridges because their cables were composed of wrought iron chains made of square bars, formed into links often ranging from 5 to 10 feet in length. Finley's Jacob's Creek span featured one-inch square bars, with vertical suspenders of varying lengths attached to each chain link and carrying the roadway's timber floor beams by means of a stirrup-like arrangement. Finley's earliest bridge was 13 feet wide and spanned 70 feet; later bridges he built, such as the famous 1807 "Chain Bridge" on the Potomac above Georgetown and a span constructed to his patent in about 1820 at Will's Creek near Cumberland in Maryland, were longer and wider, but generally followed the same chain-dependent design as his early spans. Construction of such chain bridges generally involved careful movement into place of the entire cables, which were lifted into position over the masonry towers and secured by various means to the abutments (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:79).

Wire rope for cables was first employed in 1816, for a private toll footbridge over the Schuylkill built by Josiah White and Erskine Hazard, who were co-owners of a Philadelphia wire concern. In England in 1826, highway and bridge engineer Thomas Telford, aware of Finley's accomplishments, designed the first large-scale suspension bridge in the world, over the Menai Straits. Two years later, the world's first all-steel suspension span was erected over the Danube Canal in Vienna, anticipating twentieth century structures (DeLony 1993:2-3). Under the impetus provided by the Finley spans, the White-Erskine bridge, and the European suspension bridges of the 1820s, American suspension bridge design was again materially advanced by the contemporaries and occasional rivals in the field, Charles Ellet and John A. Roebling. Although the Erskine-White wire rope structure had collapsed, wire rope spans were revived in the United States by Ellet, who had studied Europe's suspension bridges. In 1841-1842, Ellet's first major wire suspension bridge replaced Lewis Wernwag's covered timber "Colossus" bridge over the Schuylkill (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:80).

Between 1846 and 1849, Ellet designed and built his most significant structure, the Wheeling suspension bridge at Wheeling, West Virginia, whose 1,100-foot span was for many years the longest in the world. Ellet's scholarly biographer, Gene Lewis, uncovered no evidence that any Ellet suspension bridges were built in Maryland, but it is certain that Ellet proposed in 1832 and again in 1854 to erect suspension spans over the Potomac on a scale equivalent to that of the Wheeling Bridge (Ellet 1854; Lewis 1968; Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:80). John Roebling also is not known to have designed and constructed any Maryland bridges, but his signal advance, the method of building a cable in place by "spinning" or "stringing" it using a traveling sheave, dramatically affected suspension bridge technology in the nineteenth and twentieth centuries. Roebling's bridges, such as his masterpiece the 1883 Brooklyn Bridge, largely built by his son Washington, had thick cables composed of such spun wires grouped into strands and then bound together in a circular geometric form. The cables were typically clamped at intervals for attachment of the suspenders (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:82-83).

With adoption of the Ellet and Roebling techniques, twentieth century suspension bridge technology, like other types of bridge engineering, has been characterized by scientific analysis of suspension, stiffening, and anchoring principles, resulting in the design and construction of ever-larger suspension spans. During the mid-1920s, Allegheny County, Pennsylvania, Chief Engineer Vernon R. Covell designed three innovative Allegheny River suspension bridges at Pittsburgh. Lacking heavy anchorages or abutments, these spans were self-anchored because their cables at the ends were attached to a stiffening, underdeck truss system running the full length of the bridge. The stiffening truss acted like a compression member to resist the tension of the suspended cables. Covell's bridges also were the first major pin-connected eyebar chain bridges built since the previous century; their employment of eyebars, however, led to increased wear and was not generally followed in subsequent twentieth century bridge construction (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:82-84).

Significant large suspension spans of the twentieth century include Othmar Ammann's 1931 George Washington Bridge, which reached a wire cable strength of 240,000 pounds per square inch (compared to the Brooklyn Bridge's 160,000 p.s.i); the 1937 Golden Gate Bridge designed by Joseph Strauss, with innovative cofferdams utilized to sink the pneumatic caissons into the bay floor; and New York City's 1964 Verrazano Narrows Bridge, also designed by Ammann, in which the compacted cables are splayed into individual strands wrapping around massive eyebars embedded in the concrete anchorages. These bridges employed essentially the basic technology of suspension bridges in the United States, on a large scale, as pioneered by Finley, and especially Ellet and Roebling during the early nineteenth century (DeLony 1993:138-139, 143-145).

METAL SUSPENSION BRIDGES IN MARYLAND

The history of suspension bridges in Maryland parallels the technological development of such bridges in the nation. Unfortunately, it is marked by the apparent loss of all significant suspension bridges built in the state during the early nineteenth century formative period of the type's technology. Located through historical research and review of survey forms only, Maryland's nineteenth century suspension bridges included at least two bridges built by James Finley or to his patented 1808 design, as well as several suspended footbridges dating from the latter half of the century. The Finley-type chain bridge is evidently no longer extant even in ruins, while only one survivor is known among the group of suspension footbridges. By contrast, the twentieth century development of large-scale wire cable suspension spans is dramatically represented in Maryland by the Chesapeake Bay Bridge, built between 1947 and 1952 as the culmination of nearly a half century of planning and engineering discussion. Although the first Bay Bridge does not yet fall under the customary 50-years-or-older age requirement for National Register-eligible structures, its overriding technological and commercial importance renders it an exceptional resource that should be regarded as meeting the National Register eligibility criteria.

Early Suspension Bridges

The earliest suspension bridge built in the Maryland vicinity was probably James Finley's 1808 Chain Bridge, built to cross the Potomac between Virginia and the District of Columbia. By the Civil War, this bridge was no longer in existence; and Washington still labored under the heavy usage of the dilapidated timber Long Bridge, although in 1832 and 1854, Charles Ellet had offered plans, which were unaccepted, for a new suspension bridge over the Potomac on the scale of his 1846-1847 Wheeling bridge (Lewis 1968:26-27, 128-129). Early interest in suspension spans was, nevertheless present in western Maryland, where the Army's construction of the National Road, beginning in 1811, drew attention to professionally engineered bridges to cross steep streams and rivers. In 1820, Allegany County, Maryland officials hired Valentine Shockey, owner of an ironworks near Cumberland, to fabricate and erect a chain bridge to Finley's design, to be built over Will's Creek, a steep, turbulent Potomac tributary, at Cumberland (Thomas and Williams 1969:200).

Its piers repaired in 1831, the Finley bridge at Cumberland survived until April 28, 1838, when the structure gave way at the western abutment and fell into the stream (Thomas and Williams 1969:200). In 1871, prominent engineer John Trautwine included the following description of the Will's Creek Chain Bridge in the first edition of his *Civil Engineer's Pocket-Book*:

> Finley used deflections as great as 1/7, or even 1/8, of the span, and his piers were frequently single wooden posts; the two at each end being braced together at top. Such were used in a span of 151-1/2 ft. clear, across Will's Creek.….The deflection was 1/8 of the span. The double links of 1-3/8 inch squ. iron, were 10 feet long. The center link was horizontal, and at the level of the floor; and at its ends were stirruped the two central transverse girders. From the ends of this central link, the chains were carried in straight lines to the tops of the single posts, 25 feet high, which served as piers or towers. The backstays were carried away straight, at the same angle as the cables; and each end was confined to four buried stones of about 1/2 a cubic yard each [Trautwine 1872:596].

The floor of the structure was wide enough for just one lane of travel, but the bridge regularly carried carts and wagons (some pulled by six-horse teams) heavily loaded with coal and other materials. The bridge's hand railing was hinged, "so as not to be bent by the undulations" (Trautwine 1872:596). The iron used had a strength of 30 tons per square inch; citing observations made in 1838 by "an observant engineer friend" (possibly Benjamin H. Latrobe, Jr., to whom the book was dedicated), Trautwine favorably compared the bridge to the 1831 Freyburg suspension bridge (Trautwine 1872:594-596).

No accounts of other early Finley suspension bridges built in Maryland have been located. Interestingly, John Templeman, of "Allegany County, Md.," took out a patent on a chain bridge just two months after Finley's major patent in 1808. Templeman also registered another bridge patent in 1810 (U.S. Patent Office 1875:150) and was possibly associated in the 1790s with companies to build a drawbridge over the Eastern Branch of the Potomac River between Washington, D.C., and Anacostia in what was once Prince George's County. No further evidence of Templeman's engineering activities in Maryland has been found.

Swinging Footbridges

Although Ellet and Roebling were engaged between the 1830s and the 1860s in completing major suspension bridges in Maryland's neighboring states of Pennsylvania and West Virginia, no record of any spans built by them or their associates in Maryland has been found. During the latter nineteenth century, however, iron "swinging" bridges, or suspended footbridges with narrow walkways, were installed at several locations in the state. At some time between 1856 and 1904, a swinging footbridge was built at the Orange Grove Mill, a flour milling complex located near Ilchester on the Patapsco River. As the mill was situated on a narrow shelf of land between the steep B&O railroad embankment and a high retaining wall next to the river, access to the buildings was difficult. The footbridge linked both riverbanks until January 1904, when a sudden ice thaw in the river broke the structure away from its south mooring and swung it downriver. The bridge was repaired or replaced with a similar structure, which finally was completely destroyed by the Hurricane Agnes flood of 1972 (Travers 1990:90-93, 178).

A hardier survivor (as of the 1979 preparation of a Maryland Historical Trust historic resource survey form) reflective of similar suspension footbridge technology is the Pedestrian Swinging Bridge at Frederick (MHT-F-3-8). Built in 1885 to replace an existing "high footbridge" destroyed in a flood, the bridge spanned Carroll Creek and Bentz Street in Frederick until its 1928 removal to the Frederick City Park. An iron suspension bridge spanning 100 feet, the structure was constructed by Buckey and Firestone, a local foundry, under authority of the city's mayor and aldermen. The contract called for completion of "one iron suspension bridge. . .of the following dimensions, first span, one hundred feet in length, incline thirty-five feet, walk four feet, with galvanized cables, braces of iron, with iron floor beams and one and one-half inch pine floors, static load two hundred pounds per lineal foot."

By December 19, 1885, Buckey and Firestone were placing the iron work into position over the creek and street. Structurally, the bridge evidently featured rod-like suspenders that were horizontally braced and bolted to the floor beams. The cables were inclined, while the backstays were straight. The bridge cost the city $685.59; in 1928, local mason Leroy Hoke moved the bridge to the city park. This timely municipal action doubtless helped to preserve the bridge until 1979, when it was surveyed and documented by a Frederick County historic sites surveyor. The Pedestrian Swinging Bridge in Frederick is the only such bridge to have been surveyed as a historic resource in any Maryland county.

The First Chesapeake Bay Bridge

No suspension bridges built between 1890 and 1952 are known to be extant in Maryland. Nonetheless, the state holds an outstanding example of modern suspension bridge technology, the first Chesapeake Bay Bridge, built in 1947-1952 by the J.E. Greiner Company under agreement with the Maryland State Roads Commission. Design and construction of the Bay Bridge climaxed almost 50 years of debate and discussion, and fully represented the latest techniques and engineering innovations in mid-twentieth century American suspension bridge engineering design.

The earliest public proposal for bridging the Chesapeake Bay in Maryland was in 1907, when various merchants and manufacturers' associations of Maryland sponsored consideration of the issue. The result was the 1908 Hoen Committee report, which recommended engineering studies. Westinghouse, Church, Kerr & Company, consulting engineers, found construction of a bridge a feasible solution, but costly at more than 13 million dollars. In 1918, the state legislature authorized the State Roads Commission to establish auto ferry service between Annapolis and Claiborne on the Eastern Shore; such service went into effect in 1919.

Further unsuccessful attempts to incorporate and finance Bay Bridge companies culminated between 1926 and 1938 in the activities of the ill-starred Chesapeake Bay Bridge Company, which suffered a loss of some $300,000. (The J.E. Greiner Company, which had been retained as consultants by the Chesapeake Bay Bridge Company, would ultimately construct the bridge.) The Depression forced consideration of public financing rather than private bond issues for the project, and in 1937 the State Roads Commission was directed to formulate a plan for the erection of four "primary bridges" needed in Maryland: the Bay Bridge, a bridge to carry U.S. 301 into Virginia, a span to take U.S. 40 across the Susquehanna at Havre de Grace, and a proposed Baltimore Harbor crossing (which in 1957 was finally opened as the first Harbor tunnel, rather than a bridge). The resultant 1938 *Primary Bridge Program* report became the basis for construction of the Bay Bridge at the Sandy Point-Kent Island site (Hamill 1952).

Army Corps of Engineers' navigational restrictions impelled construction of the Bay Bridge on a curved alignment crossing; the alignment to be followed was normal to the ship sailing course approximately 1 1/2 miles south of Sandy Point Lighthouse. The 4.03-mile-long bridge consisted of a total of 123 fabricated steel spans including the central cable suspension span, its side spans, and a series of cantilever trusses, simple trusses, and plate girder and beam spans. The suspension span over the "Main Sailing Course" (the Bay channel) was 1,600 feet long, with towers rising 354 feet above the bay surface. The 28-foot (curb-to-curb) roadway deck at the main span cleared the water surface by 198 1/2 feet; vertical ship clearance in the 1,500-foot waterway beneath the main span was 186 1/2 feet. The suspension cables installed on the bridge were 14 inches in diameter.

Construction of the Chesapeake Bay Bridge began in 1947 and ended in 1952. Permanent steel form or "Potomac Type" piers (so-called because they were first employed in construction of the 1940 U.S. 301 Bridge between Maryland and Virginia) were utilized for Piers 11 through 40 (except for Piers 23 and 28); these were built by excavating below the bay bottom, then driving temporary piles to support a wooden platform at the pier bottom, with openings for each permanent pile. The latter were driven through such openings, whereupon permanent steel forms, prefabricated and incorporating pier-reinforcing steel, were lowered to the platforms. Piers 23 and 28, the cable anchorage piers for the suspension span cables, were built by cofferdam methods, and sand and rock islands were constructed below water level adjacent to the anchorages in order to protect them from potential ship collision. Except for the suspension span, the steel superstructure was erected mostly by floating components into place below their intended positions, then hoisting them by derrick or traveler cranes mounted on the already-built spans as they progressed out from the shore.

Testifying to the Roebling tradition of tower construction as employed for the Brooklyn Bridge and other spans, the towers for the Bay Bridge were built using special traveling booms (Chicago booms), one on each leg of a tower, which worked in pairs to raise the steel tower sections (and themselves) as the height increased. A traveling sheave arrangement was also employed to build the cables to their full diameter and span length, while workers on a temporary footbridge (also a device utilized by Ellet and Roebling) adjusted the strands for proper lay. The stiffening trusses for the main span, prefabricated in Baltimore and floated into position, were lifted into place by engines powering a secondary cable system attached to the bridge's suspension cables. Vertical suspenders were then attached to the trusses, and the permanent wire cables were wrapped by machine with No. 9 galvanized steel wire before being coated with zinc chromate.

On July 30, 1952, Governor Theodore McKeldin ceremonially opened the bridge, christened the William Preston Lane Memorial Bridge after McKeldin's predecessor, who had done much to secure its construction. McKeldin called the bridge a "friendly device and a valuable utility" and predicted that it would be among the most traveled spans in the United States. Fulfilling that prediction, the Chesapeake Bay Bridge has served continuously since 1952, augmented in the mid-1970s by the addition of a second parallel structure (Maryland State Roads Commission 1952a:1-32).

Conclusion

The following summary statements regarding structural characteristics for metal suspension bridges, key periods of significance for metal suspension bridges in Maryland, and the earliest known documented example of metal suspension bridges in the state are based solely on documentary research.

Metal suspension bridges (see Figure 16) consist of a suspended superstructure, with many components, which is anchored into a masonry or concrete substructure. The basic structural system consists of flexible cables with stiffening trusses or girders suspended from them which carry the deck system. Suspension bridges may comprise various combinations of cables, towers, suspenders, and girders or trusses added to stiffen the bridge against wind and load stresses. In a typical suspension bridge, towers are built upon the piers, and the cables are carried high above the deck in cradles located at the top of the towers. The cables run downward to anchor spans from the towers of the main span; cables are usually anchored in heavy concrete or masonry abutments or anchorages. The deck is carried by suspended stiffening structures, girders or trusses, which serve to stiffen the truss against swaying or deflection.

Prior to the development of wire-rope cable technology, earlier suspension bridges featured cables consisting of chains formed from linked eyebars. Eyebar chain suspension bridges continued to be built in the twentieth century in some regions of the United States.

Key periods of significance for metal suspension bridges in Maryland, as indicated by documentary research, include *1800-1840*, the formative era of suspension bridge development within the United States, during which the basic technology of wrought iron "chain" bridges was pioneered by James Finley and associates (one known example is a bridge built to Finley's design is known to have been erected over Will's Creek at Cumberland in 1820 by Valentine Shockey); and *1900-1960*, a period in which the wire rope suspension bridge technology, perfected by Charles Ellet and John Roebling during the nineteenth century, was refined and saw dramatic application in Maryland's first Chesapeake Bay Bridge, completed between 1942 and 1952 but planned by the State Roads Commission prior to World War II. Documentary research has also located evidence of "swinging" pedestrian footbridges built in Maryland during the *1850-1900* period; no such bridges, however, are known to have been constructed for highway use.

Maryland's only known major suspension bridge is the Chesapeake Bay Bridge, a monumental wire rope span built 1947-1952 by state authorities and designed by J.E. Greiner Company. No highway-related suspension bridges from the nineteenth century are known to have survived: field survey, which may locate such bridges or their remnants (e.g., abutments or piers), will be necessary to verify this conclusion.

HISTORICAL DEVELOPMENT: METAL ARCH BRIDGES

Like metal suspension bridges, arch bridges of iron and steel evolved in form from early types built in traditional materials. Metal arch bridges may be usefully classified by degree of articulation (type of pinned connection found at the bridge supports and at its midpoint or arch crown) or by the form or configuration of the arch employed. In a fixed, or hingeless, metal arch structure, the ends of the main spans are embedded in large supports (abutments or piers). When articulated with a pinned connection at each support (a method utilized to allow the bridge some movement under rotational forces), the bridge is a two-hinged arch. When end supports are pinned and another hinge or pin is located at or near the arch crown or midpoint, the structure becomes three-hinged. Rarely built, the one-hinged variant employs a single pinned connection near mid-span at the arch crown.

Three major varieties of metal arch bridge, categorized by type of arch configuration, may be. Solid-ribbed arches are constructed of plate girder ribs cast in a curved form. The deck of such a structure is carried on metal posts resting on top of the arches, or (if the bridge is a through, or bowstring, arch) from suspenders hung from the arch bottoms (Figure 17; Plate 12). Solid-ribbed arches were built in hingeless, one-hinged, two-hinged, and three-hinged variants. By contrast, the brace-ribbed arch features two parallel, or near-parallel, arch chords linked by a system of open webbing consisting of truss members (hence, a second name for this subtype is the trussed arch). Brace-ribbed structures were similarly erected in all hingeless and hinged variants.

The third basic subtype by arch configuration, the spandrel-braced arch, is characterized by the roadway or deck carried atop the arch (hence, these structures are deck arches). The main arch of a spandrel-braced arch consists of its curved bottom members. The roadway is carried on the horizontal top chord, while a web trussing system, typically composed of Pratt trusses, links the top chord to the arch (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:93-94).

Adapting the familiar arch form of stone bridges, metal arch technology first developed in England as a result of the mid-eighteenth century advances in the iron industry. The earliest iron bridge in the world, Ironbridge at Coalbrookdale in England, was built in 1781 and consisted of five semicircular cast-iron arch ribs with a 300x150-millimeter rectangular cross section. The eminent American revolutionary writer Thomas Paine designed an iron arch featuring a linked array of block-shaped cast iron voussoirs, but this configuration did not readily attract backers and was not regularly employed. The English pioneer in highway engineering, Thomas Telford, advanced metal arch technology considerably during the late eighteenth and early nineteenth century, with his design and construction of a number of flat (high span-to-rise ratio) cast-iron arches formed by latticed trusses rather than iron voussoirs (Lay 1992:271-272).

Telford's engineering innovations brought the metal arch into prominence in the United States. The oldest extant all-metal arch, the Dunlap's Creek Bridge at Brownsville in Fayette County, Pennsylvania, was built in 1838 under the direction of Captain Richard Delafield of the U.S. Army, who had charge of all construction and maintenance efforts along the National Road east of Ohio. This bridge, which demonstrated the feasibility of using iron in bridge construction, was an 80-foot arch with a rise of 8 feet. The arch was supported on massive sandstone abutments with heavy wingwalls. The bridge as finally erected consisted of a timber plank deck atop stringers and beams which were, in turn supported by means of a latticed frame above five hollow cast iron segmental tubes built up in short lengths and bolted together at circumferential flanges to form each arch (Schodek 1987:79-81).

The Brownsville arch inaugurated the nineteenth century period of construction and experimentation in the metal arch form. As in the case of other metal bridges such as trusses and girder spans, metal arch structures were first built of iron, then were constructed of steel in the late nineteenth century and throughout the twentieth century. A large two-span iron arch bridge (each span 185 feet long) was completed in Philadelphia in 1863 to carry Walnut Street across the Schuylkill River. In 1869, the innovative three-hinged metal arch was pioneered by Pennsylvania Railroad engineer John M. Wilson, in his bridge built to take the railroad over Philadelphia's 30th Street (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:95). Five years later, self-trained bridge engineer and Civil War hero James B. Eads successfully erected his monumental Eads Bridge over the Mississippi at St. Louis. Eads's bridge is a fixed three-span metal arch featuring tubular truss-arch ribs; also, it was the first bridge in the world to utilize high-strength steel for structural components (Lay 1992:292).

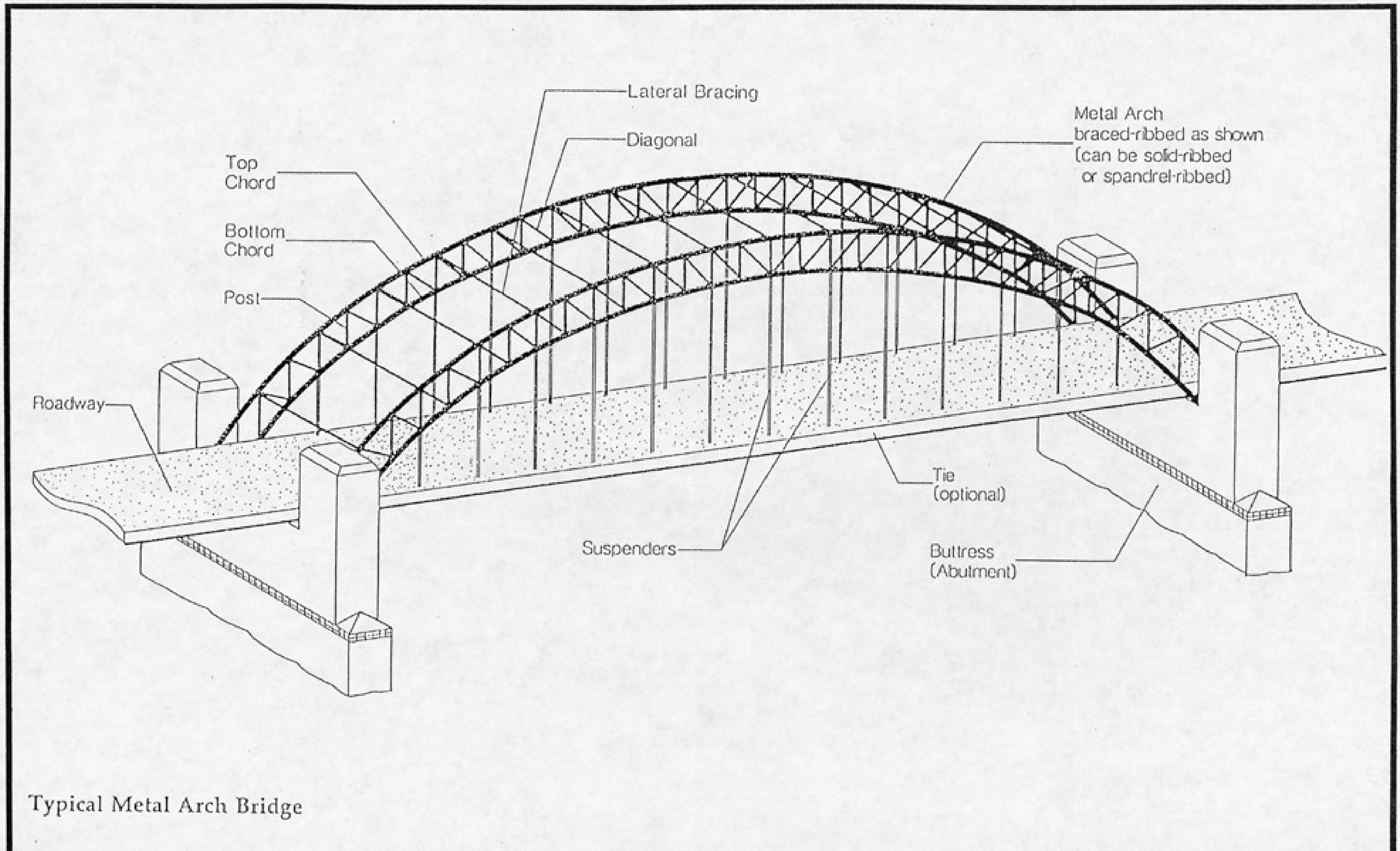


FIGURE 17: Typical Metal Arch Bridge

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986

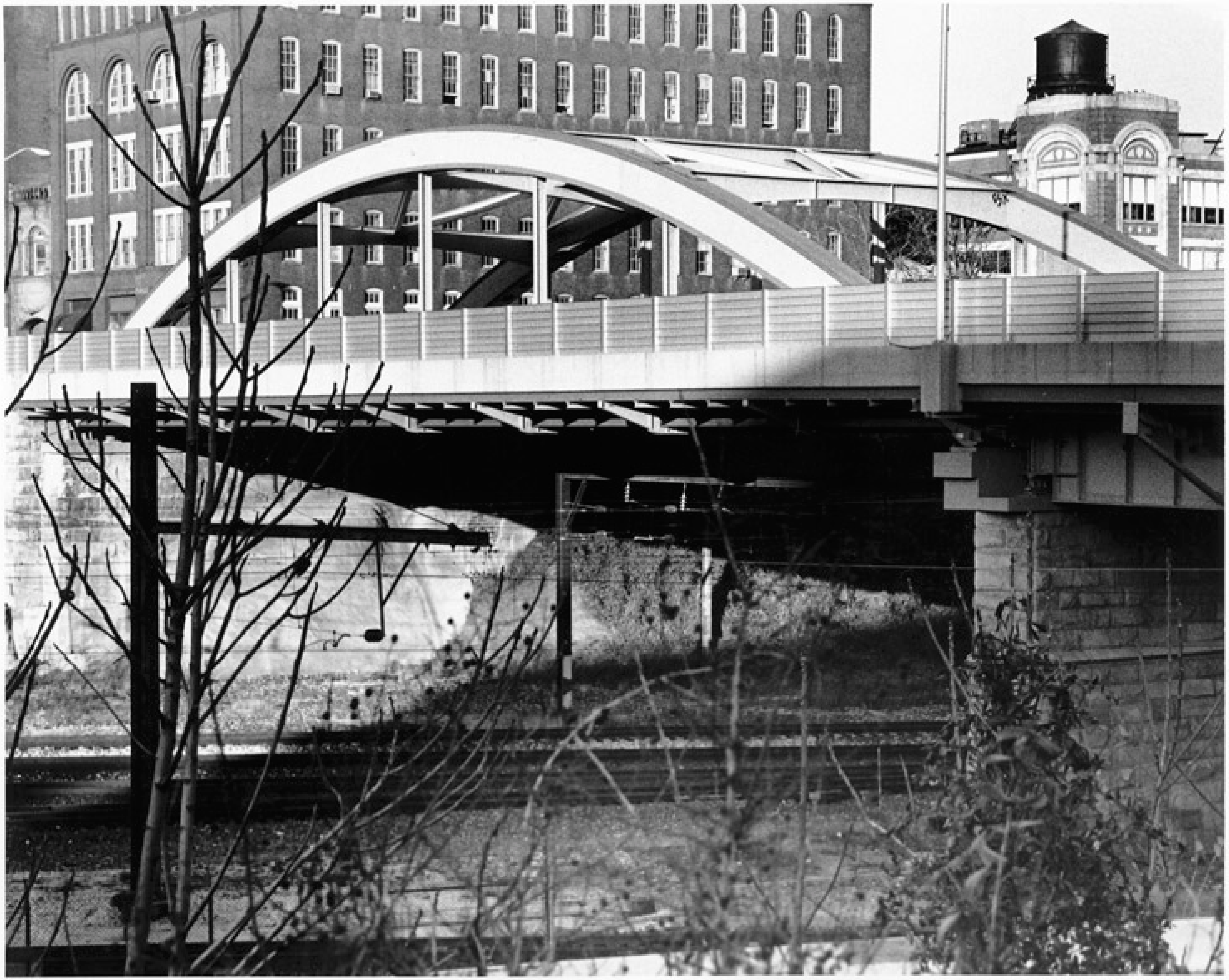


PLATE 12: Typical Metal Arch Bridge: Bridge on Guilford Avenue in Baltimore SOURCE: MDOT Photographic Archives

Bowstring metal arches, in which the arch ribs ascend above the roadway deck, became popular under the impetus of the metal bridge innovations of such engineers as Squire Whipple and Thomas Moseley. Prior to the Civil War, Whipple built bowstring arch bridges over the Erie Canal and patented a design which, though essentially a truss bridge, nonetheless relied on the inherent strength of its arched upper chord (see report section entitled "Metal Truss Bridges" for further discussion of Whipple's work with arch truss structures). Bowstring bridges incorporating features of the metal arch as well as the metal truss were frequently built during the latter half of the nineteenth century by many of the same bridge companies (such as the King Bridge Company of Canton, Ohio) that popularized Pratt and Warren trusses. In most instances, field survey alone can determine precisely whether these structures relied primarily on a truss system for support, they were essentially metal arches utilizing suspended verticals or trusses to support the roadway deck.

By 1890, the three-hinged metal arch had gained general acceptance as a suitable structure for highway bridges. Metal arch bridges in the United States during the late nineteenth and early twentieth centuries were primarily utilized in highway construction, as the railroads usually preferred metal truss bridges to carry the generally heavier loads of locomotives and trains. Perhaps the best known and most significant major metal arch bridge of the early twentieth century is the Hell Gate Bridge, a massive two-hinged through arch designed by master bridge engineer Gustav Lindenthal and built in 1914-1916. Lindenthal's Hell Gate Bridge has a clear arch span of a remarkable 977 feet; the upper chord is curved and is connected to the arch rib by a network of Pratt trusses, which together with the chord serves to stiffen the bridge against traffic and wind pressures (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:94-96).

More modest metal arch bridges continued to be built in the United States during the first half of the twentieth century. The aesthetic, classic appeal of the arch form, often a public consideration in design of stone arch and concrete arch bridges, also frequently made metal arches an attractive twentieth century alternative. J.A.L. Waddell in his 1916 *Bridge Engineering* noted that "where steel construction is adopted, attempts are being made to obtain the best possible appearance, either by means of the arch (the ideal solution when practicable) or by polygonal top chords, which tend to produce a graceful effect" (Waddell 1916:16).

In a 1912 article, however, bridge engineer and reinforced concrete arch pioneer Daniel B. Luten cautioned that "in steel bridges, the arch is difficult to fabricate and difficult to erect, and consequently steel trusses and girders have a distinct advantage" (Luten 1912:631). Although metal arch bridges in the modern, automotive era did not attain the general versatility and adaptability of steel girder and reinforced concrete structures, the metal arch form remains a significant

American historic bridge type, displaying a technological continuity of development in the United States similar to that of the more common metal truss bridges.

METAL ARCH BRIDGES IN MARYLAND

Metal arch bridges in Maryland do not comprise a large group of historic structures, but do include representative examples from both the nineteenth and the twentieth centuries. No early iron arch bridges are known to have been constructed on the Maryland section of the historic National Road, although National Road maintenance inspired Captain Delafield to build the nationally significant Dunlap's Creek Bridge in 1838. The spread and popularity of the metal arch form in Maryland appear to have occurred primarily in the years following the Civil War, as iron and steel making technology rapidly progressed and bridge building firms were founded to take advantage of a ready, growing market for metal highway spans. Small, pony bowstring arch-truss bridges were marketed by such firms as the King Iron Bridge Company and the Smith Bridge Company to county commissioners in Maryland. As already noted, such structures were essentially combination structures, and could adequately function in quite different ways although their appearance remained the same. In some structures, the arched upper member might serve primarily as an arch connected by a truss system to the bottom horizontal chord of the bridge, while in other bridges the trusses might be the primary components and simply feature an arched top chord.

Dating mainly from the 1870s and 1880s, Maryland's known dated late nineteenth century examples of the metal bowstring truss bridge include three pony spans and one larger through bridge, the Waverly Street Bridge at Williamsport (documented as HAER No. MD-83). The three pony spans recorded on prior survey forms are the Crum Road Bridge over Israel Creek in Frederick County (MHT-F-2-5; a circa 1875 King Iron Bridge Company product), the Bennies Hill Road Bridge over Catoctin Creek in Frederick County (MHT-F-2-2; also made by the King firm in about 1880), and Bridge #51 in the Whitaker Mill Historic District in Harford County (MHT-HA-1237; a bowstring arch-truss with Warren truss configuration of undetermined date). Only further field investigation of these structures can adequately determine whether they are primarily metal arch bridges, or pony trusses with arched upper chords, or a combination design.

While many Maryland county authorities found bowstring arch-truss bridges desirable during the last quarter of the nineteenth century, there is also ample evidence that Baltimore City constructed a number of important metal arch bridges between 1880 and 1900, a period which saw the 1888 annexation of a large surrounding area by the city. Few if any of these urban structures appear to have survived (the last known to have been taken down was the Cedar Avenue Bridge), yet they mark a significant chapter in the employment of the arch form in Maryland bridge building. Two familiar Baltimore City metal through arch bridges of the twentieth century, the Howard Street and Guilford Avenue bridges built over Jones Falls and railroad tracks during the 1930s, attest to the visual presence of the city's late nineteenth century metal arches, as both of these twentieth century bridges were designed to conform with the built landscape of a group of through arches then crossing the Jones Falls and the tracks.

Many of the city's early metal arch bridges over Jones Falls were built under the auspices of the Jones' Falls Improvement Commission, which in 1878 hired prominent Baltimore Bridge Company partner Charles H. Latrobe as consulting engineer. Latrobe's first accomplishment for Baltimore in metal arch bridge design was the Calvert Street Bridge, 579 feet long and consisting of two bowstring arch-truss spans of wrought iron with two viaduct approaches (Baltimore City Commissioner 1882:694). The fourth bridge erected under Jones' Falls Improvement Commission authority was the St. Paul Street Bridge, a 703-foot-long, two-hinged wrought iron, through arch structure with two through metal arch spans of 110 and 280 feet. This was the largest of all the bridges erected by the Commission between 1878 and 1882 (most of the others were metal truss bridges) (Baltimore City Commissioner 1882:393).

Latrobe's first two metal arch bridges for the city survived well into the twentieth century but were ultimately replaced as traffic loads on Calvert and St. Paul Streets increased. The Calvert Street Bridge, built at the time on the edge of the settled city limits, was pronounced by Mayor Ferdinand Latrobe (Charles Latrobe's uncle) a "suitable place to promenade for persons visiting the suburbs" (Nottrodt 1983). The four ornamental lions guarding the bridge were damaged on December 2, 1883 by Irish-American Larry Finnegan, who protested British rule of Ireland by taking an ax to the lions' tails (Nottrodt 1983). Charles Latrobe's next major metal arch bridge project for Baltimore City, the Cedar Avenue Bridge built in 1889-1890, departed from the pattern of wrought iron bowstring arches and two-hinged through arches to adopt a deck arch design. The Cedar Avenue Bridge, crossing the Northern Central Railroad, the Jones Falls valley, and Falls Road, featured a three-ribbed, three-hinged steel trussed-arch 150 feet in length, with side spans carried by three lines of Warren deck trusses (Vogel 1975:16).

Latrobe, in his 1890 report to the city commissioner, offered further instructive details regarding the Cedar Avenue Bridge and its construction. The superstructure was fabricated by the King Iron Bridge and Manufacturing Company of Cleveland, Krug & Son of Baltimore erected the ornamented hand railing, and the masonry work was done by Jones and Thorne of Baltimore. Incidentally indicating that the Warren deck truss side spans were not original to the bridge, Latrobe's description of the structure outlined why he chose a metal arch for the site:

> Owing to the solid rock at Jones' falls at this point, I concluded that a brace arch would be well adapted to the main span, and would certainly present a more graceful appearance than a rectangular truss. This being settled, girders were used for the side spans, so that the bridge as built consists of a braced arch span one hundred and fifty feet long over the water, a seventy-two-foot latticed girder over the Falls road at the eastern end, a seventy-two-foot latticed girder at the western end over the Northern

> Central Railway, and thence two plate girders twenty-four feet six inches each to reach the western abutment, which stands in Druid Hill Park [Baltimore City Commissioner 1890:936-937].

The Cedar Avenue Bridge opened a key crossing into the newly annexed Druid Hill neighborhoods; Latrobe did not know of "any recent improvement within the City limits which has been of more use to those who live within its influence" (Baltimore City Commissioner 1890:937).

Charles Latrobe's three major Baltimore metal arches were not immediately followed by similar structures, either in the city or in Maryland generally. The record of metal arch construction in the state resumed in the 1930s, when Baltimore municipal engineers and State Roads Commission officials again concentrated on improvement of key downtown crossings of the Jones Falls valley and adjacent railroad tracks. On December 23, 1935, the State Roads Commission awarded a contract, with Federal Public Works Administration (P.W.A) aid and approval, to the American Bridge Company to furnish a two-span, three-hinged, tied steel arch bridge to replace the 1879 truss bridge carrying Guilford Avenue over the Pennsylvania Railroad (see Plate 12). Complete with United Electric Railways trolley tracks and protective metal and glass screens to prevent persons from climbing up the surface of the arches, the Guilford Avenue Bridge opened on November 2, 1936 (Baltimore City Department of Public Works 1936:252).

Between 1937 and 1939, a second similar bridge, also designed by the Bridge Division of the Baltimore Department of Public Works, was built in downtown Baltimore to carry Howard Street over the B&O and Pennsylvania Railroad tracks. Built with P.W.A. funds and labor like the Guilford Avenue arch and many other Maryland bridges of the 1930s, the Howard Street Bridge featured two three-hinged, tied steel arch spans of 270.4 and 270.67 feet respectively, with plate girder side spans (Baltimore City Department of Public Works 1937:245-246). The Howard Street Bridge opened for traffic in early 1939 (Baltimore City Department of Public Works 1938:232).

Subsequent to construction of the Guilford Avenue and Howard Street spans in Baltimore, only two other mid-twentieth century through steel arch bridges are known to have been built in Maryland. In 1942, the vertical lift movable bridge crossing the Chesapeake and Delaware Ship Canal at Chesapeake City was destroyed during a collision with a freighter. Wartime priorities postponed replacement of this bridge until 1948, when a new Chesapeake City Bridge, a high-level, two-lane tied arch structure with steel hangers, was constructed (Gray 1985:261,289). Maryland's other documented mid-twentieth century metal arch bridge is the Blue Bridge, a two-span tied through arch built in 1955 under State Roads Commission authority to cross the Potomac between Cumberland and Ridgely, West Virginia (Leviness 1958:137; Maryland State Roads Commission 1956b:61). A search of all official reports of the Maryland State Roads Commission for the 1900-1960 period located no further references to design and construction of metal arch bridges in Maryland.

Conclusion

The following summary statements regarding structural characteristics for metal arch bridges, key periods of significance for metal arch bridges in Maryland, and the earliest known documented examples of metal arch bridges in the state are based solely on documentary research.

Metal arch bridges (see Figure 17 and Plate 12) consist of two (or more) parallel arches of iron or steel spanning between masonry or concrete piers or abutments. The arch member may be a curved girder or may include a truss system between curved top and bottom chords. Other components include lateral bracing, and columns or hangers for supporting the deck and floor system.

If the deck is suspended from the arch by means of vertical suspenders, the arch is termed a through arch. If the deck is carried atop the arch crown, the bridge is a deck arch structure. The deck may also be suspended or carried at various intermediate levels, allowing for half-through variants. If a tension member (or tie) is included between the ends of the span, the arch thrust is carried through this tie, and the bridge is a tied arch.

Arch bridges may also be grouped according to the degree of articulation of the arch. A fixed arch is a hingeless arch, but hinges may be included in the one-hinged variant (a single hinge at the top center, or crown, of the arch), the two-hinged variant (hinges at the points where the arch joins the abutments), and the three-hinged variant (hinges at crown of arch and at abutments).

As indicated by documentary research, key periods of significance for metal arch bridges in Maryland include *1870-1900*, during which time metal bowstring arch-truss bridges (pony spans as well as through bridges with overhead portals) were built within the state, and Charles Latrobe and Associates designed and constructed several major bowstring arches and deck arch bridges for the Jones' Falls Improvement Commission of the City of Baltimore and *1930-1960*, the period in which Baltimore City authorities built tied, three-hinged steel "Rainbow" arch bridges over the Jones Falls (1936, 1939), and the State Roads Commission constructed metal tied through arches at Chesapeake City (1948) and Cumberland (1955).

The earliest known examples of metal arch bridges in Maryland may be a group of bowstring arch pony truss bridges built on county roads in the state during the 1870s (several examples are known from prior surveys conducted in Frederick and Harford Counties). Field survey alone, however, can reveal whether these structures are primarily metal arch bridges, or pony trusses with arched upper chords, or a combination design. Other known significant examples of metal arch bridge design in Maryland include "Rainbow" arches (metal arch structures with through bowstring arches featuring overhead bracing), built by Baltimore City and the State Roads Commission between 1930 and 1960.

CANTILEVER BRIDGES: THE GOVERNOR HARRY W. NICE MEMORIAL BRIDGE

From a technical perspective, cantilever construction of a bridge defines a specific form of support of the bridge rather than a particular bridge type such as the truss or girder. Simply supported bridges are directly supported on piers and abutments, while continuous structures, as developed in both metal and reinforced concrete during the late nineteenth and early twentieth centuries, include spans that are continuous across one or more intermediate supports. By contrast, the cantilever form of support occurs when the support is at one end and the other end of the span is free. Cantilever bridges consist of a series of cantilevered spans including a main span and two anchor spans which flank it (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:124).

Based on historical research alone, cantilever bridges in Maryland appear to be represented by only one bridge, which may be briefly described in order to provide historic technological context for the evaluation of that bridge, the 1940 Governor Harry W. Nice Memorial Bridge carrying U.S. 301 over the Potomac River.

Bridge historian J.A.L. Waddell noted that "the development of the cantilever. . . did not proceed very far until modern times, when the truss form of structure had become established and when iron and steel constituted the materials of construction" (Waddell 1916:7). Waddell and subsequent technological historians dated the major advent of modern cantilever bridges to the design and construction of the high bridge over the Kentucky River at Dixville in 1876-1877. This bridge was built by Charles Shaler Smith of the Baltimore-based Baltimore Bridge Company. (for more information on Smith's firm, see the section of this report entitled "Metal Truss Bridges") (Schodek 1987:362). During the late nineteenth and early twentieth centuries, cantilever design and construction of other long-span metal bridges in the United States followed Smith's breakthrough.

Historical research has found no records of nineteenth or early twentieth century cantilever bridge construction in Maryland, by Smith's company or any other bridge firms or public authorities. The only known bridge in Maryland to have employed a cantilever system is the 9,918.84-foot-long Governor Harry W. Nice Memorial Bridge, built between 1938 and 1940 as part of the state's "primary bridge program" that also envisioned construction of the Chesapeake Bay Bridge, the first Baltimore Harbor Tunnel, and the Susquehanna River highway bridge at Havre de Grace (J.E. Greiner Company 1938). In 1938, when construction on the bridge had just begun, main designer and contractor J.E. Greiner Company offered the following description of the bridge as it was to be built:

> The main channel span and the two side spans flanking it, comprise a cantilever unit, the main span of which is 800 feet long and the side spans of which are anchor spans each 366 feet 8 inches long. The cantilever units forming the approaches to the central unit are made up of alternate

anchor spans and cantilever spans 437 feet 6 inches and 500 feet long respectively. The main section of the bridge is approached from the Virginia end by sixty-three spans of concrete pile bent and steel beam trestle construction 3873 feet long, and four plate girder spans 100 feet long, connecting the trestle with the main cantilever unit. On the Maryland side of the river, the main cantilever section of the bridge is approached by three 100 feet plate girder spans and two 250 feet simple truss spans connecting the filled approach, with the main cantilever section [J.E. Greiner Company 1938:99-101].

The bridge was built to carry U.S. 301 in a key commercial link between Southern Maryland and Virginia's Northern Neck, which hitherto had traded goods only by ship or roundabout highway or train transport. Thus, the Governor Harry W. Nice Memorial Bridge is significant as a major example (perhaps Maryland's only example) of modern cantilevered bridge engineering, and is also important because of its strategic economic usefulness as part of the successful Primary Bridge Program of the Maryland State Roads Commission.

Conclusion

The following summary statements regarding structural characteristics for metal cantilever bridges, the single documented example of a metal cantilever bridge in Maryland, and the key period of significance for this bridge type in the state are based solely on documentary research.

Cantilever bridges are defined by the structural support of the bridge rather then the individual configuration of the structural elements. Cantilever structures contrast with simply supported structures: simply supported structures are directly supported at each end, while cantilevered structures are directly supported at one end and free at the other end. Cantilever bridges consist of two anchor arms (directly supported on two piers), two cantilever arms (directly supported on one end by the anchor pier), and a central suspended span which is carried by the two anchor arms. Metal cantilever bridges may typically include cantilevered truss or girder spans.

The only known metal cantilever bridge in Maryland, as indicated by documentary research, is the Governor Harry W. Nice Memorial Bridge, carrying U.S. 301 over the Potomac River since its construction in 1940 by J.E. Greiner Company under contract to the State Roads Commission. Further field investigation, however, will be necessary to adequately document this conclusion. The period of significance for the Governor Harry W. Nice Memorial Bridge is *1900-1940*, the era in which the construction of large metal cantilever bridges was introduced and technologically developed for highway use at major crossings in the United States.

SECTION IX: CONCRETE BRIDGES

HISTORICAL DEVELOPMENT

Concrete bridges constitute the greatest number of Maryland's known historic bridges. Technologically, the development of concrete bridges is an important chapter in the history of bridge building, being the application of a rediscovered material to both traditional and new forms and largely supplanting the metal truss bridge in the spanning of short and medium distances. Aesthetically, concrete bridge design introduced a greater level of decorative treatment, as the plastic nature of concrete allowed variety and ease of construction for these decorative details. Although the greatest number of concrete bridges are the results of standardized designs, there are many concrete bridges that feature stylistic embellishment.

Although used for building by the ancient Romans, the modern rediscovery of concrete as a common building material was a nineteenth century phenomenon, with reinforced concrete developing in the late nineteenth and early twentieth centuries (Plowden 1974:297). In bridges, concrete was first used as a construction material in plain or unreinforced concrete structures. The first applications of the material were to the arch bridge, a design developed (like concrete itself) by the Romans and used, in its masonry form, in great numbers in early years of this nation. An early example of the application of concrete to the arch bridge in the United States was the 1871 Prospect Park Bridge in Brooklyn, New York (Armstrong 1976:115; Plowden 1974:297). Within two decades, the understanding of material behavior quickly had progressed to the composite use of concrete and steel, often termed "ferro-concrete."

The addition of iron reinforcement to masonry structures had been used in isolated cases for centuries, since the nature of masonry as a compressive material with inherent weaknesses in tension was appreciated by ancient engineers. The interaction of the two materials remained to be studied by late nineteenth and early twentieth century engineers (Plowden 1974:297). The incipient theoretical understanding of metal utilized to reinforce concrete in the new plastic masonry was realized by an American experimenter, Thaddeus Hyatt (1816-1901), who began to study reinforced concrete's possibilities in the 1850s and received a patent for reinforced concrete in 1878 (American Society of Civil Engineers 1976:65). However, it was French and German engineers who first studied and tested the principles of steel reinforcement for tensile stresses in concrete arches in the 1880s. A serious obstacle to the use of concrete arches was the unknown character of their behavior under live loads. From 1890 to 1895 the Austrian Society of Engineers and Architects conducted extensive experiments on full-size concrete arches and the results were published in engineering journals throughout Europe and America (Plowden 1974:298).

In 1889, prior to the publication of the Austrian reinforced concrete arch tests, the first reinforced concrete arch in the United States was built in Golden Gate Park, San Francisco. Designed by Ernest L. Ransome, it was reinforced with rods or bars, possibly of the twisted type patented by Ransome in 1884 (Armstrong 1976:115; Plowden 1974:298). Early concrete bridge development included experimentation with different forms of steel reinforcing. Bar reinforcement became the predominant type used in the early twentieth century, and is the reinforcement type encountered today; however, the predominant type through the end of the nineteenth century employed beams rather than bars. The I-beam type was introduced by Austrian engineer Joseph Melan, who patented a scheme for arched I-beam reinforcement in the United States in 1894. Melan's design was modified and patented by another Austrian engineer, Fritz von Emperger, who built a number of beam-reinforced arch bridges in the United States beginning in 1897 (Plowden 1974:298).

Beam reinforcement was soon recognized as requiring an inordinate amount of steel, and bar reinforcement began to be explored as a more efficient use of material. Bars could be bent and placed in regions of high tensile stresses, thus saving enormous quantities of materials while producing stronger bridges with lower dead loads. Many variations in shapes, patterns of surface deformation (provided to maintain the adhesion between the bars and the concrete), and bending schemes were developed and patented (Plowden 1974:298).

Among the American engineers who contributed to the development of reinforced concrete bridge technology during this formative period was Edwin Thacher (1840-1920). An 1863 civil engineering graduate of Rensselaer Polytechnic Institute, Thacher became interested in steel-reinforced concrete construction in the late 1880s, and by 1895 had made this a specialty. He designed and constructed viaducts and bridges for leading southern railroads during the period 1889-1904. Also during that period, he became the western representative of Fritz von Emperger's company, and was instrumental in disseminating the Austrian engineer's technological innovations in the United States. In partnership with W.H. Keepers, he designed the first major reinforced concrete bridge in the United States, a three-span Melan-type concrete arch with imbedded steel truss bars over the Kansas River at Topeka. Erected between 1894 and 1899, this structure was the largest of its kind at the time (Plowden 1974:299).

Thacher developed an improved reinforcing bar. Throughout the development of reinforced concrete technology, engineers sought methods of improving the adhesion between the reinforcing steel and the concrete surrounding it. Their efforts generally involved various deformations to the surface of the bar, such as the "projections" called for in Thacher's 1899 patented design. Ernest L. Ransome patented the first deformed reinforcing bar in 1884, which aimed to increase the mechanical connection between the steel and the concrete by twisting the bar. The "Thacher Bar" (U.S. Patent No. 714,971) was designed as an elongated bar with longitudinally oriented cross-shaped deformations integrally formed on the upper and lower surfaces. This configuration enabled the reinforcing steel to remain uniform in net section throughout the bar, ensuring that the strength of the bar would be the same at every point and that no unnecessary metal would be used in its manufacture. In addition, sharp corners were minimized during manufacture, so that the bond between the bar and the concrete would be further improved. William Mueser, Thacher's associate in the Concrete-Steel Engineering Company, credited the bar as the first product of its type to achieve its final shape by a direct rolling process. The Thacher bar, like those used in current concrete design, was available in a range of sizes, starting at 1/4 inch and increasing in 1/8-inch increments to 2 inches.

With growing confidence, bridge engineers made increasing use of reinforced concrete. In an 1899 *Engineering News* article, "Concrete Steel Bridge Construction," Thacher, who held patents for iron as well as concrete bridges, exemplified early enthusiasm for concrete. He wrote of concrete-steel bridges:

> They are more beautiful and graceful in design, architectural ornamentation can be applied as sparingly or as lavishly as desired; they have vastly greater durability, and generally greater ultimate economy; they are comparatively free from vibration and noise; they are proof against tornadoes, high water or fire; the cost of maintenance is confined to the pavements, and is no greater than for any other part of the street; home labor is employed in building it, and the greater part of the money that it costs is left among the people who pay for it, and its cost as a rule does not much, if any, exceed that of a steel bridge carrying a pavement. . . .Public confidence in concrete and concrete-steel construction, is gaining rapidly in this country and in Europe, where there is plenty of precedent, and where the people have been more thoroughly educated up to it, there has been no lack of confidence in it for some years. . . .We hear nothing now from intelligent men about mud bridges [Thacher 1899].

Although scientifically understood with some degree of sophistication in the 1890s, concrete began to be used more widely and in a more structurally efficient manner in the United States after the first decade of the twentieth century. In 1903-1904 the American Society of Civil Engineers formed its Joint

Committee on Concrete and Reinforced Concrete in an attempt to standardize concrete design. Their first report was published in 1909. In 1916, the Committee on Reinforced Concrete Highway Bridges and Culverts of the American Concrete Institute (ACI) issued its first report which classified highway bridges and recommended appropriate design loads. According to bridge engineer-historian Tyrrell, between 1894 and 1904 about 100 concrete bridges had been built in the United States in spans up to 125 feet (Tyrrell 1911), and in 1916 Waddell claimed that "for city bridges of short span its use is becoming almost universal" (Waddell 1916), with other wide applications noted.

The development of prestressed concrete has increased the usefulness of concrete in modern bridge design. Prestressing entails the application of a permanent load to the concrete through tensioned cables to increase its load-bearing capacity. The principle was developed in Europe during the 1930s and first applied in America to the 160-foot-long Walnut Lane Bridge erected in Philadelphia in 1949 (Plowden 1974:321). Guided by the Bureau of Public Roads' 1955 *Criteria for Prestressed Concrete Bridges*, the use of prestressed concrete in bridge design was rapidly taken up throughout the nation. The technique has found wide application in the construction of precast concrete members used on overpasses of the interstate highway system (Armstrong 1976:117).

Concrete Arch Bridges

The advent of modern concrete technology fostered a renaissance of arch bridge construction in the United States. Stone arch bridges constitute an important chapter in American bridge building, but by the second half of the nineteenth century the labor-intensive nature of masonry arch bridge construction contrasted unfavorably with the ease of metal truss erection. Reinforced concrete allowed the arch bridge to be constructed with much more ease than ever before and maintained the load-bearing capabilities of the form. Accompanying the return of the arch form were the traditional architectural decorative details that had been in abeyance during the heyday of the truss bridge. It is interesting that the renaissance of the arch bridge and its decorative elements coincides with the reintroduction of the beaux arts aesthetics following the 1893 Columbian Exposition.

Concrete arch bridges are classified into four groups based on the way the dead load of the structure is carried. The four groups are (1) filled spandrel, (2) closed spandrel, (3) open spandrel, and (4) through arches. The filled spandrel arch consists of a barrel arch which carries filling material and terminates in closed longitudinal walls that act as retaining walls for the fill. Both closed and open spandrel arch types carry the roadway loads to the arch ribs and contain no fill. The former type carries the deck loads by spandrel walls resting on the arch ribs, while the latter type carries the roadway loads to the arch ribs by spandrel columns. Through arches consist of ribs which extend above the roadway and carry the deck loads by vertical hangers (Plates 13 and 14).

PLATE 13: **Typical Concrete Closed Spandrel Arch Bridge: Bridge at Burnt Mills** SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1931)

PLATE 14: **Typical Concrete Open Spandrel Bridges Under Construction: Bridges on Loch Raven Boulevard in Baltimore**

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1933)

Early concrete arch bridges were governed by building traditions of their predecessor, the stone arch. They were shaped as traditional masonry barrels with solid, filled arches; surface treatment of important bridges incorporated stylistic "stones" such as incised voussoirs or keystones. The first known reinforced concrete arch bridge in the United States was designed by Ernest L. Ransome and built in 1889 in Golden Gate Park, San Francisco (Armstrong 1976:115; Plowden 1974:298). It was reinforced with rods or bars, probably of the twisted type patented by Ransome in 1884, and scored to imitate stone.

As the structural advantages of reinforced concrete became apparent, the heavy, filled barrel was lightened into ribs. Spandrel walls were opened, to give a lighter appearance and to decrease dead load. This enabled the concrete arch to become flatter and multi-centered, with longer spans possible. Designers were no longer limited to the semicircular or segmental arch form of the stone arch bridge.

The variety of arch types made possible through reinforced concrete design is exemplified by the designs of Daniel B. Luten, whose patented bridges were built throughout the eastern and midwestern United States. Luten was an 1894 civil engineering graduate of the University of Michigan. Upon graduation he was retained at Michigan as an instructor and assistant to Professor Charles E. Greene, whose arch analyses were noted in the ASCE *Transactions*. From 1895 to 1900, Luten was instructor of civil engineering at Purdue University and in 1900 he resigned to design bridges. One year later he was designing and patenting his designs.

In 1899, Luten applied for a patent for an arch bridge of concrete, stone, brick, iron, or steel in which ties were placed below the water, from abutment to abutment to resist the arch thrust, and the patent was granted on May 15, 1900. His ties, "which may be made of any material—as wood, iron, or steel—but in this case are shown as being made of wood or timber, as this is the best material now known to me for the purpose, it being practically everlasting when used under water." This concept developed into his patent for a tied concrete arch in which steel tie rods were embedded in a concrete pavement across the streambed. A 1906 text on reinforced concrete by Albert Buel described Luten's steel-tied, paved arch bridge.

Luten's 1907 patent No. 857,920 shows a barrel arch with recessed panel parapet walls and a similar "flat arch or girder" type design with the same parapet detail. A similar patent of 1907 lightened the bridge dead load with open spandrels but maintained a barrel arch.

In 1907, Luten patented another arch type which reinforced the arch barrel transversely as well as longitudinally. In effect, this design was a stiffened spandrel which permitted thinner arch sections. Included in this patent were several variations, one of which made parapet walls act with the superstructure to carry the loads. In patent No. 853,203, this variation was described as follows:

> A concrete bridge having a roadway bordered by a concrete wall, a longitudinal reinforcing member embedded in the walls, and transverse reinforcing members embedded in the wall and extending into the bridge under the roadway.

Other Luten patents, totaling over 30, included numerous variations, among them a hinged arch and viaducts; systems of reinforcement; ingenious centering forms and methods; methods of bridge construction; and reinforced concrete beams.

Daniel Luten was also an enthusiastic salesman of his bridge designs, emphasizing their advantages both in company catalogs and at professional presentations. In the American Concrete Institute *Proceedings* of 1912, he praised concrete arches:

> Concrete as a structural material is full of surprising possibilities and one of these is that the most beautiful and appropriate applications of concrete to bridges, that is in the arch form, is also the most satisfactory from almost every engineering standpoint [Luten 1912:631].

Luten's first bridge company was the National Bridge Company, established in 1902. A 1914 Luten publication stated that until 1905 the National Bridge Company did the contracting and constructing of its bridges, but after that it was involved only in engineering design and supervision. In 1907, a company catalog advertised a variety of earth-filled arches reinforced with steel rods. It claimed that the company had designed more than 700 bridges of this type. An interesting arch type included in this 1907 catalog was the "arch-girder" bridge, described as a flat arched floor supported on five girders.

By 1911, Luten had won national attention, and was singled out by bridge historian Henry Grattan Tyrrell as a "designer and builder of many fine concrete bridges throughout America" (Tyrrell 1911).

Luten and other bridge engineers designing concrete arch spans were directly influenced by the City Beautiful movement, an early twentieth century effort to advocate construction of public and municipal structures that were aesthetically pleasing yet still functional. The increasing popularity of gracefully curved arches and ornamented concrete parapets also reflected the early twentieth century promotion of City Beautiful ideas and goals among urban planners, highway engineers, and motorists' groups like the American Automobile Association and the Lincoln Highway Association.

A 1917 publication entitled *Reinforced Concrete Bridges* by Daniel B. Luten, "designing and consulting engineer," illustrated a broader range of arch types, although still based on the same theme as his earlier designs. In this catalog, bridge illustrations ranged from long-span, high-level open spandrel arches to small highway bridges. Luten contrasted a "Highway Bridge of Plain Design" with a "Park Bridge of Attractive Design" in the same publication. The parapet wall of the highway bridge was a solid recessed panel and that of the park bridge a balustrade type (Luten 1917).

By 1919, Luten claimed to have designed some 17,000 arches, and stated that examples of his designs could be found in all but three states of the Union. Indiana alone had some 2,000 Luten arches. Luten arch bridges known to have been built in Maryland often featured curved, simply ornamented solid parapets. Characterized by the graceful arch and curved, incised solid parapets, this bridge type was described in Luten Company catalogs as "Highway Bridge of Plain Design." This type of concrete arch was widely built as a proprietary type in the first quarter of the twentieth century. Luten's "Park Bridge of Attractive Design" also influenced concrete arch design in Maryland. Variations in the Luten style arch and parapet detail soon developed and resulted in similar nonproprietary designs prepared by highway department staffs.

Simultaneous with the development of Luten's patented types, another form of reinforced arch rib emerged, the through arch. The two arch ribs of this type rise from piers and carry the deck on vertical members suspended from their crowns. They are sometimes referred to as "Rainbow Arches" and sometimes as "Marsh Arches" after German-born engineer, Marsh, who patented his through arch and built it between 1912 and 1930.

The procedure for constructing concrete arch bridges was roughly similar to that used for stone arches. In the first phase the foundations, abutments, and piers were constructed. Next, temporary bracing or centering, also used as forms for the concrete, was erected followed by placement of reinforcement. The concrete was then placed in the forms symmetrically from each end moving in toward the crown. Longer spans, more than 80 feet, had to be poured in sections, but shorter spans could be completed in one pour. The spandrel walls, posts, or arches were formed after the arch ring was completed. The centering was gradually released after the concrete had set sufficiently, usually within the standard twenty-eight days but depending on conditions. After the formwork was removed the concrete surface was finished according to various methods. Sometimes a facing was applied as in brick or stone. Often monumental bridges had surface treatments imitating stone. If the surface was to be left exposed then it was either rubbed to produce a smooth surface or worked with tools to produce a texture.

Standardized Types: Concrete Slabs, Beams, Frames, and Culverts

The versatility of reinforced concrete permitted development of a variety of economical bridges for use on roads crossing small streams and rivers. As the nation's automotive traffic increased in the early twentieth century, local road networks were consolidated and state highway departments were formed to supervise the construction and improvement of state roads. Many state highway departments were formed on the model of New York State, which in 1910, following the recommendations of a board of consulting engineers, divided the state into districts, each of which was the responsibility of a Resident Engineer (Maryland State Roads Commission 1916:8, 9). Without a stock of standard designs to rely upon when site conditions permitted, such decentralization could easily have led to chaos as the need for inexpensive, easily built and maintained small road bridges became more and more pressing.

The concept and practice of standardization was one of the most important developments in engineering of the twentieth century. Conceptually, standardization is the reduction of nearly infinite possibilities to a finite set of variables. In practice, it entails the replacement of the individually designed and crafted object by a set of interchangeable modules which can be combined in different ways to accommodate manifold requirements.

Two national organizations, the American Association of State Highway Officials (AASHO) and the U.S. Bureau of Public Roads, were very instrumental in bringing about standard specifications and designs in the early years of the twentieth century. Although the American Association of State Highway Officials' Subcommittee on Bridges and Structures was not formed until 1921, the Association directed attention in 1904 to developing standard specifications for reinforced concrete construction. The Subcommittee on Bridges and Structures first issued its standard specifications in 1925 and has continued to issue specifications on a regular basis through the present (American Association of State Highway Officials 1953a:103, 104). Providing a great impetus toward the development and adoption of standard designs, the U.S. Bureau of Public Roads was a federal agency which conducted extensive tests on bridge types and promulgated standard designs for concrete highway bridges from 1916 to 1931 (Armstrong 1976:115, 116).

Concrete Slab Bridges

As with most modern bridge forms, the slab bridge hearkens back to precursors from the remote past. In the case of the slab, the origins are found in prehistory, as in the ancient "clapper" bridges of Dartmoor and Dartmeet, England (Whitney 1983:52). The form was subsequently abandoned at an early period because separate stones rarely have the tensile strength needed for this type of construction (Whitney 1983:213). Nonreinforced concrete suffers from the same weakness, but the advent of reinforced concrete with its increased tensile capabilities allowed the reintroduction of the slab span around the turn of the twentieth century.

The reinforced concrete slab soon became one of the most popular and expedient types of small highway bridges (Figure 18). Bridge engineering treatises such as H. Grattan Tyrrell's 1909 *Concrete Bridges and Culverts for Both Railroads and Highways* (Tyrrell 1909) and J.A.L. Waddell's 1916 *Bridge Engineering* described the versatile usefulness of reinforced concrete slabs for single spans as well as multiple spans (Waddell 1916). In his 1916 text *Concrete Construction for Rural Communities*, Roy Seaton listed the slab span as one of the principal types of small bridges and recommended slab usage for spans up to 20 feet (Seaton 1916:207). Popular trade journals such as *Public Works* found that "spans up to 20 or 30 feet, or sometimes even longer, may be made with. . .concrete floor slabs" (*Public Works* 1916:353). By 1924, the standard text *Reinforced Concrete and Masonry Structures* noted that slab bridges could be built in multiple spans as concrete pile trestles, pier trestles, and trestles with framed bents (Hool and Kinne 1924).

At an early stage, slab spans became subject to a variation that was essentially a through girder design, in which the slab was reinforced by the use of parapets functioning as girders. Houghton's 1912 *Concrete Bridges, Culverts and Sewers* observed that "where the parapet and railings are reinforced by side girders, connected with ample reinforcement in the square pilasters, at each end of the bridge, a large portion of the loading is carried to the abutment by these girders; which serve a double purpose, as reinforcement and also as a parapet" (Houghton 1912:45-46). By 1924, Walter S. Todd, in George Hool and W.S. Kinne's text *Reinforced Concrete and Masonry Structures*, included a diagram for a 24-foot reinforced concrete slab bridge, but also observed that a through girder type bridge, in which "the loads from the roadway are carried to the girders through the floor slab; and the girders in turn carry the loads to the abutments," was satisfactory for spans "from about 30 to 60 ft." (Hool and Kinne 1924:399, 407).

This type of through girder structure with a solid slab continued to be illustrated in design texts well into the 1930s (Figure 19). The 1939 text *Reinforced-Concrete Bridges* noted that "the simplest design of floor construction for a through bridge consists of a slab spanning between the main girders."

Observing that "such arrangement is economical only for narrow bridges" because "the dead load would be excessive" in wider crossings, the text's authors included diagrams for a typical "slab spanning between girders" (Taylor et al. 1939:94).

A variation of the slab design that was developed in the 1930s was the continuous slab bridge, in which a single slab extends over several spans. By 1939, structures with spans of slab up to 70 feet had been designed. Although the design has some advantages, including simpler arrangement of reinforcement and better distribution of lateral and longitudinal loading, the greater cost of materials and larger dead loads reduced its advantages over the simply supported multiple-span slab bridge (Taylor et al. 1939:35).

In both its simple and continuous span forms, the reinforced concrete slab span has continued to be used for highway bridges.

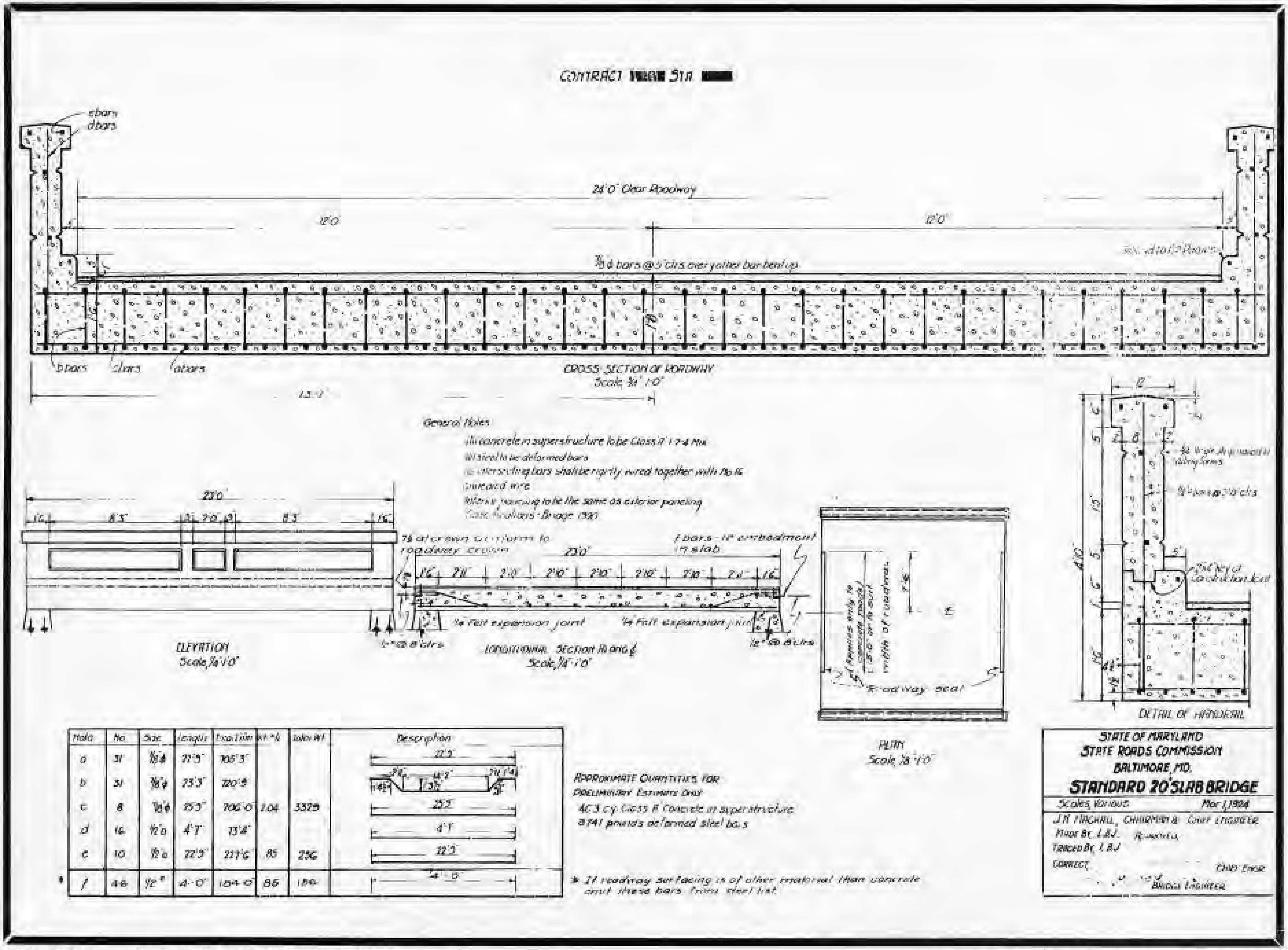
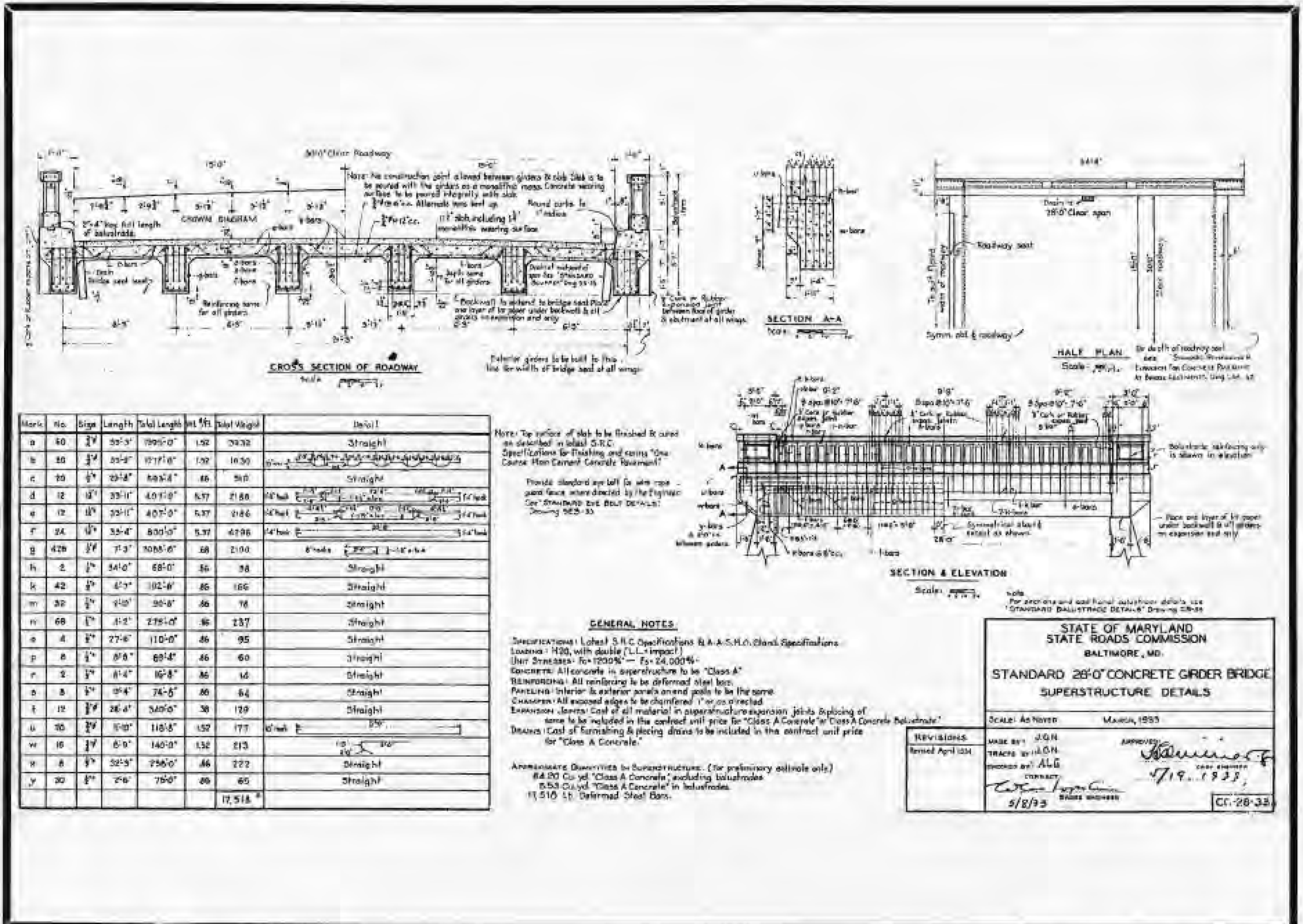


FIGURE 18: **Typical Flat Slab Concrete Bridge**

SOURCE: Maryland State Roads Commission 1924



Mark	No.	Size	Length	Total Length	Wt. #/Ft.	Total Weight	Detail
a	60	[illegible]	33'-3"	1995'-0"	1.52	3032	Straight
b	30	[illegible]	33'-9"	1117'-6"	1.52	1630	[illegible]
c	30	[illegible]	29'-8"	890'-0"	.46	410	Straight
d	12	[illegible]	33'-11"	407'-0"	5.37	2186	14" hook … 14" hook
e	12	[illegible]	33'-11"	407'-0"	5.37	2186	14" hook … 14" hook
f	24	[illegible]	33'-4"	800'-0"	5.37	4296	14" hook … 14" hook
g	426	[illegible]	7'-3"	3088'-6"	.68	2100	[illegible]
h	2	[illegible]	34'-0"	68'-0"	.46	38	Straight
k	42	[illegible]	4'-9"	102'-6"	.46	166	Straight
m	32	[illegible]	9'-10"	98'-8"	.46	78	Straight
n	68	[illegible]	4'-2"	275'-0"	.46	237	Straight
o	4	[illegible]	27'-6"	110'-0"	.46	95	Straight
p	8	[illegible]	8'-8"	69'-4"	.46	60	Straight
r	2	[illegible]	8'-4"	16'-8"	.46	14	Straight
s	8	[illegible]	9'-4"	74'-8"	.46	64	Straight
t	12	[illegible]	28'-4"	340'-0"	.38	129	Straight
u	10	[illegible]	11'-10"	118'-8"	1.52	177	10" hook …
w	16	[illegible]	8'-9"	140'-0"	1.52	213	[illegible]
x	8	[illegible]	32'-3"	258'-0"	.46	222	Straight
y	30	[illegible]	2'-6"	75'-0"	.88	65	Straight
						17,518 #	

FIGURE 19: Typical Concrete Girder Bridge

SOURCE: Maryland State Roads Commission 1933

Concrete Beam Bridges

Next to the slab bridge, the beam bridge is perhaps the simplest possible way to span an opening. Like the slab bridge, the beam bridge has the distinction of being a very ancient bridge design (Glidden 1935:11). Roman bridges are best known for their graceful masonry arches, but it appears that the beam bridges were built, especially for military uses. Julius Caesar described a temporary bridge constructed during his campaign in Gaul that is clearly a multiple-spanned beam bridge of wood; the sixteenth century architect, Andrea Palladio, presented his reconstruction of this bridge in his Third Book of Architecture (Palladio 1965:plate II; Whitney 1983:69).

The earliest concrete beam bridges in the nation were deck girder spans that featured concrete slabs supported by a series of longitudinal concrete beams. This method of construction was conceptually quite similar to the traditional timber beam bridge which had found such widespread use both in Europe and in America. Developed early in the twentieth century, deck girder spans continued to be widely used in 1920 when noted bridge engineer Milo Ketchum wrote *The Design of Highway Bridges of Steel, Timber and Concrete* (Ketchum 1920).

A variation of the girder design that was developed in the 1930s was the continuous girder bridge, in which a single set of girders extends over several spans. By 1939, structures with spans up to 348 feet had been constructed. The design offers several advantages: it requires a smaller amount of steel and concrete, fewer bearings, fewer expansion joints, and reduced deflection and vibration. Disadvantages include more complicated design and increased sensitivity to uneven settlement of foundations (Taylor et al. 1939:150).

Although visually similar to deck girder bridges, the T-beam span features a series of reinforced concrete beams that are integrated into the concrete slab, forming a monolithic mass appearing in cross section like a series of upper-case "T"s connected at the top. Milo Ketchum describes the type, as constructed in 1920, in this way:

> In beam and slab construction, an effective bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the beam, transverse reinforcement should be used extending over the beam and well into the slab. The slab may be considered an integral part of the beam, when adequate bond and shearing resistance between slab and web of beam is provided but its effective width should be determined by the following rules: (a) it shall not exceed one-fourth of the span length of the beam; (b) its overhanging width on either side of the web

> shall not exceed six times the thickness of the slab; (c) it must not exceed the distance between the beams [Ketchum 1920:290-291].

Thaddeus Hyatt is believed to have been the first to come upon the idea of the T-beam when he was studying reinforced concrete in the 1850s, but the first useful T-beam was developed by the Belgian Francois Hennebique at the turn of the present century (Lay 1992:293). The earliest references to T-beam bridges refer to the type as concrete slab and beam construction, a description that does not distinguish the T-beam design from the concrete deck girder. Henry G. Tyrrell was perhaps the first American bridge engineer to use the now standard term "T-beam" in his treatise *Concrete Bridges and Culverts*, published in 1909. Tyrrell commented that "it is permissible and good practice in designing small concrete beams which are united by slabs, to consider the effect of a portion of the floor slab and to proportion the beams as T-beams" (Tyrrell 1909:186).

By 1920, reinforced concrete, T-beam construction had found broad application in standardized bridge design across the United States (Plate 15). In his text, *The Design of Highway Bridges of Steel, Timber and Concrete*, Milo S. Ketchum included drawings of standard T-beam spans recommended by the U.S. Bureau of Public Roads as well as drawings of T-beam bridges built by state highway departments in Ohio, Michigan, Illinois, and Massachusetts (Ketchum 1920). By the 1930s the T-beam bridge was widely built in Maryland and Virginia.

Rigid Frame Bridges

Ranked by bridge historian David Plowden as a key reinforced concrete bridge engineering advance of the twentieth century, comparable to the later development of prestressed concrete, the rigid frame bridge was pioneered by German engineers and the Brazilian Emilia Baumgart. According to Plowden, it was introduced to the United States primarily through Westchester County engineer Arthur G. Hayden's Swain Street Undercrossing, the first of many short-span rigid frame bridges Hayden built for the Bronx Parkway Commission in 1922-1923 (Plowden 1974:321).

Unlike other reinforced concrete spans, in which the superstructure and the substructure were not designed as a continuous unit, the rigid frame bridge as built by Hayden and his associates was a continuous structure "from footing to handrail" (as the *Engineering News-Record* editorialized in April 1926) (Hayden 1926). An instructive 1933 booklet prepared by the Portland Cement Association noted that in a rigid frame structure, "the bearing is replaced with concrete that continues monolithically from the abutments into the deck, [so that] the altered structure becomes a frame with rigid corners." Observing that "it is generally simpler and more economical to build a concrete bridge continuous than otherwise," the Association also found that "the moments are small in the sections near the center of the deck of the rigid frame bridge compared with the corresponding moments in a simply supported deck of the same span length." The result was that "frame sections can be reduced and the bridge floor made exceptionally shallow at the center of the span" (Figure 20).

The Portland Cement Association declared in their 1933 *Analysis of Rigid Frame Concrete Bridges* that because the rigid frame structure could be built with a shallow section, "substantial reductions are obtained in volume of embankment fill or excavation, and in area of land required for the approaches." Maintenance expense was also advantageous because the rigid frame bridge was a monolith, in which "the various details where the deck bears on the abutments are eliminated." The Association declared that rigid frame reinforced concrete highway bridges with solid decks were economical up to a span length of about 70 feet, while for longer spans "the ribbed deck construction is preferred on account of its lightness" (Portland Cement Association 1933:4). As of September 1933, the longest rigid frame concrete span in the world was the 224-foot main span of the Herval bridge in Brazil.

PLATE 15: **Typical Concrete Multiple-Span Beam Bridge: Bridge Crossing Railroad Tracks at Fallston**

SOURCE: MDOT Photographic Archives (Hughes Co. Photographers, 1930)

During the early 1930s, rigid frame bridge design and analysis was the subject of specialized treatises such as Arthur Hayden's *The Rigid-Frame Bridge* (1931) and Hardy Cross's and Newlin Dolbey Morgan's *Continuous Frames of Reinforced Concrete* (1932). These texts stressed the fact that the supporting members in a rigid frame bridge provided flexure and worked as a unit with the superstructure, while such members in the non-rigid frame structure simply carried a deck at a certain desirable clearance above a roadway or watercourse. Victor Brown and Carleton Conner in their 1931 work *Low Cost Roads and Bridges* observed that "rigid frame bridges constructed of concrete possess great inherent strength and rigidity which insure their safety;" from the nature of their construction, "any overloading of one part of the bridge simply causes the stresses to be transferred to other parts until a balance is obtained" (Brown and Connor 1933:156).

By 1939, the authoritative Taylor, Thompson, and Smulski text *Reinforced-Concrete Bridges* included "multi-span rigid frames in which the girders forming the superstructure are rigidly connected with elastic vertical supports" as one of four main choices available to the engineer designing a multiple span reinforced concrete girder bridge. The other options were "a number of simply supported girder spans, a combination of girders provided with cantilevers and short spans supported by these cantilevers," and "continuous girders supported by independent piers." Recommending the rigid frame design for use "where vertical supports of the bridge are elastic, as in viaducts," the authors enumerated several advantages of rigid frame bridges over simply supported girder spans: (1) rigid frame structures required less steel and concrete; (2) the center of the span could be much shallower; (3) fewer expansion joints were required; (4) deflection and vibration were considerably reduced; (5) no bearings were required at the supports, and; (6) "owing to rigid connections between the vertical supports and the horizontal members, the stability of the vertical supports in rigid frames is much greater than that of independent piers" (Taylor et al. 1939:150-151).

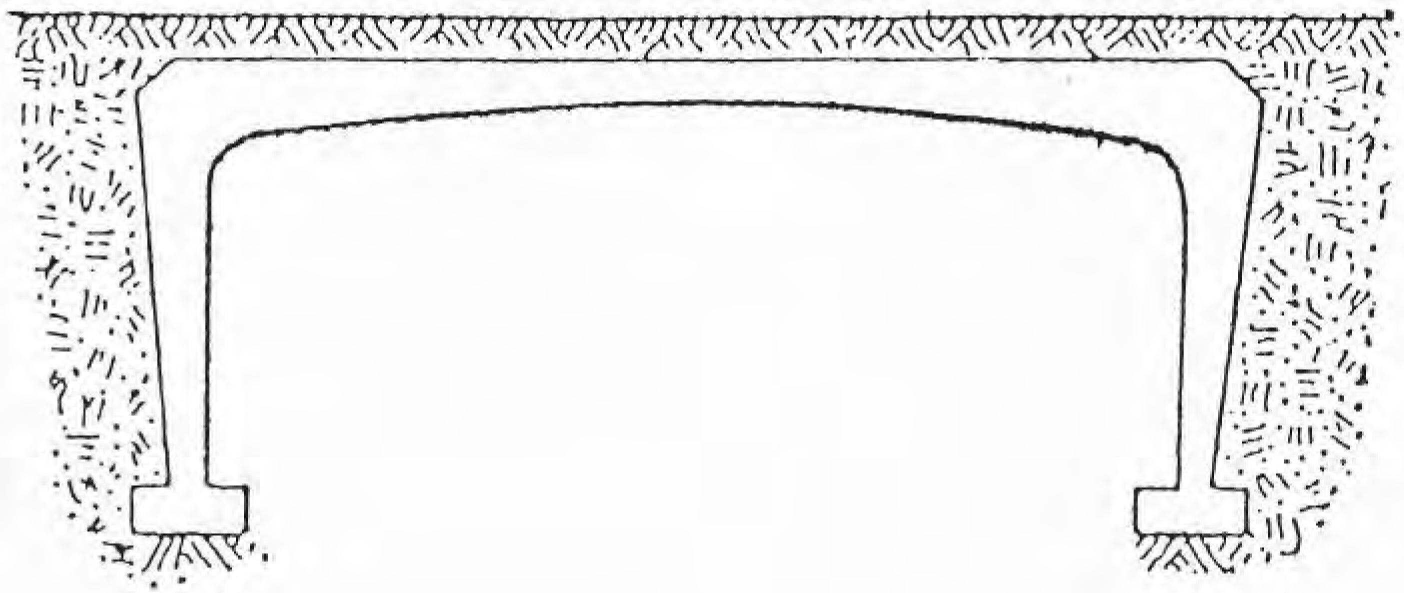


FIGURE 20: Concrete Rigid Frame Bridge Schematic SOURCE: Cross and Morgan 1932

Taylor et al. also noted certain disadvantages of rigid frame bridges, including the following: (1) rigid frames were suitable only at sites where unyielding foundations could be ensured, for uneven settlement produced a "bad effect" on their strength; (2) placing of steel reinforcement in the concrete required considerable skill; (3) the sequence of concrete placement and removal of formwork was sometimes more complicated; and (4) design of rigid frame bridges was somewhat more complex because such structures were "statically indeterminate," and analysis was not as straightforward as in the case of statically determinate, simply supported spans. In the hands of a competent engineer, the authors asserted, these disadvantages disappeared (Taylor et al. 1939:150-151).

Culverts

Technologically the culvert has been defined as "a small bridge constructed entirely below the elevation of the roadway surface and having no part or portion integral therewith. Structures over 20 feet in span parallel to the roadway are usually called bridges, rather than culverts; and structures less than 20 feet in span are called culverts even though they support traffic loads directly" (U.S. Department of Transportation 1979:G-13). As distinct from a highway bridge, a culvert is "a conduit constructed through embankments for the purpose of conducting small streams or surface water" (Hool and Kinne 1924:579). In 1924, culverts with span length of 25 to 30 feet or more were considered bridges; by 1979, spans of 20 feet or more were generally deemed bridges (Hool and Kinne 1924:579; U.S. Department of Transportation 1979:G-13). Culverts may be single-span or multiple-span structures (Figure 21).

Disregarding pipe culverts, concrete culverts can be divided into box and arch culverts. Box culverts have square or rectangular openings; arch culverts feature either a Roman or a semicircular arch. Culverts often feature a floor, but many were built without one. Given the ubiquitousness of culverts, it is not surprising that standardization was applied to their design at an early date; Ketchum's 1920 text provides examples of standard designs from the U.S. Bureau of Public Roads as well as the state highway departments of Iowa and Michigan. Also presented is an 8-foot design for the highways of Puerto Rico by Edwin Thacher (Ketchum1920)
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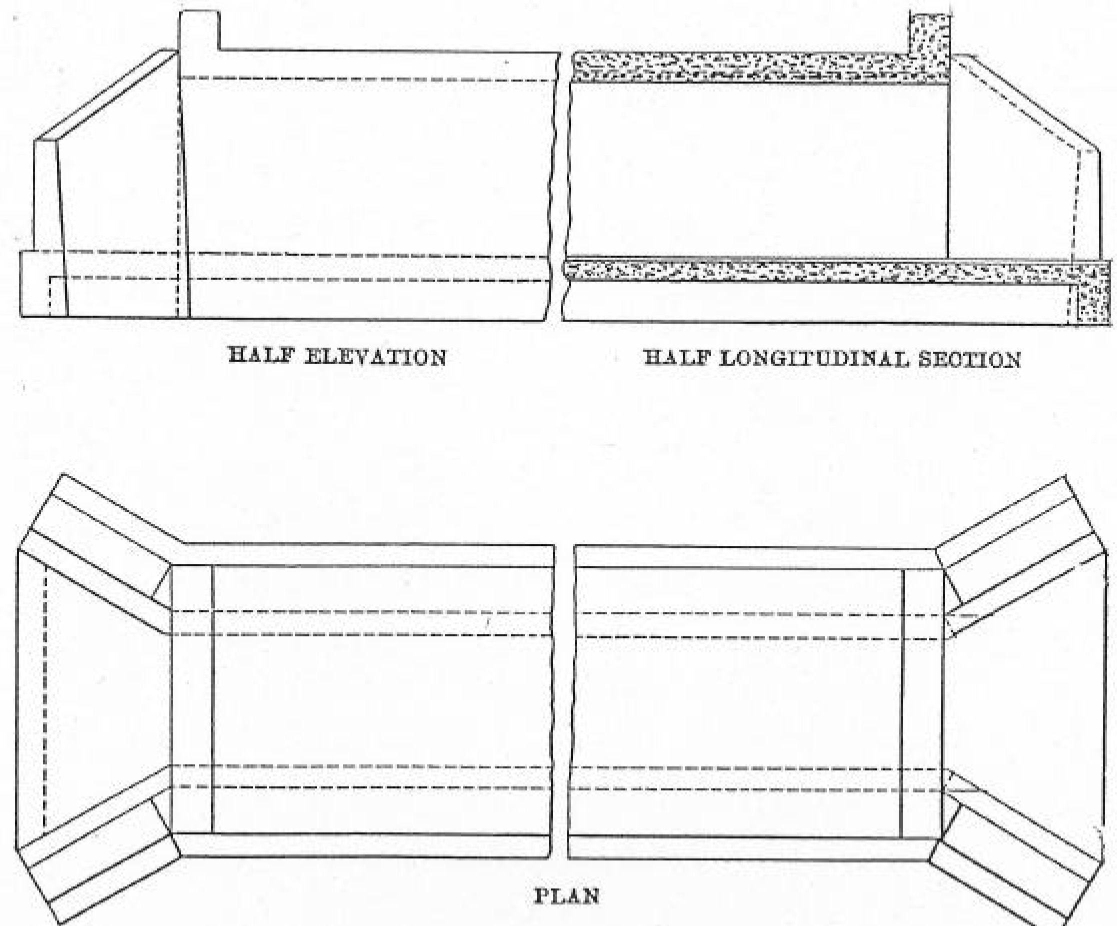

FIGURE 21: Typical Concrete Box Culvert

SOURCE: Seaton 1916

CONCRETE BRIDGES IN MARYLAND

The Advent of Concrete Bridges in Maryland

The first mention of the use of concrete occurs in the Maryland Geological Survey's *Report on the Highways of Maryland*, published in 1899. In his chapter, "The Present Condition of Maryland Highways," Arthur Newhall Johnson noted that "iron bridges are. . .fast replacing the longer wooden spans." Observing that comparatively few I-beam bridges, "one of the cheapest and best forms for spans less than 25 or 30 feet," had been built in Maryland, Johnson recommended a transitional form of reinforced concrete construction, stating "no method of construction is more durable than the combination of masonry and I-beams, between which are transverse arches of brick, the whole covered with concrete, over which is laid the roadway" (Johnson 1899:206). Hired in 1898 as the first Highway Engineer of the Maryland Geological Survey Commission, Johnson had previously been a member of the Board of Highway Commissioners of Massachusetts (Maryland State Roads Commission 1964:42).

Although the design described by Johnson appears never to have been built in Maryland, another composite design was constructed in Baltimore soon thereafter, in 1902, at Lancaster Street over the Central Avenue Sewer. Built under the "system of replacing temporary wooden structures with permanent stone, or iron, started in 1900," the Lancaster Street bridge was originally constructed with "an iron I-beam construction, with a wooden floor." The wood floor was subsequently found to be "a source of perpetual expense, very unsatisfactory, and more or less dangerous." Dissatisfied with this bridge, City engineers converted the bridge into "the most important and novel" of structures by the use of "Ferro-Concrete, or Armored Concrete" construction techniques. As

described in the 1902 *Annual Report of the Chief Engineer*, the transformation of the bridge occurred in the following fashion:

> The iron beams were first well cleaned, then covered with coal tar and surrounded with concrete; the spaces between the beams were filled with a floor of concrete six inches thick, reinforced with six-inch mesh expanded metal: on top of the concrete was placed a coating of coal tar to exclude the moisture, the whole finished with a vitrified brick pavement [Baltimore City Chief Engineer 1903:10].

The use of a metal mesh to reinforce the concrete was the first step in Maryland toward the development of true reinforced concrete construction; the concrete was no longer simply encasing the metal members for protective purposes but also contributed to the bridge's load-bearing capacity. The experiment with this type of construction was a success: "the conclusion was reached that such a floor was strong enough to withstand four times the heaviest load that could ever come upon it" (Baltimore City Chief Engineer 1903:10).

The first Maryland concrete bridge to feature reinforcing bars was the bridge at Sherwood Station, built in 1903 by Baltimore County. The announcement of this bridge's completion in the *Third Report on the Highways of Maryland* reveals the pride that was felt at its construction:

> The bridge that was built this year, 1903, near Sherwood Station shows the progressive character of the work that the County Roads Engineer is inaugurating. What is known as the steel concrete form of construction was adopted, which uses reinforced concrete beams instead of simple steel or wooden beams as in other forms of construction; this is the first example of its kind in the State [Johnson 1903:169].

The announcement goes on to report that "steel rods are imbedded in the concrete beams to enable them to withstand heavy loads; but no steel surface is exposed to air, so that there is practically no cost for maintenance of a bridge of this character" (Johnson 1903:169).

It should be pointed out that perhaps one of the reasons for the optimism expressed is that concrete construction relied upon local materials and labor. A great number of Maryland's metal truss bridges had been fabricated by out-of-state bridge companies, a fact that surely did not go unnoticed by local officials and residents. Daniel Luten certainly did not ignore this point when advocating his concrete bridges: "Concrete bridges are built with home labor and materials. The money expended for a concrete bridge returns directly to the taxpayers" (Luten 1917).

Baltimore City quickly followed with a reinforced concrete bridge of its own, at Lexington Street over Gwynn's Run. Although termed a "culvert," its 66-foot span certainly qualifies it as a full-scale bridge. The structure was "the first reinforced concrete arch which has been built by the city" (*Annual Report of the City Engineer* 1905:92) and may be the first reinforced concrete arch in the state. According to the report, "Kahn" bars were used to reinforce the concrete. However, this was not the first time that Baltimore City had built a concrete arch; a concrete arch, in an unreinforced form, was used in 1900 to lead the Schroeder's Run sewer as an open drain underneath residences (*Annual Report of the City Engineer* 1901:7).

The success of reinforced bridges at Sherwood Station and in Baltimore City quickly led to the adoption by the Maryland Geological Survey of a plan for reinforced concrete bridge construction, as described by Walter Wilson Crosby, Chief Engineer: "The general plan has been to replace these [wood bridges] with pipe culverts or concrete bridges and thus forever do way with the further expense of the maintenance of expensive and dangerous wooden structures" (Crosby 1908:379). The first noteworthy step in this plan appears to have been the construction in 1906 of a 200-foot-long, multiple-span, reinforced concrete deck girder bridge over the Choptank River (Crosby 1908:73).

Washington County, the location of many early nineteenth century stone arch bridges, built a number of arches during this early period. Maryland Historical Trust survey forms indicate that in 1906 the Nelson Construction Company of Chambersburg and Pittsburgh, Pennsylvania, built a reinforced concrete single-arch bridge for the Washington County Commissioners (MHT WA-II-128). Apparently the County Commissioners were pleased with the results; the same company (occasionally appearing as Nelson Merydith Company) built bridges of the same design for the county in 1907 (MHT WA-V-063), 1908 (MHT WA-I-344), and 1909 (MHT WA-II-176).

After the success of its first reinforced concrete bridge in 1904, Baltimore City appears to have made a commitment to the arch design. In 1908 construction of three reinforced concrete arch bridges was begun, at Hollins Street over Gwynns Run, University Parkway over Stony Run, and Edmondson Avenue over Gwynns Falls (*Annual Report of the City Engineer* 1909:12-14). The plans for the Edmondson Avenue bridge were prepared by W.J. Douglas, a bridge engineer from the District of Columbia. The Baltimore Ferro-Concrete Company constructed the multiple-span, 540-foot-long bridge between 1908 and 1910.

In the *Third Report on State Highway Construction* (1908-1910), Chief Engineer Crosby noted the construction of two double-span arch bridges built by the Luten Bridge Company, both spanning Rock Creek in Montgomery County (Crosby 1910:48). These appear to have been the first arch bridges constructed by the noted bridge company in Maryland, although only a thorough survey can confirm or deny this assessment. Luten built a number of arch bridges throughout Maryland in the following decade, including a single-span arch over Gwynns Falls at Liberty Road in 1913 (Maryland State Roads Commission 1916:67) and a four-span bridge over the Anacostia River in 1914. Built for the State Roads Commission for $11,619, the Anacostia River bridge was 199 feet long and featured a 22-foot-wide roadway. In 1919 Luten built the still-extant Sandy Island Bridge over the Choptank River at Goldsboro for the Caroline County Commissioners (MHT CAR-257). This bridge, consisting of four closed spandrel arches with a classical balustrade, is a fine illustration of the refined architectural aesthetic that Luten's "Park Bridge of Attractive Design" made possible.

The Development of Standard Plans

There are indications that standard plans for Maryland bridges were drawn up in 1909, but the first clear issue of such plans occurred in 1912, concurrent with the reorganization of the State Roads Commission, which involved the consolidation of the construction and maintenance departments and the establishment of eight districts with their own Resident Engineers (Maryland State Roads Commission 1916:57). The decentralization of the Commission "saved the State thousands of dollars yearly in expenses" and resulted in increased effectiveness, a result experienced by other states which took the same approach.

Although decentralization had its advantages, there was the danger that "the right hand wouldn't know what the left hand was doing" as the Commission embarked upon the formidable task of improving the roads and bridges of Maryland. In addition to highway resurfacing, road improvement entailed the replacement of large numbers of bridges that were inadequate to the vehicular needs of the state. If Resident Engineers were to replace all of these bridges with individually designed spans, they would not be able to keep up with the amount of work that needed to be done. Reinforced concrete construction had been successfully used to build safe bridges with reduced labor costs and, it was hoped, reduced maintenance costs, but the labor involved in individually designing all bridges would have been prohibitive. A method of reducing design time was critically needed.

The introduction of standard plans allowed the Resident Engineer to find a quick and effective solution to the problem. Although standard plans were not applicable to all bridge sites, for reasons of engineering or aesthetics, they could be used in a great number of cases.

The creation of standard plans and a description of their use was first announced in the 1912-1915 *Reports* of the State Roads Commission:

> Standard plans have been made for all bridges of spans up to 36 feet in length and it is only necessary for the Resident Engineer to investigate the foundations, then refer to the standard plan and select the type of foundation that will fit the location and conditions and take off the length of spans. The water shed is carefully figured up by the Resident Engineer when he makes his preliminary inspection and it is afterwards checked by the Engineer of Surveys. On old roads all openings of the old bridges and culverts are carefully noted, the high-water mark established and the storm areas computed. On spans exceeding 36 feet separate designs are worked up for each individual case [Maryland State Roads Commission 1916:57].

Published on a single sheet, the 1912 Standard Plans included those structures that were amenable to such an approach: slab spans, (deck) girder spans, box culverts, box bridges, abutments, and piers (Maryland State Roads Commission 1912b). Slab spans, with lengths of 6 to 16 feet in two-foot increments, featured a solid parapet railing that was integrated into the slab. (Deck) girder spans, with lengths of 18 to 42 feet in irregular increments, also featured an integrated solid parapet railing. It is interesting to note that the Standard Plan features a 42-foot span, apparently contradicting the above statement that individual plans were drawn up for spans exceeding 36 feet. The roadway for all spans was a uniform 22 feet, which exceeded by 8 feet the then current 14-foot-wide standard section for concrete road construction (Maryland State Roads Commission 1930b:85).

In the *Report* for the years 1916-1919, a revision of the standard plans was noted:

> During the four years covered by this report, it has been found necessary to revise our standard plans for culverts and bridges, to take care of the increased tonnage which they have been forced to carry. Army cantonments. . .increased their operations several hundred per cent, and the brunt of the enormous truck traffic resulting therefrom, was borne by the State Roads of Maryland. In addition to these war activities, freight motor lines from Baltimore to Washington, Philadelphia, New York, and various points throughout Maryland, and the weight of many of these trucks when loaded, was in excess of the loads for which our early bridges were designed [Maryland State Roads Commission 1920b:56].

Published on separate sheets, the new standard plans (Maryland State Roads Commission 1919) for slab bridges reveal that the major changes were an increase in roadway width from 22 feet to 24 feet and a redesign of the reinforcements. The diameter of the reinforcing bars was reduced in the 1919 slab span design (on a 10-foot span from 3/4 inch to 5/8 inch) and the space between bars was reduced (5 inches to 4½ inches), thereby increasing the number of reinforcing bars but decreasing their individual size and weight. The slab spans continued to feature solid parapets integrated into the span. The range of span lengths remained 6 to 16 feet, but the next year (1920) witnessed the issue of a supplemental plan for a 20-foot-long slab span (Maryland State Roads Commission 1920b); presumably there was also a plan for an 18-foot-long span, but this has not been located.

It should also be noted that among the 1919 standard plans for reinforced concrete structures was a design for a movable bridge operator's house. It was during this period in Maryland that reinforced concrete was gaining ascendancy over timber and steel as the material of choice for constructing the stationary approach spans of movable bridges.

The *Report* for 1920-1923 states that "new standard plans have been prepared for slab and girder spans and the type of the latter has been changed from the beam to the T-beam design, with a resulting saving in material" (Maryland State Roads Commission 1924b:58). Thus, by 1923 the State Roads Commission had decided to adopt the T-beam design which had been described by Tyrrell in 1909 (Tyrrell 1909:186), advocated by the U.S. Bureau of Roads in the teens, and already adopted by several states by 1920.

The 1924 standard plan for the T-beam spans contained a note which characterizes the new mode of construction: "No construction joint allowed between girders and slab. Girders with slab to be poured as a monolithic mass." Among the changes included in the 1924 standards for T-beams were a reduced beam section; span designs in lengths of regular two-foot increments; and a reduced range of span lengths which incorporated designs from 22 feet to 40 feet.

The 1924 standard plans remained in effect until 1930, when the roadway width for all standard plan bridges was increased to 27 feet in order to accommodate the increasing demands of automobile and truck traffic (Maryland State Roads Commission 1930b). The range of span lengths remained the same, but there were some changes designed to increase load bearing capacities. The reinforcing bars were increased in thickness for both slab and T-beams and the cross section of the T-beam bottom flange became more robust (for the 22-foot-long span, thickness was increased by 3 inches and height by 4.5 inches). Visually, the 1930 design can be distinguished from its predecessors by the pierced concrete railing that was introduced at this time.

Three years later, in 1933, a new set of standard plans was introduced (Maryland State Roads Commission 1933). This time, their preparation was not announced in the *Report*; new standard plans were by this time unremarkable. Once again accommodating the ever-increasing demands of traffic, the roadway width was increased, this time to 30 feet. The slab span's reinforcing bars remained the same diameter but were placed closer together to achieve still more load bearing capacity. In order to accomplish the same goal for the T-beam span, the number of beams was increased from five to six, the first such change since the introduction of girder spans in 1912. The increase in the number of beams allowed a decrease in section size for girders which made them equivalent to the 1924 T-beam section.

A system of standard nomenclature for plans was introduced at this time: span type was indicated by a two-letter designator followed by span length and the year of the plan. Thus, CS-18-33 indicates an 18-foot concrete slab of the 1933 standard plan design; CG-36-33 was a 36-foot concrete girder (T-beam) of the same year. The inclusion of the year designator gave ready access to design details for each bridge and indicates that the State Roads Commission anticipated revisions to standard plans.

Concrete Arch, Beam, Slab, and Rigid Frame Bridges in Maryland

In Maryland, as in the rest of the nation, the standardized concrete types became the predominant bridge types built. An examination of data on the extant concrete bridges on Maryland state roads (State Highway Administration 1993) indicates the growth of the standardized beam and slab bridge at the expense of the arch; but further research and field survey will be needed to substantiate this conclusion. In the period 1911 to 1920 (the decade in which standardized plans were introduced), beams and slabs constituted 65 percent and arches 35 percent of the extant 29 bridges built. In the following decade, 1921-1930, the beam (now the T-beam) and slab increased to 73 percent and the arch had declined to 27 percent of the 129 extant bridges; in the next decade (1931-1940) the beam and slab achieved 82 percent and arches had further declined, constituting only 18 percent of the total of extant bridges built between 1931 and 1946 on state-owned roads.

Although beam and slab bridges became the utilitarian choice, it appears that the arch was selected when aesthetic as well as other site conditions were considered. The architectural treatment of extant arch bridges supports this assessment. Baltimore's Clifton Avenue Bridge, built in 1927, features an open spandrel arch and refined architectural detailing. The Route 195 bridge over Sligo Creek (MHT M:37-7) is another example of the architectural distinction achieved by arch bridges. Built in 1932, the bridge features three open spandrel arches. In Washington County, the Route 40 bridge over the Conococheague Creek (HAER No. MD-41-17) is notable for its grace; built in 1936, it features three open spandrel arches, the spandrel openings capped by arches that complement the profile of the arch ribs. A known four-span Luten arch of the "Park Bridge of Attractive Design" was built in 1919 to carry Maryland Route 287 over the Choptank River near Goldsboro (MHT CAR-257).

Maryland state bridge inventories indicate that there are nearly 70 extant arch bridges on state highways that were constructed in the 1900-1940 period, as well as an equivalent number from the same period that are located on county or municipal roads. For the vast majority of these bridges, neither the specific form of arch (i.e., barrel, closed spandrel, or open spandrel) nor the degree of architectural detailing is known from the information available. Likewise, although it can be safely assumed that the majority of the 90 beam and 122 slab bridges built between 1900 and 1940 rigorously conform to standard plans, there may be early examples that precede standardization as well as later, individually designed and more architectural versions of these types.

Maryland's early twentieth century bridges also include at least 11 structures representative of the rigid frame bridge type, as developed during the 1930s and early 1940s in the United States. Although historical research has uncovered little more than brief references to these bridges (references primarily drawn from the 1993 Maryland Department of Transportation Inventory of Bridges), they constitute examples of a category of modern concrete bridge that has been recognized as technologically significant by historians and industrial archaeologists.

The State Highway Administration's current list of county-owned and municipal bridges references a structure that may be the earliest known example of a rigid frame bridge in Maryland. This is the bridge in Worcester County carrying Big Mill Road over Big Mill Pond, and briefly listed as a "concrete rigid frame" built in 1919 but reconstructed or rebuilt in 1930 (Maryland Department of Transportation 1993b). This may be an early example, as Westchester Parkway engineer Arthur Hayden did not pioneer small-span rigid frame bridge design until 1922-1923. The Big Mill Road Bridge warrants further investigation to determine its exact nature.

The earliest extant rigid frame bridge listed on the 1993 statewide inventory of bridges is Bridge 6031, consisting of two 35-foot spans carrying State Route 97 over Big Pipe Creek in Carroll County. The longest Maryland rigid frame structure located through historical research is Bridge 11018, a 120-foot, two-span rigid frame bridge built in 1937 to carry State Route 135 over the Savage River in Garrett County. Five out of the total of 11 rigid frame bridges constructed between 1934 and 1941 were built in connection with a major project of the Maryland State Roads Commission, the upgrading and widening of U.S. Route 40 from the Maryland-Delaware line to western Maryland.

Of these five structures, three are located in Washington County (two built in 1936 and one in 1941), and one each in Harford and Howard counties (built in 1938 and 1939, respectively). One of the five Route 40 rigid frame bridges, Bridge 12027 crossing a branch of Winters Run in Harford County, consisted of five 10-foot-long spans.

Conclusion

The following summary statements regarding structural characteristics for concrete bridges, key periods of significance for concrete bridges in Maryland, and the earliest known documented examples of concrete bridges in the state are based solely on documentary research.

Concrete bridges (see Figures 18 through 21) comprise a number of structural variants, including arches, girders, slabs, and rigid frames. Most extant concrete bridges are built of reinforced concrete, or concrete reinforced with metal components such as metal shapes, girders, beams, or reinforcing bars. Concrete bridges may be categorized by the configuration and arrangement of their major components. Substructure and superstructure are usually constructed of concrete, including parapet walls or railings.

Concrete arch bridges (see Plates 13 and 14) include closed spandrel and open spandrel variants, spanning between concrete abutments (the spandrel is the area of the arch between the ring and the roadway). The closed spandrel concrete arch bridge consists of an arch barrel, on the outermost edges of which are built spandrel walls which serve as retaining walls to contain the fill material (rubble, stones, or dry soil) deposited over the arch. The spandrel walls of a closed spandrel concrete arch may extend above the roadway deck level to form the parapet walls of the bridge. When viewed in elevation, the open spandrel arch is pierced above the arch ring. The arch ring of an open spandrel concrete arch bridge may be a barrel or it may be further divided into parallel arch ribs. The open spandrel variant of concrete arch does not contain fill material between the spandrel walls; deck loads are carried by cross walls or spandrel columns supported by the concrete arch ring. A special variant of concrete arch bridge is the through arch, or "Rainbow" arch, characterized by a concrete arch extending above the level of the roadway deck and supporting the deck by means of concrete posts, or suspenders.

Concrete slab bridges (see Figure 18) consist of a concrete slab spanning between concrete abutments and wingwalls, and flanked by concrete parapets. The slab bridge is typically constructed entirely of reinforced concrete, with minimally ornamented parapet walls.

Concrete beam, or girder, bridges (see Figure 19 and Plate 15) consist of a concrete deck, supported on concrete beams (I-beams or T-beams, in cross section), spanning between concrete abutments and wingwalls, and flanked by concrete parapets. In certain concrete beam bridges, the concrete parapet is a structural, reinforced concrete component acting with the beams to support the deck loads; sometimes the parapet walls are treated with linear ornamentation.

Concrete rigid frame bridges (see Figure 20) are structures in which the reinforced concrete continues monolithically from the abutments into the superstructure, thus eliminating the bearings characteristic of slab and beam bridges. The monolithic concrete construction of the rigid frame bridge makes it a bridge with four rigid joints. In multiple-span rigid frame concrete bridges or viaducts, the girders forming the superstructure may also be rigidly connected with intermediate vertical supports or concrete piers.

As indicated by documentary research, key periods of significance for concrete bridges in Maryland include *1890-1910*, the era in which reinforced concrete bridge construction was introduced and popularized within the state, by Baltimore City and Baltimore County officials as well as state highway engineers in the Maryland Geological Survey and State Roads Commission; *1910-1940*, when reinforced concrete bridge building in the state was characterized by the increasing standardization of small slab, beam, frame and culvert spans, and the introduction of special subtypes of reinforced concrete bridges such as the Luten arch (in various patented designs), the open spandrel ribbed arch, the rigid frame bridge and concrete girder bridges built as grade crossing elimination structures; and *1940-present*, when reinforced concrete prestressing, to increase the load-bearing capacity of bridges, was introduced in the state for highway bridge use.

The earliest reinforced concrete bridges built in Maryland were the Lancaster Street Bridge built in 1902 by Baltimore City (featuring a reinforced concrete deck), and the Sherwood Station Bridge built in 1903 by Baltimore County (including reinforced concrete beams). Early concrete arch bridges in Maryland included the bridge carrying Lexington Street over Gywnn's Run (1904) and a group of reinforced concrete arch spans built between 1906 and 1909 in Washington County by the Nelson Construction Company. An early, multiple-span reinforced concrete deck girder bridge was built by state highway engineers in 1906 to cross the Choptank River. The earliest known reinforced concrete arch bridges built by Daniel Luten's National Bridge Company in Maryland were two double-span arch bridges built between 1908 and 1909 to span Rock Creek in Montgomery County. Field survey and further research will be necessary to determine the earliest open spandrel ribbed arch and the first reinforced concrete rigid frame bridges built in Maryland. As few concrete or reinforced concrete bridges have been previously surveyed or studied in Maryland, field survey and additional research will also be required to identify significant extant concrete bridges located in the state.

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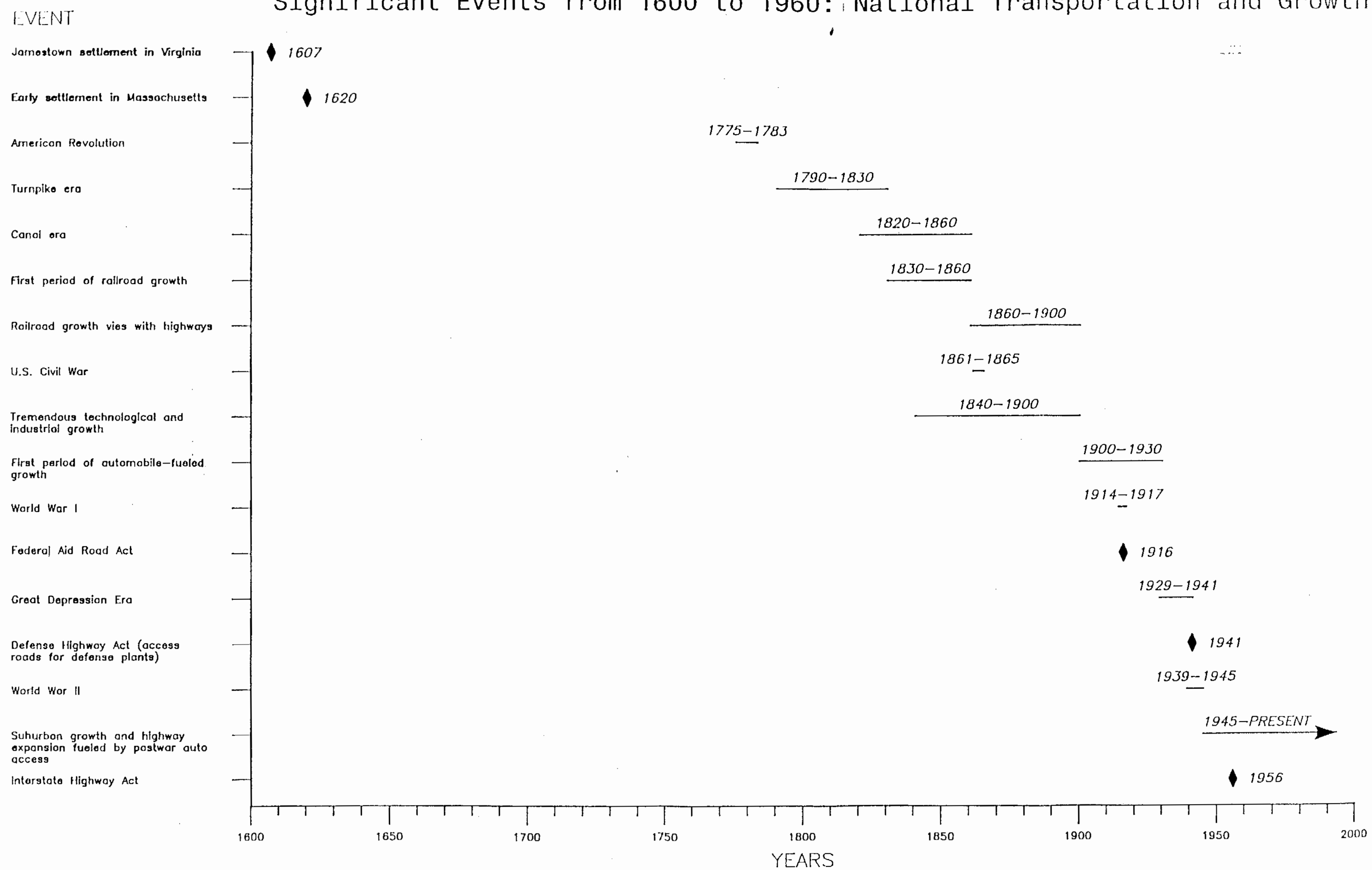
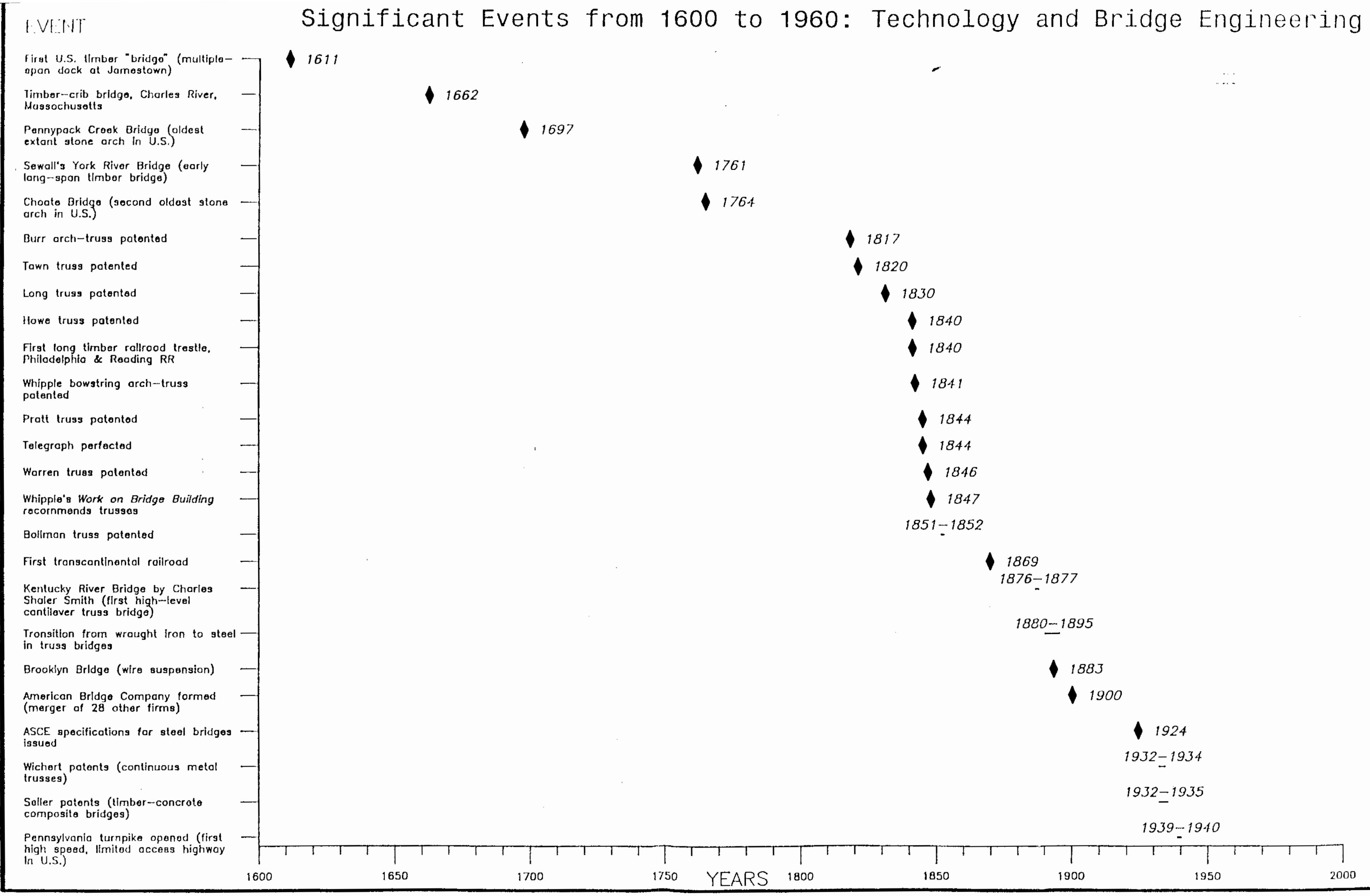
Appendix A:

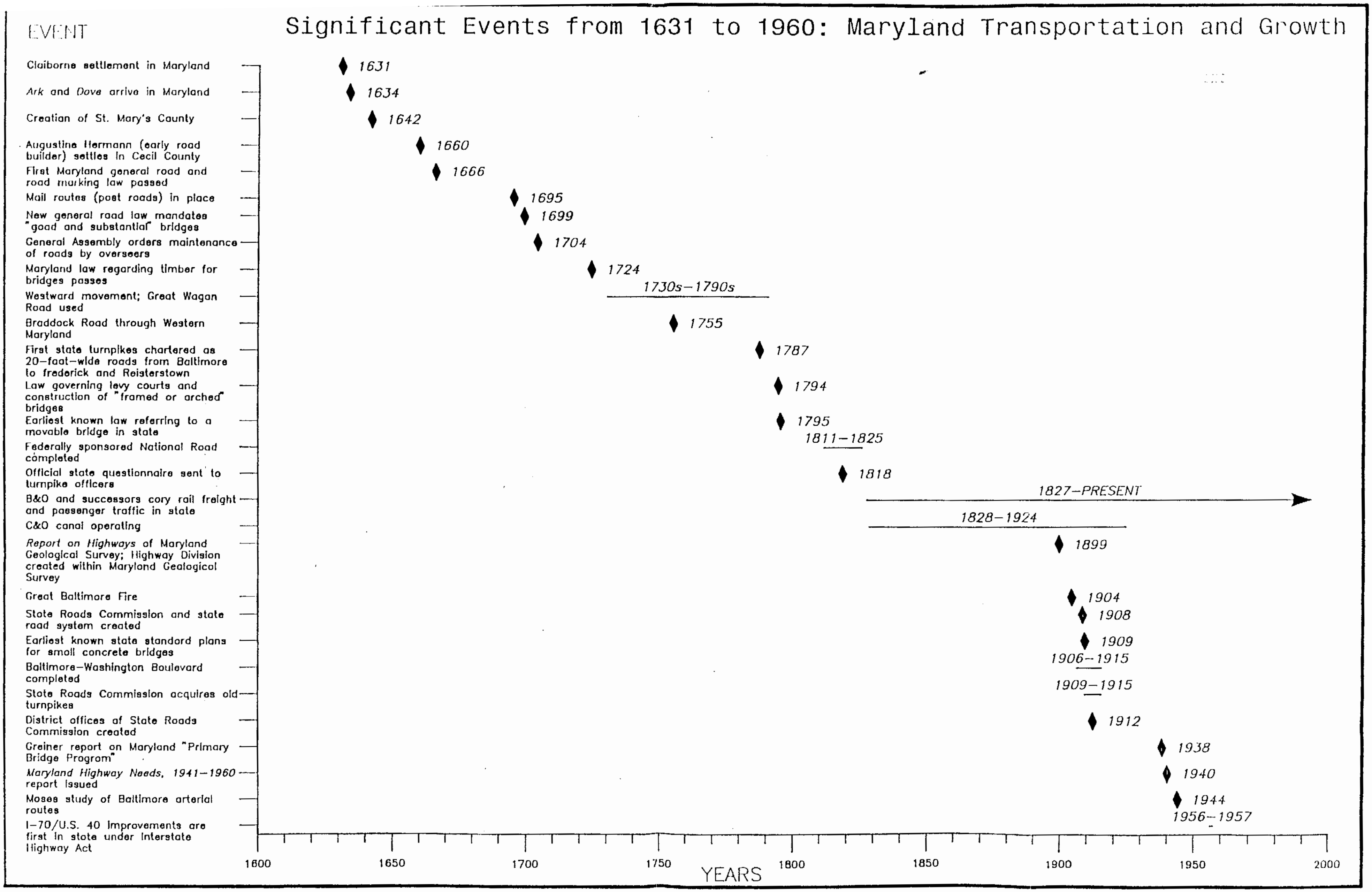
Historical Timetable: Maryland Historic Bridges

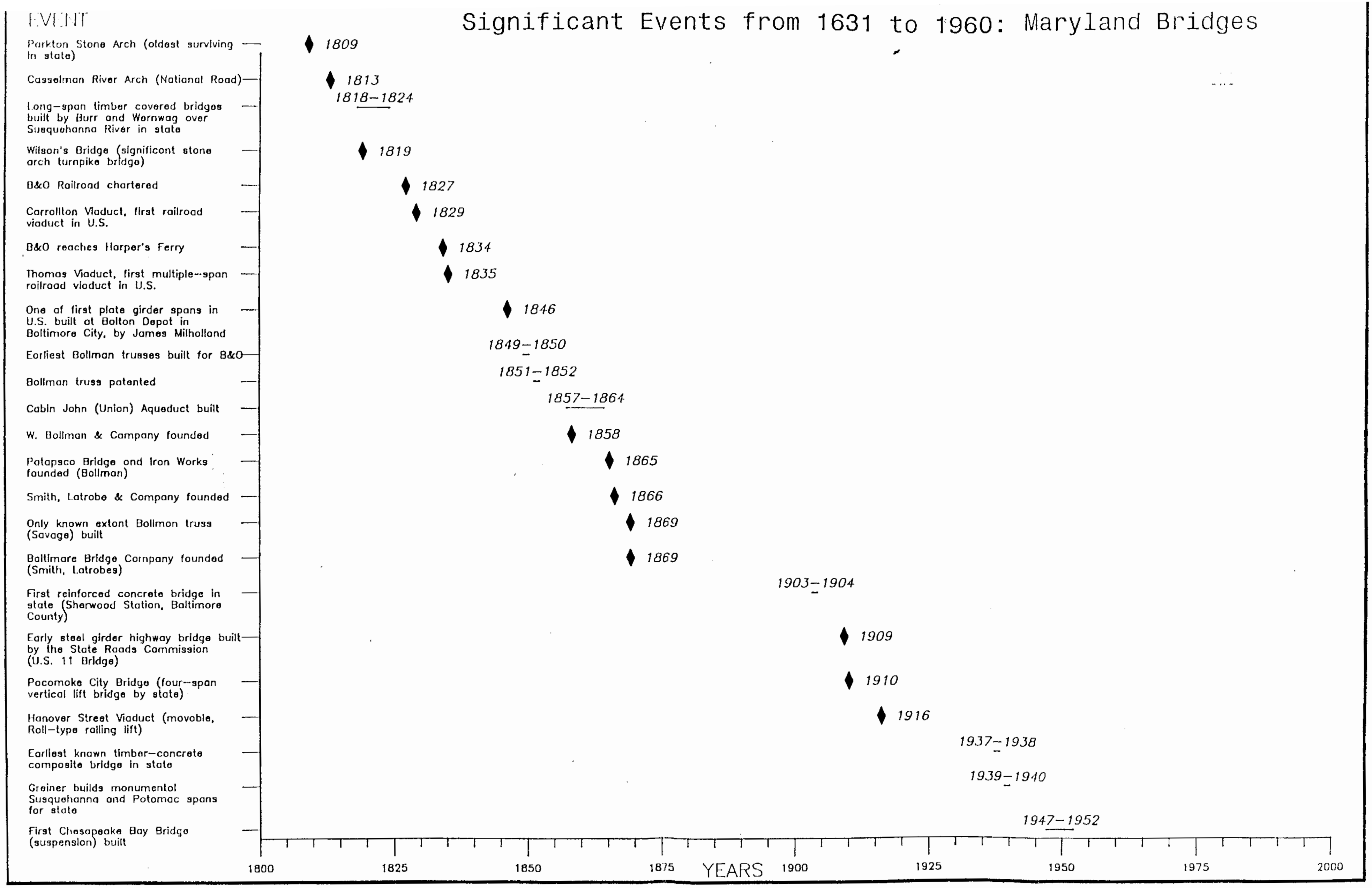
Significant Events from 1600 to 1960: National Transportation and Growth



Significant Events from 1600 to 1960: Technology and Bridge Engineering




Significant Events from 1631 to 1960: Maryland Transportation and Growth
EVENT
Claiborne settlement in Maryland
1631
Ark and Dove arrive in Maryland
1634
Creation of St. Mary's County
1642
Augustine Herrmann (early road builder) settles in Cecil County
1660
First Maryland general road and road marking law passed
1666
Mail routes (post roads) in place
1695
New general road law mandates "good and substantial" bridges
1699
General Assembly orders maintenance of roads by overseers
1704
Maryland law regarding timber for bridges passes
1724
Westward movement; Great Wagon Road used
1730s–1790s
Braddock Road through Western Maryland
1755
First state turnpikes chartered as 20-foot-wide roads from Baltimore to Frederick and Reisterstown
1787
Law governing levy courts and construction of "framed or arched" bridges
1794
Earliest known law referring to a movable bridge in state
1795
Federally sponsored National Road completed
1811–1825
Official state questionnaire sent to turnpike officers
1818
B&O and successors cary rail freight and passenger traffic in state
1827–PRESENT
C&O canal operating
1828–1924
Report on Highways of Maryland Geological Survey; Highway Division created within Maryland Geological Survey
1899
Great Baltimore Fire
1904
State Roads Commission and state road system created
1908
Earliest known state standard plans for small concrete bridges
1909
Baltimore–Washington Boulevard completed
1906–1915
State Roads Commission acquires old turnpikes
1909–1915
District offices of State Roads Commission created
1912
Greiner report on Maryland "Primary Bridge Program"
1938
Maryland Highway Needs, 1941–1960 report issued
1940
Moses study of Baltimore arterial routes
1944
I-70/U.S. 40 Improvements are first in state under Interstate Highway Act
1956–1957
1600
1650
1700
1750
1800
1850
1900
1950
2000
YEARS



Significant Events from 1631 to 1960: Maryland Bridges
EVENT
Parkton Stone Arch (oldest surviving in state)
1809
Casselman River Arch (National Road)
1813
Long-span timber covered bridges built by Burr and Wernwag over Susquehanna River in state
1818–1824
Wilson's Bridge (significant stone arch turnpike bridge)
1819
B&O Railroad chartered
1827
Carrollton Viaduct, first railroad viaduct in U.S.
1829
B&O reaches Harper's Ferry
1834
Thomas Viaduct, first multiple-span railroad viaduct in U.S.
1835
One of first plate girder spans in U.S. built at Bolton Depot in Baltimore City, by James Milholland
1846
Earliest Bollman trusses built for B&O
1849–1850
Bollman truss patented
1851–1852
Cabin John (Union) Aqueduct built
1857–1864
W. Bollman & Company founded
1858
Patapsco Bridge and Iron Works founded (Bollman)
1865
Smith, Latrobe & Company founded
1866
Only known extant Bollman truss (Savage) built
1869
Baltimore Bridge Company founded (Smith, Latrobes)
1869
First reinforced concrete bridge in state (Sherwood Station, Baltimore County)
1903–1904
Early steel girder highway bridge built by the State Roads Commission (U.S. 11 Bridge)
1909
Pocomoke City Bridge (four-span vertical lift bridge by state)
1910
Hanover Street Viaduct (movable, Roll-type rolling lift)
1916
Earliest known timber-concrete composite bridge in state
1937–1938
Greiner builds monumental Susquehanna and Potomac spans for state
1939–1940
First Chesapeake Bay Bridge (suspension) built
1947–1952
1800
1825
1850
1875
1900
1925
1950
1975
2000
YEARS

Periods of Significance for Bridge Types (based on documentary research alone)

Bridge Type	Period	Years
TIMBER	Simple timber beam bridges built in state	1724–1900
	Era of timber truss covered bridges	1800–1900
	Era of timber trestle bridges	1840–1900
	Period of timber–concrete composite structures	1935–1960
STONE ARCH	Era of initial use of stone arches on highways and turnpikes in state, including National Road	1790–1830
	First period of stone arch use for railroad viaducts and bridges (Carrollton Viaduct, Thomas Viaduct, etc.)	1825–1850
	Stone arch bridge utilized on C&O Canal	1828–1924
	Continued railroad use of stone arches and refinement of stone arch highway bridge construction	1850–1910
METAL TRUSS	Period of transition from timber trusses to iron trusses; significant patents (Howe, Pratt, Warren)	1840–1860
	Era of metal truss bridge popularization and scientific standardization for highway use	1860–1900
	Period of increasing standardization of highly useful, simply designed truss types (Pratt, Warren) for highway usage and (1930–present) select use in monumental spans and their approaches (e.g., Greiner–built bridges over Potomac, Susquehanna, and Chesapeake Bay)	1900–1960
MOVABLE	Period of early timber bascule and swing spans built in Maryland	1790–1850
	Era of scientific technological improvements in movable bridge design and construction, such as employment of metal and development of new variants of bascule, swing, and vertical lift	1850–1900
	Period of major modern significant movable spans built in Maryland (1916 Hanover Street Viaduct; a group of early State Roads Commission bridges)	1900–1940
METAL GIRDER	Era of introduction of metal girder bridge technology in state, including one of first plate girders (Milholland's 1846 span at Bolton Depot)	1846–1870
	Period of popularization and standardization for highway usage, and continued railroad use and standardization	1870–1920
	Era of heavy State Roads Commission employment of girder bridges for highway bridges, and particularly grade crossing elimination structures	1920–1965
METAL SUSPENSION	Period of introduction of metal cable and wire rope suspension span technology (Finley, Ellet) in surrounding states, with influence and possible examples (Finley bridge at Will's Creek) built in Maryland	1800–1840
	Period of locally engineered swinging footbridges built for pedestrian access to commercial and industrial sites in Maryland	1850–1900
	Era of influence in Maryland of Roebling through Ammann monumental wire rope suspension bridge technology, exemplified primarily in first Chesapeake Bay Bridge built 1947–1952	1900–1960
METAL ARCH	Introduction of metal bowstring arch and deck arch technology to state, in small rural bowstring arch–truss bridges as well as larger, more ornamented Baltimore City structures of the 1880s	1870–1900
	Era of construction of modern through bowstring arches by State Roads Commission and Baltimore City authorities	1930–1960
METAL CANTILEVER	Period of scientific development and refinement of cantilever truss design and construction, as exemplified in Maryland by Governor Harry W. Nice Memorial Bridge, built in 1940 by J.E. Greiner Company for state	1900–1940
CONCRETE BRIDGES	Period of introduction of concrete and reinforced concrete technology to state, and leadership by Baltimore City, Baltimore County, Maryland Geological Survey Highway Division, and State Roads Commission officials in advocacy of reinforced concrete highway spans	1890–1910
	Era of increasing standardization of small concrete bridges (beam, simple arch, culverts) by state and local authorities; influence of "City Beautiful" movement on concrete arch bridge construction, exemplified by Luten arches and concrete open spandrel ribbed arches; and development and introduction in state of rigid frame bridges and concrete grade crossing elimination structures	1910–1940
	Period of continuing scientific testing of concrete highway bridge technology and development of prestressing	1940–PRESENT

1700 1800 1900 2000

YEARS

Appendix B:

Bridge Builders and Designers Active in Maryland

Bridge Builders and Designers Active in Maryland

The following companies and individuals are known to have designed and built bridges in Maryland, based on documentary research alone. Descriptive information on each company or person was compiled from several sources, including prior historic resource survey data, historical research materials, lists provided by Rita Suffness of the Maryland State Highway Administration, prior bridge inventories performed in Pennsylvania and Delaware, and Victor Darnell's *Directory of American Bridge Building Companies*.

A. and W. Denmead & Sons, Baltimore, Maryland

This firm, located on the Canton waterfront of Baltimore, built bridges for Baltimore City during the 1850s.

A. J. Boyle, Baltimore, Maryland

This firm built SHA bridge 3010, US 1 over the Patapsco River, in 1915.

American Bridge Company, Pittsburgh and Ambridge, Pennsylvania

Founded in 1900, this massive bridge building company was the result of financier and U.S. Steel magnate J.P. Morgan's consolidation of twenty-eight formerly independent bridge companies, including several known to have marketed bridges in Maryland. In 1903, the American Bridge Company opened a huge new plant at Ambridge (Economy), Pennsylvania. Four additional companies, including the Toledo Bridge Company and the Virginia Bridge and Iron Company, were bought between 1901 and 1936.

American Bridge Company is known to have fabricated or built numerous bridges for the State Roads Commission between the 1920s and the 1960s.

Baltimore Bridge Company, Baltimore, Maryland

Organized in 1869, this company was the direct successor to Smith, Latrobe and Company. The company was a major local competitor of Wendel Bollman's Patapsco Bridge Company and other Baltimore-based bridge building firms such as Campbell & Zell and H.A. Ramsay. Principals in the firm were the distinguished bridge engineers Charles Shaler Smith, Benjamin H. Latrobe, Jr., and his son Charles H. Latrobe. In 1876-1877, Smith built the nation's first high metal cantilever bridge, to carry the

Southern Railway over the Kentucky River. Charles H. Latrobe also served as chief engineer for the City of Baltimore's Jones' Falls Improvement Commission during the 1880s, and designed several truss bridges and three metal arch bridges for the city during his tenure.

Baltimore Ferro-Concrete Company, Baltimore, Maryland

This firm constructed the Edmonson Avenue Bridge in Baltimore City, a multiple-span reinforced concrete arch bridge built between 1908 and 1910.

Bethlehem Steel Corporation, Bethlehem, Pennsylvania

This mammoth steel corporation, engaged in many different steel-related manufacturing activities during the late nineteenth and twentieth centuries, is known to have built bridges in Maryland, such as the Paper Mill Road Bridge over the Gunpowder and the Deep Creek Bridge over Deep Creek Lake on U.S. 219 (MHT-G-III-B-028; no longer extant). One of the company's main plants was located at Sparrows Point, east of Baltimore City.

Buckey and Firestone, Frederick, Maryland

This Frederick foundry built the Pedestrian Swinging Bridge (MHT-F-3-8), a suspension footbridge of iron, for the City of Frederick in 1885.

Campbell and Zell Company, Baltimore, Maryland

This firm is known to have fabricated or built metal bridges in Maryland (primarily Baltimore City) during the late 1890s, including the fourteen-span plate girder Lexington Street-Douglas Street Bridge built for the city in 1892.

Charles Perring Company, Baltimore, Maryland

This firm constructed the Cambridge movable span bridge over the Choptank River. The principle, Charles Perring, was listed in the 1937 "Who's Who in Engineering" as holding various bridge positions from 1898 to 1905 when he became the Chief Engineer for the Keystone Fireproofing Company in 1905. In 1910 he became associated with the firm, firm, Barber and Perring, in Philadelphia. He was the Chief Engineer for the City of Baltimore from 1920 to 1928, and was consulting engineer from 1928 to 1941 in the firm of Perring and Remington.

Columbia Bridge Works, Dayton, Ohio

This bridge company originated in 1848 as a builder of timber bridges under the management of D.H. and C.C. Morrison. Morrison received patents for his bridge design in 1858, 1867, and 1871. Bridges marketed by the firm included Pratt, Whipple, Triangular, and Arch Trusses, as well as several rigid suspension spans. The company was active until at least 1898. The company is reputed to have built the 1889 Devilbiss Bridge over the Monocacy River in Frederick County (MHT-F-3-2), a two-span pin-connected Pratt through truss, in conjunction with the Wrought Iron Bridge Company.

Fairchild Engineering and Airplane Corporation

Harry Kahn of this firm designed the only aluminum bridge in Maryland, SHA bridge 13046 in 1961.

Forsyth, Thomas S.

Built Bridge B4, the Jericho Covered Bridge (BA 361) over the Little Gunpowder River, in 1865. He was listed in Houston's 1867 city directory as a "machinist" at 116 North Bond Street, and listed in the 1877 patron list in Hopkin's atlas as a resident of Pikesville and still a machinist. He had moved there that year from his native Baltimore City.

Fort Pitt Bridge Company, Pittsburgh and Canonsburg, Pennsylvania

The main office of this firm was located in Pittsburgh, but in 1894 the old Canonsburg shop of the Pittsburgh Architectural Iron Works were purchased. In 1933, the Fort Pitt Bridge Company bought the Massilon Bridge Company of Massilon, Ohio. The Fort Pitt company is known to have built the Rocks Bridge, a riveted Pratt through truss crossing Deer Creek and erected in 1934 (MHT-HA-1576).

Groton Bridge and Manufacturing Company, Groton, New York

This company began in 1878 as the Groton Iron Bridge Company; its name was changed to Groton Bridge and Manufacturing Company in 1887 and then to Groton Bridge Company in 1901. In addition to metal bridges, the firm made woodworking machinery, straightening machines, and metal punches. The company was acquired by the American Bridge Company in 1900, but sold to its former owners in 1901. The firm continued to build bridges at least as late as 1914. Several pin-connected Pratt pony trusses of the mid-1890s (MHT-F-3-5, MHT-F-4-5, and MHT-F-4-6) are known to have been fabricated or built by the Groton Bridge and Manufacturing Company in Maryland.

H.A. Ramsay and Sons, Baltimore, Maryland

This prominent Baltimore iron works was responsible for fabrication and construction of at least three Baltimore City metal truss bridges built under authority of the Jones' Falls Improvement Commission during 1881.

Henry G. Perring Company, Baltimore, Maryland

This firm, led by prominent Baltimore City civil engineer and sometime planning official Henry G. Perring, is known to have built at least one movable bridge for the State Roads Commission, Bridge 9008 carrying State Route 795 over Cambridge Creek, a double-leaf bascule flanked with six concrete girder spans and built in 1938.

J.E. Greiner Company (later Greiner Engineering), Baltimore, Maryland

This Maryland-based bridge design company was founded in 1908 by John Edwin Greiner, a distinguished bridge engineer who had previously specialized in railroad bridges for the Baltimore and Ohio Railroad and other railways. Led by Greiner and longtime associate Hershel Heathcote Allen, the J.E. Greiner Company designed many significant bridges for the State Roads Commission, including the 1916 Hanover Street Bridge, a Rall-type rolling lift bascule bridge; the Thomas J. Hatem Memorial Bridge and Governor Harry W. Nice Memorial Bridge, major Susquehanna and Potomac river crossings built in 1940; and the first Chesapeake Bay Bridge, built between 1947 and 1952. The latter three monumental bridges were built as a result of the state's acceptance of the Greiner firm's significant planning report, *Maryland's Primary Bridge Program*, completed in 1938 for the State Roads Commission.

J.G. Clarke and Company (later Clarke Bridge Company), Baltimore, Maryland

This Baltimore company is known to have built bridges between 1879 and 1883, for Baltimore City.

J.L. Robinson Construction Company, Baltimore, Maryland

Founded in 1912 by James L. Robinson, this company built several significant spans for Baltimore City between 1925 and 1935, including the Clifton Avenue Bridge, the Mount

Washington Viaduct, and the Forty-first Street Bridge. The firm was no longer in business after 1936.

Jones and Thorne, Baltimore, Maryland

This company performed the masonry abutment construction for the Cedar Avenue Bridge in Baltimore City in 1889-1890.

King Iron Bridge and Manufacturing Company, Cleveland, Ohio

The King Bridge Company was begun in 1858 by Zenas King, who had built iron bridges as well as timber spans and combination structures, designing his first all-iron bridge in 1859. In 1861, King patented a tubular arch bridge; in 1871, he incorporated his company, which by 1884 possessed the largest highway bridge works in the United States. In 1893, the name of the firm was changed to King Bridge Company; the company was active until several years after World War II. The King company is known to have built several pin-connected Pratt pony trusses and bowstring arch pony trusses in Maryland between 1870 and 1895, including the Waverly Street Bridge at Westernport, a bowstring through arch truss built in 1892 (HAER No. MD-83; no longer extant).

Lloyd Family and their associates, Chambersburg, Pennsylvania

During the early nineteenth century, the Lloyd family of Chambersburg, Pennsylvania (north of Hagerstown, Maryland), were prominent master masons who built numerous stone arch bridges throughout western Maryland (primarily Washington County). James Lloyd, one of the family's most experienced masons, was also involved in the B&O Railroad's construction of the 1829 Carrollton Viaduct, a stone arch bridge that was the earliest railroad viaduct constructed in the United States. Associates of the Lloyd family included Silas Harry, John Weaver, and Jabez Kenney.

McClintic-Marshall Construction Company, Pittsburgh, Pennsylvania

This significant twentieth century bridge building firm was founded in 1900 by Howard Hale McClintic and Charles Donnell Marshall, fellow Lehigh University graduates who had both been employed by Shiffler Bridge Works before that company was absorbed by the American Bridge Company. An independent firm until it became a division of Bethlehem Steel in 1931, McClintic-Marshall designed and fabricated structural steel components for numerous large-scale engineering and architectural projects, including the lock gates for Gatun Locks at the Panama Canal (1913), the steel supports for the dome of Pittsburgh's Cathedral of Learning, and the George Washington Bridge over the Hudson at New York City (1929-1931). During the 1920s, the company was the world's largest independent steel fabricating firm, with numerous branch offices and plants throughout the United States. In 1924, the McClintic-Marshall company built the Glendale Road Bridge over Deep Creek Lake in Garrett County, a two-span Pennsylvania (Petit) truss with substruts (MHT-G-III-B-083; HAER No. MD-88). McClintic-Marshall also is known to have fabricated the 1913 Matthews Bridge, a two-span Parker truss crossing Loch Raven Reservoir (no longer extant), and the 1932 Fairview Bridge (MHT-WA-I-462), a riveted Pratt through truss in Washington County.

Murray and Hazelhurst, Baltimore, Maryland

This company is known to have built bridges for Baltimore City between 1857 and 1869.

National Bridge Company, York, Pennsylvania

Founded in 1902, this was the first company formed by Daniel B. Luten, whose concrete arch designs attained prominence and popularity throughout the eastern United States between 1900 and 1930. An 1894 civil engineering graduate of the University of Michigan who was influenced by the City Beautiful movement, Luten held more than thirty bridge-related patents, including ones for a "Highway Bridge of Plain Design" and a "Park Bridge of Attractive Design." By 1907, according to a company catalog, Luten's firm had designed more than 700 bridges; by 1919, some 17,000 spans had been designed by the company. Luten's firm is known to have built a number of reinforced concrete arches, to Luten designs, in Maryland.

Nelson & Buchanan (also Gilbert & Nelson and Nelson Construction Company), Chambersburg, Pennsylvania

Nelson & Buchanan were agents for the Pittsburg Bridge Company until about 1900, when they began a series of independent bridge companies. The Nelson Construction Company is known to have built early reinforced concrete arch bridges in Washington County Maryland, between 1906 and 1910.

Palmer and Lambdin

This firm built SHA bridge 3071 in 1947.

Patapsco Bridge and Iron Works, Baltimore, Maryland

This was Wendel Bollman's second independent firm and was the direct successor to W. Bollman and Company. The Patapsco Bridge Company was formed in 1865 by Bollman and built numerous bridges in Maryland and throughout the United States until the company was dissolved upon Bollman's death in 1884. The only known extant Bollman truss bridge built by the firm is the nationally significant Bollman truss at Savage, Maryland.

Penn Bridge Company, Beaver Falls, Pennsylvania

This firm was organized in 1868 by T.B. White & Sons, with its original plant at New Brighton, Pennsylvania. In 1878, the bridge works were moved to Beaver Falls; the firm was reorganized and incorporated as the Penn Bridge Company in 1887. In Maryland, Penn Bridge Company may possibly have built the 1878 Poffenberger Road Bridge crossing Catoctin Creek in Frederick County, a Double-Intersection Pratt truss span (MHT-F-2-5, Bridge # F-2203).

Pennsylvania Steel Company, Steelton, Pennsylvania

This firm is known to have built a riveted Pratt through truss for the Western Maryland Railroad in 1905, to cross the C&O Canal near Kiefers, and the Bush River Bridge, a single-leaf bascule span built in 1913 for the Philadelphia, Baltimore and Wilmington Railroad (photographed for HAER No. MD-45, Northeast Railroad Corridor Recordation).

Phoenix Bridge Company, Phoenixville, Pennsylvania

This firm built the Baltimore City bridge BC6510 for the Baltimore Department of Public Works for the Loch Raven Reservoir in 1922.

It was formed in 1884 from Clarke, Reeves and Company, a Philadelphia firm, which was formed in 1870 by Thomas C. Clarke and the Reeves Company which controlled the Phoenix Iron Company. When Clarke left in 1884, the company was succeeded by the Phoenix Bridge Company. The company is known to have published its "Album of Designs" in 1870, 1873, 1884, 1885, and 1888; however, it was probably an annual issue. Phoenix was a vertical operation, from smelting its own ore to designing and erecting its own bridges. The firm favored the through or high Pratt and Whipple truss systems and patented a compression member called the Phoenix column, which was a series of vertical segments riveted together and forming a cylindrical column. The company primarily built railroad bridges but not exclusively. An unattributed advertisement boasted a rather comprehensive repertoire, being "engineers and builders of bridges, viaducts, roofs, turntables, elevated railroads, ocean piers, and all structures of iron and steel." Poors' Directory (1887) listed David Reeves as president and W. H. Reeves as superintendent. The "Album of Designs" for 1888 listed Adolphus Bonzano as chief engineer and contained an extensive list of constructed bridges. It is also of interest that James A. L. Waddell, noted bridge engineer and historian, worked for Phoenix between 1886 and 1892.

Pittsburg Bridge Company, Pittsburgh, Pennsylvania

This company was established in 1878, incorporated in 1881, and was a major manufacturer of metal truss bridges prior to its absorption by the American Bridge Company in 1900 (the Pittsburg Bridge Company, though a division of American Bridge, operated under its own name as late as 1903). The Pittsburg Bridge Company is known to have fabricated and built the Old Mill Road Bridge over Owens Creek in Frederick County, an 1882 pin-connected Pratt through truss (MHT-F-6-2).

Roanoke Iron and Bridge Company (also Roanoke Bridge Company), Roanoke, Virginia

This firm, which built primarily metal truss bridges, was organized in 1906 and merged with the Camden Iron Works of Salem, Virginia, in 1914. During the 1920s and 1930s, the Roanoke Iron and Bridge Company built several spans under State Roads Commission auspices, including the 1923 Patuxent River Bridge carrying State Route 214 (MHT-AA-761), a riveted Camelback through truss, and two 1932 Camelback pony truss bridges (MHT-CE-999 and MHT-HA-1577).

Smith Bridge Company (later Toledo Bridge Company), Toledo, Ohio

This company was founded by Robert W. Smith in 1867, initially to manufacture Smith's patented pre-cut timber trusses. By 1875, Smith Bridge Company had begun building and heavily marketing wrought iron truss bridges, although the firm continued to advertise its capabilities in timber and combination timber-and-iron design and fabrication. Smith sold the company in 1890 and its name was changed to Toledo Bridge Company. In 1901, the firm was one of twenty-eight bridge companies consolidated by J.P. Morgan to form the American Bridge Company. The Smith Bridge Company, and the Toledo Bridge Company, built several Pratt trusses in Maryland during the late nineteenth century.

Smith, Latrobe and Company, Baltimore, Maryland

This firm was organized in 1866 by distinguished bridge engineers Charles Shaler Smith and Benjamin H. Latrobe, Jr. In 1869, the firm became the Baltimore Bridge Company.

Strobel Steel Construction Company, Chicago, Illinois

The Strobel Company provided the Rall-type rolling lift bascule machinery for use on the 1916 Hanover Street Bridge, built by J.E. Greiner Company for the State Roads Commission.

Valentine Shockey Ironworks, Cumberland, Maryland

This Cumberland area ironworks built an iron cable suspension bridge over Will's Creek in 1820, to a design by suspension bridge pioneer James Finley.

Vincennes Bridge Company, Vincennes, Indiana

This Indiana company is known to have designed and built the Westernport Bridge, a riveted Pratt through truss at Westernport, Maryland, crossing the Potomac River, between 1910 and 1923 (MHT-AL-VI-D-227).

W. Bollman and Company (later Patapsco Bridge Company), Baltimore, Maryland

Based in Baltimore, this highly significant bridge building company was founded in 1858 by former B&O master of road Wendel Bollman, to market his patented Bollman truss (patented 1851-1852) as well as other proprietary or patented bridges such as the Pratt truss. Bollman joined John Clark and John H. Tegmeyer as partners in the firm (Tegmeyer had advertized the Bollman truss as early as 1855 in trade periodicals). W. Bollman and Company was active in building metal truss bridges for the B&O until the firm was reorganized in 1865 as the Patapsco Bridge Company (see reference).

Waddell and Hardesty, New York, New York

This firm was the third successor of a bridge firm founded in 1887 by noted bridge engineer and historian of civil engineering, J. A. L. Waddell. In existence from 1927 to 1945 as Waddell and Hardesty, the firm developed the vertical lift bridge as a specialty. This firm is responsible for Bridge 2053, which carries Maryland 181 over Spa Creek in Annapolis, Maryland. Bridge 17006, Maryland 18 over Kent Narrows, was designed in

1952 by the seventh generation firm, Hardesty and Hanover. Both bridges are Chicago trunnion bascule bridges.

Wrought Iron Bridge Company, Canton, Ohio

Organized in 1864 by David Hammond and incorporated in 1871, the Wrought Iron Bridge Company heavily marketed a patented metal arch-truss bridge throughout the eastern United States. Job Abbott, who joined the firm in 1872, later organized the Toronto Bridge Company and the Dominion Bridge Company of Canada. In 1874, the firm published its *Book of Designs*, which included a patented "Hammond and Abbott Arch Bridge." One of the leading metal bridge manufacturers in the nation during the latter part of the nineteenth century, the Wrought Iron Bridge Company was a strenuous advocate of the advantages of wrought iron bridges over timber or cast iron spans. The Wrought Iron Bridge Company was taken over by the American Bridge Company in 1900. The Wrought Iron Bridge Company is known to have built several Pratt through trusses in Maryland during the late nineteenth century.

York Bridge Company, York, Pennsylvania

This company, formed circa 1900, was a successful marketer of metal truss bridges to Maryland state and county officials during the first two decades of the twentieth century, building both Pratt through trusses and Pratt pony spans.

Youngstown Bridge Company, Youngstown, Ohio

The firm known as Morse Bridge Company operated from 1878 to ca. 1888 when the name was changed to the Youngstown Bridge Company. It advertised in <u>Engineering News</u> as producing "bridges and buildings". In operation until 1900, when it was absorbed by the American Bridge Company, the firm built Waverly Street Bridge over George's Creek in Westernport, Allegany County, in 1891.

Appendix C:

Identifying and Evaluating Maryland's Historic Bridges

IDENTIFYING AND EVALUATING MARYLAND'S HISTORIC BRIDGES

The purpose of this addendum is to aid in the identification and evaluation of Maryland's historic bridges. It is provided to serve as a guideline for understanding the issues to consider when evaluating historic bridges. It is intended as an aid to interpretation, and not to be considered as a rigid rule for interpretation.

Because the survey of Maryland's bridges has not yet been undertaken, the information in this addendum is presented at an extremely detailed level and organized by bridge subtype. It is assumed that surveyed resources will have been built and used by the transportation industry for the transportation of goods and people.

Section A presents general expanded National Register criteria for bridge evaluation. Based upon the historic context developed for this project, Section B describes the patterns, events, persons, cultural values, and locational patterns associated with specific bridge types in Maryland. Physical and associative characteristics and how they relate to the historic integrity of specific bridge types are presented in Section C. A bridge may also be a contributing resource within a National Register-listed or eligible historic district. Section D, "Bridges as Contributing Resources within Historic Districts," presents guidelines relating to contributing resource determination.

SECTION A. EXPANDED NATIONAL REGISTER CRITERIA FOR BRIDGE EVALUATION

The following expanded National Register criteria are recommended for evaluating bridges. In order to qualify for listing, the resources must be intact examples of one of the subtypes. They must possess integrity of location, design, setting, materials, and association, except where noted (e.g., C.6.).

Examples offered below to illustrate the following criteria are intended to guide, rather than limit, application of the criteria in bridge evaluation. These examples and those offered in Section B provide general guidelines for criteria application.

A bridge is eligible for the National Register of Historic Places if it meets one of the following criteria:

(A) It is associated with events that have made a significant contribution to the broad pattern of our history.

A.1. reflects trends in the social, economic, industrial, and transportation development of the locality, state, region, or nation;

A.2. is associated with historical crossings.

(B) It is associated with the lives of persons significant in our past.

B.1. is associated with the efforts of specific individuals or groups significant in the history of the locality, region, state, or nation.

(C) It embodies the distinctive characteristics of a type, period, or method of construction, or represents the work of a master, or possesses high artistic values.

C.1. is significant in the history of bridge engineering, in the history of bridge design principles, or in the development of bridge construction techniques;

C.2. is an example of bridges designed or built by renowned engineers, craftsmen, bridge companies, or contractors;

C.3. is a significant example of engineering solutions developed in response to conditions characteristic of the locality or region;

C.4. reflects traditional forms or construction techniques, or exemplifies innovative technological solutions;

C.5. retains sufficient integrity of design, materials, workmanship, association, setting, and location to stand as a representative example of a specific bridge type which may survive in substantial numbers;

C.6. exemplifies a bridge type which is now rare, even though its integrity may be compromised to a greater degree;

C.7. possesses architectural or artistic distinction in overall design or detailing.

(D) It has yielded, or may be likely to yield, information important in history or prehistory.

D.1. is likely to reveal important information on the development of bridge technology;

D.2. may yield important information on the work of a currently unknown or little-known bridge builder.

A Note on Criterion D Eligibility

In certain instances, a bridge may be eligible for the National Register of Historic Places under Criterion D, for properties that have yielded, or may be likely to yield, information important in prehistory or history. Criterion D is intended to address the need for data obtained directly from physical structures to answer important research questions. Criterion D eligibility has two initial requirements, *both of which must be met in order for a bridge to qualify*:

1. The bridge must have, or have had, information important to our understanding of human history or prehistory, and

2. The information must be considered important.

Under the first requirement, a bridge may be eligible for the National Register if it has been used as a source of data and contains more as yet unretrieved data. A bridge may also be eligible if it has not yet yielded information but, through testing or research, is determined a likely source of data.

Under the second requirement, the information must be carefully evaluated within an appropriate context to determine its importance. Information is considered important when it is shown to have a significant bearing on a research design that addresses current data gaps, alternative theories that challenge existing ones, or priority areas identified under a State or Federal agency management plan.

Bridges must meet these two requirements in order to be eligible under Criterion D. Additionally, a bridge must be, or must have been the *principal* source of the information. Generally, bridges may be likely to reveal important information on the development of bridge technology, or on the work of a currently unknown or little-known bridge builder. Bridges likely to be eligible under Criterion D may include:

1. Bridges of types rarely represented in the state, region, or nation.

2. Bridges of technologically innovative types or designs, where little or no additional information is available about the innovations employed.

3. Bridges built or designed by little-known persons, groups, bridge builders, engineers, or firms.

4. The oldest Maryland examples of each particular bridge type and subtype (including twentieth century structures of standardized or common design or configuration). Such bridges are eligible as the principal sources for important information concerning the introduction and early development of bridge technologies within Maryland. For each bridge type or subtype, more than one such early bridge may be evaluated as eligible under Criterion D.

SECTION B. PATTERNS, EVENTS, PERSONS, CULTURAL VALUES, AND LOCATIONAL PATTERNS TO CONSIDER BY SUBTYPE

1. TIMBER BRIDGES

A. Timber-Beam Bridges

Patterns:

Timber-beam bridges are generally associated with the steady expansion of the rural road network throughout Maryland in the period of significance (1724-circa 1900), under local and county authority. Multiple-span timber-beam highway bridges may be associated with the growing professionalism of highway engineering in Maryland during the latter part of the period.

Events:

Timber-beams should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A timber-beam bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Timber-beams should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular timber-beam bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Persons:

Timber-beams should be evaluated for significant association with specific builders, engineers or architects, or builders. These may include individual professionals, engineering or architectural firms of local, state, or national importance, government agencies, as well as significant nonprofessional builders. *Timber-beams known to have been built by local labor are not eligible through such association alone.*

Timber-beam bridges like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Timber-beam bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a timber-beam bridge associated with the group may be eligible. Otherwise, a timber-beam bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Cultural Values:

Timber-beam bridges are not generally associated with specific cultural values. Like stone arches, they embody a craftsman tradition deriving from colonial and European sources.

Locational Pattern:

In Maryland, timber-beam bridges may be expected to have been built throughout the state, but with a likely preponderance in low-lying Tidewater areas.

B. Timber-Truss (Uncovered) Bridges

Patterns:

Timber-truss (uncovered) bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the period of significance (1800-1900), under local and county authority. Long-span timber-truss (uncovered) highway and railroad bridges were built during the early part of the period for major river crossings of highways and railroads.

Timber-truss (uncovered) bridges are also associated with the transition to professionalism within American civil engineering during the period of significance. Many timber-truss (uncovered) bridges were built to popular proprietary or patented designs (Burr, Town, Howe, and others) developed during the early nineteenth century by bridge builders.

Events:

Timber-truss (uncovered) bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A timber-truss (uncovered) bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Timber-truss (uncovered) bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular timber-truss (uncovered) bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Since many timber-truss (uncovered) bridges were built to popular proprietary or patented designs (Burr, Town, and others) developed during the early nineteenth century by bridge builders, a timber-truss (uncovered) bridge also may retain significance as a good or representative Maryland example of a particular proprietary or patented type (*earliest* and *longest* examples included).

<u>Persons</u>:

Timber-trusses should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. *Timber-truss (uncovered) bridges known to have been built by local labor are not eligible through such association alone.*

Timber-truss (uncovered) bridges like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Timber-truss (uncovered) bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a timber-truss (uncovered) bridge associated with the group may be eligible. Otherwise, a timber-truss (uncovered) bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

<u>Cultural Values</u>:

Timber-truss (uncovered) bridges are not generally associated with specific cultural values. Like timber-beam and stone arch bridges, they do embody a craftsman tradition deriving from colonial and European sources. Associated with the craftsman tradition as well as proprietary or patented designs, timber-truss (uncovered) bridges represent the nineteenth-century transition toward professional bridge engineering.

Locational Pattern:

In Maryland, timber-truss (uncovered) bridges were built throughout the state, but with a probable predominance in the Piedmont and Appalachian Plateau areas.

C. Timber-Truss Covered Bridges

Patterns:

Timber-truss covered bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the period of significance (1800-1900), under local and county authority. Long-span timber-truss highway and railroad bridges were built during the early part of the period for major river crossings of highways and railroads.

Timber-truss covered bridges are also associated with the transition to professionalism within American civil engineering during the period of significance. Many timber-truss bridges were built to popular proprietary or patented designs (Burr, Town, Howe, and others) developed during the early nineteenth century by bridge builders.

Events:

Timber-truss covered bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A timber-truss covered bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Timber-truss covered bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular timber-truss bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Since many timber-truss bridges were built to popular proprietary or patented designs (Burr, Town, and others) developed during the early nineteenth century by bridge builders, a timber-truss bridge also may retain significance as a good or representative Maryland example of a particular proprietary or patented type (*earliest* and *longest* examples included).

Persons:

Timber-trusses should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. *Timber-truss covered bridges known to have been built by local labor are not eligible through such association alone.*

Timber-truss bridges like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Timber-truss bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a timber-truss bridge associated with the group may be eligible. Otherwise, a timber-truss bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Cultural Values:

Timber-truss bridges are not generally associated with specific cultural values. Like timber-beam and stone arch bridges, they do embody a craftsman tradition deriving from colonial and European sources. Associated with the craftsman tradition as well as proprietary or patented designs, timber-truss bridges represent the nineteenth-century transition toward professional bridge engineering.

Locational Pattern:

In Maryland, timber-truss bridges were built throughout the state, but with a probable predominance in the Piedmont and Appalachian Plateau areas.

D. Timber-Trestle Bridges

Patterns:

Timber-trestle bridges are generally associated with the steady expansion of the rail transportation network, including railroads and street railways, throughout Maryland in the period of significance (1840-1900).

Timber-trestle bridges are also associated with the rise of professionalism within American civil engineering during the period of significance. Timber-trestle bridges were typically built by railroads or street railways to carry rail traffic efficiently and inexpensively over deep ravines or gorges.

Events:

Timber-trestle bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A timber-trestle bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Timber-trestle bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular timber-trestle bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Persons:

Timber-trestle bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. *Timber trestles known to have been built by local labor are not eligible through such association alone.*

Timber-trestle bridges like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Timber-trestle bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a timber-trestle bridge associated with the group may be eligible. Otherwise, a timber-trestle bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Cultural Values:

Timber-trestle bridges are not generally associated with specific cultural values.

Locational Pattern:

In Maryland, timber-trestle bridges were built throughout the state, but with a probable predominance in the more rugged Piedmont and Appalachian Plateau areas.

E. Timber-Concrete Composite Bridges

Patterns:

Timber-concrete composite bridges are specifically associated with the expansion and improvement of the Maryland state roads network, under the aegis of the State Roads Department, during the period of significance (1935-1960).

Events:

Timber-concrete composite bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A timber-concrete composite bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Timber-concrete composite bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular timber-concrete composite bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Persons:

Timber-concrete composite bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Many timber-concrete composite bridges derive significance from association with the effort of engineers of the Maryland State Roads Commission to improve Tidewater highways, during the period of significance. *Timber-concrete composite bridges known to have been built by local labor are not eligible through such association alone.*

Timber-concrete composite bridges like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Timber-concrete composite bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a timber-concrete composite bridge associated with the group may be eligible. Otherwise, a timber-concrete composite bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

<u>Cultural Values</u>:

Timber-concrete composite bridges are not generally associated with specific cultural values.

<u>Locational Pattern</u>:

In Maryland, timber-concrete composite bridges were built primarily, if not exclusively, in the lower-lying Tidewater area, where conditions favored their construction by the Maryland State Roads Commission at important highway crossings over water bodies.

2. STONE ARCH BRIDGES

<u>Patterns</u>:

Stone arch bridges are generally associated with the steady expansion of the transportation network, including roads, railroads, and canals, throughout Maryland in the periods of significance.

Stone arch highway bridges constructed during the 1790-1830 period are typically associated with the improvement of Maryland's road system through construction of turnpikes and the National Road. Stone arch highway bridges built after 1830 reflect the further expansion of the road system, and the gradual refinement of stone arch bridge engineering and construction.

Stone arch railroad bridges built between 1825 and 1850 are associated with the initial founding and expansion of railroads (notably the B&O Railroad) throughout Maryland. Stone arch railroad bridges built between 1850 and 1910 reflect the further expansion and improvement of the rail network, and the gradual refinement of stone arch bridge engineering and construction.

Stone arch canal bridges (including aqueducts and culverts) built between 1828 and 1924 are generally associated with the construction and operation of the C&O Canal, Maryland's prime canal through the Piedmont and Appalachian Plateau.

<u>Events</u>:

Stone arch bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A stone arch bridge may derive significance from such association alone, under the historic period theme of "transportation", as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Stone arch bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular stone arch bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Stone arches may be associated with specific transportation-related events of significance that occurred over time, such as the construction of the National Road or specific turnpikes, the building and expansion of the B&O Railroad and other railroads, and the building and operation of the C&O Canal and other canals.

<u>Persons</u>:

Stone arch bridges should be evaluated for significant association with specific builders, masons, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad, canal) engineering departments.

Stone arches like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Stone arch bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a stone arch bridge associated with the group may be eligible. Otherwise, a stone arch bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Cultural Values:

Stone arch bridges are not generally associated with specific cultural values. They do embody a craftsman tradition derived from colonial and European sources. Stone arch highway bridges built between 1790 and 1830, and stone arch railroad bridges built between 1825 and 1850, are often associated with locally prominent craftsmen such as the Lloyds and their associates. Refining the basic earlier craftsman tradition, stone arch highway and railroad bridges built after 1850 may be associated with specific engineers, or highway and railroad engineering departments.

Locational Pattern:

In Maryland, stone arch bridges were built primarily in the Piedmont and Appalachian Plateau areas, where building materials were readily found and site conditions were favorable such as long-standing fords and mill sites.

3. METAL TRUSS BRIDGES

Patterns:

Metal truss bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the periods of significance.

Metal truss highway and railroad bridges of the 1840-1860 period are significantly associated with the initial development of metal truss bridge design, and the transition from truss building solely in timber to iron truss design and construction. Truss bridges built in this period are also often associated with early proprietary or patented designs.

Metal truss highway and railroad bridges of the 1860-1900 period are associated with the late nineteenth century popularization and scientific standardization of truss design and construction for highway and railroad use. Truss bridges built in this period also often are associated with a wide variety of proprietary or patented designs.

Metal truss highway and railroad bridges of the 1900-1960 period are associated with the increasing standardization of highly useful simply-designed truss types (primarily Pratt and Warren variants), and are also associated with select use in Maryland's monumental highway spans and their approaches.

Events:

Metal truss bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A metal truss bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Metal truss bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular metal truss bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Metal trusses may be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific turnpikes, highways, or railroads, and the expansion of the B&O Railroad and other railroads.

Metal trusses may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented truss designs.

Persons:

Metal truss bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Metal truss bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, owing to the design of such bridges to a wide variety of patented or proprietary truss types during all periods of significance. Metal trusses should be evaluated for their association with particular proprietary or patented design types, and their designers (including less well-represented types as well as the more commonly found Pratt and Warren variants).

Metal truss bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a metal truss bridge associated with the group may be eligible. Otherwise, a metal truss bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Metal trusses like other bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Metal truss bridges are not generally associated with specific cultural values.

Locational Pattern:

Metal truss bridges were built throughout the state.

4. MOVABLE BRIDGES

Patterns:

Movable bridges of all types are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the periods of significance. Movable bridges are also generally associated with the maritime history of Maryland, the maritime history of specific regions and jurisdictions (counties, towns, cities, other communities), and specifically with the maritime and navigation history of particular navigable bodies of water or canals.

Movable bridges of the 1790-1850 period are associated with the introduction and initial Maryland use of movable spans (primarily swing and bascule bridges) at key highway and railroad crossings of navigable bodies of water.

Movable bridges of the 1850-1900 period are generally associated with scientific and technological improvements in movable bridge design and construction, such as the employment of metal and the development of new variants of bascule, swing, and vertical lift designs and patents.

Movable bridges of the 1900-1940 period are generally associated with the design and construction of major, modern significant movable spans built in Maryland, by the State Roads Commission and other governmental authorities as well as major railroads.

<u>Events</u>:

Movable bridges should be evaluated for any specific association with maintenance of important stream and river crossings (and for association with navigation on the relevant water body) near individual communities, farmsteads, mills, commercial sites, or industrial sites. A movable bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Movable bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular movable bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Movable bridges may also be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific highways or railroads, or the improvement of navigation along a specific body of water or within a specific jurisdiction.

Movable bridges may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented movable bridge designs.

<u>Persons</u>:

Movable bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Movable bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, owing to the design of such bridges to a wide variety of patented or proprietary movable bridge types during all periods of significance. Movable bridges should also be evaluated for their association with particular proprietary or patented movable bridge design types, and their designers (including well-known variants as well as lesser-known types).

Movable bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a movable bridge associated with the group may be eligible. Otherwise, a movable bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Movable bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Movable bridges are not generally associated with specific cultural values.

Locational Pattern:

In Maryland, movable bridges of all types were built primarily in the lower-lying Tidewater area, where the need to preserve the commercial navigability of bodies of water favored their construction in all periods of significance.

5. METAL GIRDER BRIDGES

Patterns:

Metal girder bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the periods of significance.

Metal girder bridges built between 1846 and 1870 are generally associated with the introduction and early spread of metal girder bridge technology in Maryland, for railroad and highway use.

Metal girder bridges built between 1870 and 1920 are generally associated with the late nineteenth century and early twentieth century popularization and scientific standardization of metal girder design and construction for highway and railroad use.

Metal girder bridges built between 1920 and 1965 are generally associated with increasingly heavy employment of metal girder bridges for highway and railroad bridges, by governmental authorities (the State Roads Commission and county and municipal agencies) and corporate organizations such as railroads. Many metal girder bridges of this period are associated with the state and national grade crossing elimination movement, a continuing public effort to eliminate dangerous at-grade crossing of railroad tracks by automotive and wagon traffic.

Events:

Metal girder bridges should be evaluated for any specific association with maintenance of important stream and river crossings (and for association with navigation on the relevant water body) near individual communities, farmsteads, mills, commercial sites, or industrial sites. A metal girder bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Metal girder bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular metal girder bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Metal girder bridges may also be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific highways or railroads. Many metal girder bridges built between 1920 and 1965 are associated with the grade crossing elimination movement, a continuing public effort to eliminate dangerous at-grade crossing of railroad tracks by automotive and wagon traffic.

Metal girder bridges may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented metal girder bridge designs.

Persons:

Metal girder bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Metal girder bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, owing to the design of such bridges to a variety of patented or proprietary girder types during all periods of significance. Metal girder bridges should be evaluated for their association with particular proprietary or patented metal girder bridge design types, and their designers (including well-known variants as well as lesser-known types).

Metal girder bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a metal girder bridge associated with the group may be eligible. Otherwise, a metal girder bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Metal girder bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Metal girder bridges are not generally associated with specific cultural values.

Locational Pattern:

Metal girder bridges were built throughout the state.

6. METAL SUSPENSION BRIDGES

Patterns:

Metal suspension bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the periods of significance.

Metal suspension bridges built between 1800 and 1840 are generally associated with the introduction of metal cable and wire rope suspension span technology in Maryland and surrounding states, by suspension bridge pioneers Finley and Ellet and associates.

Metal suspension bridges built between 1850 and 1900 are generally associated with the popularization and spread of metal cable and wire rope suspension span technology in Maryland and surrounding states. A select, known specific class of metal suspension bridge built in this period of significance are locally engineered swinging footbridges built for pedestrian access to commercial and industrial sites in Maryland.

Metal suspension bridges built between 1900 and 1960 are generally associated with the refinement of wire rope suspension bridge technology, reflecting the influence of master engineers such as the Roeblings and Othmar Ammann.

Events:

Metal suspension bridges should be evaluated for any specific association with maintenance of important stream and river crossings (and, in the case of high, monumental fixed spans, for association with navigation on the relevant water body) near individual communities, farmsteads, mills, commercial sites, or industrial sites. A metal suspension bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Metal suspension bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular metal suspension bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Metal suspension bridges may also be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific highways or railroads. Monumental, metal suspension bridges of the 1900-1960 period are specifically associated with the Maryland State Roads Commission's continuing effort to improve significant major water crossings (the notable example is the Chesapeake Bay Bridge).

Metal suspension bridges may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented metal suspension bridge designs.

Persons:

Metal suspension bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Metal suspension bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, owing to the design of such bridges to a variety of patented or proprietary suspension bridge types during all periods of significance. Metal suspension bridges should be evaluated for their association with particular proprietary or patented metal suspension bridge design types, and their designers (including well-known variants as well as lesser-known types).

Metal suspension bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a metal suspension bridge associated with the group may be eligible. Otherwise, a metal suspension bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Metal suspension bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Metal suspension bridges are not generally associated with specific cultural values.

Locational Pattern:

Metal suspension bridges were built throughout the state.

7. METAL ARCH BRIDGES

Patterns:

Metal arch bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the periods of significance.

Metal arch bridges built between 1870 and 1900 are generally associated with the introduction of metal bowstring arch and deck arch technology to the state, exemplified by small rural bowstring arch-truss bridges as well as larger, more ornamented Baltimore City structures of the 1880s.

Metal arch bridges built between 1930 and 1960 are generally associated with the design and construction of modern through bowstring arches by the State Roads Commission, Baltimore City, and other authorities.

Events:

Metal arch bridges should be evaluated for any specific association with maintenance of important stream and river crossings (and, in the case of high, monumental arch spans, for association with navigation on the relevant water body) near individual communities, farmsteads, mills, commercial sites, or industrial sites. A metal arch bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Metal arch bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular metal arch bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Metal arch bridges may also be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific highways or railroads. Monumental, metal arch bridges of the 1930-1960 period are specifically associated with the Maryland State Roads Commission's continuing effort to improve significant major water crossings.

Metal arch bridges may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented metal arch bridge designs.

Persons:

Metal arch bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Metal arch bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, owing to the design of such bridges to a variety of patented or proprietary metal arch types during all periods of significance. Metal arch bridges should be evaluated for their association with particular proprietary or patented metal arch bridge design types, and their designers (including well-known variants as well as lesser-known types).

Metal arch bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a metal arch bridge associated with the group may be eligible. Otherwise, a metal arch bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Metal arch bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Metal arch bridges are not generally associated with specific cultural values.

Locational Pattern:

Metal arch bridges were built throughout the state.

8. METAL CANTILEVER BRIDGES

Patterns:

Metal cantilever bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the period of significance.

Metal cantilever bridges built between 1900 and 1940 are generally associated with the scientific development and refinement of cantilever truss design and construction (exemplified by Maryland's outstanding monumental cantilever, the 1940 Governor Harry W. Nice Memorial Bridge).

Events:

Metal cantilever bridges should be evaluated for any specific association with maintenance of important stream and river crossings (and, in the case of high, monumental cantilever spans, for association with navigation on the relevant water body) near individual communities, farmsteads, mills, commercial sites, or industrial sites. A metal cantilever bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Metal cantilever bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular metal cantilever bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Metal cantilever bridges may also be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific highways or railroads. Monumental, metal cantilever bridges of the 1900-1940 period are specifically associated with the Maryland State Roads Commission's continuing effort to improve significant major water crossings.

Metal cantilever bridges may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented metal cantilever bridge designs.

Persons:

Metal cantilever bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Metal cantilever bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, due to the design of such bridges to a variety of patented or proprietary cantilever types during all periods of significance. Metal cantilever bridges should be evaluated for their association with particular proprietary or patented metal cantilever bridge design types, and their designers (including well-known variants as well as lesser-known types).

Metal cantilever bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a metal cantilever bridge associated with the group may be eligible. Otherwise, a metal cantilever bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Metal cantilever bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Metal cantilever bridges are not generally associated with specific cultural values.

Locational Pattern:

Metal cantilever bridges were likely built throughout the state.

9. CONCRETE BRIDGES

Patterns:

Concrete bridges are generally associated with the steady expansion of the transportation network, including roads and railroads, throughout Maryland in the period of significance.

Concrete bridges built between 1890 and 1910 are generally associated with the introduction of concrete and reinforced concrete technology to the state, under the leadership of Baltimore City, Baltimore County, the Maryland Geological Survey Highway Division, and the State Roads Commission.

Concrete bridges built between 1910 and 1940 may generally be associated with the increasing standardization of small concrete bridges (notably beam bridges, simple arches, and culverts) by state and local authorities. Some bridges of this period are associated with the further refinement of concrete bridge design and technology (notably open-spandrel ribbed arches and rigid frames).

Concrete bridges built between 1910 and 1940 may also be associated with the influence in Maryland of the nationwide "City Beautiful" movement (notably Luten arches and open-spandrel ribbed arches).

Concrete bridges built between 1910 and 1940 may also be associated with the grade crossing elimination, a continuing public effort to eliminate dangerous at-grade crossing of railroad tracks by automotive and wagon traffic (notably concrete beam bridges).

Concrete bridges built between 1940 and the present are generally associated with continuing scientific testing and standardization of concrete highway bridge technology, and the development of prestressing techniques.

Events:

Concrete bridges should be evaluated for any specific association with maintenance of important stream and river crossings near individual communities, farmsteads, mills, commercial sites, or industrial sites. A concrete bridge may derive significance from such association alone, under the historic period theme of "transportation," as defined in Maryland Historical Trust, *Maryland Supplement to National Register Bulletin* 16A (1992).

Concrete bridges should also be evaluated for significant association with specific Maryland political, economic, social, or military events. To be eligible under association with such specific events, a particular concrete bridge must have played a direct, documented historical role in such events. For this kind of specific event association, it is not sufficient for the bridge to be a *successor* to the actual bridge where the event took place.

Concrete bridges may also be associated with specific transportation-related events of significance that occurred over time, such as improvement of specific highways or railroads. Technological innovations of the late nineteenth and early twentieth century, many concrete bridges are associated with local and state governmental efforts to improve Maryland's road system.

Concrete bridges may also be associated with events important in the history of bridge engineering, such as the evolution of specific proprietary or patented concrete bridge designs.

Persons:

Concrete bridges should be evaluated for significant association with specific builders, engineers, or architects. These may include individual professionals, engineering or architectural firms of local, state, or national importance, as well as significant nonprofessional builders. Also included are governmental (state, county, city, or local) and corporate (railroad) engineering departments.

Concrete bridges may be significantly associated with individual bridge builders, engineers, or bridge-building companies, owing to the design of such bridges to a variety of patented or proprietary concrete types during all periods of significance. Concrete bridges should be evaluated for their association with particular proprietary or patented concrete bridge design types, and their designers (including well-known variants as well as lesser-known types).
Concrete bridges may also be eligible for the National Register if they are associated with the efforts of specific individuals or groups significant in the history of a Maryland community, region, the state itself, or the nation. If a group includes members of individual distinction, a concrete bridge associated with the group may be eligible. Otherwise, a concrete bridge associated with a group should be evaluated for association with specific Maryland political, economic, social or military events associated with the group (see "Events" discussion above).

Concrete bridges may also be associated with specific persons of local, state, or national importance, through association with specific political, economic, social, or military events.

Cultural Values:

Concrete bridges are not generally associated with specific cultural values.

Locational Pattern:

Concrete bridges were built throughout the state.

10. BROAD PATTERNS

Geographical and Topographical Association:

Geography and topography exert influence over bridge building throughout all periods of significance. This geographical or topographical association appears to be strongest in Maryland for movable bridges (Tidewater), stone arches (Piedmont, Appalachian Plateau), and timber-concrete composite bridges (Tidewater).

Bridge types often tailored for Tidewater conditions include timber beam, timber-concrete composite structures, movables of all types, and high, fixed spans of many types, including long timber covered bridges, suspension spans, metal arches, and cantilevers. Due to unavailability of locally quarried stone, the Tidewater does not generally feature stone arch bridges. Where watercourses were not or were no longer required for navigation, lower fixed spans of all types were built.

Bridge types often tailored for Piedmont conditions include nearly all types, although movable bridges were rare (confined to railroad spans over the C&O Canal). Stone arches on turnpike routes leading out of Baltimore are a special category of bridge adapted for the Piedmont. The versatile covered timber and metal truss bridges gained ascendancy at small and medium-sized crossings during the nineteenth century; their moderate-span successors, concrete bridges, also superseded many stone arches.

Bridge types often tailored for Appalachian Plateau conditions include nearly all types, although movable bridges were rare (confined to railroad spans over the C&O Canal). Conditions familiar in the Piedmont (steep cuts, limited available crossings) were accentuated in the Plateau area; bridge types built, however, were essentially the same as those seen in the Piedmont.

SECTION C. PHYSICAL AND ASSOCIATIVE CHARACTERISTICS AND HISTORIC INTEGRITY CONSIDERATION

Historic integrity evaluation will depend on the level of integrity of location, design, setting, materials, and association. Materials evaluation requires clearly delineated characteristics of the resource type, with orders of importance stated. This is presented below. Integrity of location, setting, and association is a subjective evaluation, which needs to be considered as a part of the total resource integrity. Materials integrity will depend on the compromise to primary elements, with consideration of secondary elements for most bridge types. Commonly built, standardized bridge types which survive in large numbers should present integrity of all primary and secondary elements, and in some cases, tertiary elements.

For bridges being evaluated as possible contributing resources in a historic district, an additional guide to assessing character-defining elements has been provided (see Section D below for further discussion of bridges as contributing and noncontributing resources). Those elements which are character-defining elements are designated with [CDE]. In most cases those elements designated as primary [P] are also designated as character-defining elements [CDE], but not always. For example, identifying plaques, plates, and imprints, while helping to establish a bridge's individual eligibility, are not essential in determining a bridge's ability to contribute to the historic architectural qualities, historic associations, or archeological values for which a district is significant. For guidelines concerning bridges as contributing resources in historic districts, see Section D.

Element Importance

Element importance is dependent on the type of bridge in question. For each type of bridge there is a hierarchy of elements: those with primary importance [P] contribute in a major way to the structure's essential characteristics; those with moderate importance [S] are less crucial to those characteristics; tertiary elements [T] are incidental to the structure's essential characteristics. It should be noted that there are some elements, i.e., bridge plaques, that are very desirable when extant; they are given the highest element importance rating, as they often perform a major role in establishing the structure's significance. With regard to ornamentation, it should be noted that applied ornamentation is considered as a separate element; integral ornamentation, e.g., panels on a concrete arch bridge spandrel, are subsumed under the element itself.

If a bridge was designed with another design co-objective, additional functional features, e.g., water flow control devices, have an increased importance. Such additional functional features are considered later in this section.

Degree of Compromise

Degree of compromise refers to the amount of element destruction or replacement that has occurred. Obviously, total destruction or replacement of an element has a major impact on that element's historic integrity, and depending on the element's importance, on the historic integrity of the bridge as a whole.

Total replacement of an element is a major compromise, except in the case of in-kind replacement. Elements may be replaced by like-dimensioned elements when original elements have been damaged by accident or material deterioration; the fundamental material must be the same (i.e., timber must be replaced by timber, stone by stone, iron and steel by a ferric material, concrete by concrete), but materials with increased strength and/or reliability may be substituted if safety or availability requirements dictate. Thus, untreated wood may be replaced by treated wood, iron by steel, stone by concrete veneered appropriately with stone, etc.

The texture and color of such replacements should not be visually intrusive to the structure as a whole. Such in-kind replacements would be considered minor compromise of historic integrity; mass replacement of elements would need to be evaluated for historic integrity loss on a case-by-case basis.

Elements replaced by materials that fall short of in-kind replacement, but are not disruptive to the element's as-built structural and visual impact, should be considered as having suffered a moderate loss of historic integrity. Elements that have been replaced by totally inappropriate elements have suffered a major loss of historic integrity.

In some instances, an existing bridge has been strengthened by another structural system, while the original structure remains largely intact. The degree of compromise would depend on the amount of the original structure which remains intact. Bridges reinforced or strengthened by added structural systems would need to be evaluated on a case-by-case basis.

Alteration Assessment

Evaluation of the individual National Register eligibility of a bridge assumes a knowledge of all alterations and changes made to the bridge since its construction. Such knowledge may be gained from a thorough investigation of existing official bridge records, plans, and historical sources regarding the bridge. Assessment of the alterations or changes made to a bridge should gauge the impact of the alterations or changes upon the overall significance and historic integrity of the bridge. Certain alterations or changes made within the period of significance may be considered significant alterations or changes which contribute to the overall historical and technological significance of the bridge. That assessment should be made on a case-by-case basis.

The period in which an alteration occurred is relevant to gauging the seriousness of its impact on the structure. A recent alteration is more serious than one which occurred within the structure's period of significance; not only is the degree of alteration likely to be greater, but a modern change most often will reflect technology and engineering solutions that were not available during the structure's period of significance, thus skewing the overall impact of the structure. An exception to this is in-kind replacement which attempts to mimic the original appearance of the replaced element; an in-kind replacement should be considered neutral with regard to period of alteration. That is, there should be no period penalty for in-kind replacement.

Contributing and Noncontributing Resources

A bridge may also be a contributing resource within a National Register-listed or National Register-eligible historic district. If a bridge retains certain character-defining elements [CDE], it may be listed as a contributing resource to a historic district. For each type and subtype of bridge, the character-defining elements [CDE] have been indicated. All character-defining elements [CDE] for contributing resource evaluation are also primary elements [P] for individual National Register eligibility.

As indicated, serious alterations of a bridge at any time since its construction may reduce the bridge's individual eligibility for the National Register, if the alterations reduce the overall historical and technological significance of the bridge. For contributing resource determinations, however, alterations or changes made to a bridge *during the related historic district's period of significance* may reflect the significant historical and architectural themes and associations that characterize the district. Such alterations or changes do not automatically disqualify a bridge from status as a contributing resource to a National Register-listed or eligible historic district.

If sufficiently serious, alterations and changes made to a bridge may render the bridge a noncontributing resource to a district. Alterations made to a bridge after a related historic district's period of significance may render the bridge a noncontributing resource if such alterations have seriously impacted the bridge's character-defining elements.

I. TIMBER BRIDGES

A. Beam Bridges

Note: beam bridges may be used as culverts (bridges with spans of less than 20 feet)

1. Superstructure

   a. longitudinal beams (stringers) [P] [CDE]

   b. floor system [S]

   c. deck [T]

   d. railing [P] [CDE]

   e. applied ornamentation (rare) [T]

   f. identifying plaques, plates, or imprints [P]

   g. additional functional features* ([T] unless a primary design co-objective, then [P])

   h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

*additional functional features could include:

1. lamp posts - if designed for bridge and integrated into design, their loss or disharmonious replacement becomes more serious; importance declines with technological interest of bridge type
2. streetcar tracks - if provision for streetcars was a primary design co-objective, tracks increase in importance
3. streetcar catenary supports and lines - if provision for streetcars was a primary design co-objective, catenary supports and lines increase in importance
4. toll houses - if designed as an important architectural element of the bridge, toll houses increase in importance
5. signage and traffic control devices - gates for movable bridges are more important than signage on other types of bridges
6. manhole covers - if designed specially for bridge, manhole covers increase in element importance, but never to exceed secondary importance.
7. utility pipes and conduits - if integrated into design as visually or structurally important element, their loss is important; otherwise, they are of negligible importance, unless the retrofitting of them has seriously compromised design
8. water flow control devices - if bridge was designed with the control of water flow as a primary co-objective, the device should be accorded a primary element status; retrofitted devices should be accorded secondary status if fitted within the structure's period of significance; otherwise they are tertiary.

2. Substructure

   a. abutments [P] [CDE] - timber, masonry, or concrete

   b. pile bents or piers of timber, masonry, or concrete [P] [CDE]

   c. applied ornamentation [S]

   d. identifying plaques, plates, or imprints [P]

   e. endpost section of railing, attached to abutment [S]

   f. additional functional features* ([T] unless a primary design co-objective, then [P])

   g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Truss - Uncovered

Note: uncovered truss bridges may be used as culverts (bridges with spans of less than 20 feet)

1. Superstructure

   a. Truss (types = king-post, queen-post, Pratt [timber & iron], Haupt (e.g. 1866 Susquehanna River bridge [w/swing span])

      i. endpost [P] [CDE]

      ii. bottom chord [P] [CDE]

      iii. vertical(s) [P] [CDE]

      iv. top chord (not present on king-post) [P] [CDE]

      v. floor beams [P]

      vi. stringers - [P]

   b. deck [S]

c. railing [S]

d. applied ornamentation [T]

e. identifying plaques, plates, and imprints [P]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural properties, historic associations, or archeological values for which a district is significant)

2. Substructure

a. abutments of timber, masonry or concrete [P] [CDE]

b. pier(s) of timber, masonry or concrete - [P] [CDE] when present

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [T]

e. endpost section of railing, attached to abutment [S]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural properties, historic associations, or archeological values for which a district is significant)

C. Truss - Covered

1. Superstructure - structural

a. Truss (types = king-post, queen-post, Town, Burr, Burr-arch, Long)

i. endpost [P] [CDE]

ii. bottom chord [P] [CDE]

iii. vertical(s) [P] [CDE]

iv. top chord (not present on king-post) [P] [CDE]

v. arch (present in Burr-arch) [P] [CDE]

vi. floor beams [P]

vii. stringers [P]

b. deck [S]

c. railing (n/a)

d. applied ornamentation (probably not an issue)

e. identifying plaques, plates, and imprints [P]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. Superstructure - covering

a. Framing [S]

b. Roof [P] [CDE]
roofing material [S]

c. Siding [P] [CDE]

d. Portals [P] [CDE]

e. applied ornamentation [S]

f. identifying plaques, plates, and imprints [P]

g. additional functional features* ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

3. Substructure

a. abutments of masonry or concrete [P] [CDE]

b. pier(s) of masonry or concrete [P] - when present [CDE]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. endpost section of railing, attached to abutment [S]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

D. Trestle

1. Superstructure

a. beams [P] [CDE]

b. railing of timber [S]

2. Substructure

a. abutments of timber, masonry or concrete [P] [CDE]

b. piers of timber [P] [CDE] (or)

c. bents of timber [P] [CDE]

3. applied ornamentation [T]

4. identifying plaques, plates, and imprints [P]

5. additional functional features* ([T] unless a primary design co-objective, then [P])

6. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

E. Timber and concrete Composite

1. Superstructure

    a. composite timber and concrete slab [P] [CDE]

    b. railing of timber or concrete [P] [CDE]

    c. applied ornamentation [T]

    d. identifying plaques, plates, and imprints [P]

    e. additional functional features ([T] unless a primary design co-objective, then [P])

    f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. Substructure

    a. timber piers (or) [S] [CDE]

    b. timber bents [S] [CDE]

    c. applied ornamentation [T]

    d. identifying plaques, plates, and imprints [P]

    e. endpost section of railing, attached to abutment

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

II. STONE ARCH BRIDGES

Note: stone arch bridges may be used as culverts (bridges with spans of less than 20 feet)

A. material

1. stone

2. brick (rarely)

B. fabrication: masonry

1. rubble (rough unfinished and untooled stones)

2. squared (stones tooled to rectangular shape and roughly finished)

3. ashlar (squared stones given more refined finish)

C. structure

1. superstructure

a. arch ring [P] [CDE]

b. barrel [P] [CDE]

c. spandrel wall [P] [CDE]

d. parapet [P] [CDE]

e. fill [S] [CDE] - incapable of compromise

f. roadway [T]

g. applied ornamentation [T]

h. identifying plaques, plates, and imprints [P]

i. additional functional features* ([T] unless a primary design co-objective, then [P])

j. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. abutments [P] [CDE]

b. wing walls [P] [CDE]

c. pier(s) [P] [CDE]

d. applied ornamentation [T]

e. identifying plaques, plates, and imprints [P]

f. endpost section of parapet, attached to abutment [S]

g. additional functional features* - ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

III. METAL TRUSS BRIDGES

A. Superstructure

1. Truss

a. Truss elements (built-up members composed of channels, angles, metal lacing bars, gussets, and cover plates)

i. endpost [P] [CDE]

ii. bottom chord [P] [CDE]

iii. top chord [P] [CDE]

iv. verticals [P] [CDE]

v. diagonals [P] [CDE]
looped bottom (or)
eye bars

vi. floor beams [P] [CDE]

vii. stringers [S]

viii. bottom lateral bracing [T]

ix. sub-struts [S] [CDE]

x. sub-ties [S] [CDE]

The following additional elements are found in through truss bridges:

xi. portal strut [P] [CDE]

xii. portal bracing [P] [CDE]

xiii. top lateral bracing [S] [CDE]

b. Method of truss connection

i. pinned [S] [CDE]
cotter pins (or)
square nuts (or)
hexagonal nuts (or)

ii. riveted [S] [CDE]

2. deck (timber) [T]

3. railing [S]

4. applied ornamentation [T]

5. identifying plaques, plates, and imprints [P]

6. additional functional features* ([T] unless a primary design co-objective, then [P])

7. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Substructure

1. abutments of stone, concrete, or timber [P] [CDE]

2. bearing seats and shoes [S]

3. piers (when present) of stone or concrete [P] [CDE]

4. applied ornamentation [T]

5. identifying plaques, plates, and imprints [P]

6. endpost section of railing, attached to abutment [S]

7. additional functional features* ([T] unless a primary design co-objective, then [P])

8. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

IV. MOVABLE BRIDGES

A. Swing Bridges

1. superstructure

a. swing span (beam or truss)

i. pivot girder [P] [CDE]

ii. pivot [P] [CDE]
   - center-bearing type
     - discs
     - balance wheels
     - circular track
   - rim-bearing type
     - load-bearing wheels or bearings
     - circular track or drum

iii. drive machinery (including motive power, if not hand-operated) ([P], except motive power, which is [S])

iv. wedge end lifts (or equivalent mechanism) [P]

b. approach spans [S]

c. operator's house (optional) - [P or S]

d. deck [T]

e. railing [S]

f. applied ornamentation [T]

g. identifying plaques, plates, and imprints [P]

h. additional functional features* ([T] unless a primary design co-objective, then [P])

i. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. swing span related

i. central pier of masonry or concrete (supports center of swing span) [P] [CDE]

ii. end rest (supports end of swing span) [P] [CDE]

iii. fenders of timber (protects central pier and end rests) [T]

b. approach span related

i. piers of masonry or concrete or timber bents [S]

ii. piles of timber, steel, concrete [S]

iii. abutments [T]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. endpost section of railing, attached to abutment [S]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Bascule Bridges (single or multiple leaf)

1. superstructure

a. trunnion (or)

i. single trunnion (simple) or three trunnions (multiple) [P] [CDE]

ii. integral counterweight [P] [CDE]

iii. struts (multiple trunnion) [P] [CDE]

iv. drive machinery, including motive power ([P], except motive power, which is [S])

b. rolling lift

i. segmental girder [P] [CDE]

ii. track [P] [CDE]

iii. counterweight [P] [CDE]

iv. drive machinery, including motive power ([P], except motive power, which is [S])

c. operator's house (optional) [P or S]

d. deck [T]

e. railing [S]

f. applied ornamentation [T]

g. identifying plaques, plates, and imprints [P]

h. additional functional features* ([T] unless a primary design co-objective, then [P])

i. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. bascule span related

i. piers or piles [P] [CDE]

ii. fenders [T]

b. approach span related

i. piers [S]

ii. timber piles [S]

iii. abutments [T]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. endpost section of railing/parapet, attached to abutment [S]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

C. Vertical Lift Bridges

1. superstructure

a. movable section

i. towers (two) [P] [CDE]

ii. lifting span [P] [CDE] (supported by deck or through truss) - consult relevant span type

iii. overhead truss [P] [CDE] (optional; not needed if towers alone were sufficiently stable)

iv. drive machinery, including motive power if not hand-driven ([P] [CDE], except motive power, which is [S])

v. operator's house [P or S] (optional)

vi. applied ornamentation [T]

vii. identifying plaques, plates, and imprints [P]

viii. additional functional features* ([T] unless a primary design co-objective, then [P])

ix. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

b. approach spans [S]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. additional functional features* ([T] unless a primary design co-objective, then [P])

f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. movable span related

i. piers or piles [P] [CDE]

ii. fenders [T]

b. approach span related

i. piers [S]

ii. timber piles [S]

iii. abutments [T]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. additional functional features* ([T] unless a primary design co-objective, then [P])

f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

D. Retractile Bridges

1. superstructure

a. movable span related

i. stationary support span with track (supports movable span when open) [P] [CDE]

ii. movable span (beam or truss) equipped with load-bearing wheels or bearings [P] [CDE]

iii. drive machinery, including motive power if not hand-driven ([P], except motive power, which is [S])

b. approach spans [S]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. additional functional features* ([T] unless a primary design co-objective, then [P])

f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. movable span related

i. piers or piles [P] [CDE]

ii. fenders [T] -

b. approach span related

i. piers [S]

ii. timber piles [S]

iii. abutments [T, unless immediately adjoining movable span, then S]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. additional functional features* ([T] unless a primary design co-objective, then [P])

f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

E. Pontoon Bridges

1. superstructure - deck-timber [P] [CDE]

2. substructure

a. boats (or pontoons) [P] [CDE]

b. abutment, or bank anchor [P] [CDE]

3. applied ornamentation [T]

4. identifying plaques, plates, and imprints [P]

5. additional functional features* ([T] unless a primary design co-objective, then [P])

6. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

V. METAL GIRDER BRIDGES

Note: metal girder bridges may be used as culverts (bridges with spans of less than 20 feet)

A. Rolled Girder Bridges

1. superstructure

a. rolled longitudinal I-beams or wide flange beams [P] [CDE]

b. floor system [S]

c. deck [S]

d. railing [S]

e. applied ornamentation [T]

f. identifying plaques, plates, and imprints [P]

g. additional functional features* ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. abutments of stone, concrete, or timber [P] [CDE]

b. pier(s) (when present) of stone or concrete [P] [CDE]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. endpost section of railing, attached to abutment [S]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Rolled Girder Bridges (Concrete Encased)

1. superstructure

a. rolled longitudinal I-beams or wide flange beams [P] [CDE]; concrete encasement [P] [CDE]

b. floor system [S]

c. deck [T]

d. railing [S]

e. applied ornamentation [S]

f. identifying plaques, plates, and imprints [T]

g. additional functional features* ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. abutments of stone, concrete, or timber [P] [CDE]

b. pier(s) (when present) of stone or concrete [P] [CDE]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P] [CDE]

e. endpost section of railing, attached to abutment [S]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

C. Plate Girder Bridges

1. superstructure

a. plate girders [P] [CDE]

b. floor system [S]

c. deck [T]

d. applied ornamentation [T]

e. identifying plaques, plates, and imprints [P]

f. additional functional features* ([T] unless a primary design co-objective, then [P])

g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. abutments of stone, concrete, or timber [P] [CDE]

b. pier(s) (when present) of stone or concrete [P] [CDE]

c. applied ornamentation [T]

d. identifying plaques, plates, and imprints [P]

e. additional functional features* ([T] unless a primary design co-objective, then [P])

f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

D. Plate Girder Bridges (Concrete Encased)

1. superstructure

a. plate girders [P] [CDE]

b. concrete encasement [P] [CDE]

c. floor system [S]

d. deck [T]

e. applied ornamentation [S]

f. identifying plaques, plates, and imprints [P]

g. additional functional features* ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

a. abutments of stone, concrete, or timber [P] [CDE]

b. pier(s) (when present) of stone or concrete [P] [CDE]

c. applied ornamentation [S]

d. identifying plaques, plates, and imprints [P]

e. additional functional features* ([T] unless a primary design co-objective, then [P])

f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

VI. METAL SUSPENSION BRIDGES

A. Superstructure

1. tower [P] [CDE]

2. cradles [P] [CDE]

3. cable (or chain) [P] [CDE]

4. suspenders [P] [CDE]

5. stiffening truss [P] [CDE]; if absent [NA]

6. floor system [S]

7. deck [T]

8. applied ornamentation [S]

9. identifying plaques, plates, and imprints [P]

10. additional functional features* ([T] unless a primary design co-objective, then [P])

11. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Substructure

1. anchors (abutments) [P] [CDE]

2. piers [P] [CDE]

3. applied ornamentation [S]

4. identifying plaques, plates, and imprints [P]

5. additional functional features* ([T] unless a primary design co-objective, then [P])

6. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

VII. METAL ARCH BRIDGES

A. Superstructure

1. arch member

    a. curved girder [P] [CDE] (or)

    b. curved truss [P] [CDE]

        i. top chord [P] [CDE]

        ii. bottom chord [P] [CDE]

        iii. post (truss diagonal) [P] [CDE]

2. suspenders [P] [CDE]

3. ties [P] [CDE]

4. floor system [S]

5. deck [T]

6. applied ornamentation [T]

7. identifying plaques, plates, and imprints [P]

8. additional functional features* ([T] unless a primary design co-objective, then [P])

9. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Substructure

1. buttresses (abutments) [P] [CDE]

2. pier(s) - when present [P] [CDE]

3. applied ornamentation [T]

4. identifying plaques, plates, and imprints [P]

5. additional functional features* ([T] unless a primary design co-objective, then [P])

6. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

VIII. METAL CANTILEVER BRIDGES

A. Superstructure (truss or girder--see type for individual members)

1. anchor arms (2) [P] [CDE]

2. cantilever arms (2) [P] [CDE]

3. central suspended span (carried by anchor arms) [P] [CDE]

4. applied ornamentation [T]

5. identifying plaques, plates, and imprints [P]

6. additional functional features* ([T] unless a primary design co-objective, then [P])

7. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Substructure

1. piers supporting anchor arms [P] [CDE]

2. anchor piers supporting cantilever arms [P] [CDE]

3. abutments [S]

4. applied ornamentation [T]

5. identifying plaques, plates, and imprints [P]

6. additional functional features* ([T] unless a primary design co-objective, then [P])

7. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

IX. CONCRETE BRIDGES

A. Concrete Arch Bridges

Note: concrete arch bridges may be used as culverts (bridges with spans of less than 20 feet)

1. filled spandrel bridges

   a. superstructure

      i. arch ring [P] [CDE]

      ii. barrel [P] [CDE]

      iii. spandrel wall [P] [CDE]

      iv. fill [S] - incapable of compromise

      v. railing or parapet [P] [CDE]

      vi. applied ornamentation [S]

      vii. identifying plaques, plates, and imprints [P]

      viii. additional functional features* ([T] unless a primary design co-objective, then [P])

      ix. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

   b. substructure

      i. abutments [P] [CDE]

ii. wing walls [P] [CDE]

iii. pier(s) - when present [P] [CDE]

iv. applied ornamentation [S]

v. identifying plaques, plates, and imprints [P]

vi. endpost section of railing or parapet, attached to abutment [S]

vii. additional functional features* ([T] unless a primary design co-objective, then [P])

viii. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. closed spandrel bridges

a. superstructure

i. arch ribs [P] [CDE]

ii. spandrel wall [P] [CDE]

iii. railing or parapet [P] [CDE]

iv. applied ornamentation [S]

v. identifying plaques, plates, and imprints [P]

vi. additional functional features* ([T] unless a primary design co-objective, then [P])

vii. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

b. substructure

i. abutments [P] [CDE]

ii. wing walls [P] [CDE]

iii. pier(s) - when present [P] [CDE]

iv. applied ornamentation [S]

v. identifying plaques, plates, and imprints [P]

vi. endpost section of railing or parapet, attached to abutment [S]

vii. additional functional features* ([T] unless a primary design co-objective, then [P])

viii. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

3. open spandrel bridges

a. superstructure

i. arch ribs [P] [CDE]

ii. spandrel [P] [CDE]
    spandrel column [P] [CDE]

    spandrel arch [P] [CDE]

iii. arch ribs [P] [CDE]

iv. railing or parapet [P] [CDE]

v. applied ornamentation [S]

vi. identifying plaques, plates, and imprints [P]

vii. additional functional features* ([T] unless a primary design co-objective, then [P])

viii. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

b. substructure

i. abutments [P] [CDE]

ii. wing walls [P] [CDE]

iii. pier(s) - when present [P] [CDE]

iv. applied ornamentation [S]

v. identifying plaques, plates, and imprints [P]

vi. additional functional features* ([T] unless a primary design co-objective, then [P])

vii. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

4. through (or rainbow) arch bridges

a. superstructure

i. arch ribs [P] [CDE]

ii. ties [S] [CDE]

iii. lower chord [P] [CDE]

iv. suspenders [P] [CDE]

iv. floor beams [P] [CDE]

v. deck [S]

vi. railing [T]

vii. applied ornamentation [S]

viii. identifying plaques, plates, and imprints [P]

ix. additional functional features* ([T] unless a primary design co-objective, then [P])

x. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

b. substructure

i. abutments [P] [CDE]

ii. wing walls [P] [CDE]

iii. pier(s) - when present [P] [CDE]

iv. applied ornamentation [S]

v. identifying plaques, plates, and imprints [P]

vi. endpost section of railing, attached to abutment [S]

vii. additional functional features* ([T] unless a primary design co-objective, then [P])

viii. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

B. Concrete Slab Bridges

Note: concrete arch bridges may be used as culverts (bridges with spans of less than 20 feet)

1. superstructure

   a. slab [P] [CDE]

   b. parapet or railing [P] [CDE]

   c. roadway [T]

   d. applied ornamentation [S]

   e. identifying plaques, plates, and imprints [P]

   f. additional functional features* ([T] unless a primary design co-objective, then [P])

   g. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

   a. abutments [P] [CDE]

   b. wing walls [P] [CDE]

   c. pier(s) - when present [P] [CDE]

   d. applied ornamentation [S]

   e. identifying plaques, plates, and imprints [P]

   f. endpost section of parapet or railing, attached to abutment [S]

   g. additional functional features* ([T] unless a primary design co-objective, then [P])

   h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

C. Concrete Beam Bridges

1. superstructure

   a. slab [P] [CDE]

   b. longitudinal beams (on T-beam bridges, slab and longitudinal beams are integrated) [P] [CDE]

   c. parapet or railing, when integral [P] [CDE]

   d. roadway [T]

   e. applied ornamentation [S]

   f. identifying plaques, plates, and imprints [P]

   g. additional functional features* ([T] unless a primary design co-objective, then [P])

   h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

   a. abutments [P] [CDE]

   b. wing walls [P] [CDE]

   c. pier(s) - when present [P] [CDE]

   d. applied ornamentation [S]

   e. identifying plaques, plates, and imprints [P]

   f. endpost section of parapet or railing, attached to abutment [S]

   g. additional functional features* ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

D. Rigid Frame Bridges

Note: Rigid frame bridges are designed as monolithic structures, in which the superstructure and the substructure are of one continuous fabric; possibly used for culverts (bridges with span length under 20 feet)

1. superstructure

   a. deck [P] [CDE]

   b. parapet or railing [P] [CDE]

   c. applied ornamentation [S]

   d. identifying plaques, plates, and imprints [P]

   e. additional functional features* ([T] unless a primary design co-objective, then [P])

   f. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

2. substructure

   a. abutments [P] [CDE]

   b. wing walls [P] [CDE]

   c. piers (when present) [P] [CDE]; large multi-span rigid frame bridges feature:
      stiff towers

      slender expansion piers

   d. applied ornamentation [S]

   e. identifying plaques, plates, and imprints [P]

f. endpost section of parapet or railing, attached to abutment [S]

g. additional functional features* ([T] unless a primary design co-objective, then [P])

h. additional functional features* for contributing resources within historic districts ([CDE] if the feature contributes to the historic architectural qualities, historic associations, or archeological values for which a district is significant)

SECTION D. BRIDGES AS CONTRIBUTING RESOURCES WITHIN HISTORIC DISTRICTS

1. Introduction

Although sometimes neglected as possible contributing resources in National Register historic districts, bridges were often important elements in the formation and development of both large and small communities and industrial areas in the state. For a variety of reasons, communities and industries frequently took root and flourished in close proximity to rivers, creeks, and inlets; bridges served as essential links in the transportation system that connected developing areas with one another. The rapidity with which damaged or destroyed bridges were repaired or replaced by public or private means underscores the importance of bridges to the areas they served. Historically, Maryland's road network has depended upon bridges, as have canals and railroads as well.

Bridges are conceived, built, and used as functional structures, but they have also served, by design or accident, objectives and purposes beyond transportation. Bridges connect, but they can also act as a demarcation; a bridge often serves as a portal to a community. When located within a community, the bridge may reflect the architectural values displayed by the area's buildings. Regardless of the builder's intent, the bridge also frequently serves a community as a place where locals can fish, swim, meet, or dance, or conduct other social events. As with any building, a bridge can be a place where local residents interact with each other; a bridge can serve a community in numerous and diverse ways.

Bridges of all types may thus be possible contributing resources in Maryland's National Register-listed or eligible historic districts. In order to determine the ways in which bridges might be included as contributing resources in National Register historic districts, an examination was made of 161 historic districts in the state of Maryland. Maryland's historic districts show great diversity in size, character, period of significance, and the architectural character of contributing buildings and structures. The size of Maryland's historic districts ranges from a handful of resources to areas containing thousands of buildings or acres. Urban, rural, residential, and industrial themes are all found.

The history of Maryland is well illustrated by its existing historic districts, which encompass a broad chronological range from the seventeenth through the twentieth centuries. The following table indicates the breadth of historical time represented in the periods of significance associated with existing Maryland historical districts:

Centuries Represented by Historic Districts

Century	Number of Districts
17th	9
18th	64
19th	142
20th	142

As indicated, the nineteenth and twentieth centuries are represented most heavily; the eighteenth century's representation is less than half of either of the succeeding centuries, and the seventeenth century is only rarely included in a period of significance.

Aside from a few districts with periods of significance of five years or less, the periods of significance of most districts encompass the founding, maturation, and transformation of communities over a span of at least several generations. Very frequently both the nineteenth and twentieth centuries are included in a district's period of significance, and a sizable number of Maryland historic districts span the eighteenth through the twentieth centuries. The average span for all Maryland historic districts is over 100 years; more than a quarter of the districts feature a period of significance exceeding 150 years.

Districts with long periods of significance (over 100 years) are not restricted to any particular type; they are found in cities or towns (37 districts); rural, agricultural areas (16 districts); rural industry/industry-centered areas (10 districts); and civic or educational areas (8 districts).

The architectural styles of buildings within these chronologically broad-based districts reflect the changing aesthetic conventions of the communities. The full gamut of eastern U.S. residential architectural styles is encountered, sometimes in homogeneous groupings, sometimes in groupings where an early Federal-style house is near a twentieth-century bungalow. Commercial and industrial architecture is also varied, and the state historic districts include a range of civic buildings, farmsteads, institutional complexes, and waterfronts.

Reflecting the changing technologies used to span rivers and roads, Maryland's bridges reveal diversity in bridge building technology. Virtually every type of bridge has been built within the state at one time or another, and extant examples can still be found of many of these types. In addition to illustrating technology, bridges also reflect the aesthetic conventions of the period when they were built. As with buildings, bridges may reflect high-style design or vernacular trends, and the aesthetic decisions made in designing a bridge may add to the historical and architectural significance of a district. Along with buildings, bridges may make a significant contribution to defining the character of Maryland's historic districts.

2. Guidelines for Contributing Resource Determination

Specific guidelines may aid in the evaluation of bridges as possible contributing resources to National Register-listed or National Register-eligible historic districts in Maryland. National Register Bulletin 14, *Guidelines for Contributing and Noncontributing Resources for National Register Documentation* (5/85, revised 11/86) defines contributing and noncontributing resources as follows:

> "A contributing building, site, structure, or object adds to the historic architectural qualities, historic associations, or archeological values for which a property is significant because a) it was present during the period of significance, and possesses historic integrity reflecting its character at that time or is capable of yielding important information about the period, or b) it independently meets the National Register criteria."
>
> "A noncontributing building, site, structure, or object does not add to the historic architectural qualities, historic associations or archeological values for which a property is significant because a) it was not present during the period of significance, b) due to alterations, disturbances, additions, or other changes, it no longer possesses historic integrity reflecting its character at that time or is incapable of yielding information about the period, or c) it does not independently meet the National Register criteria."

Bulletin 14 requires that all contributing and noncontributing resources within a National Register-eligible historic district be counted. The following expanded criteria are recommended for evaluating bridges for their potential status as contributing or noncontributing resources to historic districts:

> A bridge may be a contributing resource to a National Register-listed or National Register-eligible historic district for any of the following reasons:
>
> a) It was present or originally built during the district's period of significance, and possesses historic integrity reflecting its character during the district's period of significance, or is capable of yielding important information about the period. All extant bridges built during the district's period of significance and possessing sufficient historic integrity may be listed as contributing resources. It should be noted that certain alterations and changes to a bridge made during the district's period of significance may themselves be significant. Assessment of the significance of alterations should be

made on a case-by-case basis. Alterations and changes may also occur to a bridge after a district's defined period of significance. In order to document alterations and changes, a thorough effort must be made to determine the construction and maintenance history of each bridge, through consultation of all available official records and plans. If a bridge built within ten years of the close of a district's period of significance complements the historical and architectural character of the district in style, scale, and materials, the bridge may be a contributing resource and the district's period of significance may be extended to include the bridge's date of construction.

b) It independently meets the National Register criteria. All bridges meeting the National Register criteria for individual eligibility and originally built during the district's period of significance may be listed as contributing resources. This may include National Register-listed or eligible bridges built elsewhere, moved to their current location at any time, and reerected there at any time *without loss of individual National Register-eligibility* (such as a National Register-eligible metal truss bridge moved to a new location). A bridge may contribute to a district on the basis of significance unrelated to that of the district, provided the bridge independently meets the National Register criteria for individual eligibility.

A bridge may be a noncontributing resource for any of the following reasons:

a) It was not present or not originally built during the district's period of significance.

b) Due to alterations, disturbances, additions, or other changes, it no longer possesses historic integrity reflecting its character during the district's period of significance, or is incapable of yielding information about the period.

c) It does not independently meet the National Register criteria.

Section C, "Physical and Associative Characteristics and Historic Integrity Consideration," above, presents an additional guide to assessing character-defining elements [CDE] of bridges being evaluated as possible contributing resources in National Register-listed or eligible historic districts.