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The Potential of Virtual Heritage Reconstruction in Lost Ansonborough

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THE POTENTIAL OF VIRTUAL HERITAGE RECONSTRUCTION IN LOST ANSONBOROUGH

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ABSTRACT

The virtual reconstruction of vanished heritage is a well-known practice in the preservation field. The constant development in computer technologies has been improving visualization and interpretation techniques for virtual reconstructions of no longer extant or inaccessible sites. Reconstruction projects of vanished heritage sites implement various approaches because of different challenges at each site. This research involves 3D reconstructions, as well as historical research of early nineteenth century residences, Radcliffe-King and Gabriel Manigault houses in the Ansonborough neighborhood of Charleston, South Carolina, USA.

The demolition of these two mansions in the first half of the twentieth century leads to the loss of the residential character at the intersection of George and Meeting Streets in Ansonborough. Photogrammetry and rectification techniques established the dimensions and the scale for these buildings from salvaged architectural details and early photographs to recreate the lost residential character. Other sources, like maps and drawings are used to supplement the photographs and salvaged materials for virtual reconstruction.

ACKNOWLEDGMENTS

It is a pleasure to thank those whose support made this thesis possible. I would like to acknowledge the advice and guidance of my supervisor Ashley R. Wilson. I also owe my gratitude to members of the supervisory committee, Carter L. Hudgins and James L. Ward. Special thanks also to all my graduate friends and my family for their encouragements.

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CHAPTER ONE

INTRODUCTION

Cultural and natural heritage sites around the world have been threatened by urban sprawl, speculative development, neglect, wars, looting, even from tourism. Some of these important sites are no longer extant while others only exist in museums as fragments of their original form. A vast majority of these sites still stand in danger. In the 21st century, a new digital preservation method has emerged communicating these significant treasures of the world to the public.

Ever-changing improvements in computer hardware and software capabilities have solved the limitations of earlier digital technology. This has led to the rapid development of three-dimensional imaging and processing. As a result, it is possible to create digital architectural models of heritage sites in virtual environments. *UNESCO* announced an alliance with *Google* to provide virtual visits, via *Google*'s "Street view", to 19 of 890 listed World Heritage sites in 2009.[1] Virtual representations of heritage sites create accurate 3D models, and not only help to disseminate them to the public, but help preservation specialists to conserve, study, and restore them.[2]

The process of creating digital models of lost heritage sites involves locating accurate dimensions, photographs and any prior documentation of the site. At times, theoretical interpretations are necessary to fill in gaps on parts of the sites where accurate information is

[1] UNESCO, "Google and UNESCO announce alliance to provide virtual visits of several World Heritage sites," <http://whc.unesco.org/en/news/570> (accessed January 4, 2012).
[2] Massimiliano Pieraccini, Gabriele Guidi, and Carlo Atzeni. "3D digitizing of cultural heritage." Journal of Cultural Heritage 2, no. 1 (January-March 2001): 63.

unavailable. Comparable details drawn from similar buildings of the same era or style help to complete virtual models. Some scholars question about the validity of theoretical interpretations in virtual heritage models. They argue the need for “transparency” and insist that areas of a model that are based on conjecture be portrayed as such. In response, London Charter has defined principles to convey distinctions between evidence and hypothesis in models. All of these sources and standards make it possible to bring back vanished cultural monuments in an accurate and scientific way.

The focus of this thesis is to use virtual reality to recreate lost residential buildings character at the intersection of George and Meeting Streets in Charleston, South Carolina. Specifically this project recreates two lost buildings in Ansonborough, Charleston’s first neighborhood: the Radcliffe-King Mansion and the Gabriel Manigault House. Photogrammetry and rectification techniques established the dimensions and the scale for these buildings from salvaged architectural details and early photographs. The Radcliffe-King Mansion only had a single image for all the facades while the Gabriel Manigault house had multiple photographs available. For the Radcliffe-King Mansion, the “single image” technique was used to help reconstruct the lost heritage. For the Gabriel Manigault house, the “single image” technique was applied to multiple calibrated images. The implementation of these techniques is found in many digital reconstruction projects because they prove to be accurate and efficient. Other sources, like maps and drawings are used to supplement the photographs and salvaged materials because they often provide additional information. Successful digital reconstruction of these two lost residences indicates that this technique holds significant potential to re-establish, virtually, entire streetscapes as well as single buildings, very instructive for a city that has lost much of its early architectural fabric to hurricane, fire, tornado and war.

CHAPTER TWO

A BRIEF HISTORY OF THE INTERSECTION

Charleston after Revolution

Charles Town, as the community was first named, was established in 1670 by English pioneers. While the first settlers were mainly from England, Charles Town accommodated different ethnic and religious groups, such as African, French, Scotts, Irish, and German immigrants in the following decades. In the beginning, the settlement thrived economically by exporting naval stores, deerskins, furs, and provisional crops and the Indian trade.[3] The colonists experimented with rice and, later, indigo cultivation. These commodities brought the great wealth and prosperity to the settlement. Charles Town had become a hub for the Atlantic trade. It was the fourth largest American port in the colonial era after Boston, New York and Philadelphia. The cultural and social life of the community also flourished, the first theater, Dock Street Theatre, and the oldest municipally-supported college, College of Charleston, as well as the Charleston Library Society were established in the eighteenth century.

The American Revolution changed Charles Town, its government, and its way of life. The city adopted its current name, Charleston, and became the first city of South Carolina in 1783.[4] Three years later, Columbia took the "capitol of South Carolina" title from Charleston. By 1785, the previously ostentatious grand city was experiencing economic hardship. The main economic resource of Charleston, rice and indigo cultivation, had been interrupted by harsh weather.

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[3] Walter J. Fraser, Charleston! Charleston!: The History of a Southern City (University of South Carolina Press, 1991), 5.

[4] Robert N. Rosen, A short history of Charleston (University of South Carolina Press, 1997), 47.

Commerce and trade had almost disappeared due to the closure of the traditional markets for South Carolina rice, constraints on the West Indies trade, and the cessation of Indian fur trade.[5] The lack of a stable system of currency and the lack of available credit worsened the economic condition.

Charleston regained its prosperity in the plantation-dominated economy of the post-Revolutionary years. The city recovered from this economic crush by the introduction of cotton cultivation and rapid expansion of rice-growing by clearing and diking the suitable swamps and rivers. Water mills replaced the manual processes of cleaning and polishing the grain, bringing more profit to planters. Moreover, the economy, freed of British constraints and supported by the establishment of stable banks and foreign trade to all parts of Europe, thrived.[6]

With this post-revolutionary economic recovery, Charlestonians initiated the construction of many commercial, religious, domestic, and institutional buildings. Between 1790 and 1825, a new architectural style appeared with an assortment of plan variations of the traditional single and double houses. One of the plan variations had entrance, staircase and hall on the north side of the house and other rooms located on the south side with generally wide piazzas. The second plan variation of the era featured a winding staircase, the bay, and the oval

[5] Walter J. Fraser, Charleston! Charleston!: The History of a Southern City (University of South Carolina Press, 1991), 173.
[6] Albert Simons and Samuel Lapham, The Early Architecture of Charleston (Univ of South Carolina Press, 1990), 102.

drawing room to their plans.[7] Figure 2.1 and Figure 2.2 shows the plan types before and after the Revolutionary War.

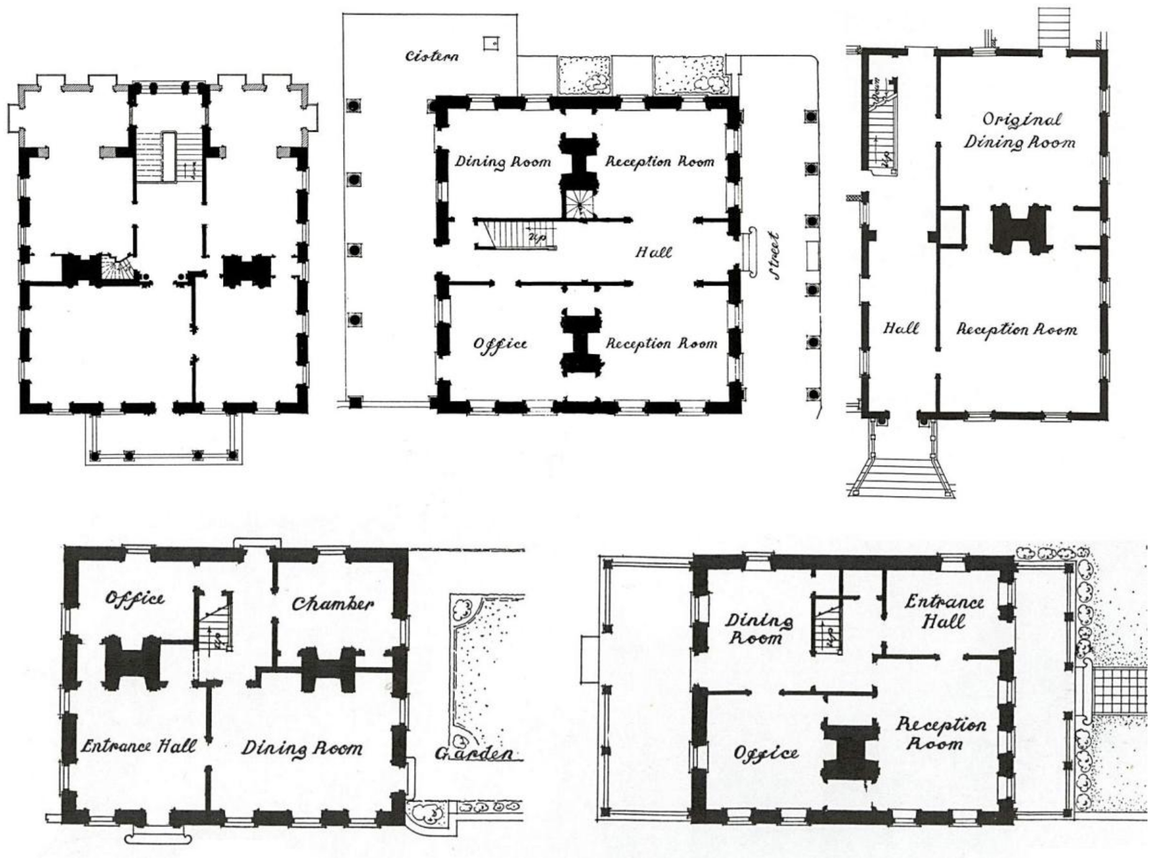

Figure 2.1: Plan of the houses before the Revolutionary War. The plans are gathered from Albert Simons's book, *The Early Architecture of Charleston*. Houses from left to right: Mills Brewton House, the Horry House, Colonel John Stuart's House, Ralph Izard's House, George Eveleigh House.

[7] Daniel Elliott Huger Smith, The dwelling houses of Charleston, South Carolina (J.B. Lippincott Company, 1917), 131.

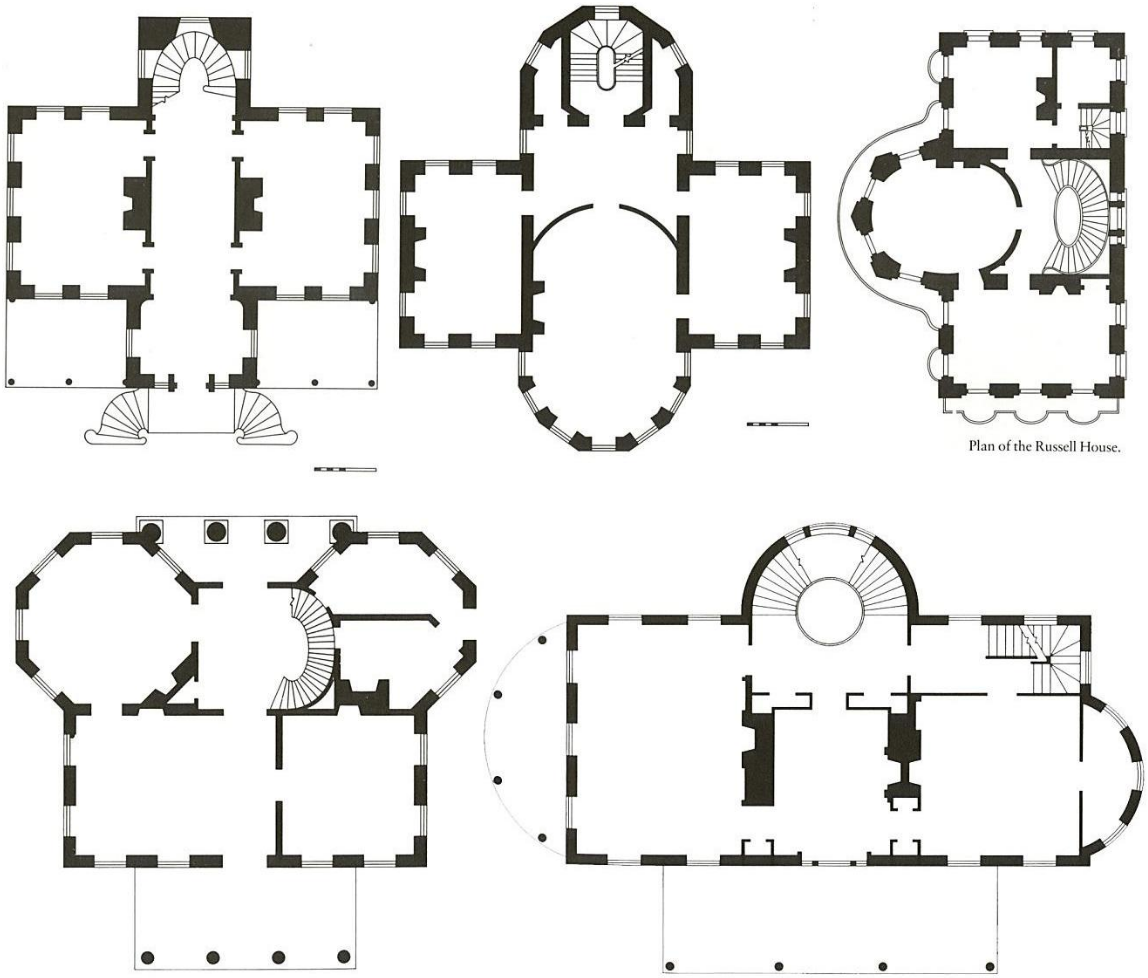

Figure 2.2: Plan of the houses after the Revolutionary War. The plans are gathered from Mills Lane's book, *Architecture of the Old South: South Carolina*. Houses from left to right: Radcliffe-King Mansion, Middleton-Pinckney House, Nathaniel Russell House, the Elms house, Joseph Manigault House.

This new architectural style played a significant role in shaping the initial residential character of intersection of Meeting and George streets. Gabriel Manigault's house followed the former plan variation while the Radcliffe-King Mansion and the Middleton-Pinckney house followed the latter plan formation. These houses were the most important architecture in Ansonborough.

History of Ansonborough

Ansonborough was the first neighborhood built outside the walled city in the early eighteenth century. The name of the suburb derived from George Anson who was sent on patrol duty to protect South Carolina from pirates in 1724. Two years later, Captain Anson acquired the tract that became the neighborhood from Thomas Gadsden. The area which was part of the original grant to immigrant, Isaac Mazyck, in 1696, was bounded by Calhoun Street, King Street, Cooper River, and a line halfway between Society and Wentworth streets. Isaac Mazyck sold sixty-four of ninety acres of land, which contained the west side of the current Anson Street, to Thomas Gadsden.[8]

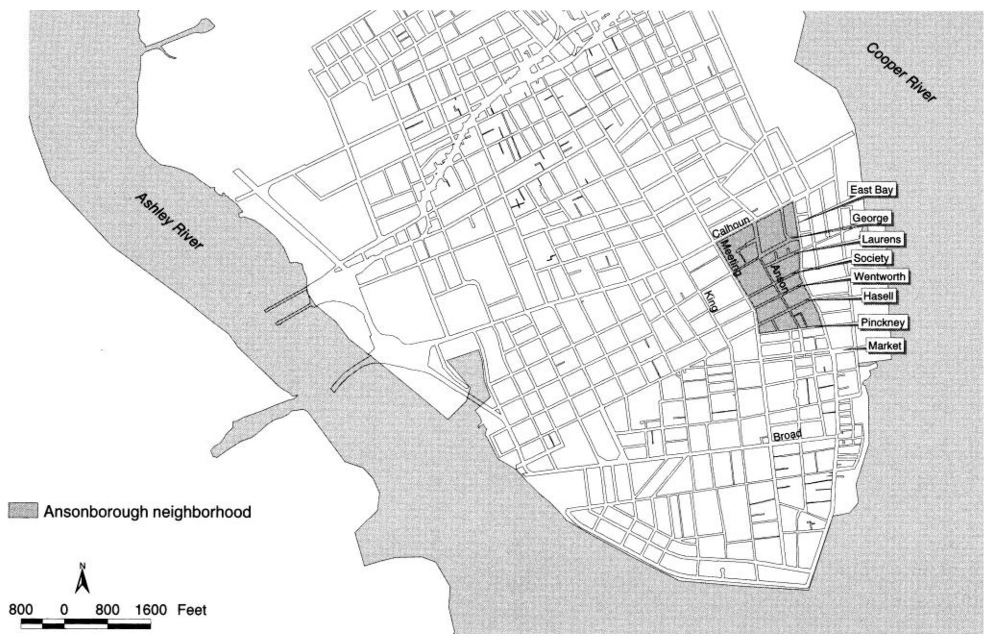

Figure 2.3: Current Ansonborough boundaries in downtown Charleston. From the *Historic Preservation for a Living City* book*, 57.*

[8] Charleston County Public Library, "History of Ansonborough and Nearby Neighborhoods," <http://www.ccpl.org/content.asp?id=15841&catID=6062&action=detail&parentID=6046> (accessed January 6, 2012).

George Hunter's plat of the Ansonborough, which dates to 1746, shows twenty-five lots and three of the five streets that George Anson named. George and Anson streets honored the captain himself. Centurion, Scarborough, and Squirrel were named for his ships. These three streets later became part of Society, Anson, and Meeting streets respectively.[9]

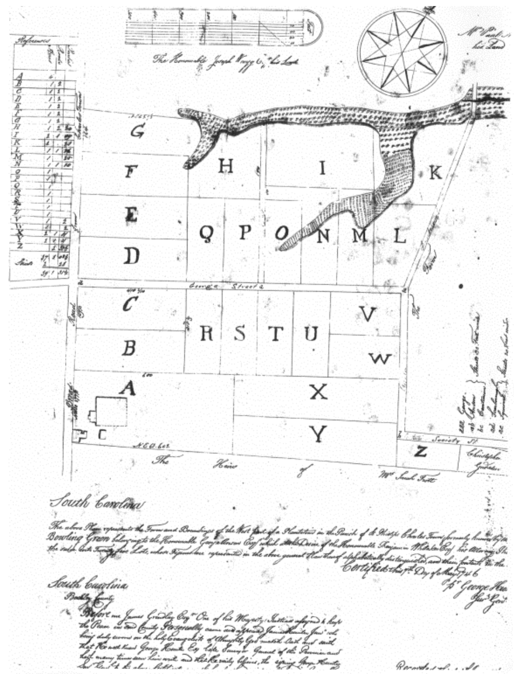

Figure 2.4: George Hunter's plat of Ansonborough, 1746. From *Plat Book in South Carolina Room in Charleston County Public Library.*

The early residents of the neighborhood include merchants, tradesman, planters, and also free blacks and slaves who dwelled in the inner streets. Dry good stores, confectioners, saddlers, cabinetmakers, cobblers, grocers, fruiterers, and milliners occupied the boundaries of the neighborhood. German immigrants concentrated in the area in the mid-nineteenth century. The most visible sign of their presence today is the two Lutheran churches and the German Catholic church.[10]

On April 24, 1838 a disastrous fire, the largest fire in the city to that date, swept through Ansonborough. The fire started in the southwestern point of the neighborhood and spread to the northeast burning most of the structures on its way. After the fire, the Bank of the State of South Carolina offered loans to rebuild with the stipulation that brick be used as the main building material to make new structures fireproof. Loans authorized by the "Act for Rebuilding

[9] George C. Rogers, Charleston in the age of the Pinckneys (Univ of South Carolina Press, 1980), 57.
[10] Jonathan Poston, The Buildings of Charleston (Columbia, SC: University of South Carolina Press, 1997), 412.

the City of Charleston" were enacted by the General Assembly in 1838.[11] The result of the catastrophic fire can be seen in the streetscapes today as the majority of the structures in Ansonborough date from the 1840s and are brick buildings with elements of Greek Revival and Regency styles.

The northwest side of the neighborhood included the best architecture in the borough and was not affected by the fire. The corner of Meeting and George streets contained the mansions of Thomas Radcliffe and Gabriel Manigault. Prominent families and cultural benefactors of the city lived within a few blocks of this corner; however, the only building that still stands today is Middleton Pinckney's House, now the headquarters of Spoleto Festival USA. All of these magnificent structures were constructed about 1800 and competed architecturally with other Federal-Style buildings which were constructed in the same period such as Nathaniel Russell House (1808), Joseph Manigault House (1803), and William Blacklock House (1800).

The prosperity of the neighborhood declined after the first quarter of twentieth century. Most of the colonial and antebellum residences were subdivided into rental units for workers employed by the adjacent port facilities during World War II. After the war, the area deteriorated further. Many buildings stood vacant or fell into severe disrepair giving the neighborhood the appearance of a slum with its many tenements. Historic Charleston Foundation, seeking to alleviate this condition of the neighborhood, initiated the Ansonborough Rehabilitation Project in 1958. This was the first revolving fund enterprise for area rehabilitation

[11] Charleston County Public Library, "History of Ansonborough and Nearby Neighborhoods," <http://www.ccpl.org/content.asp?id=15841&catID=6062&action=detail&parentID=6046> (accessed January 6, 2012).

in the United States.[12] The project focused primarily on restoration of building exteriors and stabilization of the structures for further rehabilitation. Restoration of interiors was left to preservation-minded investors. While this rehabilitation process successfully recovered the neighborhood, this revolving fund also caused, as intended, residential displacement and neighborhood gentrification. Middle and upper-class home owners replaced poor African-American renters.

Rehabilitation and preservation of Ansonborough caused the complete loss of the adjacent Middlesex neighborhood, located on the northern border of Ansonborough. Charleston city council proposed construction of a municipal auditorium and exhibition hall on Calhoun Street by eradicating the Middlesex neighborhood, a three-block area bounded by Calhoun, Anson, Alexander, and an extended George Street.[13] Historic Charleston Foundation saved four of the larger houses in Middlesex and moved them to empty lots in Ansonborough. One of the objectives of constructing the auditorium in this location was to provide a block-wide geographical and social barrier for Ansonborough separating it from an even more blighted residential area north of Calhoun Street. The president of Historic Charleston Foundation at the time, Ben Scott Whaley, said that the "eradication of urban blight in the heart of our community … would greatly improve the setting of the six blocks of significant period architecture in which we are working, and help us toward our goal of giving Charleston in-city residential areas which are also tourist attractions of great value."[14] By the mid 1970s the success of the Ansonborough Rehabilitation project was clear. Most of the houses in the district had been restored or

[12] Historic Charleston Foundation. "Ansonborough: An Historic Residential Area in Old Charleston," (1967).
[13] Robert R. Weyeneth, Historic preservation for a living city: Historic Charleston Foundation*,* 1947-1997 (University of South Carolina Press, 2000), 64.
[14] Ibid., 65.

improved and the area attracted many private investors. The executive director of Historic Charleston Foundation, Frances R. Edmunds announced that “this is now a stable area with good real estate market and superior home owners, and this was our goal.”[15]

Ironically, while much of the ‘good’ architecture in Ansonborough was saved, the neighborhood lost the important early nineteenth century Federal residences at the corner of George and Meeting streets. Both the Thomas Radcliffe and Gabriel Manigault houses were destroyed by twentieth-century urban improvements. A College of Charleston gymnasium replaced the Radcliffe-King Mansion. The Manigault house was razed for a gas filling station. Albert Simons, the architect of these two new buildings, shaped the new character of the intersection by designing both corners. Albert Simons and Samuel Lapham’s firm Simons & Lapham was one of the first firms to specialize in the restoration of historic structures. They had worked earlier to create, and implement, the first historic zoning ordinance in the United States.[16] As preservationists, they were aware of the importance of the structures being demolished, and they tried to mitigate the damage to the historic fabric by recording, salvaging and saving as much of their architectural elements as possible. Many of these artifacts were recycled into new projects by Simons & Lapham.

The intersection of George and Meeting Street was a residential hub until construction of the first institutional building at 289 Meeting Street, the southwest corner, in 1870 (Figure 2.6). The other three corners were occupied by John T. Leonard’s house on the north-east (Figure 2.7 & Figure 2.8), Gabriel Manigault’s house on the southeast (Figure 2.21), and the

[15] Ibid., 67.
[16] Ernest E. Blevins, "Documentation of the Architecture of Samuel Lapham and the Firm of Simons & Lapham," (MA Thesis, Savannah College of Art & Design, 2001), 1.

Radcliffe-King Mansion on the northwest corner (Figure 2.20). The house at the northeast corner was replaced by a medical clinic in the 1960s it then became an academic center (Figure 2.10). Currently, plans are in place by Clemson University to build a new 30,000 square foot academic building on this site. Two later building have filled the southeast corner, a gas station built in 1929 (Figure 2.23), which was followed a commercial building in 1984 (Figure 2.11). A College of Charleston Gymnasium building was constructed at the northwest corner in 1939 (Figure 2.12). Even the Middleton-Pinckney house, located to the east of the former John T. Leonard property, was first sold to the Water Works Company, and then became the headquarters for the Spoleto Festival U.S.A. in 1988 (Figure 2.13). Today, this intersection has lost its residential character and remains predominantly institutional in use and appearance.

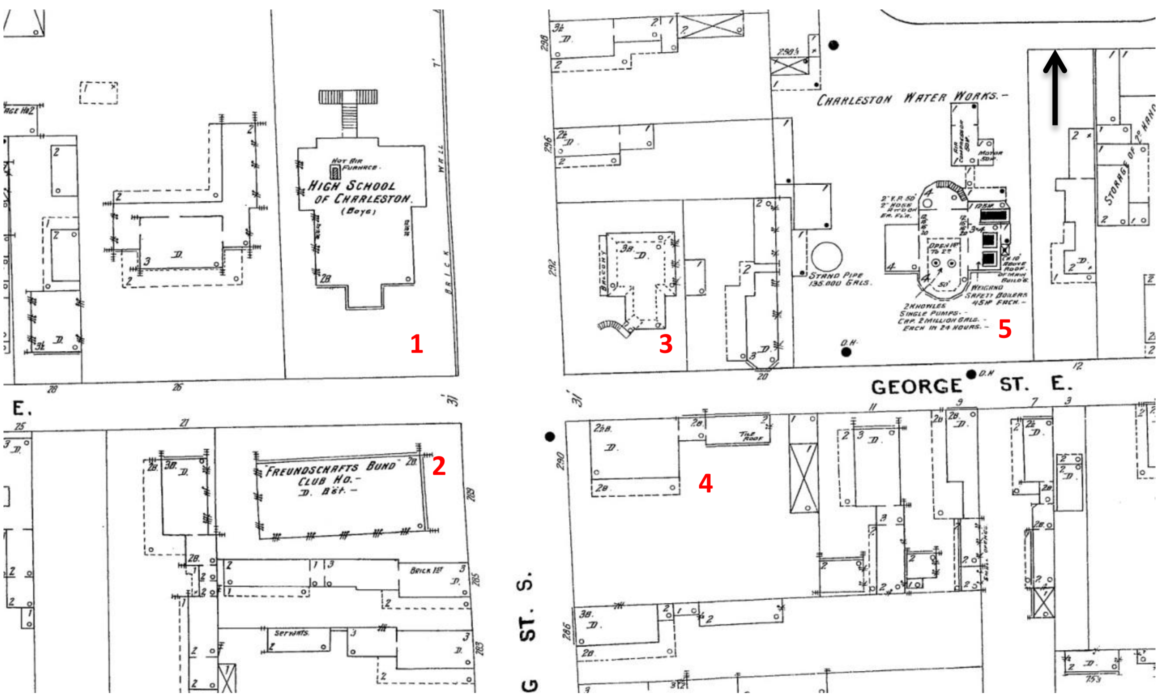

Figure 2.5: The intersection of George and Meeting streets. 1)Radcliffe-King Mansion, 2)289 Meeting Street, 3) John T. Leonard house, 4)Gabriel Manigault house, 5)Middleton-Pinckney house. 1888 Sanborn Fire Insurance Map of Charleston, SC. From sanborn.umi.com, edited by author in *Photoshop*.

Figure 2.6: 289 Meeting Street. Photo taken by the author.

Figure 2.7: John T. Leonard's house. Courtesy of the Charleston Museum.

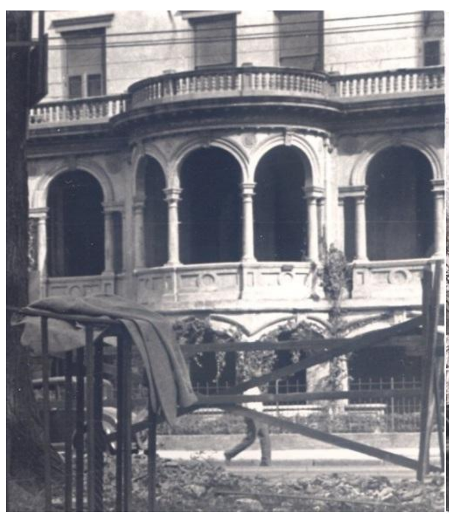

Figure 2.8: John T. Leonard's house. Courtesy of the Charleston Museum.

Figure 2.9: John T. Leonard's house. Courtesy of the Historic Charleston Foundation.

Figure 2.10: Current building on 292 Meeting Street. Photo taken by the author.

Figure 2.11: Current building on 288 Meeting Street. Photo taken by the author.

Figure 2.12: Silcox Gymnasium. Photo taken by the author.

Figure 2.13: Middleton-Pinckney House. Photo taken by the author.

The Radcliffe-King Mansion, 24 George Street, c. 1802

Thomas Radcliffe, one of the wealthiest merchants in Charleston at the beginning of the nineteenth century, built what was later called the Radcliffe-King Mansion in 1802. He bought the northwest corner lot at the intersection of Meeting and George streets where his house would rise in 1800 from Mrs. Mary Petrie, widow of Edmund Petrie.[17] Lucretia Radcliffe lived alone in the house for fifteen years until her death in June of 1821. The first plat of the property was drawn two years after her death.

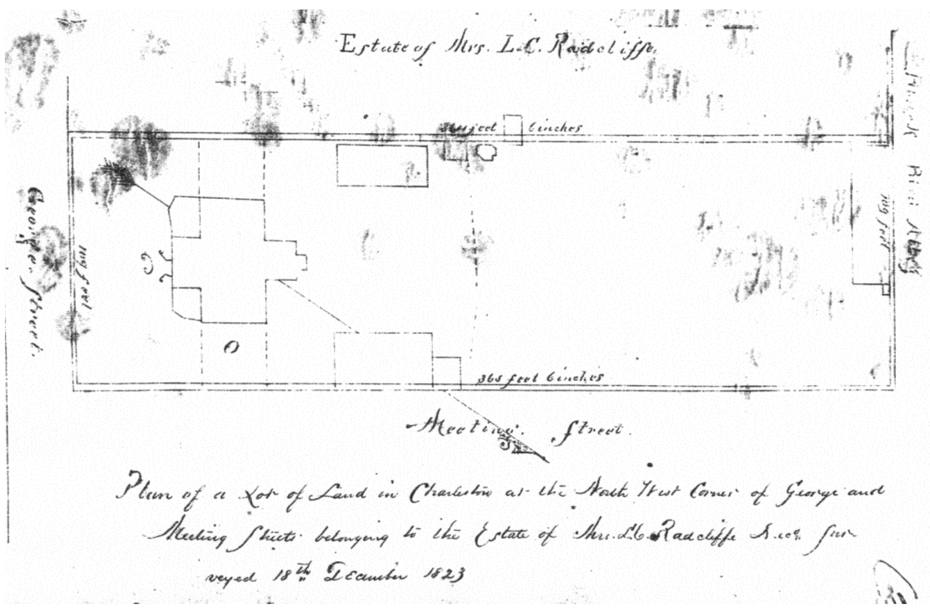

Figure 2.14: 1823 plat of Radcliffe property.

The 1823 plat shows the house and its outbuildings; however, it does not label these structures or their functions. It is evident that three structures in the middle of the property at the rear of the house in what was probably the work yard most likely served as kitchen, laundry,

[17] Daniel Elliott Huger Smith, The dwelling houses of Charleston, South Carolina (J.B. Lippincott Company, 1917), 141.

stables, and slave housing. The small structure shown on the northeast part, above the 'Meeting Street' label, was likely a shed addition to the adjacent building. The rest of the property, from a fence line that divided the lot in half north to Burns Alley, was probably a formal garden with a greenhouse structure at the end of the lot. Dash lines on the sides of the main building and between work yard and formal garden show a paling fences which separated those sections from each other. Walls along the property lines prevented the view of both work yard and formal garden to approaching visitors.[18]

Judge Mitchell King, a prominent member of the bar and leading South Carolina jurist, bought the estate in 1824. He was a Scotsman who was escaping from Spanish authorities in Malaga when he immigrated to United States. [19] His house became a center of Charleston's literary life and hospitality as King hosted grand race-week balls.[20] The pictures of the pediment of the house entrance shows the date sign "1839" which suggests that Judge King may had replaced or improved the entrance of the house with Coronthian plasters and pediment during his ownership;

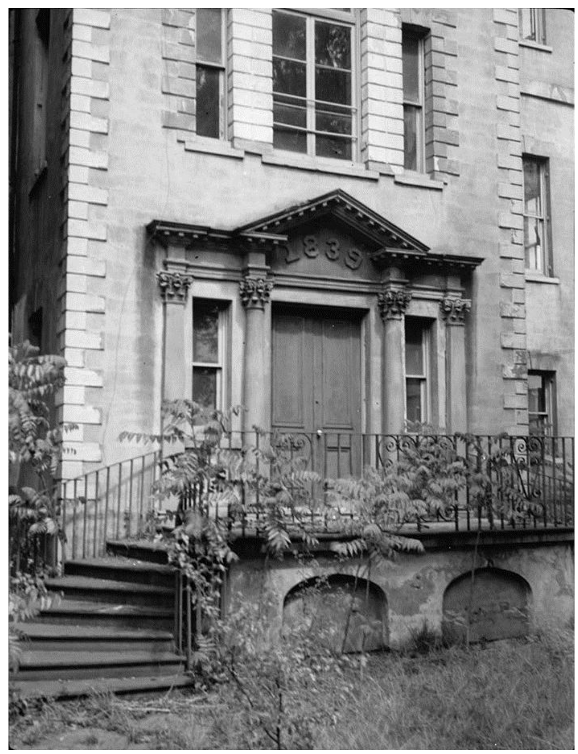

Figure 2.15: The entablature of the entrance. From *loc.gov*, Thomas Ratcliffe House, 24 George Street, Charleston, SC

[18] Carol E. Borchert, "The inventory of Lucretia Constance Radcliffe: the material world of elites in Federal period Charleston, South Carolina," (MA Thesis, University of Delaware, 1996), 17.
[19] Historic Charleston Foundation. "24 George Street," Vertical Files, n.d
[20] "Do you know your Charleston, Old high school," The News and Courier, Charleston, S.C., August 1922.

however, there is no record proving the change. King passed away 1862 but the family ownership of the house continued until his son sold the property to the city in 1880. Charleston city council purchased the residence for $11,700 and spent an additional $4,000 for repairs and changes to adapt the structure for educational use.[21]

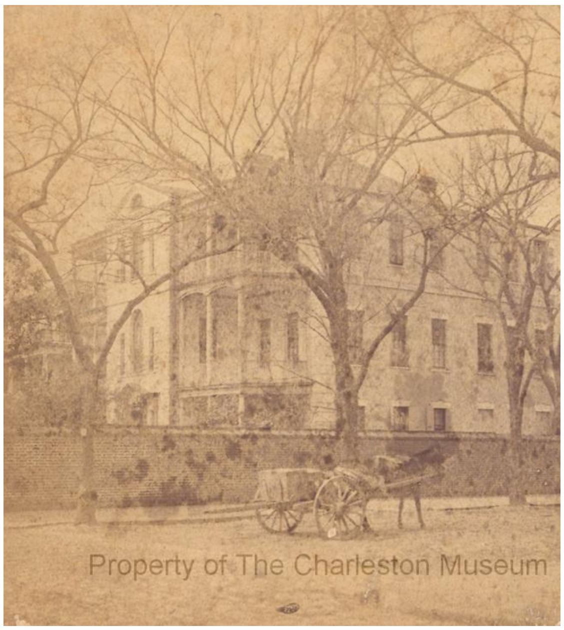

Figure 2.16: Joseph H. Anderson's photo of the mansion. Courtesy of Charleston Museum.

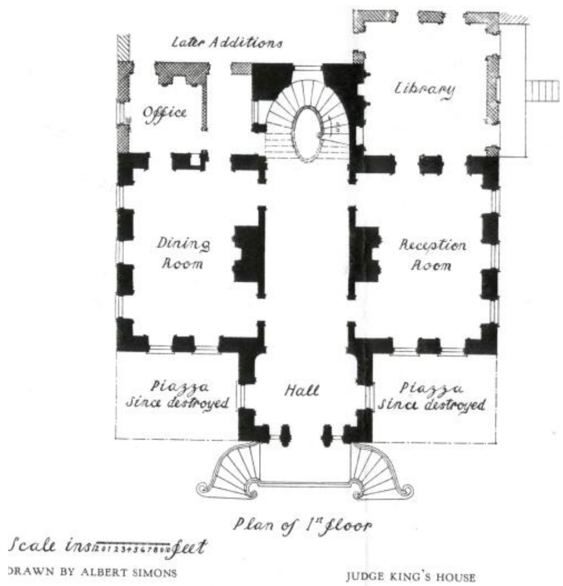

Figure 2.17: Albert Simons' plan drawing. From *The Early Architecture of Charleston*. 120.

A photograph of the mansion was taken by Joseph H. Anderson and found in the Charleston Museum archives. It is the only surviving picture that shows the original piazzas of the structure (Figure 2.16). Anderson opened his photography gallery by 1876 or 1877 in

Figure 2.18: C. Drie's Bird's Eye View of Charleston, 1872.

[21] Eugene Clifford Clark, A history of the first hundred years of the High School of Charleston, 1839-1938 (CHS Alumni Association, 1998), 18.

Charleston and is listed in the city directories until 1886.[22] This picture of the Radcliffe-King Mansion was most probably taken in that period. C. N. Drie's 1872 Bird's Eye View also indicates that an addition to the back of the mansion which included a library and office rooms had been completed about the same time (Figure 2.18). Another picture from 1885, also in the Charleston Museum Collection, shows that the piazzas were removed between 1876-1885 (Figure 2.20). A second significant alteration occured in 1895 with a new addition which cost $12,000 (Figure 2.19).[23] Pictures of the building after the alteration confirms that nine-over-nine sash windows, which were seen in Anderson's photograph, had been replaced by two-over-two sash windows. The school eventually expanded to more than five hundred pupils and abandoned the structure because of limited space in 1922. The high school moved to a new location at 147 Rutledge Aveneu.[24] The Radcliffe-King House was used as a warehouse by the city until its demolition on 27 October, 1938 to make way for the College of Charleston gymnasium.[25] Designed by Albert Simons, the gymnasium as one of several large projects funded by Works Progress Administration (WPA). Simons incorporated the perimeter iron fence and masonry walls of the mansion in his design. The iron fence and masonry wall on George Street remained standing until 1982, when the

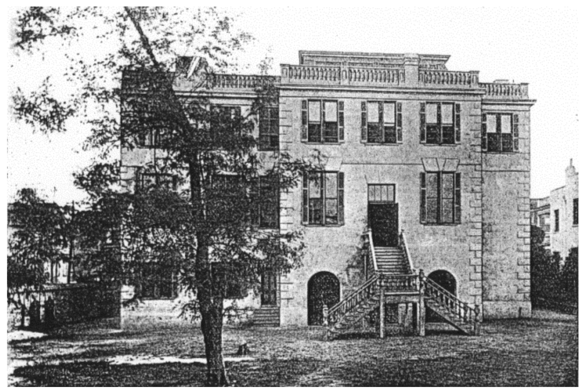

Figure 2.19: The rear addition to the building.

[22] Harvey S. Teal, Partners with the sun: South Carolina photographers, 1840-1940 (University of South Carolina Press, 2001), 138.
[23] Historic Charleston Foundation. "24 George Street," Vertical Files, n.d
[24] Eugene Clifford Clark, A history of the first hundred years of the High School of Charleston, 1839-1938 (CHS Alumni Association, 1998), 43.
[25] Ibid., 43.

college removed without approval. The fence was one of the finest examples of the early nineteenth century ornament ironwork and it was used as a model for a fence at the Nathaniel Russell House.[26]

Figure 2.20: Radcliffe-King Mansion, 1885. Courtesy of the Charleston Museum.

Before the mansion's demolition, Albert Simons, recognizing the importance of the building, documented and salvaged architecturally significant elements. Much of this historic fabric was later integrated into the interior of another WPA project, the Dock Street Theatre, also designed by Albert Simons. The architectural elements reused in that project included woodwork, wainscoating, door and window trims, mahogany doors, and plaster ornaments and

[26] Historic Charleston Foundation. "24 George Street," Vertical Files, n.d.

cornices. The Green Room and the Drawing Room of the theatre now house these elements.[27] The Charleston Museum became the repository for the ironwork, capitals of the front door pediment and second floor vestibule's archway and columns. These items were later loaned to Historic Charleston Foundation.[28]

Thomas Radcliffe

The builder of the mansion at 24 George Street, Thomas Radcliffe was another wealthy Charlestonian. The son of a tanner, Radcliffe gradually improved his lot in life as a merchant, planter, and eventually a local politician. He increased his wealth through trade, agriculture, and land speculation. His company, Radcliffe & Sheperd, was one of the most respected of the seventeen trading houses in Charleston by 1774. Radcliffe was mainly exporting rice and naval stores, as well as importing manufactured goods, foodstuffs, and slaves.[29] He established Radcliffeborough by acquiring the tract of land bounded by King, Vanderhorst, Smith and Radcliffe streets by the mid-1780s.[30] His title changed to "planter" from "merchant" in the city directories by 1790. During the American Revolution, he was a Loyalist and was protected by the British. However being a Loyalist did not change his position in Charleston society. He served in many community activities, such as vestryman and churchwarden in St Philip's parish, city's commissioner of streets, city's commissioner for stamping and issuing currency, city's fire

[27] Laura Burghardt, "The Movement of Architectural Elements Within Charleston, South Carolina," (MA Thesis, Clemson University. 2009), 63.
[28] Carol E. Borchert, "The inventory of Lucretia Constance Radcliffe: the material world of elites in Federal period Charleston, South Carolina," (MA Thesis, University of Delaware, 1996), 5.
[29] Ibid., 7.
[30] Charleston County Public Library, "History of Ansonborough and Nearby Neighborhoods," <http://www.ccpl.org/content.asp?id=15841&catID=6062&action=detail&parentID=6046> (accessed January 6, 2012).

master and warden, and commissioner for tobacco inspection for the city. He represented St. Philip and St. Michael parishes three times in the General Assemblies. Moreover, he was a member of the Charleston Library Society, the state House of Representatives, the South Carolina Society, and the Society for the Relief of Widows and Orphans of the Clergy of the Protestant Episcopal Church of South Carolina, as well as the director of the Charleston Mutual Insurance Company. Most of these community activities took place before his transition to planter status.[31] His life ended when he was lost at sea in September 15, 1806.

Judge Mitchell King

After Thomas Radcliffe's widow passed away, the mansion had another prestigious owner Judge Mitchell King. King was a teacher, lawyer, and the judge of the Charleston City Court. He was born in Craill, Fife Shire, Scotland in June 8, 1783.[32] He came to Charleston in 1805 when he was escaping from Spanish authorities in Malaga. Upon arrival in Charleston, he established a school to make a living. His talents in poetry allowed him to publish some of his poems in The Courier. He received an offer from the president of the College of Charleston for a position on the college faculty and began working there March 6, 1806. He studied law in the George Warren Cross's office and continued teaching at the same time. He temporarily became the president of the College of Charleston right before he was admitted to the bar in November, 1810. He received a prominent position due to his skills and worked as a recorder in 1819. He

[31] Carol E. Borchert, "The inventory of Lucretia Constance Radcliffe: the material world of elites in Federal period Charleston, South Carolina," (MA Thesis, University of Delaware, 1996), 8.
[32] University of North Carolina at Chapel Hill's Southern Historical Collection, "Mitchell King Papers, 1801-1862," <http://www.lib.unc.edu/mss/inv/k/King,Mitchell.html> (accessed January 11, 2012).

rose to the position of Judge of the Charleston City Court in 1842.[33] King participated in many local activities and supported the Library Society of Charleston and the College of Charleston. He was involved in the management and affairs of Presbyterian and Episcopal churches in Charleston and North Carolina, where he had a summer retreat house. He passed away at Flat Rock, North Carolina on November 12, 1862.[34]

Gabriel Manigault House, 288 Meeting Street, c. 1802

Gabriel Manigault, a well-respected amateur architect in Charleston, designed and built his own house at the southeast corner of the Meeting and George streets intersection in 1802. He purchased the lot on April 4, 1793, and sold his house in March 12, 1805.[35] Manigault's house was unlike any built to that date in Charleston. While it boasted a spacious south-facing piazza, a feature that had by the early nineteenth century become more and more typical in the city, its plan was unusual. Exterior steps led to a shallow, unshaded stoop on the Meeting Street façade where a door provided entry to an entrance hall that contained stairs to the second floor. Other examples of stoops can be seen at City Hall, William Blacklock house and 329 East Bay, which has a very

Figure 2.21: The Gabriel Manigault house at 288 Meeting Street. Courtesy of the Charleston Museum.

[33] "Do you know your Charleston, Old high school," The News and Courier, Charleston, S.C., August 1922.
[34] University of North Carolina at Chapel Hill's Southern Historical Collection, "Mitchell King Papers, 1801-1862," <http://www.lib.unc.edu/mss/inv/k/King,Mitchell.html> (accessed January 11, 2012).
[35] Gene Waddell, "The Introduction of Greek Revival Architecture to Charleston," In Art in the lives of South Carolinians: nineteenth-century chapters, by Carolina Art Association, edited by David Moltke-Hansen (Carolina Art Association, 1979), GWa-9.

similar stoop compared to the Manigault house. Double parlors (noted in an early 20th century drawing as a "drawing room" and a "chamber") were the most unusual aspect of Manigault's plan. The Ionic columns on the first story piazza were one of the first Greek details used in the United States. They were based on the columns of the Ionic Temple on the Illissus; however, the second story of the piazza had columns with the Corinthian order.[36]

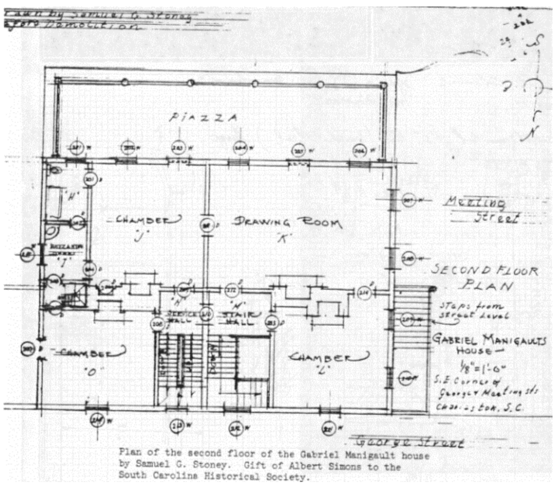

Figure 2.22: The second floor of the Manigault house. Courtesy of the Historic Charleston Foundation.

Figure 2.23: The filling station on the Manigault house site. Courtesy of the Charleston Museum.

The Manigault House was razed in 1929 to make way for a filling station. Demolition of this and other structures for filling stations by Standard Oil Company caused a public outcry. To minimize any possible damage on the company's image, Standard Oil retained the Charleston preservation architect Albert Simons to design new filling stations into which he incorporated brickwork and woodwork from the Manigault house.[37] These stations included one built on the Manigault House site, one on the northeast corner of Calhoun Street and Rutledge Avenue, and a third at 108 Meeting Street. 108 Meeting Street is the only one that survives today. First story

[36] Ibid., GWa-2.
[37] Jonathan Poston, The Buildings of Charleston (Columbia, SC: University of South Carolina Press, 1997), 188.

window surrounds and Ionic columns from the Manigault house are used in this structure, which stands, ironically, across from, Hibernian Hall, one of the best Greek Revival buildings in the United States. The filling station situated on the Manigault house site reused the second story window surrounds and Corinthian columns from the piazza. Historic Charleston Foundation's warehouse holds the architectural elements that were salvaged when these filling stations demolished.[38] The woodwork used in the new filling stations included columns, pilasters, window surrounds, doors, door architraves, balusters, and interior woodwork.[39] Demolition of the Manigault House inspired passage of America's first historic zoning ordinance in 1931, the creation of the nation's first historic district and its Board of Architectural Review.[40]

Gabriel Manigault

Gabriel Manigault was the best-known amateur architect of Charleston who implemented his works in the post-revolutionary period. Although he was renowned by his architectural skills, his main professions were lawyer and rice planter. He was one of the interpreters of the Adamesque style in the United States.

Manigault was sent to study in Geneva and London by his grandfather and then his guardian in 1775. He studied law at Lincoln's Inn, London, between 1777-1779. When he returned to Charleston in 1780, he carried a valuable architectural library from England. He was a loyalist during the Revolution; and, after the city fell, he stayed in Charleston and started rice

[38] Brent Lanford, "Station to Station: How gas stations have transformed Charleston (and vice versa)," Charleston City Paper, May 14, 2003: 15.
[39] Laura Burghardt, "The Movement of Architectural Elements Within Charleston, South Carolina," (MA Thesis, Clemson University, 2009), 144.
[40] Jonathan Poston, The Buildings of Charleston (Columbia, SC: University of South Carolina Press, 1997), 188.

planting. During his lifetime Manigault wholly or partially owned some plantations that included the Barony of Auendaw, the Salt Ponds, Pompion Hill, the Club House tract, and a plantation at Willtown.[41] He was active in public affairs like his ancestors: He served in the General Assembly, became a member of the state convention to ratify the U.S. Constitution, was a trustee of the College of Charleston, and was a member of South Carolina Society. Before he left Charleston in 1804, he advertised all of his properties for sale, and then he lived in New York from 1805-1807. Later he moved to Philadelphia and passed away in 1809.[42] His architectural works included the Joseph Manigault House, the Orphan House Chapel, South Carolina Hall, and the Bank of the United States. [43]

The intersection of George and Meeting streets lost most of its historic character in the first half of the twentieth century. While the intersection has evolved into a large-scale institutional node, replacing two demolished houses which represented the social and cultural life of the nineteenth century Charleston. The Radcliffe-King Mansion was one of the best Federal Style houses in the city. Today, it is not possible to experience the same historic fabric at this intersection; however, virtual heritage reconstruction helps restoring this lost aspect of Charleston's architecture to public memory.

[41] Beatrice St. Julien Ravenel, Architects of Charleston (University of South Carolina Press, 1992), 54.
[42] Gene Waddell, Charleston Architecture, 1670-1860: Text (Wyrick, 2003), 132.
[43] Now it is called the City Hall

CHAPTER THREE

VIRTUAL HERITAGE

The history of virtual reality as a simulation of the real world can be traced back to the 1960s. Ivan Sutherland's experiments on a virtual flight simulator led to the first virtual reality systems in 1968. The technology was not mature enough at the time. Jaron Lanier established VPL Research, one of the first companies to specialize in developing hardware and software systems. Lanier, considered the father of "virtual reality", described it as "an open world where your mind is the only limitation."[44] The first virtual reality systems were ones used in research laboratories and were limited by their ergonomically constrained head-mounted displays. These old fashion systems were later replaced with projective display and online virtual reality communities. Virtual environment systems have evolved in the last two decades with the improvement of technology. It has been adopted in a variety of professions for simulation, entertainment, medicine and education. Hospitals have been using the system for pain management, therapy, and rehabilitation researchers see it as a promising tool.[45] Literature shows that virtual environments has been accepted in many fields and has been classified in four general types: work-related; informative; entertainment; education and training.[46]

Virtual heritage can be work-related, informative, and educational according to Alonzo C. Addison who says that virtual reconstruction projects target three groups: the

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[44] Colleen L. Morgan, "(Re)Building Çatalhöyük: Changing Virtual Reality in Archaeology," Archaeologies: Journal of the World Archaeological Congress (2009): 470.
[45] Albert Rizzo and Gerard Jounghyun Kim, "A SWOT Analysis of the Field of Virtual Reality Rehabilitation and Therapy," Presence: Teleoperators and Virtual Environments, (April 2005): 119.
[46] Tim Marsh, Peter Wright and Shamus Smith, "Evaluation for the Design of Experience in Virtual Environments: Modeling Breakdown of Interaction and Illusion," CyberPsychology & Behavior, (April 2001): 226.

preservationist’s documentation, the historian’s interpretation, and the public’s visual realism.[47] Virtual heritage is the intersection of virtual environment and cultural heritage. Jeffrey Jacobsen and Lynn Holden describe virtual heritage as “the use of electronic media to recreate or interpret culture and cultural artifacts as they are today or as they might have been in the past.”[48] Most scholars stress the possibilities offered by virtual heritage through new technological improvements. There is also an educational usage which Robert Stone and Takeo Ojika emphasize in their definition: “the use of computer-based interactive technologies to record, preserve, or recreate artifacts and sites of historic, artistic, religious and cultural significance, and to deliver the results openly to global audience in such a way as to provide a formative educational experience through electronic manipulations of time and space.”[49] Virtual heritage projects chiefly recreate or reconstruct the history by 3D models and animations while the main goal is to comprehend early cultures. The recreation of the heritage sites in virtual environment can be accomplished in three ways:

- 3D capturing, automatic laser scanning of photogrammetry of the existing objects.
- Hand modeling of the damaged or non-extant objects.
- Hybrids, combination of the above methods.[50]

[47] Alonzo C. Addison, "Emerging trends in virtual heritage," IEEE multimedia, (April 2000): 22.
[48] Jeffrey Jacobsen and Lynn Holden, "Virtual Heritage: Living in the Past," Techné: Research in Philosophy and Technology 10, no. 3 (Spring 2007).
[49] Robert Stone and Takeo Ojika, "Virtual heritage: what next?," IEEE multimedia, (April 2000): 73.
[50] David Koller, Bernard Frischer and Greg Humphreys, "Research Challenges for Digital Archives of 3D Cultural Heritage Models," ACM Journal on Computing and Cultural Heritage 2, no. 3 (December 2009): 2.

Two international charters define the principles of virtual heritage and emphasize the importance of communicating it. The London Charter aims to set rigorous procedures on the use of 3D visualization in the creation of virtual heritage. It advocates that 3D visualization should be implemented with scholarly rigors, and should "accurately convey to users distinctions between evidence and hypothesis, between different levels of probability." It defines the objectives and principles in relation to intellectual integrity of the relevant research sources, reliability of the visualization, documentation of sufficient information, long-term sustainability of the visualization, and access to cultural heritage.[51] The Ename ICOMOS Charter advises that the goals of the virtual systems are: to facilitate understanding and appreciation, communicate, safeguard, respect the authenticity, contribute to, encourage inclusiveness, and develop technical guidelines for cultural heritage sites.[52]

The terms virtual heritage and "virtual archaeology" sharing similarities. While "virtual heritage" commonly focuses on architectural reconstructions, virtual archaeology is most often applied to the reconstruction of archaeological ecosystems. Reilly links both terms in his definition of virtual archaeology: "[it] encompasses the modeling of landscapes, excavations, buildings, cities, and environments built with a variety of computer applications in order to test scientific questions, communicate impressions of the past to others, and invite outside

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[51] "The London Charter for the Computer-based Visualisation of Cultural Heritage," The London Charter, <http://www.londoncharter.org/fileadmin/templates/main/docs/london_charter_2_1_en.pdf> (accessed January 24, 2012).

[52] "The ICOMOS Charter for the Interpretation and Presentation of Cullturall Heritage Sites," ICOMOS Ename Charter, <http://www.enamecharter.org/downloads/ICOMOS_Interpretation_Charter_EN_10-04-07.pdf> (accessed January 24, 2012).

participation in the construction of the past."[53] Virtual archaeology initially appeared as a tool for archaelogical recording and presentation and replaced series of disconnected 2D static images. Daniel Pletinckx mentions that documentation and conservation efforts are complemented by virtual archaeology, and it combines all information in a structured way that can contribute and allow long term preservation.[54]

As a preservation tool, virtual heritage provides an opportunity to experience cultural heritage without disturbing the site. Some of the heritage sites are so popular and host a great number of tourists which can lead the destruction of local life and culture. For instance, several scholars complain about the effects of mass tourism on Venice. Many other sites, such as Stonehenge and Machu Piccu, are also threatened by tourists and listed in the most endangered destinations by UNESCO and World Monument Funds.[55] Even though it is not logical to close these cultural heritage sites to tourist, digital simulations of heritage sites will help us to save them from ourselves by experimenting without risk to the original. Maria Roussou categorized five beneficial aspects of virtual heritage:

- Make the sites that are extinct and unreachable accessible.
- Present and visualize diverse interpretations and theories.
- Maintain attraction and interest on heritage.
- Serve as a distance-learning tool.

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[53] Colleen L. Morgan, "(Re)Building Çatalhöyük: Changing Virtual Reality in Archaeology," Archaeologies: Journal of the World Archaeological Congress (2009): 471.
[54] Daniel Pletinckx, "Virtual Archaeology as an Integrated Preservation Method," Virtual Archaeology Review 2, no. 4 (May 2011): 33.
[55] Maev Kennedy, Stonehenge on 'most threatened' world wonders list, <http://www.guardian.co.uk/uk/2010/jan/12/stonehenge-threatened-wonder-of-world> (accessed January 9, 2012).

- Improve informal education. [56]

Virtual Reconstruction

Creating three dimensional models for visualizing historical structures has a long history, and is not specific to the digital era. Virtual reconstruction is the modern version of hand-drawn reconstructions like axonometric and perspective drawings.[57] These old techniques produce reconstructions from acquired three dimensional information and aim to improve understanding of lost buildings. However, virtual reconstruction is a structured way to record data in a more complete form than earlier techniques. Virtual reconstruction is thus not just an instrument of presentation, it is a tool for analysis. Virtual reconstruction projects about different cultures, countries and eras have been completed. These projects conclude virtual reconstructions of the Forbidden City and Xian terracotta soldiers in China, the Mughal city of Fatephur Sikri in India, Egyptian pyramids and temples, Greek agoras, Roman forums and theatres, Mayan and Aztec cities, European cathedrals, and the temples of Angkor Wat in Cambodia.[58] To be able to reconstruct virtual models of these cultural heritage sites, Juan A. Barceló outlines four necessary steps: data research, pre-processing, parameter estimation, and modeling.[59]

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[56] Maria Roussou, "Virtual Heritage: From the Research Lab to the Broad Public," Edited by Franco Niccolucci, Proceedings of the VAST 2000 Euroconference, (Arezzo, Italy: Archaeopress Oxford, 2002), 94.
[57] Jose M Kozan, "Virtual Heritage Reconstruction: The Old Main Church of Curitiba, Brazil,"(MS Thesis, University of Cincinnati, 2004), 33.
[58] Bharat Dave, "Virtual heritage: Mediating space, time and perspectives," In New heritage: new media and cultural heritage, by Yehuda E. Kalay, (Taylor & Francis, 2008), 40.
[59] Juan A. Barceló, "Visualizing what might be: An Introduction to Virtual Reality Techniques in Archaeology." In Virtual reality in archaeology, Volume 1, by Juan A. Barceló, Maurizio Forte and Donald H. Sanders. (Archaeopress, 2000).

Virtualization of cultural heritage is a growing practice. Decreasing costs to creating computer-generated models in the late 1990s lead many archaeologists to record cultural heritage objects in 3D environments. This rapid increase in generating virtual heritage, however, brought new problems. Early virtual reconstruction projects have been criticized for their questionable accuracy and lack of visual realism.[60] They are criticized too as more hype than help in accomplishing the often stated goal of assisting historical understanding. Advances in computer hardware and 3D modeling software overcame some of the issues. Alonzo C. Addison groups these emerging technologies projects in three domains:

- 3D documentation – information acquisition and site investigation
- 3D representation – "historic reconstruction to visualization"
- 3D dissemination – make access available to created content "from immersive networked worlds to "in situ" augmented reality" [61]

However, new problems and new ideas continue to appear. Addison says that without careful planning, many of these 3D models will not help to protect the cultural heritage that we want to save. He has identified new challenges that face the digital recreation of existing, threatened or lost landmarks:

- Lack of coordination/collaboration and sharing data
- Efforts for creating virtual heritage "focus on quantity versus quality."
- Accuracy/reliability of the collected data.

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[60] Alonzo C. Addison, "Emerging trends in virtual heritage." IEEE multimedia, (April 2000): 22.
[61] Ibid., 22.

- Data longevity – “lack of convenient data portability leads many to re-gather and abandon or ignore past data” [62]

Addison advises the creation of a metadata which could be included in virtual heritage models. From this data, digital heritage community can retrieve information about the reconstruction project.[63] Furthermore, David Koller, Bernard Frischer and Greg Humphreys share the same ideas and argue that the virtual heritage community needs to establish a centralized digital archive for collection, peer review, publication, revision, preservation, and distribution of 3D models. They outline the technical challenges that should be considered before the establishment of an ideal digital archive as follows:

- Digital rights management for 3D models – to protect and secure the dissemination of the intellectual property;
- Clear depiction of uncertainty in 3D reconstructions;
- Version control for 3D models – to be able to track any addition, deletion, and alteration to the models;
- Effective metadata structures – to achieve transparency by providing catalog, commentary, bibliographical metadata, like traditional academic print publication;
- Long-term preservation – to ensure “the survivability of the models”;

[62] Alonzo C. Addison, "The vanishing virtual: Safeguarding heritage's endangered digital record." In New heritage: new media and cultural heritage, by Yehuda E. Kalay, (Taylor & Francis, 2008).
[63] Ibid., 35.

- Interoperability – common data format usage and access to georeference metadata by different modeling software would "allow different models to be properly located relative to one another in the same coordinate system"; and
- 3D searching – to create a search engine, such as Google and Yahoo, to search and discover whether a cultural heritage site is digitally captured or modeled.[64]

Uncertainty

The accuracy and scientific reliability of 3D models of cultural heritage sites have been one of the biggest concerns of the virtual heritage community. Authenticity problems arise in reconstruction and visualization phases. Advanced computer graphics and imaging offer many tools capable of creating realistic models. Visually compelling models could easily make people think that very detailed information about lost architecture is gathered from actual field observation and that the model has high degree of certainty.[65] Thus, virtual heritage reconstructions may be suspicious because of lack of visualization techniques that clearly convey the uncertainty of underlying references.

Thomas Strothotte, Maic Masuch and Tobias Isenberg categorize the accuracy issues of virtual reconstruction in two groups. First is "uncertainty," described as "the absence of information due to some reason." They affirm that uncertainty could result from two sources: "Imprecision," that is, "the existence of a certain feature can be safely assumed, but not its dimensions" and "Incompleteness," refers to "the fact that certain information is unavailable."

[64] David Koller, Bernard Frischer and Greg Humphreys, "Research Challenges for Digital Archives of 3D Cultural Heritage Models," ACM Journal on Computing and Cultural Heritage 2, no. 3 (December 2009), 1.
[65] Simon Haegler, Pascal Muller and Luc Van Gool, "Procedural Modeling for Digital Cultural Heritage," EURASIP Journal on Image and Video Processing (Hindawi Publishing Corporation, 2009), 1.

Second, "design decisions" consists of analogies and deductions.[66] Analogies and deductions are required ways to complete the missing and hidden pieces of the cultural heritage. Frischer, Niccolucci, Ryan and Barceló suggests that the reconstruction process of models involve three stages: verify sources; analyze their reliability; and integrate/interpret data with the hypothetical elements.[67]

Many virtual reconstructions of heritage sites no longer extant or fully documented contain a variety of hypothetical data. Koller et al. defined the types of uncertainties in such sites as: structural architecture, geometric dimensions, stylistic features, temporal correspondence, and construction materials. The recent London Charter establishes principles for visualization of virtual heritage and demands transparency of the models in its principles. According to the fourth principle of the charter, different levels of information should be clearly represented in 3D visualization is necessary as well "to disseminate documentation of the interpretative decisions made in the course of a 3D visualization process" for public.

Many scholars proposed different uncertainty representation methods to overcome the authenticity problem. Strothotte et al. suggest usage of non-photorealistic rendering to balance illusive effects of photorealistic images.[68] They created a visualization system and replaced the photorealistic images with less detailed images based on sketch-like renditions and variable

[66] Thomas Strothotte, Maic Masuch and Tobias Isenberg, "Visualizing knowledge about virtual reconstructions of ancient architecture," Computer Graphics Internationa,(Los Alamitos, CA: IEEE Computer Society, 1999), 39.
[67] Bernard Frischer and others, "From CVR to CVRO: the Past, Present and Future of Cultural Virtual Reality," Proceedings of VAST EuroConference, (Arezzo, Italy, 2000).
[68] Thomas Strothotte, Maic Masuch, and Tobias Isenberg, "Visualizing knowledge about virtual reconstructions of ancient architecture," Computer Graphics Internationa, (Los Alamitos, CA: IEEE Computer Society, 1999).

transparency that can be easily and rapidly altered. Another group, Torre Zuk and Sheelagh Carpendale, focused on the specific aspect of visualizing temporal uncertainty.[69] Johnson and Anderson show several variations of uncertainty visualization methods, which include usage of error bar glyphs, blurring, fuzzy surfaces, and false coloring.[70] Simon Haegler, Pascal Muller and Luc Van Gool advocate producing several realistic models rather than using coloration, levels of transparency and non-photorealistic rendering; moreover, creating several realistic models leads to the idea of "probability distrubitions" based on uncertainty.[71] As Barceló argues, virtual reality is the new way of generating possible reconstruction using water-colors. Excluding uncertain elements and realistic visualizations would simplify the process and render it more reliable.[72]

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[69] Torre Zuk and Sheelagh Carpendale, "Theoretical analysis of uncertainty visualizations," Proc. of SPIE-IS&T Electronic Imaging, (2006), 606007-606007-14.

[70] Chris R. Johnson and Allen R. Sanderson, "A Next Step: Visualizing Errors and Uncertainty," IEEE Computer Graphics and Applications 23, no. 5 (September/October 2003).

[71] Simon Haegler, Pascal Muller and Luc Van Gool, "Procedural Modeling for Digital Cultural Heritage," EURASIP Journal on Image and Video Processing (Hindawi Publishing Corporation, 2009), 2.

[72] Juan A. Barceló, "Visualizing what might be: An Introduction to Virtual Reality Techniques in Archaeology," In Virtual reality in archaeology, Volume 1, by Juan A. Barceló, Maurizio Forte and Donald H. Sanders. (Archaeopress, 2000).

CHAPTER FOUR

RECONSTRUCTION OF THE INTERSECTION

Data Research

Images

The initial goal of the reconstruction of the intersection of George and Meeting streets was to find images of its lost buildings. Clear photographs, plans and drawing would support a virtual reconstruction. Those failed to deliver clear data would be set aside. Reliable images of both the Manigault and Radcliffe-King Houses were gathered from the Charleston Museum Archives, the Library of Congress' website, Gibbes Museum Archives, and miscellaneous books. Some of these images were taken by unknown photographers, and dates were not always clear.

The earliest image taken in the intersection is most probably Joseph H. Anderson's photograph that shows the Radcliffe-King Mansion with piazzas. The date of this photograph, however, is unknown and the image is not clear. Even so, Anderson created a visual historic record for the piazzas, an important element of this house. Another image by an unknown photographer dates to 1885 and shows the entire Radcliffe-King Mansion taken across Meeting Street from the Manigault House. This is the photograph principally used for the reconstruction of the Radcliffe-King Mansion. Other photographs of this mansion taken by E. Milby Burton in 1938 show conditions both before and after demolition of the structure. All of these photographs were gathered from the Charleston Museum Archives. The Gibbes Museum contained some interior images of the mansion taken by Albert Simons took before its demolition. Although these pictures provide information about the mansion's interior, and provided glimpses of specific elements, and they were not helpful for reconstructing interior spaces. The photographs held in the collections of the Library of Congress show the details of the main iron gate which was removed in 1982. Photographs of the Gabriel Manigault House survived only in the Charleston Museum Archives. These photographs have no information about date nor photographer. There are a couple of photographs showing the building that occupied the 292 Meeting Street site, the northeast corner of the intersection

These diverse views capture most but not all sides of the Radcliffe-King and Manigault houses. With the exception of the original north façade of the Radcliffe-King Mansion, photographs for almost all facades of the buildings survive. Even so, other data sources were used to reconstruct this side of the mansion. Reliable photographic sources for the facades of the rear stairwell section of the Radcliffe-King Mansion do not exist.

Maps

Images are used to place individual details on the façade of the buildings. Maps are used to place buildings in context. Sanborn Fire Insurance Maps provide imprecise locations of the buildings and trace changes that occurred at the intersection. These maps date from 1888 to 1955 and confirm that the general configuration of the intersection has not changed.

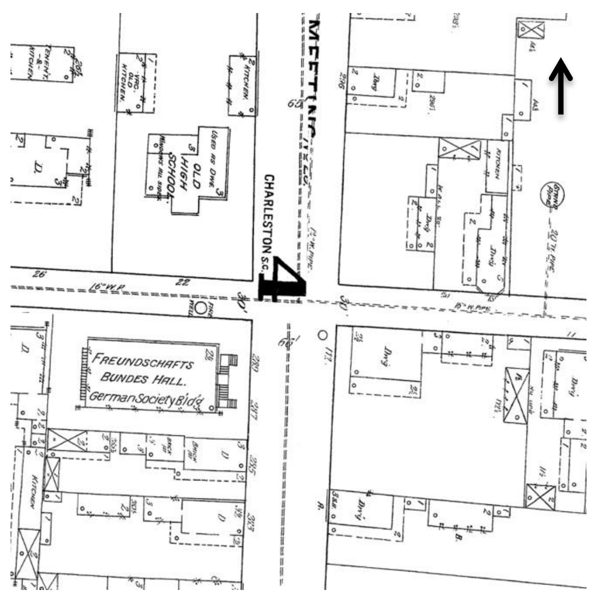

Figure 4.1: 1888 Sanborn Fire Insurance Map of Charleston, SC. From sanborn.umi.com, edited by author in *Photoshop*.

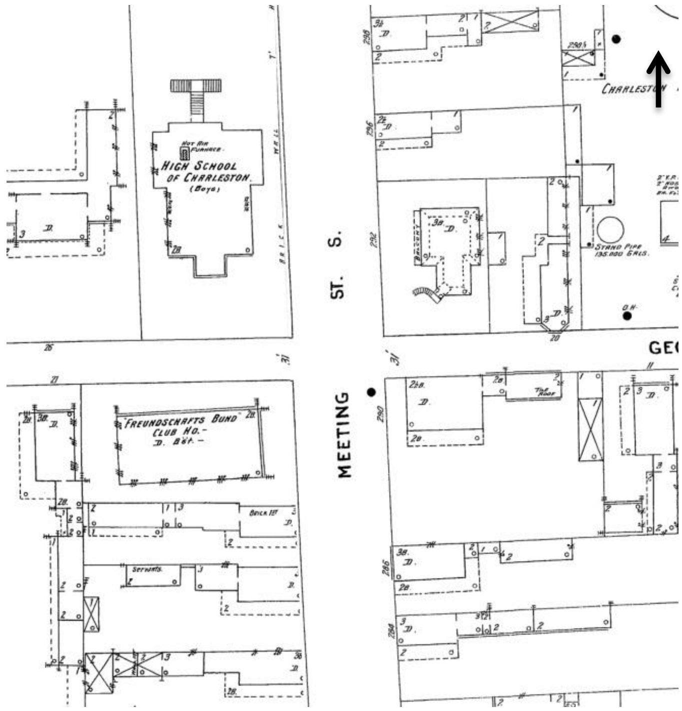

Figure 4.2: 1902 Sanborn Fire Insurance Map of Charleston, SC. From sanborn.umi.com, edited by author in *Photoshop*.

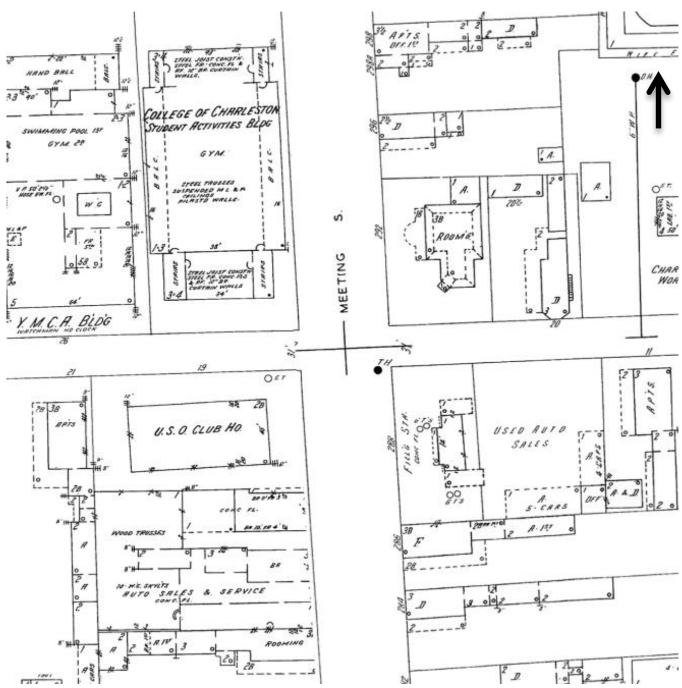

Figure 4.3: 1955 Sanborn Fire Insurance Map of Charleston, SC. From sanborn.umi.com, edited by author in *Photoshop*.

Salvaged Materials

Salvaged materials are another source for accurate dimensions, thus aiding reconstruction. Two preservationist architects, Albert Simons and Samuel Lapham, salvaged many architectural elements from these two structures and reused them in new projects. Interior elements of the Radcliffe-King Mansion went into Dock Street Theatre. Other elements were stored in the Historic Charleston Foundation's (HCF) warehouse. 108 Meeting Street now HCF museum shop contains exterior architectural elements such as window surrounds and Ionic columns from the first story of the Manigault House.

Figure 4.4: 108 Meeting Street, Ionic columns and window surrounds of Gabriel Manigault House. Photo is taken by author.

Documents/Drawings

While Simons & Lapham were salvaging architectural elements, they also documented some of the features of the houses. Their accurate plan drawing of Radcliffe-King Mansion was published in several books. In contrast, an imprecise plan drawing of Manigault house was found in the HCF vertical files. HCF archives also contained measured drawings of balusters and Ionic columns of the Manigault house. Simons' drawings of the interior architectural elements of the Radcliffe-King Mansion have been located at the South Carolina Historical Society archives, which includes measured drawings of interior doors, windows, fireplaces, a pilaster, wainscoting, and other trim. The aim of this project is not to reconstruct the interior of either house.

3D Modeling

Google SketchUp was chosen to render reconstructions of both houses because of its availability, its easy usage compared to *ImageModeler* and *PhotoModeler*, and its ease of use without additional training. The modeling tools in *ImageModeler* are not so flexible as *SketchUp*, and PhotoModeler requires camera properties or reference points in the picture which are not available in the historic photographs used for this project. Moreover *SketchUp* is compatible with the digital design formats developed by *Autodesk.*[73] *SkecthUp* offers a photogrammetric solution based on a vanishing point technique with its "Match Photo" function. It also allows calibration of multiple images.

[73] Autodesk is a corporation that focuses on 2D and 3D computer aided design (CAD) software for use in many industries.

Photogrammetry is a tool that enables reconstruction of the position, orientation, shape and size of objects from pictures.[74] Its use in architecture is well established. The German architect Albrecht Meydenbauer introduced the photogrammetric technique for documenting buildings in 1885, and established the first photogrammetric institute at the same time. Meydenbauer Archives collected 20,000 negative plates of 2,000 buildings between 1885 and 1920.[75] Today, educators teach how to reconstruct historical buildings based on images from this archive. Nevertheless, extracting 3D geometric information from images remains a labor intensive and complicated process.

Architectural image-based modeling systems can be grouped in three categories: single image, multiple image, and aerial image architectural modeling. Single image photogrammetry is a unique way to obtain information about a historic structure. Linearity, parallelism, perpendicularity and symmetry make camera calibration and reconstruction from a single image feasible when the image is taken by an uncalibrated camera. Prior to the reconstruction process, the interior orientation of the image should be determined, identification of parallelism and perpendicularity constraints of the building lead to the detection of vanishing points. This in turn helps to determine the interior orientation of the image without additional input.[76]

Limitations of the single image photogrammetry are discussed by Streilein and Heuvel who observe that “a monocular image alone does not contain sufficient information to uniquely

[74] Karl Kraus, Photogrammetry: geometry from images and laser scans, Volume 1, (Walter de Gruyter, 2007), 1.
[75] Albert Wiedemann, Matthias Hemmleb and Jörg Albertz, "Reconstruction of historical buildings based on images from the Meydenbauer archives," (Amsterdam, 2000), 888.
[76] Frank A. van den. Heuvel, "Reconstruction from a single architectural image from Meydenbauer archives," Proceedings of the XVIII International Symposium of CIPA, 18-22 September, (Potsdam, 2001), 699.

retrieve 3D information." They assert two major limitations are "incompleteness of the 3D object model" and, second, the "need for additional object information." Alternative techniques were established to recover building dimensions from a single image by using what Streilein and Heuvel call "certain visual cues" like size, shade, distortion, vanishing points. [77]

Gui-zhen HE, Xiao-jun CHENG and Cheng-quan XU have also evaluated the accuracy of single image photogrammetry in the reconstruction process. After they reconstructed a structure from a single image, they compared the positional accuracy of the coordinates and distance accuracy of feature lines with the help of a high-precision total station. They affirmed that total root mean square error of the both tests meet the requirements and achieve the accuracy evaluation.[78]

The second system, multiple image based modeling, provides more geometric constraints by utilizing different viewpoints. Corresponding points of images should be matched to acquire 3D information. A disadvantage of this approach is the need for several images of the same structure with different viewpoints. This is not always possible.[79] The third method uses aerial images to reconstruct buildings and usually merges ground-level pictures for acquiring 3D information. This technique mainly used for modeling very large images such as cities.

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[77] Frank A. van den Heuvel and Andre Streilein, "Potential and limitation for the 3D documentation of cultural heritage from a single image," CIPA International Symposium, (Olinda, Brazil, 1999), 2.
[78] Gui-zhen HE, Xiao-jun CHENG and Cheng-quan XU, "The 3D Reconstruction Based on Single Image and Accuracy Analysis," 2010 International Conference on Computer Application and System Modeling, (Taiyuan, China, 2010), 212.
Total root mean square error: It is a frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed.
[79] Nianjuan Jiang, Ping Tan and Loong-Fah Cheong, "Symmetric architecture modeling with a single image," ACM Transactions on Graphics 28, no. 5 (December 2009), 2.

Although several images of the both Radcliffe-King and Manigault Houses were found, only a limited number of them were suitable for use in *SketchUp*. Some of these photographs are reproductions of originals and their resolution is not good enough to detect edges of the structures needed to get accurate dimensions. Some photos set aside because of barrel distortion on the images.[80] Other photos lacked multiple vanishing points; however, some of these images were used for rectification procedure to acquire missing details on the main pictures. Only one photograph shows the whole Radcliffe-King Mansion in one frame, two photographs of the Manigault house were suitable to use in *SketchUp*.

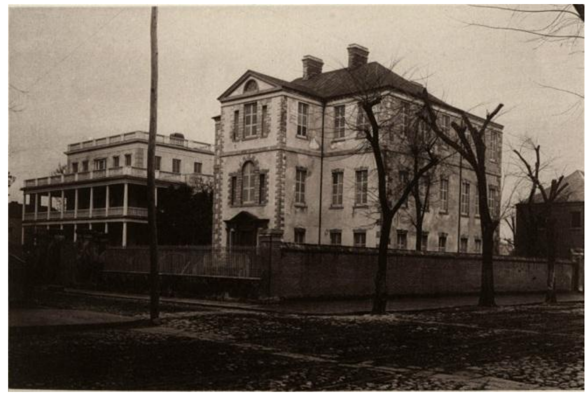

Figure 4.5: Selected image of the Radcliffe-King Mansion. Courtesy of Lowcountry Digital Archives.

Figure 4.6: Selected image of the Manigault house. Courtesy of the Charleston Museum.

Figure 4.7: Selected image of the Manigault house. Courtesy of the Charleston Museum.

[80] Barrel distortion is a lens effect which causes images to be spherised or inflated.

There are two steps necessary to the building reconstruction process from an image with an uncalibrated camera. The first step is to calibrate the image through line extraction, vanishing point detection, and scale adjustment. There are two green and red lines in the “Match Photo” plugin use to define the parallelism and perpendicularity constraints on the straight edges of the buildings (Figure 4.9). These constraints lead to detection of vanishing points automatically (Figure 4.8). The software creates a grid system based on these vanishing points. The grid is scaled and adjusted based on the real dimensions of the buildings, salvaged materials, and drawings. The scaled plan drawing of the Radcliffe-King Mansion was used as reference. For the Manigault house, salvaged window surrounds were used to scale and align the grid system. After setting these parameters, *SketchUp* locates the cameras in the model space.

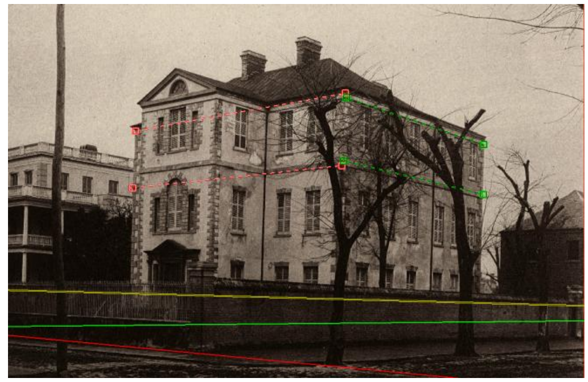

Figure 4.9: Parallel and perpendicular constraints by line extraction.

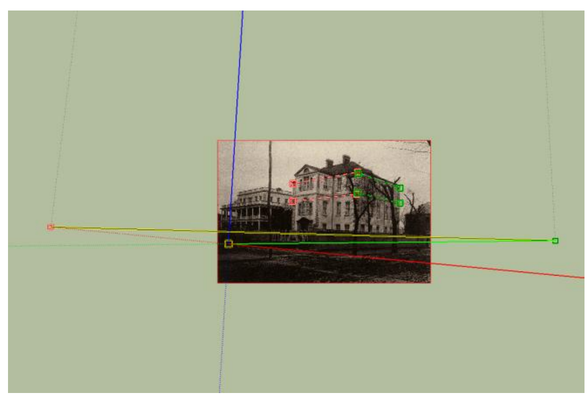

Figure 4.8: Vanishing points of the image.

Figure 4.10: Determined camera locations for the images of the Manigault house. Image gathered from SketchUp.

The second step is the modeling process. This requires extracting edges from the image that align to building edges. This manual edge recognition process takes considerable time to detect openings and feature edges of buildings. The results of the detected edges for each building are shown in the following images.

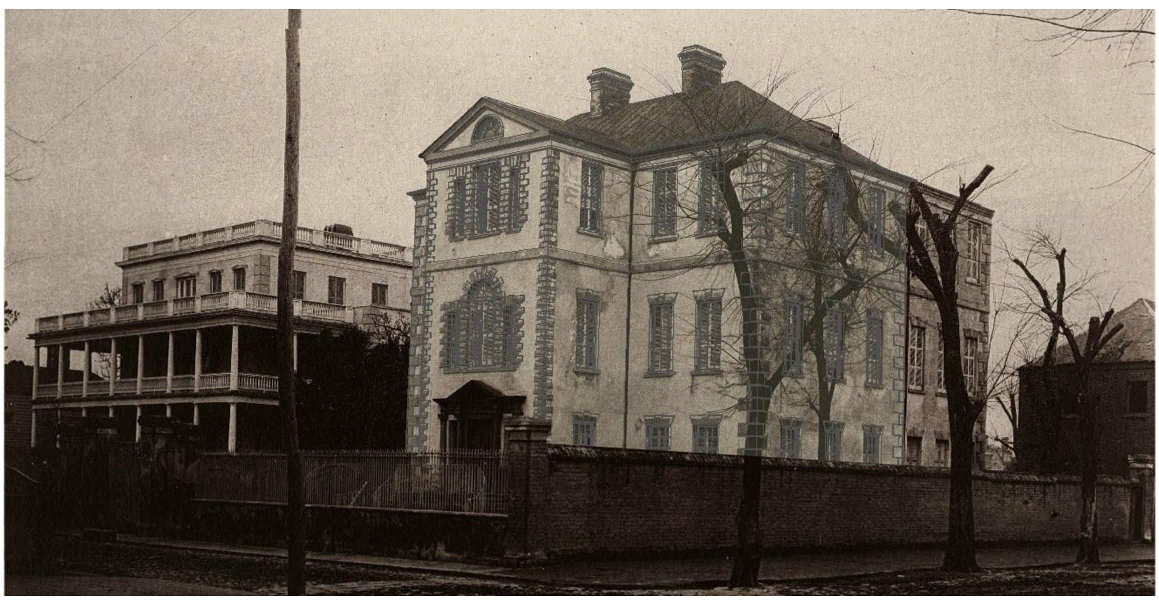

Figure 4.11: 3D model drawing over the image of Radcliffe-King Mansion.

Figure 4.12: 3D model drawing over the south-west corner image of the Manigault house.

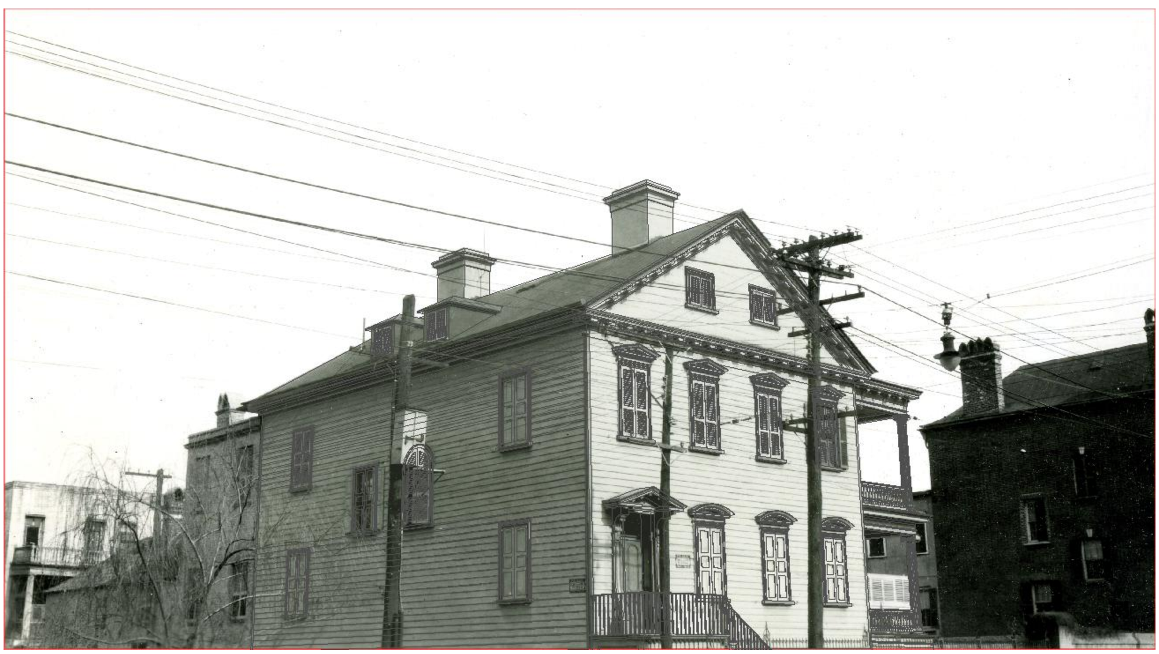

Figure 4.13: 3D model drawing over the north-west corner image of the Manigault house.

The ironwork details of the Radcliffe-King Mansion were extracted from on Alston Deas's book *The Early Ironwork of Charleston*. They provide the scaled drawing of the iron gate and ironwork detail of the entrance. The photograph and the detail, however, have different finial details; it is modeled according to the picture and based on the dimensions of the drawing.

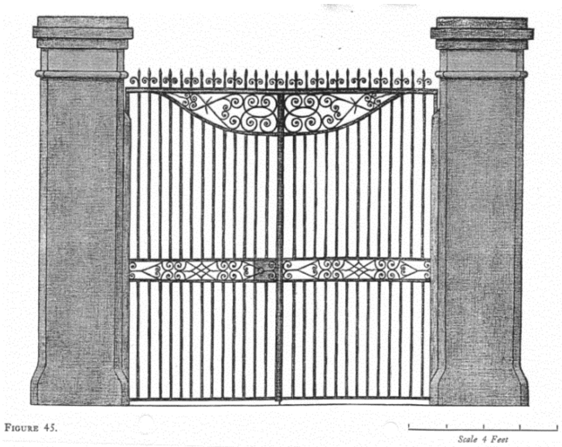

Figure 4.14: The Iron Gate drawing. From the Early Ironwork of Charleston.

Figure 4.15: HABS picture of the Iron Gate. From <http://www.flickr.com/photos/hdescopeland/2235425904/in/photostream/>

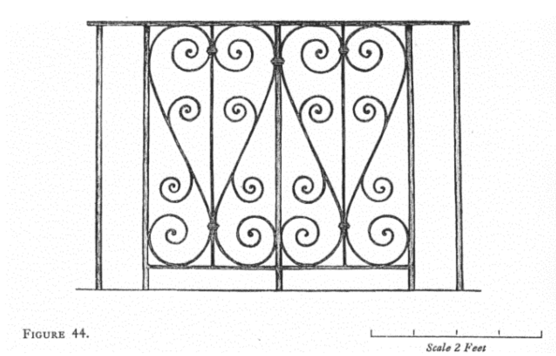

Figure 4.16: The ironwork detail of the entrance. From the Early Ironwork of Charleston.

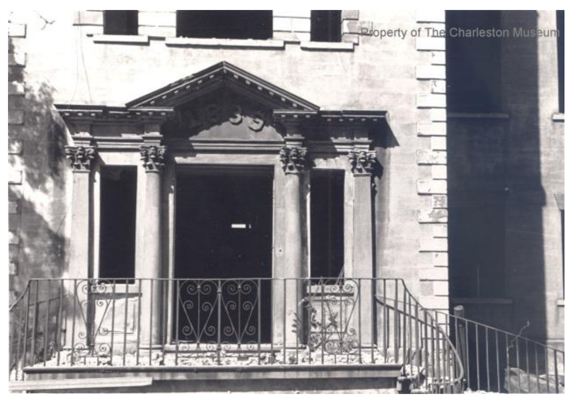

Figure 4.17: Picture of the Radcliffe-King entrance. Courtesy of the Charleston Museum.

Rectification

The images selected for modeling did not provide necessary geometrical information for some parts of the buildings. For example, the entablature section of the Radcliffe-King Mansion is obscured by the ironwork fences. In addition, the bottom portions of the both houses are not present in the selected images. These details were acquired by rectification from other pictures which are not suitable to use with “Match Photo” plugin of *SketchUp*.

Rectification is a process for transforming a photographic perspective and generating an image as if taking the photograph exactly perpendicular to the object surface without normal distortion of perspective. The best results are obtained if the object surfaces are plain.[81] Heuvel and Streilein assert that the suitable choice from several rectification procedures depends on the type of object information:

- Planar objects – projective rectification
- Piecewise (multiple) planar objects – combination of projective rectification
- Any object (Organic – amorphous shapes) – non-parametric rectification
- Mathematically definable object – parametric rectification
- Digital surface model – differential rectification[82]

The most appropriate rectification method for the images of the two mansions is the projective rectification because both mansions have rectangular plans and flat facades. Heuvel

[81] Amparo Núnez Andrés and others, "Generation of virtual models of cultural heritage," Journal of Cultural Heritage, 2011, 1.
[82] Frank A. van den Heuvel and Andre Streilein, "Potential and limitation for the 3D documentation of cultural heritage from a single image," CIPA International Symposium, (Olinda, Brazil, 1999), 3.

and Streilein also indicate that the selected method for rectification does not need any camera parameters or information about the camera type; however, to be able to rectify the photographs, at least four control points in two dimensions of the each facades have to be known. The required reference points are gathered from the both mansions' partial models. The rectification process is implemented by *PhotoPlan* software, which is chosen because of its availability and easy usage. The 2D model of the entablature section of the Radcliffe-King Mansion is gathered by overlapping two rectified images.

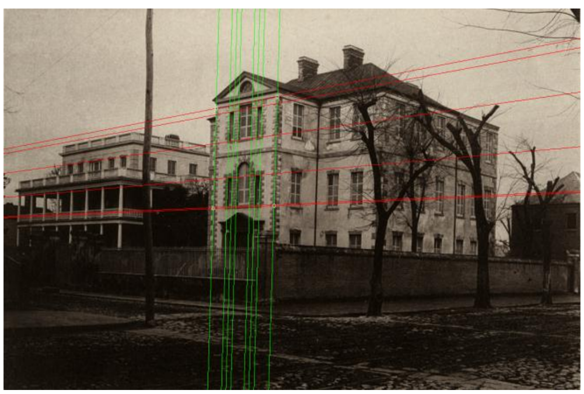

Figure 4.18: Rectification grid on the front façade. Courtesy of the Lowcountry Digital Archives.

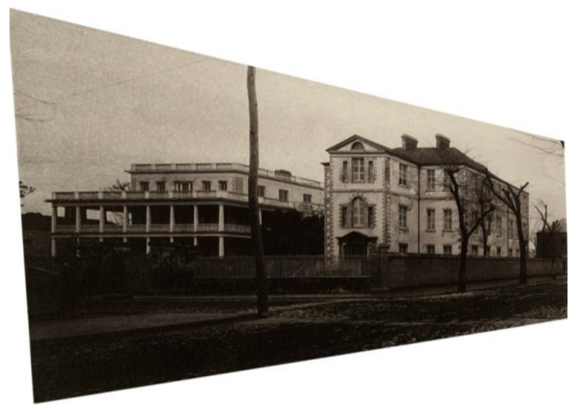

Figure 4.19: Rectified image with front façade parameters.

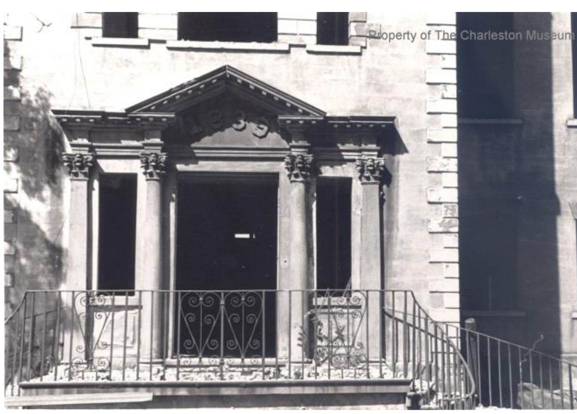

Figure 4.20: The entablature. Courtesy of the Charleston Museum.

Figure 4.21: Rectified image with the front façade parameters.

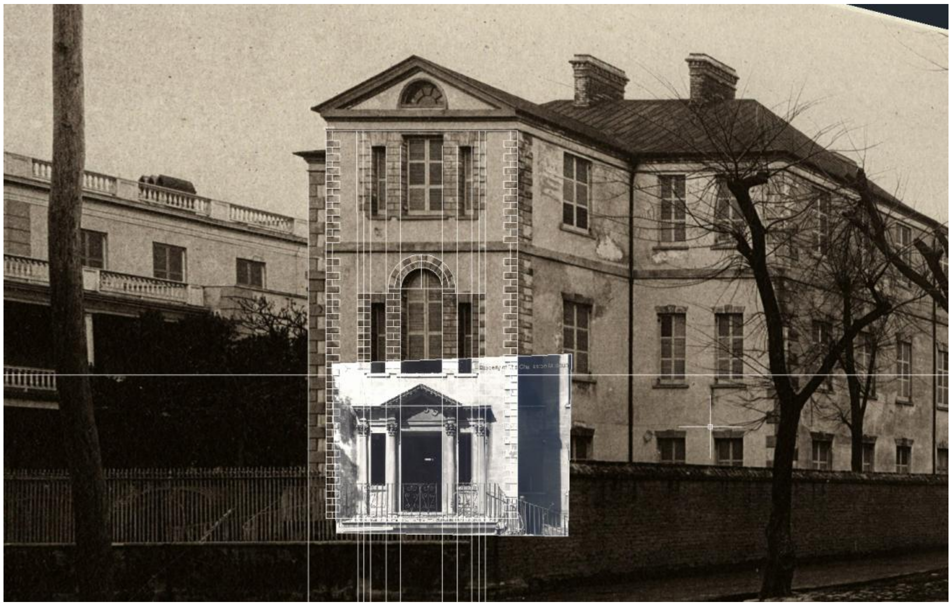

Figure 4.22: Overlapped two rectified images, and 2d drawing of the façade and entablature.

Another image of this section taken during demolition shows details of the wood. Dimensions of the details are gathered and modeled based on the Figure 4.23.

Figure 4.23: Detected edges of the entablature in *SketchUp*. Courtesy of the Charleston Museum.

The same rectification procedure was applied to the Manigault House to get the bottom section of the facades. Except for the east façade, geometric information of the other facades were acquired from the images.

Figure 4.24: Rectification grid on the west façade. Courtesy of the Charleston Museum.

Figure 4.25: Rectified image with the west façade parameters.

Figure 4.26: Rectification grid on the north façade. Courtesy of the Charleston Museum.

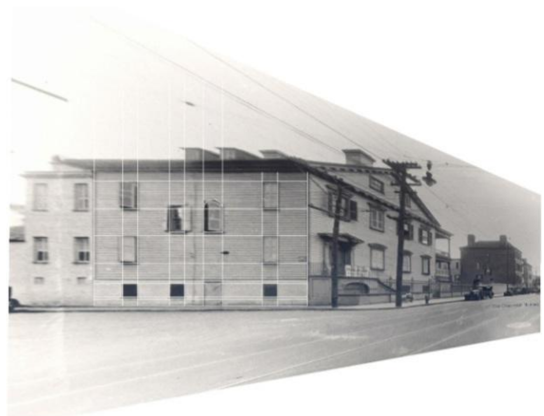

Figure 4.27: Rectified image with the north façade parameters.

Figure 4.28: South façade of the Manigault house. Courtesy of the Charleston Museum.

Figure 4.29: Rectified image with the south façade parameters.

Map Reference

The precise locations of the both mansions could not be determined, and archaeological survey does not seem fruitful given the current conditions of the area. Modern buildings occupy the sites of both subject houses. Early Sanborn Fire Insurance Maps, however, show building positions and dimensions and provide the dimensions of Meeting and George streets. According to these dimensions, the image was scaled to overlap with the models of the mansions. Models placed on the map to show the relation of each building to their site.

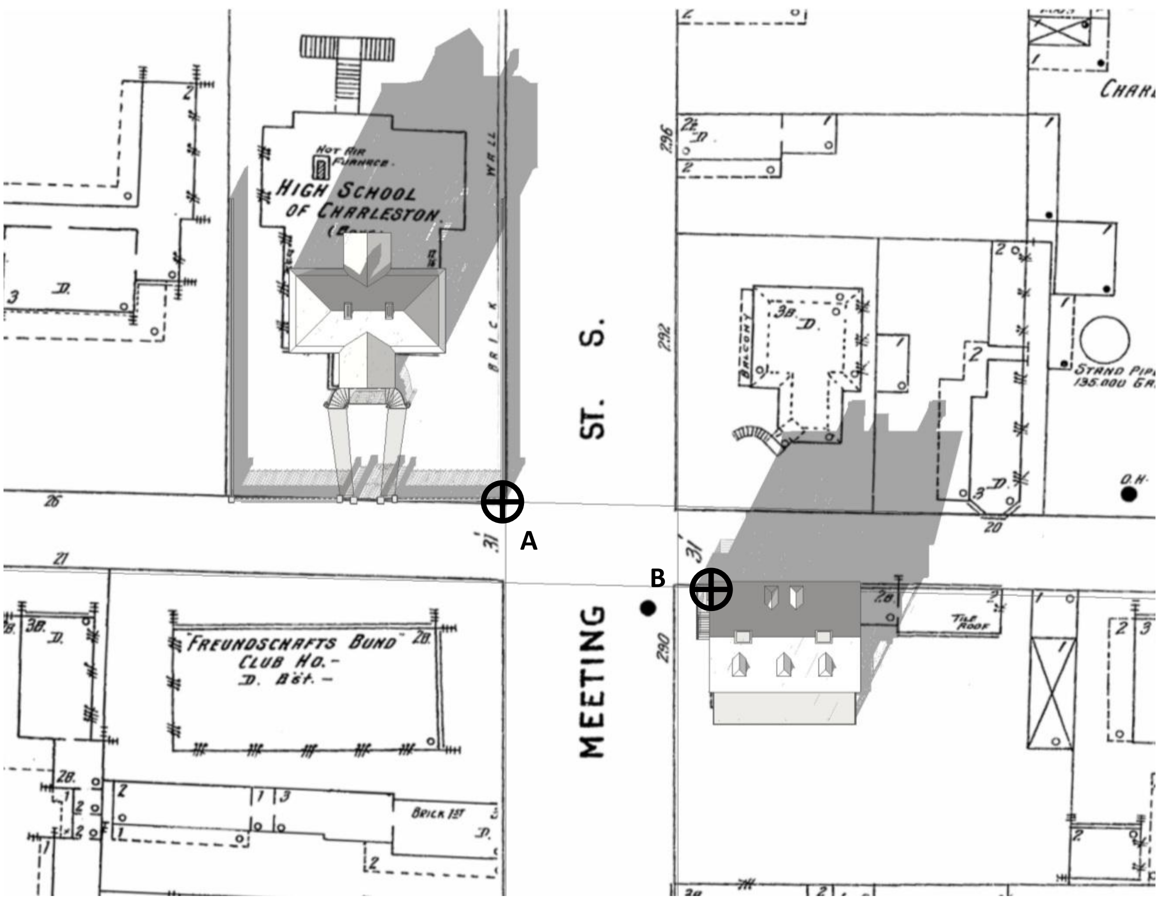

Figure 4.30: The models of the mansions are placed according to Sanborn Fire Insurance Map.

The models did not match with the Sanborn Fire Insurance Map's plan dimensions of either house. Radcliffe-King Mansion appeared to be smaller, and Manigault house seems bigger than the outline on the map. This disparity is resolved by setting the A and B corner points of the lots according to the Sanborn Insurance Map and adjusting for small differences (Figure 4.30).

3D Model

Creating the three-dimensional models of both houses proved to be time consuming, almost 110 hours. The models were created based on the photographs, documents, and salvaged materials. Some parts of the houses, such as the stairwell section of the Radcliffe-King Mansion and the cornice details of the piazza on the Manigault house, could not be modeled because of a lack of information. The finished virtual models of the houses were reconstructed by photogrammetry and rectification processes with the most reliable sources.

Figure 4.31: View of the both houses from west side of the George Street.

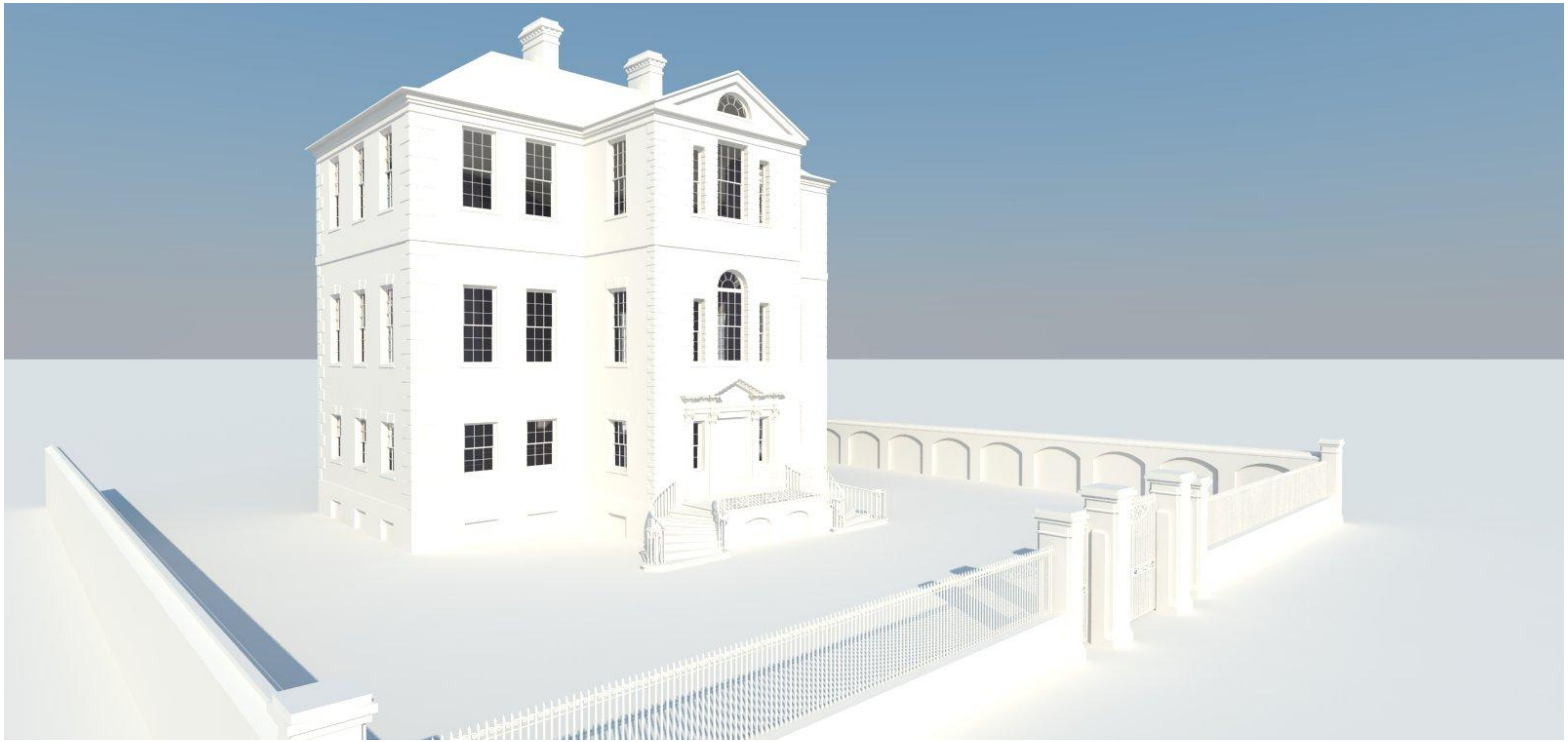

Figure 4.32: Model of the Radcliffe-King Mansion.

Figure 4.33: Model of the Gabriel Manigault house.

Uncertainty of the model

According to the London Charter, virtual heritage reconstruction projects should inform users about the different levels of accuracy, the distinction between evidence and hypothesis, and different levels of probability. Jose Kozan created a gradient chart, which represents the uncertainty level codification.[83] Based on this color scale, the color codes are applied directly to the 2D drawings to interpret the certainty level of the models. This coding was applied to the exterior elevations of both houses.

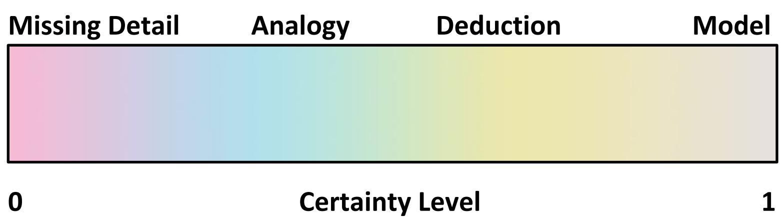

Figure 4.34: Color scale for uncertainty level representation.

[83] Jose M Kozan, "Virtual Heritage Reconstruction: The Old Main Church of Curitiba, Brazil,"(MS Thesis, University of Cincinnati, 2004), 85.

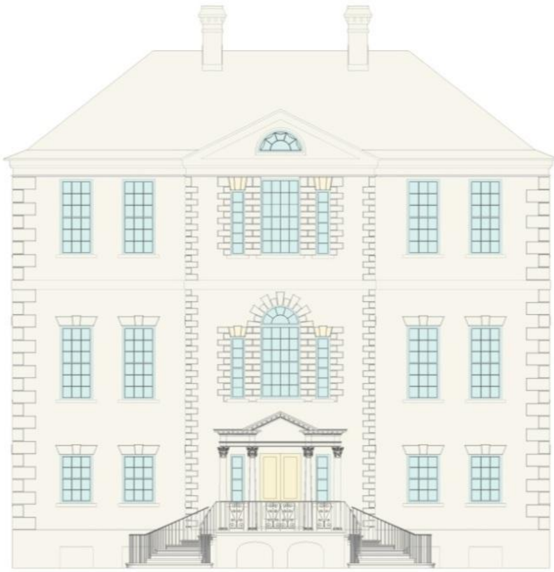

Figure 4.35: Color coded south façade of Radcliffe-King Mansion presents the certainty level.

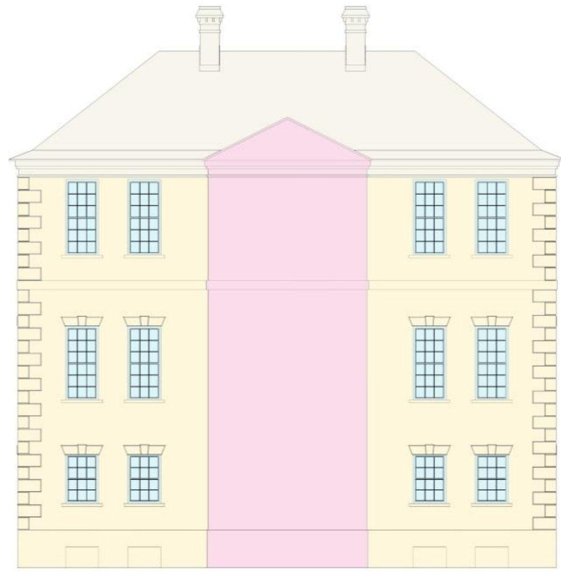

Figure 4.36: Color coded north façade of Radcliffe-King Mansion presents the certainty level.

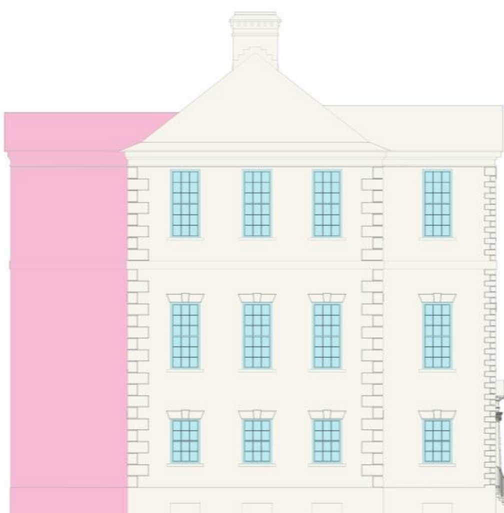

Figure 4.37: Color coded west façade of Radcliffe-King Mansion presents the certainty level.

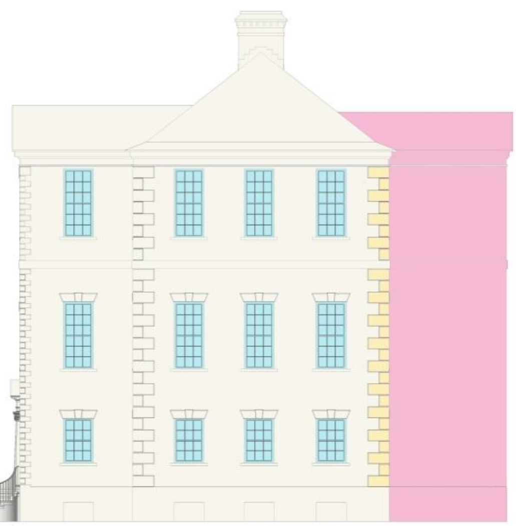

Figure 4.38: Color coded east façade of Radcliffe-King Mansion presents the certainty level.

Figure 4.39: Color coded west façade of Manigault house presents the certainty level.

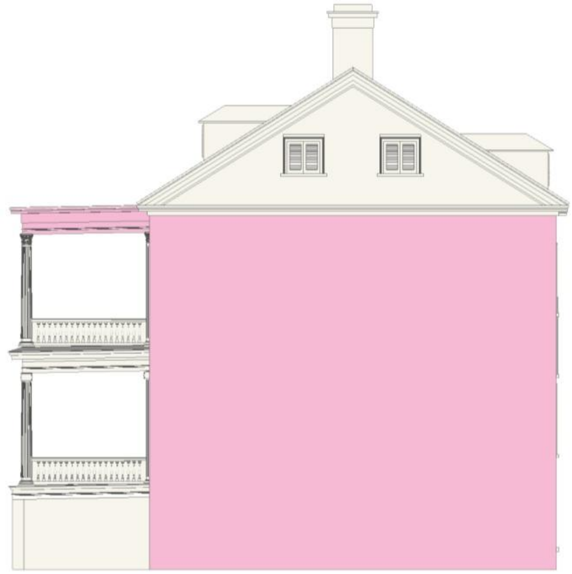

Figure 4.40: Color coded east façade of Manigault house presents the certainty level.

Figure 4.41: Color coded south façade of Manigault house presents the certainty level.

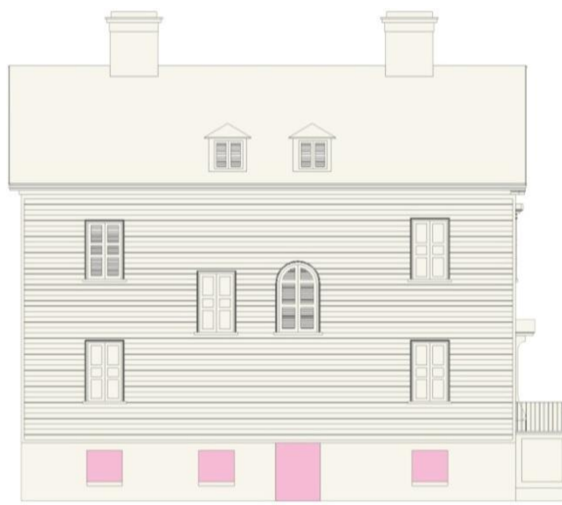

Figure 4.42: Color coded north façade of Manigault house presents the certainty level.

CHAPTER FIVE

CONCLUSIONS

The no longer extant Radcliffe-King and the Gabriel Manigault residences, at the intersection of George and Meeting Streets, were regionally significant structures in Ansonborough due to their architectural design and connection to significant community leaders. This thesis has 'preserved' the memory of these buildings through digital three dimensional models. This was done accurately with the use of historic photographs and salvaged materials. Since there was no information about camera parameters of the original images, substantial measured remnants and scaled plan drawings of the buildings provided the essential dimensions. Furthermore, the rectification process helped to gather additional information pertaining to the details of the houses not gained from the photogrammetry process. The applied methodology delivered adequate outcomes for the 3D reconstruction of the mansions.

The aim of this thesis, to recover the forgotten residential character of the intersection, was achieved by reconstructing the mansions; however, some sections of the models are missing because of lack of information. This is evident in the stairwell section of the Radcliffe-King Mansion and the entrance door and cornice details of the piazza on the Manigault house. In some cases, missing details were filled in with hypothetical information based on analogies and deductions from similar buildings. This is common in most virtual heritage reconstruction projects. The London Charter suggests that the distinction between evidence and theoretical information should be depicted; and an uncertainty representation scale, be applied to the elevation drawings of the models; this was adhered to. The selection of the appropriate software package involved addressing the pros and cons with each. For this project, *SketchUp* was chosen because it presented a faster and easier modeling and calibration experience than *ImageModeler* and *Photomodeler*. Additionally, *SketchUp* offered a basic virtual walkthrough experience.

The digital models for the Radcliffe-King house and the Gabriel Manigault house could be further enhanced by virtual reconstruction of the interiors of the mansions based on salvaged materials and other similar structures, reconstruction of the surrounding environment with additional buildings and the refinement of the mystery date "1839" on the entablature of Radcliffe-King Mansion.

Due to its simplicity and visual effectiveness, virtual heritage models lure a wider audience to the preservation field. Bringing cultural heritage sites to the public can be achieved by integrating the reconstructions into a game engine, which provides better walkthrough experiences than *SketchUp*. It can also attract children and pupils who are familiar with the concept of walking and navigating in virtual worlds. Moreover, creating an interactive website for this kind of models is a well-established practice that provides easy and quick worldwide access.

The potential of virtual heritage models is not limited to the interpretation of historic sites. Virtual models include combined information about heritage sites that could be integrated with GIS systems like in CyArk digital archives.[84] Furthermore, this combined information could also compile historic structure reports or any conservation documents as a separate layer in

[84] CyArk is a non-profit organization with the mission of: digitally preserving cultural heritage sites through collecting, archiving and providing open access to data created by laser scanning, digital modeling, and other state-of-the-art technologies. http://archive.cyark.org/

models. A conservation report about ironwork at the Radcliffe-King Mansion's site is included in Appendix B for possible integration into the model.

The virtual heritage community has been missing a crucial structure for their models. There has been a number of 3D archives of cultural heritage models created in recent years; however, they appear to be just display stage of the art, none of them satisfy the need of peer-reviewed and interoperable repository of 3D models. As of now, all the virtual heritage model works are completely ephemeral, and long term consideration must be taken in account before launching costly virtual heritage campaigns. Establishment of a central archive and an interoperable 3D data file type should be the next step for the preservation community.

APPENDICES

Appendix A

Record Photographs

Radcliffe-King Mansion

From the Charleston Museum Archives

Figure A.1: 1938; photographer E. Milby Burton

Figure A.2: 1938; photographer E. Milby Burton

Figure A.3: 1938; photographer E. Milby Burton

Figure A.4: 1938; photographer E. Milby Burton

Figure A.5: 1938; photographer E. Milby Burton

Figure A.6: 1937; photographer E. Milby Burton.

Figure A.7: circa 1930; photographer assumed to be Harriette Kershaw Leiding.

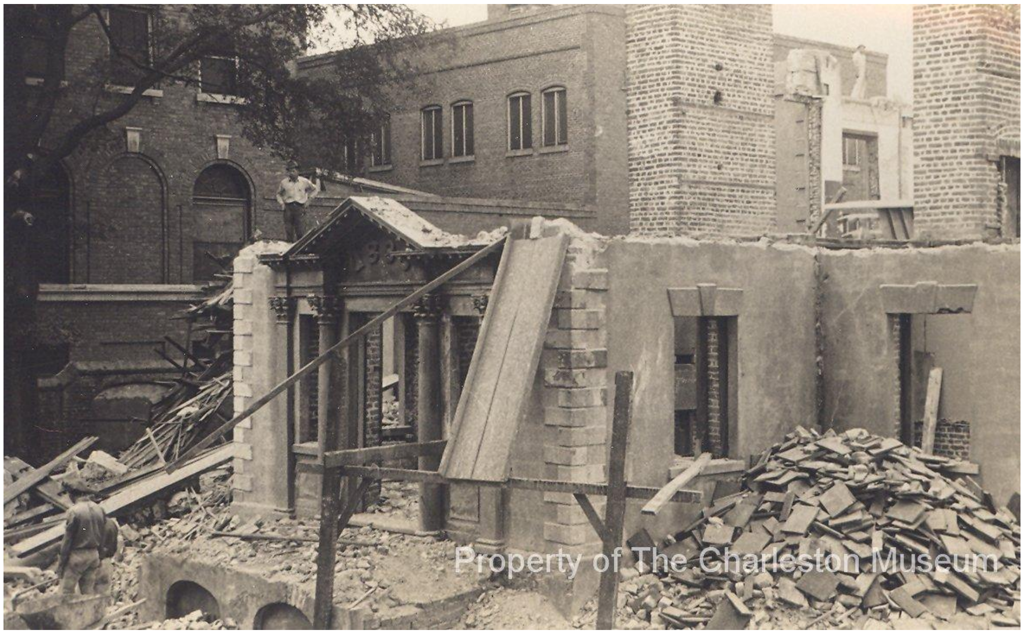

Figure A.8: 1938; photographer assumed to be E. Milby Burton

From the Gibbes Museum Archives

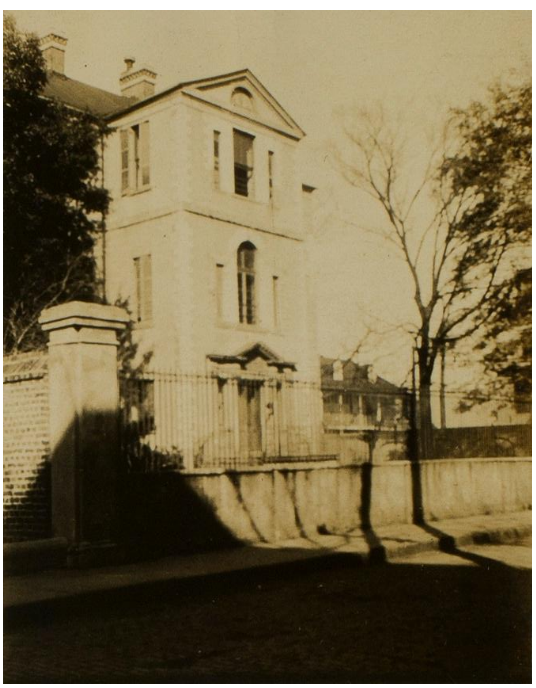

Figure A.9: View from George Street. Photographer Albert Simons.

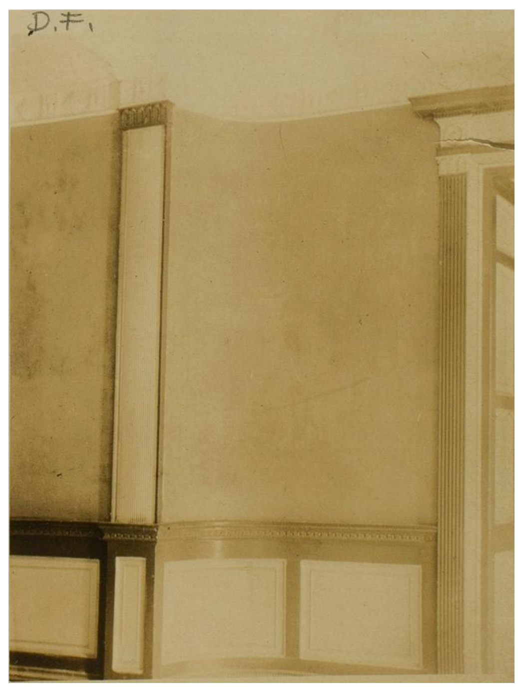

Figure A.10: Wainscoting. Photographer Albert Simons.

Figure A.11: Interior door. Photographer Albert Simons.

Figure A.12: Window surround. Photographer Albert Simons.

Figure A.13: Stair entry of the mansion. Photographer Albert Simons.

Figure A.14: Stairwell. Photographer Albert Simons.

Figure A.15: Stairwell. Photographer Albert Simons.

Figure A.16 Pilaster and interior door. Photographer Albert Simons.

Figure A.17: Pilaster. Photographer Albert Simons.

Figure A.18: Hallway. Photographer Albert Simons.

Figure A.19: Palladian window on South façade. Photographer Albert Simons.

Figure A.20: Interior door. Photographer Albert Simons.

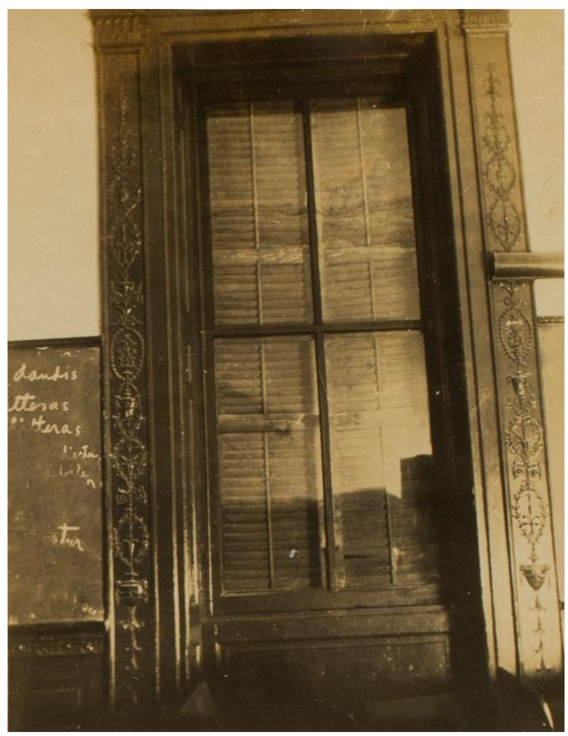

Figure A.21: Window details. Photographer Albert Simons.

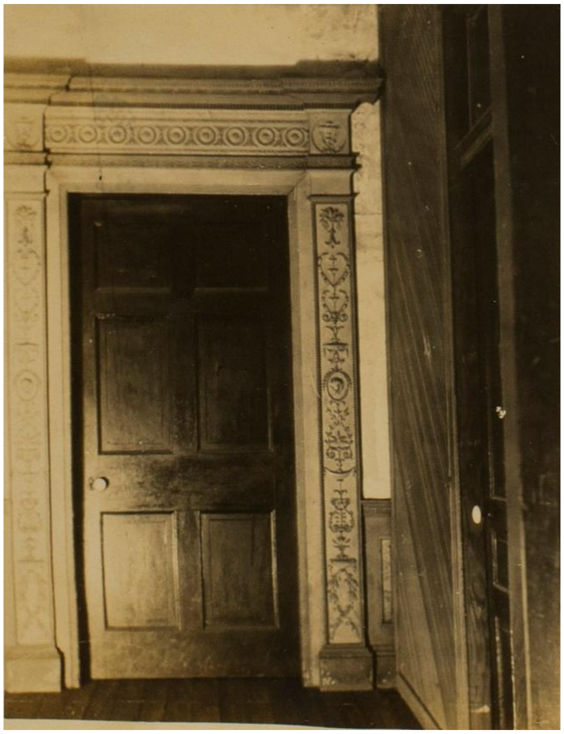

Figure A.22: Interior door. Photographer Albert Simons.

Figure A.23: Interior of a room. Photographer Albert Simons.

Figure A.24: Ceiling ornament. Photographer Albert Simons.

Figure A.25: Fireplace. Photographer Albert Simons.

Figure A.26: Fireplace. Photographer Albert Simons.

Figure A.27: Fireplace. Photographer Albert Simons.

Appendix B

Conservation of the Ironwork Fence at the Radcliffe-King Mansion's Site

The Ironwork Fence

This historic wrought ironwork probably dates back to construction of the main building. Therefore it is most likely to be made of either 'charcoal iron' which was produced until the late 18th century or, 'puddled iron' which was invented by Henry Cort in 1784. The ironwork stands on a brick wall, and it is located between two brick piers. Alston Deas' book *The early ironwork of Charleston* describes the fence as below:

> *The fence is of heavy bars, square in cross section and set edgewise to the street and capped with alternate spear and javelin heads, the barbs of the spear heads being scrolled. Spaced along its length are urn shaped terminals of turned brass. The connection bars of the fence, also square in cross section, are set flat edge to the front, with an overthrow continuing this pattern. …*
>
> *The design of the whole is rather "tight" and squeezed in, and of provincial quality. In spite of the presence on the fence of brass urns of the Adam period, it seems not altogether unlikely that the construction of fence antedates that of the house…*[85]

Figure B.1: One section of the historic wrought ironwork.

[85] Alston Deas, The Early Ironwork of Charleston (Linden Publishing, 1997), 88.

Conservation issues

Atmospheric Corrosion

The ironwork which is subject to this paper stands in an outside environment and exposed to corrosive effects of atmosphere. Atmospheric corrosion, which is also known as weathering, is an electrochemical process that takes place between base metal, surface electrolytes, metallic corrosion products, and the atmosphere. Corrosion due to atmosphere influenced by many variables; relative humidity, temperature, sulfur dioxide content, hydrogen sulfide content, chloride content, amount of rainfall, dew formation, dust , geographic location, and even the position of the exposed metal. Local conditions of the areas affect the atmospheric corrosion rates, thus atmospheres are classified in five sections according to exposure levels: rural, urban, industrial, marine, and indoor.[86]

Urban atmospheres accumulate pollution from road traffic and the usage of fossil fuels even when they are free from industrial pollution. Road traffic generates oxides of nitrogen, which may be turned into nitric acid by oxidisation. Usage of fossil fuels has the possibility to produce sulfur dioxide, which is converted to sulfuric and sulfurous acid in the presence of moisture. In addition to these, there may also be other specific contaminants in this area.

---

[86] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 1.

Factors Affecting Atmospheric Corrosion

Time of Wetness

Corrosion is the deterioaration of materials by chemical interactions with their environment. This natural process, which depends on the presence of an electrolyte, convert man-made ironwork back to its original form as oxides of iron. The electrolyte related with atmosphheric corrosion is water which depends on rain, fog, dew, melting snow, or high humidity. Atmospheric corrosion is not a constant process because of the presence of electrolyte does not always oocur. Water provides a path for ion transfer between anodes - the areas where metal is lost - and cathodes - the other surface areas -, where released electrons are consumed to form oxides and hydroxides.[87] Corrosion rate is affected by the total time of wetness, the composition of electrolyte, and the temprature. “Time of wetness”, which is the main factor that initiates the corrosion, refers to the length of time during which the metal surface is covered by a film of water.

Rain

Atmospheric corrosion due to precipitation in the form of rain has dual effect on the ironwork. “It affects atmospheric corrosion by forming a phase layer of moisture on the material surface and by adding corrosion stimulators in the form of H^+ and SO_4^{2-}.”[88] However, it also clean the contaminants deposited on the surface during the preceding dry period. Rain can either supports or prevents corrosion.

[87] Willie L. Mandeno, "Conservation of iron and steelwork in historic structures and machinery," Department of Conservation Te Papa Atawha, 2008, 6.
[88] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 7.

Dew

Dew is more severe than rain in atmospheric corrosion, especially in under sheltered conditions. When the temperature of the metal falls below the dew point of the atmosphere, it forms dew on the surface. Dew can occur outdoors either during the night when the surface temperature of the ironwork is lowered as a result of radiant heat transfer between the metal and the sky, or during the early morning hours when the air temperature rises more quickly than the metal temperature.

- The concentration of contaminations in dew is higher than in rainwater, which leads to more acidic pH values.
- The washing effect, which occurs with rain, is usually, slight or negligible. With little or no run-off, the pollutants remain in the electrolyte and continue their corrosive action. As the dew dries these contaminants remain on the surface to repeat their corrosive activity with subsequent dew formation.[89]

Fog

Fog is not really a problem in Charleston environment; however, in areas of high pollution, fog droplets will have a high acidity and contain high concentrations of sulfates and nitrates.

Dust

Most places dust is the primary air contaminant on a weight basis. Dust can promote corrosion, by forming galvanic cells when combined with moisture and in contact with metallic

[89] Ibid., 8.

surfaces. The settled dust may promote corrosion by absorbing sulfur dioxide from burned fossil fuels and water vapor from the air in urban atmosphere.

Temperature

Temperature also has complex effects in atmospheric corrosion. It has little or no effect on the corrosion rate during long term exposure in a moderate climatic place. Increase on temperature increases the rate of electrochemical and chemical reactions as well as the diffusion rate, thus corrosive attack increases. As a result, in a high humidity conditions like Charleston, a temperature increase will promote corrosion. On the other hand, it can decrease the corrosion which is started by rain or dew, due to evaporation of water on metal surface which reduces the time of wetness.

Current Condition

Most surfaces of the ironwork, almost 80%, have discoloration due to oxidization. Some surface of it has paint bubbles which are sign of a hidden corrosion, and peeled paint is another problem on the surfaces. In the north section of the ironwork, where it connects with the brick masonry wall, the connection rod is delaminated due to constant water penetration from masonry pier. Rust is also visible where the ironwork parts connect to each other. On these connection points, two of the cast details are missing.

Figure B.2: Paint bubbles.

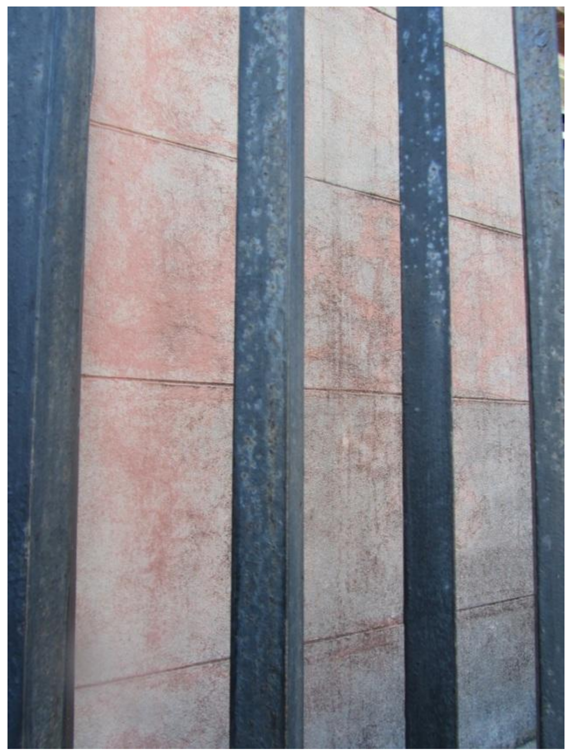

Figure B.3: Discoloration due to oxidization.

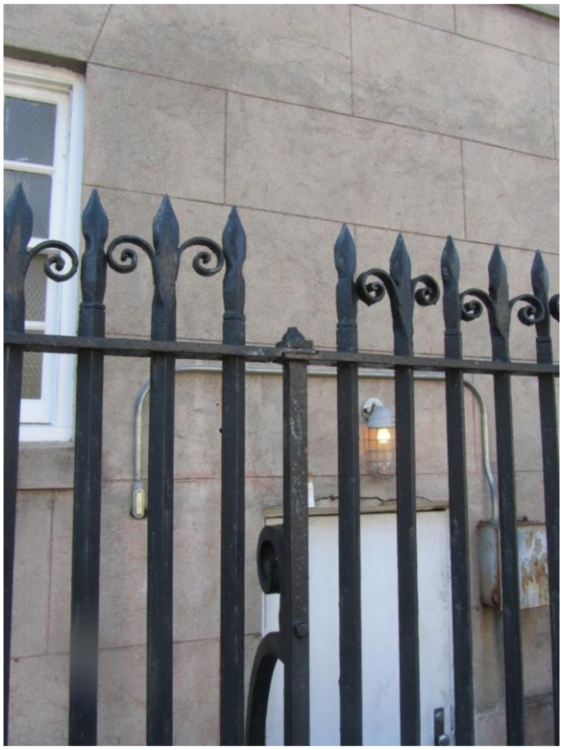

Figure B.4: Missing part.

Figure B.5: Rust on connection point.

Figure B.6: Paint peeling.

Figure B.7: Delamination.

Protection of the Ironwork

The most widely used means of protection for outside structures is painting. Protection of wrought iron by means of painting involves three basic steps: coating selection, surface preparation, coating application. The coating selection depends on the environment and what pollutants are present. This can best be ascertained by sampling the air and analyzing to determine corrosive conditions. Once this has been completed, a coating selection can be made.

The ironwork which is subject to this paper is exposed to road traffic (which generates nitric and sulfuric acid), high moisture, high temperature and possible salt solutions from ocean. The properties of the most commonly used paints to protect metals are shown in the table in next page.[90]

According to this table, the best coating choices for this specific ironwork are vinyl, epoxy, and urethanes, which are all have resistance to acid, alkali, moisture, and salt solutions. Urethane catalyzed coating seems like the best solution for the problem; however, it is an expensive product. Either vinyl or epoxy base coatings could be chosen for maintaining the ironwork.

[90] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 223.

Coating type	Resistance to: Sunlight	Weather	Acid	Alkali	Moisture	Salt solutions	Comments
Vinyls dissolved in aromatics, ketones, or esters			R	R	R	R	Adhesion may be poor until all solvents have vaporized from the coating.
Chlorinated rubbers dissolved in hydrocarbon solvents	N		R	R	R		Excellent adhesion to metals, concrete, and masonry. Used on structures exposed to water and marine atmospheres.
Epoxies, polyamide plus epoxy resin	N		R	R	R	R	Harder and less flexible than other epoxies. Greatest chemical resistance of the epoxies.
Polyamide plus epoxy resin (polyamide epoxy)	N		PR	PR	R	PR	Chemical resistance inferior to that of the polyamine epoxies.
Aliphatic polyamine			PR	PR		PR	Flexible film.
Esters of epoxies and fatty acids (epoxy ester)	R	R		N			On surfaces requiring the properties of a high-quality oil-based paint.
Coal tar plus epoxy resin	N	N	R		R		Used on clean blast-cleaned steel for immersion or below-grade service.
Oil-based coatings with vehicle (alkyd, epoxy, urethane)	R	R		N			Lower cost than most coatings. Used on exterior wood surfaces.
Urethane moisture-cured	R	R	Weak R	Weak R	R	Weak R	May yellow under UV light. High gloss and ease of cleaning.
Urethanes, catalyzed		R	R	R	R	R	Expensive. Used as coating on steel in highly corrosive areas.
Silicones, water-repellent in water or solvent	R	R	N	N	R		Used on masonry surfaces.
Silicones, water-based aqueous emulsions of polyvinyl acetate, acrylic, or styrene-butadiene latex	R	R	N	N			May flash rust as a primer on steel.
Polyesters; organic acids combined with polybasic alcohols. Styrene is a reaction diluent	PR	R	R	N			Must be applied with special equipment.
Coal tar	N	N	Weak R	Weak R	R		Used on submerged or buried steel.
Asphalt; solids from crude oil refining, in aliphatic solvents	R	R	Weak R	Weak R	R	Weak R	Used in above-ground weathering environments and chemical fume atmospheres.
Zinc-rich metallic zinc in an organic or inorganic vehicle							Used as primer for steel. Zinc powders in paint provide cathodic protection to steel substrate.
Acrylic resin water emulsion base	R	R	Weak R	Weak R			

R, resistant; N, not resistant; PR, poor resistance.

Figure B.8: Properties of coatings. From *Atmospheric Degradation and Corrosion Control*. 222-223

Vinyl Coatings and Chlorinated Rubber

These are most widely used resins for industrial coatings, which have good resistance to freshwater, marine and chemical environments. Most vinyl coatings must be applied in numerous thin coats of approximately 1 – 1.5 mil per coat. To be able get enough protection, it may be required to apply at least five times, which makes this system highly labor-intensive. Some of the vinyl coatings have been formulated to permit 2 – 2.5 mil per coat.[91] Nevertheless, this formula have made it more susceptible to environmental and moisture penetration, thereby reducing their effectiveness.

Chlorinated rubber paints have very similar properties to vinyl coatings and they have both notable self-recoatability properties as they cure by solvent evaporation. These two products now less widely used due to their high solvent content and higher cost of resin manufacture due to environmental constraints.[92]

Epoxy Coatings

Epoxy resins by themselves are not suitable for protective coatings, thus epoxy coatings are based on cross-linked polymers that are formed by the reaction of a resin with a variety of different curing agents, such as amine, polyamide resins, or esterified with fatty acids.[93] Epoxy coatings have good chemical, solvent and water resistance, and excellent adhesion. They can provide high-build coatings with little or no solvent; however, they usually require favorable conditions - dry and temperature above 13°C for - application and curing. When combined with

[91] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 224.
[92] Willie L. Mandeno, "Conservation of iron and steelwork in historic structures and machinery," Department of Conservation Te Papa Atawhai, 2008, 15.
[93] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 224.

approximately 50% of refined coal tar the amine- and polyamine-cured epoxies are one of the best water resistant coatings available, but its use has been largely discontinues because of the carcinogenic properties of the coal tar pitch used in its manufacture.[94]

Urethane Coatings

Urethane resins are another type of cross-linked polymer used for protective coatings, which have better weather-ability and flexibility than epoxies. Catalyzed urethanes are used as architectural, marine and automotive finish coats, as they are one of the best finish coats for retaining gloss and color.[95] Their self-recoatability improved by adding acrylic to urethane resin.

Surface Preparation

The most important process affecting the life of a paint coating system is the preparation of the surface to which the coating is to be applied. Chemical or mechanical processes can be used to pretreat the surface for paint coatings.[96] It is important that the surfaces are cleaned to remove any salts that could draw moisture by osmotic action and could also disrupt passive surfaces.[97] Rust and iron scale should be fully removed before protective coatings are applied.

Removal is best achieved by slurry blasting, where an abrasive medium is introduced into a jet of water, or by alternate water blasting and dry blasting. 'Wetting' of the surface and rinsing efficiency can be improved by adding a surfactant, such as non-ionic detergent, to the

[94] Willie L. Mandeno, "Conservation of iron and steelwork in historic structures and machinery," Department of Conservation Te Papa Atawhai, 2008, 14.
[95] Ibid., 14.
[96] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 228.
[97] Willie L. Mandeno, "Conservation of iron and steelwork in historic structures and machinery," Department of Conservation Te Papa Atawhai, 2008, 9.

washing water. Because salts can be concentrated in pits under rust, they cannot be effectively removed by low-pressure rinsing unless the rust is removed first. While abrasive blast cleaning by dry blasting or wet slurry blasting is ideal for rust removal and also creates a surface profile that anchors the protective coating, the complete removal of rust is not always practical and abrasive blasting can also be damaging to thin sections. [98]

The below table provides a summary of the some different techniques. [99]

SSPC specification	Description
SP 1: Solvent cleaning	Removal of oil, grease, dirt, soil, salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion, or steam
SP 2: Hand-tool cleaning	Removal of loose rust, mill scale, and paint, to degree specified, by hand chipping and wire brushing
SP 3: Power-tool cleaning	Removal of loose rust, mill scale, and paint, to degree specified, by power tool, chipping, descaling, sanding, wire brushing, and grinding
SP 5: White-metal blast cleaning	Removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning, by wheel or nozzle, dry or wet, using sand, grit, or shot for very corrosive atmospheres where high cost of cleaning is warranted
SP 6: Commercial blast cleaning	Blast cleaning until at least two-thirds of the surface area is free of all visible residues (for severe exposure)
SP 7: Brush-off blast cleaning	Blast cleaning of all except tightly adhering residues of mill scale, rust, and coatings, exposing numerous evenly distributed flecks of underlying metal
SP 8: Pickling	Complete removal of rust and mill scale by acid pickling, duplex pickling, or electrolytic pickling
SP 10: Near-white blast cleaning	Blast cleaning to near−white metal cleanliness until at least 95% of the surface area is free of all visible residue (for high-humidity, chemical atmosphere, marine, and other corrosive environments)

Figure B.9: Summary of Surface Preparation Specifications.

[98] Ibid., 10.
[99] Philip A. Schweitzer, Atmospheric Degradation and Corrosion Control (CRC Press, 1999), 111.

Conclusion

The current observation on the ironwork shows it needs immediate maintenance. From the coating review, epoxy resins with polyamide resins are the best choice for the particular environment site. For the surface preparation, hand tools or one of the blasting systems could be chosen. Slurry blasting system is the best solution for surface preparation for the last decade, which is most preferable system right now.

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