A Hydrologic and Hydraulic Assessment of Cypress Creek for the Identification of the Potential Habitat for the Bald Cypress and Water Tupelo

Tara Gracer
Southern Illinois University Carbondale, taragracer@gmail.com

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A HYDROLOGIC AND HYDRAULIC ASSESSMENT OF CYPRESS CREEK FOR
THE IDENTIFICATION OF THE POTENTIAL HABITAT FOR
THE BALD CYPRESS AND WATER TUPELO

by

Tara Gracer

B.A., Economics, Illinois Wesleyan University, 2013
B.A., Environmental Studies, Illinois Wesleyan University, 2013

A Thesis
Submitted in Partial Fulfillment of the Requirements for the
Master of Science Degree

School of Earth Systems and Sustainability
in the Graduate School
Southern Illinois University Carbondale
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AN ABSTRACT OF THE THESIS OF

Tara Gracer, for the Master of Science degree in Geography and Environmental Resources, presented on November 13, 2019, at Southern Illinois University Carbondale.

TITLE: A HYDROLOGIC AND HYDRAULIC ASSESSMENT OF CYPRESS CREEK FOR THE IDENTIFICATION OF THE POTENTIAL HABITAT FOR THE BALD CYPRESS AND WATER TUPELO

Major Professor: Dr. Jonathan W. Remo

Cypress Creek is an under researched sub-watershed of the larger Cache River system located in Southern Illinois and is managed by the Cypress Creek National Wildlife Refuge (CCNWR). In 1996, the Cypress Creek Watershed and its encompassing wetlands were listed under the United Nations Education, Scientific, and Cultural Organization (UNESCO) and Ramsar as a “Wetland of International Importance”. These wetland habitats house unique aquatic woody species, such as the Bald Cypress and Water Tupelo, and have diminished in size due to agricultural priorities and changes in hydrology (Demissie et al. 1990; Illinois Department of Natural Resources 1997). Heitmeyer and Mangan (2012) conducted by the U.S. Fish and Wildlife Service (USFWS), assessed the Cypress Creek Watershed using historical references of pre-settlement topography and geomorphology and present-day soils to determine habitat potential. These variables alone do not address the needs of the aquatic woody species who require flood inundation to survive. This hydrologic and hydraulic assessment examines the present-day hydrologic conditions within the boundary limits of CCNWR by collecting channel geometry and stream discharges, building flow frequencies, and constructing a hydraulic model of Cypress Creek to simulate water surface elevations (WSELs) for the bankfull, 2-year, 5-year, 10-year, 20-
year, and 25-year exceedance probabilities. Flood inundations were generated from simulated WSELS and local topography. The calculated potential habitat for Bald Cypress and Water Tupelo is 289 hectares and is located in the northwest part of the study area, south of Cypress Creek Road and above Hickory Bottoms Bridge on CCNWR land. Potential habitat overlap found between Heitmeyer and Mangan (2012) and this assessment is roughly 19 hectares.
ACKNOWLEDGEMENTS

A very big and special thank you to my advisor, Dr. Jonathan Remo for the technical, instrumental guidance and inspiration to tackle explorative research in an under researched and biologically significant watershed.

Thank you to my committee, Dr. Justin Schoof and Dr. Trent Ford, for being patient and for the final input for the last push to complete my study.

The research and the data collected would not have been possible without the cooperation and aid of the Cypress Creek National Wildlife Refuge staff. In the early stages of my research, I was given permission to collect channel geometry, but as my work progressed, I was given the chance to become an AmeriCorp member. As a result, I learned more than I ever thought I would just through literature research alone. I now know a complete anthropocentric history, the biological diversity composition, and management and restoration initiatives for the fauna and flora. Because of the refuge staff and my AmeriCorp position, I was also given another invaluable opportunity: to live within the watershed. Cypress Creek National Wildlife Refuge was my backyard for 7 months when I was stationed as an AmeriCorp member and experiencing its aura and magic will stay with me forever.

Thank you to Refuge Manager Liz Jones for believing in the value of my research, vehicle rescue, and for giving me the approval to conduct my research within the Refuge.

Thank you to Refuge Biologist Karen Mangan for additional moral support and providing me with the biological knowledge of the Cypress Creek Watershed.
I would also like to thank my fellow AmeriCorp member, Sara Stoneski, for putting up with my long thesis nights and discussions about my thesis.

Thank you to my improvisational field crew, Ann Rushing, Eric Sirvid, and Zoran Gracer for assisting me in collecting cross sectional data in the cold, muddy trenches of Cypress Creek.

Thank you to Goya Gracer and Lyka Gracer for being the best companions during solo data collection times through summer thunderstorms and cold, rainy December days.

For the most important thank you of all goes to my parents, Zoran Gracer and Nina Baksaj-Gracer. They told me to finish what I started and to never give up in myself, the most important motivation and support a researcher needs in the field of new discoveries and unknown territory.
DEDICATION

This thesis is dedicated to Cypress Creek and its surrounding wetlands. I hope all those that get to study you are stirred by your biological glory and understand the importance of the water you carry, not just for life, but for beauty.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xi</td>
</tr>
</tbody>
</table>

## CHAPTERS

- **CHAPTER 1 – Introduction** ................................................................. 1
  1.1 Background ....................................................................................... 1
  1.2 Purpose ................................................................................................ 7
  1.3 Research Questions ......................................................................... 10

- **CHAPTER 2 – Literature Review** ..................................................... 11
  2.1 The Geologic History of Cypress Creek and The Cache River Watershed .. 11
  2.2 Conservation Efforts in the Cache River Watershed ......................... 12
  2.3 Simon and Hupp Channel Evolution Model ...................................... 14
  2.4 Hydrogeomorphic Assessment ......................................................... 15

- **CHAPTER 3 – Methodology** ............................................................... 18
  3.1 Study Area ....................................................................................... 19
  3.2 Geospatial Data ............................................................................... 22
  3.3 Channel Elevation Post-Processing and Screening ............................ 23
  3.4 Discharge Measurements ................................................................ 24
  3.5 Estimate of Flood Frequency ............................................................ 25
  3.6 Developing the HEC-RAS Hydraulic Model for Cypress Creek .......... 26
APPENDICES

APPENDIX A. The WSEL results by the Cypress Creek hydraulic model for the four exceedance probabilities and their 99 cross sections. .............................................................. 64

APPENDIX B. The WSEL results by the Cypress Creek hydraulic model for the sensitivity trial on the variable Manning’s $n$ and the 2-year and 20-year exceedance probabilities......................... 67

APPENDIX C. The WSELs absolute differences and percent change for the 2-year 20% increase and decrease in Manning’s $n$ relative to the original 2-year WSELs....................... 70

APPENDIX D. The WSELs absolute differences and percent change for the 20-year and 20-year 20% increase and decrease in Manning’s $n$ relative to the original 20-year WSELs........... 73

APPENDIX E. The WSELs of the Manning’s $n$ sensitivity trial for each cross section and the 2-year exceedance probability.............. 76

APPENDIX F. The WSELs of the Manning’s $n$ sensitivity trial for each cross section and the 20-year exceedance probability............ 77

APPENDIX G. The WSEL results by the Cypress Creek hydraulic model for the sensitivity trial on the variable peak discharge and the 2-year and 20-year exceedance probabilities......................................................... 78

APPENDIX H. The WSELs absolute differences and percent change for the 2-year 20% increase and decrease in peak
discharge relative to the original 2-year WSEL. ......................... 81

APPENDIX I. The WSELs absolute differences and percent change
for the 20-year 20% increase and decrease in peak
discharge relative to the original 20-year WSEL....................... 84

APPENDIX J. The WSELs of the peak discharge sensitivity trial for each
cross section and the 2-year exceedance probability. ............... 87

APPENDIX K. The WSELs of the peak discharge sensitivity trial for each
cross section and the 20-year exceedance probability. ............. 88

VITA ............................................................................................................................. 89
# LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1 List of Endangered and threatened species in Alexander, Johnson, Pulaski, and Union Counties (U.S. Fish and Wildlife Service 2019).</td>
<td>9</td>
</tr>
<tr>
<td>Table 3.1 Calculated Manning’s $n$ for five cross section locations in the study area.</td>
<td>28</td>
</tr>
<tr>
<td>Table 4.1 USGS StreamStats Peak Discharges for Cypress Creek and Adds Branch in cms.</td>
<td>34</td>
</tr>
<tr>
<td>Table 4.2 Statistics on the WSELs for the four Manning’s $n$ sensitivity trials</td>
<td>40</td>
</tr>
<tr>
<td>Table 4.3 Statistics on the WSELs for the four peak discharge sensitivity trials</td>
<td>42</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1 A pre-settlement land use map of the state of Illinois on the left and The Cypress Creek Watershed on the right. The majority of Cypress Creek Watershed is covered by dark green, labeled as bottomland forests, while the remaining coverage is purple signifying water.</td>
<td>4</td>
</tr>
<tr>
<td>Figure 1.2 The 2011 National Land Cover Dataset map of Cypress Creek (USGS 2011).</td>
<td>5</td>
</tr>
<tr>
<td>Figure 3.1 A Digital Elevation Model of the Cypress Creek Watershed with the Study area indicated. The study area is within the lowermost portion of the watershed located just upstream of the lower Cache River Valley and its wetlands.</td>
<td>21</td>
</tr>
<tr>
<td>Figure 3.2 A satellite image of the study area in 2016.</td>
<td>22</td>
</tr>
<tr>
<td>Figure 4.1 The unit hydrograph for selected return periods of Cypress Creek Upstream of Adds Branch.</td>
<td>35</td>
</tr>
<tr>
<td>Figure 4.2 The unit hydrograph for the selected return periods at the Adds Branch confluence with Cypress Creek.</td>
<td>36</td>
</tr>
<tr>
<td>Figure 4.3 The unit hydrograph for the selected return periods for Cypress Creek at the confluence with the Cache River.</td>
<td>36</td>
</tr>
<tr>
<td>Figure 4.4 Modeled water surface profile for the lower Cypress Creek study reach area.</td>
<td>38</td>
</tr>
<tr>
<td>Figure 4.5 The extent of inundation for the 2-year, 5-year, 10-year, and 20-year return periods. The extent of inundation are labeled in blue color and</td>
<td></td>
</tr>
</tbody>
</table>

xi
incrementally change to a darker shade as the return period increases.

Cypress Creek is mapped as the yellow line and the red line is the extent of the study area. 

Figure 4.6 Potential habitat for Bald Cypress and Water Tupelo.

Figure 4.7 The potential habitat of the bald cypress and water tupelo in this study and Mangan and Heitmeyer (2012).

Figure 5.1 Sub-reach 1 with the greatest potential for Bald Cypress and Water Tupelo habitat.
CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Southern Illinois houses a unique juxtaposition of four United States’ eco-regions. It is one of the six areas in the entire United States where four or more eco-regions converge together. The intersection of these regions has resulted in abnormally high levels of biodiversity (Illinois Department of Natural Resources 1997).

The Cypress Creek Watershed is approximately 11,200 hectares and is a principle sub-basin of the Cache River Watershed. Portions of the Cypress Creek Watershed and its principle basin, the Cache River Watershed, are located within federally protected Cypress Creek Wildlife Refuge (CCNWR), which is comprised of 31,500 hectares of discontinuous forest and wetland habitats. The CCNWR is home to 91% of Illinois’ wetlands. These wetlands contain a substantial amount of biodiversity, containing 128 songbirds, 49 mammals, 32 amphibians, 43 reptiles, 84 freshwater fish, 47 native mussels, and 34 crustaceans species (CCNWR Habitat Management Plan 2014).

On May 4th, 1996, the Cypress Creek Wetlands were listed by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and Ramsar as a “Wetland of International Importance” because of the “critical waterfowl breeding habitat, its wintering and migratory waterfowl, and its shorebirds using the Mississippi flyway” (The Ramsar Convention Secretariat 2014). The Cypress Creek Wetlands were the 15th Ramsar site to receive recognition in the United States. Approximately, 15,300 hectares, comprised of aquatic woody species such as the Bald Cypress (Taxodium
distichum) and the Water Tupelo (Nyssa aquatic), regionally 103 endangered species, 1% of the largest population of Chorus frog (Pseudacris streckeri Illinoiensis), and 84 endemic species of fish, were conserved to positively influence and preserve the biodiversity of the wetlands (The Ramsar Convention Secretariat 2014).

Prior to European settlement, the Cypress Creek Watershed was predominately covered by bottomland forests (~90%; see Figure 1.1). The historical bottomland forest communities were derived by species that could survive flooding events, such as the Bald Cypress (Taxodium distichum) and Water Tupelo (Nyssa aquatic), to the frequency of inundation in the portion of the floodplain these trees inhabited (Leitner and Jackson 1981). Other tree species commonly found in the bottomland forest community in southern Illinois were Water Locusts (Gleditsia aquatic), Pecan (Carya illinoinensis), and Water Elms (Planera aquatic; Robertson et al. 1984).

In the mid-1800s, European settlers started to arrive in Southern Illinois where they immediately began to change the landscape to meet their needs. The Cache River Watershed, in which Cypress Creek is located, was logged intensively for the lumber industry which grew out of the mill town of Karnak and the development of agricultural lands so that the settlers would have a means to survive (Gough 2005; Hutchinson 1984).

Land use data from the U.S. Geological Survey’s 2011 National Land Cover Dataset (NLCD) shows the current land cover of the Cypress Creek Watershed that consists predominantly of agricultural land use (54%; Figure 1.2). Much of the bottomland forest communities were converted to hay and pasture, deciduous forests, and cultivated crops. Of the agriculture land use in the watershed (41% was hay and
pasture and 13% cultivated crops) the remaining portion of the watershed is 35% deciduous and evergreen forest, 5% wood and emergent herbaceous wetland, 5% developed, and 1% open water (USGS 2011; Figure 1.2).

The change from predominately forest land cover in the early to mid-1800s to a majority agricultural land use today has adversely impacted native wildlife and plant species by reducing and fragmenting their habitat. In addition, poor agriculture practices of the late 19th through the mid-20th centuries in the relatively steep headwaters in the Cypress Creek Watershed have led to substantial amounts of upland erosion and consequently, sedimentation in the surrounding floodplain wetlands. The deposition of the up-land sediments in the Cypress Creek wetland bottoms has resulted in equally substantial in filling of these internationally significant wetlands. In addition, the changes in land cover also caused Cypress Creek and its tributaries to become flashier. The increased flashy hydrologic response of Cypress Creek and its tributaries has resulted in an increase in their erosive power causing more sediment erosion and deposition into the wetlands further exacerbating wetland sedimentation (Demissie et al. 1990; Hutchinson 2000).
Figure 1.1 A pre-settlement land use map of the state of Illinois on the left and the Cypress Creek Watershed on the right. The majority of Cypress Creek Watershed is covered by dark green, labeled as bottomland forests, while the remaining coverage is purple signifying water.
Figure 1.2 The 2011 National Land Cover Dataset (NLCD) map of Cypress Creek (USGS 2011).
Cypress Creek is not only a principle tributary of the Cache River, but also an important source of water for the Lower Cache River and its associated wetlands. Land use change in the Cache River Watershed throughout the late-19th century have drastically altered the hydrologic flow regime of the Cache River and its tributaries like Cypress Creek.

The largest hydrologic intervention in the Cache River Watershed was the Post Creek Cutoff. The Post Creek Cutoff divided the Cache River into two sections: the Upper and Lower Cache River. This diversion was constructed in 1915 to divert water from the Upper Cache River Watershed directly to the Ohio River in order to reduce flooding throughout the Cache River Valley and make its floodplain more suitable for agriculture and silviculture (Demissie et al. 1990; Illinois Department of Natural Resources 1997). Due to this flow diversion and shift in land use to agriculture within the basin, flow along the Lower Cache River decreased and sediment rates increased. The increased sediment loads attributed to land use change coupled with decreases in Cache River flows, resulted in rapid infilling of many wetlands and floodplains found along the Cache River and its major tributaries like Cypress Creek (Demissie et al. 1990; Demissie et al. 1992; Demissie et al. 2001). In the early 1950s, two levees, the Reevesville and Cache River were originally constructed to mitigate constant flooding in the towns of Karnak and Ullin. The placement and location of these levees further altered the hydrology of the Lower Cache River Valley. The Reevesville Levee prevented inundation of the Lower Cache River Valley from the Ohio River and the Cache River Levee protected the valley from flooding by the Cache River. In addition, the Cache River Levee further restricted flow from the Upper Cache River, which
increased the importance of Cypress Creek as a principle source of water and nutrients for the Lower Cache River wetlands (Demissie et al. 2001).

To further improve conditions for agriculture on Cypress Creek’s floodplains, landowners substantially altered the creek’s channel geometry by straightening and deepening the channel. Straightening the channel simplified the use of large farm equipment to tend the floodplain fields while deepening the channel lowered the water table. By lowering the water table, the floodplain soils dried out, which in turn allowed the land to be farmed and increased crop yields (Demissie et al. 1990; Demissie et al. 1992; Demissie et al. 2001; Gough 2005; Heitmeyer and Mangan 2012).

The net impacts of land use change and channel alterations in the Cypress Creek Watershed have substantially altered the hydrologic connectivity between Cypress Creek, its floodplain, and its associated wetlands. These land use changes and channel alterations have caused a serious decrease in the availability of floodplain habitats, which are essential to the threatened and endangered wetland species found in this region (Gough, 2005; Heitmeyer 2008). Along Cypress Creek, these changes have reduced the Bald Cypress and Water Tupelo wetland habitat, which used to predominate the lower portions of the Cypress Creek Watershed (Heitmeyer and Bartletti 2012).

1.2 PURPOSE

The research presented in this thesis is intended to help inform the U.S. Fish and Wildlife Service (USFWS) and activities focused on rehabilitating the hydrologic connectivity between Cypress Creek and its floodplain wetlands. Specifically, “there is a need to examine the hydrology of existing sites, and to determine whether there is a
need and/or potential to restore a more natural hydrology within existing swamps”, specifically Bald Cypress and Water Tupelo habitats (CCNWR Habitat Management Plan 2014, 75). By identifying possible habitat for Bald Cypress and Water Tupelo, “effective restoration and management of all bottomland hardwood forests on CCNWR will provide important habitat for migrating waterbirds, as well as amphibians, reptiles, fish and other wildlife” as well as providing habitat for species who are on the federal endangered and threatened lists, which are listed in Table 1.1 (CCNWR Habitat Management Plan 2014, 63).

In addition, another goal of this research is to increase the overall knowledge of Cypress Creek. Direct, published research about Cypress Creek has been minimal in comparison to the broader Cache River Watershed, and as a result there is an absence of information about this important sub-basin. Cypress Creek also has no long-term, continuous hydrologic monitoring data such as the U.S. Geological Survey’s Forman Gage (USGS 03612000) located along the mainstream of the Cache River. Also, prior to this study, there was no hydraulic model available based on the direct measurements of channel geometry and floodplain topography for Cypress Creek. This study provides the first assessment of the flood discharges and hydrographs for the lower Cypress Creek. In addition, a hydraulic model based on the real-world geometry of Cypress Creek was created to model the water-surface elevations (WSELS) for flood discharge. Using the WSELS of flood discharges for ecologically important return periods, the extents of these flood scenarios where estimated to inform where hydrologic and hydraulic conditions may exist along Cypress Creek which are suitable for Bald Cypress and Water Tupelo habitat.
Table 1.1 List of Endangered and threatened species in Alexander, Johnson, Pulaski, and Union Counties (U.S. Fish and Wildlife Service 2019).

<table>
<thead>
<tr>
<th>Common Name (Genus species)</th>
<th>Status</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray Bat (Myotis grisescens)</td>
<td>Endangered</td>
<td>Alexander, Hardin, Jackson, <strong>Johnson</strong>, Monroe, Pike, Pope, <strong>Pulaski</strong></td>
</tr>
<tr>
<td>Northern long-eared bat (Myotis septentrionalis)</td>
<td>Threatened</td>
<td>Statewide (IL)</td>
</tr>
<tr>
<td>Least Tern bird (Sterna antillarum)</td>
<td>Endangered</td>
<td><strong>Alexander</strong>, Jackson, Madison, Massac, Monroe, Pope, Randolph, St. Clair, <strong>Union</strong>, Wabash</td>
</tr>
<tr>
<td>Pallid Sturgeon fish (Scaphirhynchus albus)</td>
<td>Endangered</td>
<td><strong>Alexander</strong>, Jackson, Madison, Monroe, Randolph, St. Clair, <strong>Union</strong></td>
</tr>
<tr>
<td>Orangefoot pimpleback mussel (Plethobasus cooperianus)</td>
<td>Endangered</td>
<td>Massac, <strong>Pulaski</strong></td>
</tr>
<tr>
<td>Rabbitsfoot mussel (Quadrula cylindrica cylindrica)</td>
<td>Threatened</td>
<td><strong>Alexander</strong>, Clark, Crawford, Jasper, Lawrence, Massac, <strong>Pulaski</strong>, Vermilion, Wabash, White</td>
</tr>
<tr>
<td>Sheepnose mussel (Plethobasus cyphyus)</td>
<td>Endangered</td>
<td><strong>Alexander</strong>, Hancock, Kankakee, Massac, <strong>Pulaski</strong>, Rock Island, Whiteside, Will</td>
</tr>
</tbody>
</table>
1.3 RESEARCH QUESTIONS

The compelling biological and hydrologic significance coupled with the existing international and federal protection of the Cypress Creek Wetlands promote the need for preservation and restoration. The objective of this research is to increase the overall hydrologic, hydraulic, and geomorphic knowledge of Cypress Creek to help steer future researchers and decision-making of government officials on restoration efforts of Cypress Creek Watershed. The questions below are formulated to focus this research to identify geographic locations for Bald Cypress and Water Tupelo habitat using contemporary hydrologic evidence, which is one of the objectives of the 2014 CCNWR Habitat Management Plan.

1. Under present day conditions along lower Cypress Creek, where are the areas with the proper hydrologic and hydraulic characteristics that are suited for aquatic woody species, such as Bald Cypress and Water Tupelo?

2. How do current hydrologic and hydraulic characteristics used in this study to identify suitable habitat compare to other assessments of these suitable Bald Cypress and Water Tupelo habitats?

3. Are there any areas along the lower Cypress Creek which can be reasonably and easily restored to increase suitable habitat for Bald Cypress and Water Tupelo in the floodplain?
2.1 THE GEOLOGIC HISTORY OF CYPRESS CREEK AND THE CACHE RIVER WATERSHED

The hydrology of both the Cypress Creek and the Cache River watersheds are affected by their physical characteristics such as geology, geomorphology, and land use. To fully understand the Cache River Watershed, characteristics of the physical aspects and glacial history need to be summarized.

Although glaciers once covered 85% of the Illinois, they never reached the area of the Cache River Watershed (Demissie et al. 1990; Illinois State Geological Survey). If the Cache River Watershed was glaciated, the topography would be similar to other portions of Illinois. Instead, there is relatively substantial topography in the form of distinct valley walls and prominent hills and bluff lines, which make the southern Illinois geographic eco-region so unique. Approximately 300,000 years ago during the Illinois glaciation, the Teays River, the river system which predated the Ohio River, shifted southward. Then after repeated glacial advances during the Wisconsin Glaciation (75,000 to 11,000 years before present) the Teays River system progressed further south and was reworked into the modern Ohio River drainage (Walker 1957; Leverett 1903). The final major adjustment to the Ohio River occurred between 12,000 and 8,500 years before present when it avulsed from the lower Cache River Valley to its current geographic position. This avulsion was attributed to the Cache River Valley being filled with glaciofluvial sediment, which led to the Ohio River capturing a steeper bedrock valley into the Lower Mississippi River embayment (Esling et al., 1989).
The physiography of the Cache River Watershed is generated by the “topography of the bedrock surface, the extent of glaciation, differences in the ages of the uppermost drift, height of the glacial plain above main lines of drainage, and glaciofluvial aggradation” (Demissie et al. 1990, 10; Gough 2005). The Cache River Watershed is located within three physiographic provinces, Ozark Plateaus Province, Interior Low Plateaus Provinces, and the Coastal Plain Province, and borders the Central Lowland Province to the north. The intersection of these provinces creates the uplands hills, the alluvial plains, and the lowland floodplains. The Upper and Lower Cache River Watersheds differ greatly in their physiographic character and consequently their appearances. The Upper Cache River Watershed is comprised of relatively steep stream valleys with a narrow floodplain that dissect flat-lying Mesozoic bedrock where the Lower Cache River is a wide, relatively low-gradient valley with numerous wetlands formed by the Ohio River terraces or other large river fluvial landforms (Gough 2005).

2.2 CONSERVATION EFFORTS IN THE CACHE RIVER WATERSHED

There are several state and federal agencies and non-governmental organizations actively working on the conservation of the Cache River Watershed under the Joint Venture Partnership to protect the Cache River wetlands and the surrounding ecosystems. The Illinois Department of Natural Resources and U.S. Fish and Wildlife Service (known through the Cypress Creek National Wildlife Refuge), joined by Ducks Unlimited, Friends of the Cache, and the Nature Conservancy, have primarily focus on reconnecting the Upper and Lower Cache River which has been bifurcated by the Post Creek Cutoff. The efforts of the JVP have also prevented up to 88,900 metric tons of
sediment every year, which predominantly originates from Big Creek and Cypress Creek, from entering the Cache River, by creating 90 retention ponds in the Big Creek Watershed and dredging over 2,700 meters of river (The Cache River Wetlands Joint Venture; Treacy 2011). Other methods of reducing sediment include reforestation efforts and in-stream rock to reduce channel erosion and incision by placing 48 riffle weirs (The Cache River Wetlands Joint Venture; Treacy 2011).

There are two other groups that have been assisting with conservation efforts in the Cache River Watershed: Ducks Unlimited and the Friends of the Cache. While both groups focus on wetland conservation, they differ in their focused interest. Namely, Ducks Unlimited started in 1937 in response to the 1930s drought, known as the Dustbowl, in hopes of increasing waterfowl by habitat conservation (Tyler 2013). As of January 1st, 2013, Ducks Unlimited in a national organization has conserved over 19,000 km² of wetlands in the United States. Since the organization is grassroots and volunteer-based, revenues are raised through hosting fundraising events. Of the 2012 total revenue generated, 83% of expenditures were directed into waterfowl and wetland conservation and education programs. Thus, Ducks Unlimited is currently an influential player in wetland conservation efforts throughout the United States.

Conversely, Friends of the Cache is run by a group of citizens from southern Illinois. Their main accomplishments are restoring 2,300 hectares of forest, 5,000 hectares of wetland, and a 51.5 km of the Cache River. The successes were attributed to the 2014 CCNWR Habitat Management Plan, which mandated prioritizing forest and wetland restoration efforts in CCNWR. In addition to providing volunteered manpower for restoration efforts, the Friends of the Cache promotes educational ventures for all
ages to the Cache River, Barkhausen Cache River Wetlands Center, and surrounding wetlands, such as Heron Pond and Bottomland Swamp.

2.3 SIMON AND HUPP CHANNEL EVOLUTION MODEL

To identify the levels of hydrologic connectivity and gain a better understanding of the current hydrologic conditions of Cypress Creek, this study uses Simon and Hupp (1986) channel evolution model to characterize the reaches of Cypress Creek. The channel evolution model identifies six distinct evolutionary stages of a channel based on the hydrologic and geomorphologic characteristics. Stage one identifies the channel as pre-modified and sinuous and well connected to the surrounding floodplain. Stage two exemplifies channel modification through channelization and the initial disconnection of the floodplain to the channel. Over time, the channel banks begin to degrade and the channel is classified as stage three. Degradation of the channel is visible by channel incision, vegetation collapse, and increasing sedimentation. As more time passes, the channel banks, in stage four, continue to degrade, but the channel begins to widen, which continues to disconnect the former floodplain from the channel, creating a terrace. Stage four is depicted by channel slumping, a wider channel cross section, more vegetation collapse, and greater sedimentation. As the channel continues to widen, in stage five the sediment begins to accumulate in the channel and the floodplain remains a disconnected terrace. Stage five is exemplified by channel widening and sediment aggradation through increased channel slumping, sediment deposition in the channel, and an even wider channel cross-section. The floodplain continues to be disconnected from the channel in stage five. Stage six finalizes the channel evolution
model where the channel returns to quasi-equilibrium and the floodplain remains an isolated terrace.

2.4 HYDROGEOMORPHIC ASSESSMENT

A federally mandated Water Resources Inventory Assessment (WRIA) report was completed in 2016 to determine the threats and needs of CCNWR’s water resources. Out of the 48 present water resources in CCNWR, only 20 threats and 23 needs were identified to be present. The types of threats identified in the report included loss and alteration of stream channels, habitat shifting and alterations, altered flow regimes, excess surface water, insufficient surface water, sedimentation, altered thermal regimes, mercury, nutrient pollution, pathogens, pesticides, and other contaminants and altered water chemistry. The discovered needs fell under several categories such monitoring and measurement, coordination and support, mapping and geospatial data and analysis, modeling-research-assessment, water quality mitigation, and habitat improvement. In addition to determining the threats and needs of the CCNWR’s water resources, the WRIA compiled the following information: “local soils, geology, and natural setting information, historic, current, and projected climate information, inventory of surface water and groundwater resource features, inventory of relevant infrastructure and water control structures, summaries of historical and current water resource monitoring, brief water quality assessments for relevant water resources, summary of state water laws, and a compilation of main findings and recommendations for the future” (Gerlach 2016, iv). Additionally, a hydrogeomorphic (HGM) assessment, titled “Hydrogeomorphic Evaluation of the Ecosystem Restoration Options for Cypress Creek National Wildlife Refuge, Illinois”, was issued in conjunction
with the WRIA to evaluate the “current and historic geomorphology, soils, hydrology, topography, physical anthropogenic features, and the flora and fauna” (Heitmeyer and Mangan 2012; Gerlach 2016, iv). The HGM assessment was generated as a “useful tool for Refuge management and future assessments” (Gerlach 2016, iv).

The HGM assessment objectives concentrated on the ecosystem conditions at the pre-settlement and at the current level to formulate habitat restoration techniques to reach the federal management designated pre-settlement ecological conditions within the CCNWR’s acquisition boundary. Maps, historical accounts, and published literature on the Cache River Valley, suggested to Heitmeyer and Mangan (2012) that vegetative communities were distributed by physiographic features of the land such as topography, geomorphology, and hydrology (25). After extensive historical research, topographic, geomorphic, and hydrologic classifications created the following vegetative communities in the HGM matrix: bottomland lake, cypress-tupelo swamp, low bottomland hardwoods, terrace hardwoods, slope forest, and mesic upland forest. Their respective historical flood frequencies were marked as annual to permanent to semi-permanent, annual to semi-permanent, annual with four to six months of dormant season flooding, annual with two to three months of dormant season flooding, greater than a 20-year flood frequency, and onsite.

The general wetland restoration ideas that evolved from Heitmeyer and Mangan (2012) originate by first classifying current conditions into the physiographic categories of the HGM matrix and then restoring vegetative communities if current conditions meet the appropriate pre-settlement characteristics in topography and geomorphology. Nevertheless, topography and geomorphology are not the only factors in assessing

In addition to the Heitmeyer and Mangan (2012) study, there was a separate hydrologic and hydraulic assessment conducted on the Cache River Valley by the Illinois State Water Survey that focused on the Cache River corridor’s floodplain physical reconnection potential (Demissie, et al, 2008: Demissie, et al, 2010). In addition, in Demissie et al, (2008), a hydrologic model (HEC-HMS model) of Big Creek, a tributary in the Lower Cache River, was used to simulate flow in the adjacent Cypress Creek watershed to present floodplain restoration alternatives and scenarios with particular water levels along the Cache River Floodplain. However, these studies did not directly assess hydrologic and hydraulic conditions along the lower Cypress Creek which is the focus of this study.
CHAPTER 3

METHODOLOGY

Hydrologic analyses and hydraulic modeling were preformed to assess floodplain connectivity along a portion of lower Cypress Creek. The purpose of this assessment is to illustrate the differences between the historic stream connectivity indicated in the Cypress Creek Hydrogeomorphic Assessment (Heitmeyer and Mangan 2012) and the present-day conditions. To accomplish this task, a flow frequency analysis was performed to estimate discharges for specific flood exceedance probabilities.

Topographic and land cover datasets were compiled to construct a hydraulic model to determine water surface elevations (WSELs) for specific flood exceedance probabilities. The topographic data for the creek channel was surveyed and floodplain topography was extracted from high-resolution digital elevation models (DEM) constructed from Light Detection and Ranging (LiDAR) surveys. Discharges were measured to estimate Manning’s $n$, an important parameter in the hydraulic model, and provide assessment of the flow conditions in the channel from which to assess the results of the model. WSELs from the hydraulic model were subtracted from a high-resolution DEM to estimate inundation extent across the floodplain for a suite of habitat relevant flood discharges. The differences in the extent of floodplain inundation was used to infer the state of hydrologic connectivity along a given segment of lower Cypress Creek. The present-day floodplain connectivity assessment was then compared to the historic hydrogeomorphic assessment to evaluate the changes in the creek-floodplain connectivity along the lower most portion of Cypress Creek.
3.1 STUDY AREA

The lower Cypress Creek study reach is located within the southern portion of the watershed between Cypress Creek and Quarry Roads (Figure 3.1; 3.2). This reach was selected because it is comprised of a relatively large floodplain area where the bottomland forests should thrive and it is mostly contained on public lands within the CCNWR. In addition, because this reach is mostly contained within the CCNWR it is a focus area for potential restoration efforts by the USFWS.

The lower Cypress Creek study reach can be divided into three sub-reaches based on human alternations to the channel. The first sub-reach extends from Cypress Creek Road to Hickory Bottoms Management Unit of the CCNWR (Figure 3.2). Along this sub-reach, channel modifications such as ditching were employed to drain the floodplain and its associated wetlands for the facilitation of agriculture. However, the channel along this sub-reach is no longer maintained as a ditch. These modifications have substantially straightened the creek channel along this sub-reach relative to its historic sinuous form by substantially shortening the channel length. The substantial decrease in channel length has caused in an increased in channel slope and consequently, increased the stream power, which has resulted in channel incision of up to four meters along the sub-reach. The substantial incision along this reach has reduced the lateral hydrologic connectivity between the creek and its floodplain, slowly abandoning the floodplain into a terrace. The incision along this sub-reach has also resulted in bank slumping consequentially causes bank vegetation to collapse into the streambed and failed bank material to increase sedimentation, which causes even more instability along this sub-reach. The channel along this sub-reach is in the degradation
phase, stage three, of Simon and Hupp's (1986) channel evolution model for modified streams. Attempts were made to stop destabilization. Observations from field work identified rock weirs and back protection located throughout Cypress Creek, which were put in place to attempt to dissipate flow velocities.

The second sub-reach extends downstream of the Hickory Bottoms Management Unit to approximately the straightened channel near Quarry Road. This is a less impacted sub-reach with channel planform and dimension more like its historic condition, however exemplifies aggradation and widening characteristics. Due to the alterations of the upstream sub-reach, this middle sub-reach exhibits stage five channel evolution model properties (Simon and Hupp 1986). The sinuosity of this reach is substantially higher and the channel is less incised with stream banks heights of generally less than two meters, however sediment aggradation is visible in the streambed as the channel continues to widen to equilibrium. Consequently, the lateral hydrologic connectivity between the creek and its floodplain along the second sub-reach is higher than in the first sub-reach.

The third sub-reach is located parallel to Quarry Road (Figure 3.2). This sub-reach is also ditched, but unlike the first sub-reach still maintained (i.e. periodically dredged). There is almost no channel sinuosity along this sub-reach and bank heights range from 3 to 4.5 meters. Like the first sub-reach, lateral hydrological connectivity between the creek channel and its floodplain has been substantially reduced because of channelization and channel depth and is classified as stage 3 in the channel evolution model (Simon and Hupp 1986).
Figure 3.1 A Digital Elevation Model of the Cypress Creek Watershed with the study area indicated. The study area is within the lowermost portion of the watershed located just upstream of the lower Cache River Valley and its wetlands.
Figure 3.2 A satellite image of the study area in 2016.

3.2 GEOSPATIAL DATA

The geospatial data use in this study includes a high-resolution digital elevation model (DEM) constructed from Light Detection and Ranging (LiDAR) data, Global Position System (GPS) measured cross sectional channel elevations for channel geometry, and the HGM layer from Heitmeyer and Mangan (2012). Surveying channel geometry was a necessary step in constructing a hydraulic model of the lower Cypress Creek study reach because the Digital Elevation Model (DEM) did not fully represent the entire streambed from which to construct a robust hydraulic model. In order to compile the topographic data required for channel geometry construction, the channel was
surveyed by means of a Geo 7x Trimble dual frequency GPS using the quick point survey mode. A minimum of 5 points were collected to determine the elevation of a given location as to construct the channel geometry.

The HGM matrix from Heitmeyer and Mangan (2012) polygon layer was separated into classifications based on vegetative communities (i.e. bottomland lake, Cypress-Tupelo swamp, low bottomland hardwood, shallow floodplain bottomland hardwood, terrace hardwood, slope forest, and mesic upland forest), which were determined by extensive historical research that built relationships between the topographic, geomorphic, and hydrologic data. Hydrologic data consisted of aggregate historical flood frequencies for the general region of southern Illinois and the data layer was obtained from the USFWS (Heitmeyer and Mangan 2012).

3.3 CHANNEL ELEVATION POST-PROCESSING AND SCREENING

Post processing and correcting of GPS measured channel elevations was performed using Trimble’s Pathfinder GPS software using the Continuously Operating Reference Station (CORS) from providers in Paducah, Kentucky and Cape Girardeau, Missouri. After post processing, the surveyed points were exported into an ESRI Shapefile. The shapefiles, which contained more than 52,000 channel locations and their associate elevations were managed in the ESRI ArcMap software. Within ArcMap the survey points for each cross-section were screened for errors, such as horizontal and vertical accuracy. Each cross-section contained no less than four points so a realistic trapezoidal representation of the stream channel could be made. In most cases, only the channel locations with vertical and horizontal accuracy of less than one meter were used to construct the channel’s cross section. However, in areas with dense
vegetation or in locations where high channel banks resulted in less than optimal satellite signal, the uncertainty for some channel elevations exceeded one meter. In a limited number of cases, channel elevations exceeding one meter were used to construct the channel cross section.

3.4 DISCHARGE MEASUREMENTS

Discharge measurements were collected to determine Manning’s $n$, in the creek channel for use in the hydraulic model. The discharge measurements also provided insights into the hydraulics of the Cypress Creek’s bankfull condition. Discharge measurements of Cypress Creek were computed using the velocity-area method. Each discharge measurement location was chosen to represent a location of substantial hydrologic change along lower Cypress Creek study reach. The detailed measurements of channel geometry and stream velocity were made downstream of Cypress Creek Road (the most northern location), downstream of the Tributary Adds Branch, downstream of the Hickory Bottoms Bridge, Natural Meander Area (Sub-reach 2), and downstream of the Quarry Road Bridge (the most southern location; Figure 3.2).

Detailed cross-sectional heights and widths were measured using a tape measurer, a stadia rod, and an eye-leveler. Elevation from the tape measurer to the channel bottom was recorded every one to two meters, depending on the width of the channel. Velocity measurements were taken at three points along the cross-section for an average of 40 seconds using a United States Geology Survey Pygmy Current Meter at 60% of the depth. The continuity equation was used to calculate the discharge using the velocity and area measurements described above:
\[ Q = A \cdot v \]  

Q = discharge  
A = area  
v = velocity

3.5 ESTIMATE OF FLOOD FREQUENCY

Since Cypress Creek is an ungauged stream and the discharge measurements were collected in the study were too few to estimate flood frequencies, the U.S. Geological Survey's StreamStats application was used to estimate flood discharges for select return periods. StreamStats uses regression equations developed by Soong et al. to estimate peak discharges for ungagged streams in Illinois (2004). Using this tool, flow frequency estimations were made for the following return periods: 2, 5, 10, 20, and 25-year. Further, the 20-year return period was added in order to match the exceedance probabilities from Heitmeyer and Mangan (2012) in order to compare results between this and their study. The discharge for the 20-year return period was interpolated using the 10-year and 25-year flood discharge estimates from the StreamStat results. Lastly, longer return periods were not evaluated because the longest return period used by Heitmeyer and Mangan (2012) was the 20-year event.

The rural stream regression equations in Soong et al. (2004) were first created base on the specific physiographic features and hydrologic characteristics of each region, region 7 for southern Illinois. There were 38 basin characteristics that were used to build the initial regression equations and some of the main characteristics used were morphometric, soil, precipitation, and land use. The dummy variables in the regression equations represented the regional factor. The final regression equation included the following variables: total drainage area, main channel slope, average soil permeability,
percent open water, and basin length. Total rainfall in depth was not distinguished in the regression analysis and average soil permeability, percent open water, and basin length were selected instead (Soong et al. 2004).

Flood flow frequencies were determined above and below a substantial tributary along the study reach, Adds Branch. Flow frequencies were estimated for Cypress Creek just upstream of Adds Branch and at the southern end of the study just downstream of Quarry Road. In addition, flow frequency estimates were made for Adds Branch just above its confluence with Cypress Creek (Figure 3.2).

3.6 DEVELOPING THE HEC-RAS HYDRAULIC MODEL FOR CYPRESS CREEK

The United States Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis Software (HEC-RAS) is a commonly used hydraulic model which models water-surface elevations (WSELS) for a wide array of streams and rivers. This software was selected to simulate WSELS for discharge and for flood return periods of interest because of its functionality to obtain these results. In addition, the software is freely disseminated to the hydrologic research and engineering community by the USACE. HEC-RAS also comes with a GIS-based data processing tool, HEC-GeoRAS, to extract and compile model parameters from geospatial data sources.

3.6.1 MODEL GEOMETRY

Model geometry was first digitized using the HEC-GeoRAS Tools which utilize the geospatial operations within ArcMap. Model parameters digitized included bank lines, flow direction lines, and topographical cross-sections. Bank lines were digitized to depict the main channel constraints. Flow direction lines were extended from the northern most point of the study reach, following the channel, to the southernmost point
of the study reach to represent the primary flow direction within the thalweg of the creek and its floodplain. Cross-sectional transects extracted elevations from the DEM to represent the topography in the hydraulic model. All parameters were then exported from ArcMap using HEC-GeoRAS tool.

The export file generated using HEC-GeoRAS was then imported into HEC-RAS. Since the creek channel was not well defined in the DEM, the surveyed channel elevations for the cross-sections were manually entered into HEC-RAS. Ineffectual flow areas were added to the HEC-RAS model of Cypress Creek to prevent flow across the floodplain before bankfull conditions were reached.

3.6.2 DETERMINATION OF HYDRAULIC ROUGHNESS PARAMETERS

Estimation of the hydraulic model roughness parameter, Manning’s $n$, was estimated using the data employed to calculate discharge at the five locations listed in Table 3.1. Equation (2) from Gauckler (1867) and Manning (1891) was employed to calculate Manning’s $n$:

$$ n = \left( \frac{R^{2/3}}{S^{1/2}} \right) \frac{1}{v} $$

Equation (2) from Gauckler (1867) and Manning (1891) was employed to calculate Manning’s $n$:

$$ n = \left( \frac{R^{2/3}}{S^{1/2}} \right) \frac{1}{v} $$

$n = $ Manning’s $n$

$R = $ ratio of the cross-sectional area to wetted perimeter

$S = $ slope value

$v = $ velocity

Slope was calculated by subtracting the channel elevations at 85% and at 10% Cypress Creek’s length from a topographical map and then dividing this change in elevation by the distance along the stream channel between these two elevations. This calculation yielded a slope of 0.00149 for the study reach. Average velocity ($v$) was calculated from measured velocities at each discharge measurement location. The
hydraulic radius was determined using the measured cross-sectional area divided by the wetted perimeter of the channel. At the five discharge measurement locations, a bankfull flow condition was only measured at the Hickory Bottoms discharge measurement location. For the other four measurement locations, only sub-bankfull flow conditions were measured.

The calculated estimates of channel Manning’s $n$ ranged between 0.037 and 0.049 with an average value of 0.043. A Manning’s $n$ of 0.04 was chosen for the channel roughness because of the channel type and characteristics. Cypress Creek is an open channel, natural stream with a low slope and is relatively straight with hardly any riffles or deep pools and has significant bank vegetation (Chow 1959). For the floodplain, land cover was used to inform the selection of Manning’s $n$ values. Land cover across most of the floodplain along the study reach was forest, hence a Manning’s $n$ for a forested floodplain, 0.1, was used in the hydraulic model (Remo et al. 2009).

Table 3.1 Calculated Manning’s $n$ for five cross section locations in the study area.

<table>
<thead>
<tr>
<th>Cross Section Location</th>
<th>Slope</th>
<th>Velocity (m/s)</th>
<th>Ratio</th>
<th>Manning’s $n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cypress Creek Road</td>
<td>0.00149</td>
<td>0.58</td>
<td>0.63</td>
<td>0.04</td>
</tr>
<tr>
<td>Downstream Adds Branch</td>
<td>0.00149</td>
<td>0.79</td>
<td>1.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Hickory Bottoms</td>
<td>0.00149</td>
<td>0.75</td>
<td>0.92</td>
<td>0.03</td>
</tr>
<tr>
<td>Natural Area</td>
<td>0.00149</td>
<td>0.57</td>
<td>0.62</td>
<td>0.04</td>
</tr>
<tr>
<td>Quarry Rd</td>
<td>0.00149</td>
<td>0.50</td>
<td>0.51</td>
<td>0.04</td>
</tr>
</tbody>
</table>

3.6.3 UNIT HYDROGRAPH

Lower Cypress Creek has a very large floodplain for the size of the stream. To realistically simulate floodplain inundation in such a stream system requires the use of a hydrodynamic model. Since Cypress Creek is an ungauged stream and no continuous
discharge data has ever been collected by the U.S. Geologic or Illinois State Water Surveys, this precluded the use of observed data to create a hydrograph to run the model hydrodynamically. Therefore, in this study, synthetic hydrographs were generated using a unit hydrograph approach. Time to concentration was estimated using the Kirpich equation (1940). The time to concentration was calculated for the upstream discharge boundary condition near Cypress Creek Road and for the lateral input discharge hydrograph representing Adds Branch (see Figures 4.1, 4.2, and 4.3).

First, Kirpich's equation (3) was used to calculate the time of concentration, \( t_c \), which is also equal to (4) with \( t_L \) known as lag time (Kirpich, 1940):

\[
t_c = \frac{0.006628L^{0.77}}{S^{0.385}} \quad (3)
\]

\[
t_c = \frac{t_L}{0.6} \quad (4)
\]

\( t_c \) = time of concentration (hours)
\( L \) = length of reach (km)
\( S \) = slope (%)

Moreover, length of reach in kilometer, \( L \), and average slope along a hydraulic length expressed as a fraction, \( S \), were calculated using tools in ArcGIS. It is known that lag time, \( t_L \), and time of peak flow, \( t_p \), are equal, giving the precise time in hours where flows peak.

Next, the unit hydrograph approach was used to generate the synthetic hydrograph. Further, to generate the synthetic hydrograph, the time to peak flow, discharges for the select recurrence intervals from the USGS StreamStats tool were
applied. Additionally, to determine the end of the storm hydrograph, the relationship where \( t_b \) is base time was applied (5).

\[
2.67t_p = t_b \tag{5}
\]

\( t_p \) = time of peak flow  
\( t_b \) = base time

After the generation of the end of the storm hydrograph, a linear regression equation was calculated for the rising and falling limbs of the hydrograph. These linear regression equations were used to estimate specific discharges at certain time steps to generate the synthetic hydrograph. Lastly, the synthetic hydrographs were then imported into the HEC-RAS model to perform the unsteady flow analysis.

3.7 HEC-RAS SETUP AND MODEL RUNS

The HEC-RAS model was run hydrodynamically. First all geometric data, including 99 cross-sectional transects, channel boundary lines, bank boundary lines, and mid-channel identification lines, from HEC-GeoRas was uploaded to HEC-RAS. To run an unsteady flow simulation, the external boundary conditions of the model were identified in the unsteady flow data editor. A normal depth downstream boundary option was selected at the confluence of Cypress Creek and the Cache River and the frictional slope entered equaled the calculated slope of Cypress Creek (see Chapter 3.6.2; Table 3.1). A flow hydrograph was selected for the upstream boundary and previously calculated unit hydrograph inputs of flow and fixed time were entered (see Chapter 3.6.3). A lateral inflow hydrograph was selected to add Adds Branch’s flow information. Additionally, the roughness coefficient, Manning’s \( n \), for the channel and bank was entered into the model as well as the calculated slope of lower Cypress Creek.
Model simulation was trialed in six scenarios that reflected the number of selected return periods of interest (low flow discharge of 0.28 cms, bankfull discharge, 2-year, 5-year, 10-year, and 20-year floods).

3.8 SENSITIVITY ANALYSIS

Sensitivity analyses were performed on the HEC-RAS Cypress Creek model to determine the impact of uncertainty of model parameters on modeled WSELs; the analyses were performed on the two primary variables which impact the accuracy of the modeled results - Manning’s $n$ and peak discharge. For this analysis, the values of Manning’s $n$ and discharge were increased and decreased by 20%. The hydraulic model was run eight times with corresponding changes in values for Manning’s $n$ and discharge for the 2-year and 20-year return periods. Statistics, mean, standard deviation, and kurtosis, were calculated on the eight sets of WSELs that were produced from the eight sensitivity analyses.

3.9 FLOOD DEPTH GRIDS

The exported HEC-RAS output from the model was imported into ArcMap using the tools in HEC-GeoRAS. Water-surface raster layers were constructed for six scenarios: low flow discharge of 0.28 cms, bankfull discharge, 2-year, 5-year, 10-year, and 20-year floods. These layers were created by interpolating WSELs for each model cross-section for each of the six scenarios using the Topo to Raster tool in ArcMap. Next the Flood Depth Grids (FDGs) were created by subtracting the water-surface layer from the DEM using the tools in ArcMap to create FDGs. A discharge of 0.28 cms represents a low flow condition for Cypress Creek. Field observations suggest that this discharge condition is commonly exceeded along lower Cypress Creek.
3.10 ASSESSMENT OF POTENTIAL FLOODED HABITAT FOR BALD CYPRESS AND WATER TUPELO

Bald Cypress and Water Tupelo require unique habitats and growth conditions. Regeneration only occurs during periods of drought, which is marked by a period with no flood inundation. However, flooding is necessary for Bald Cypress and Water Tupelo saplings and elder trees to outcompete other bottomland woody species. In addition, flooding is essential for seed dispersal and colonization. Constant flooding, generating deeper waters, on the other hand, will eradicate the species (Brugam et al. 2007; Conner and Flynn 1989; DuBarry 1963; Keim and Amos 2012; Mattoon 1916; Middleton 1995, 1999; Ningchuan et al. 2002; Schneider and Sharitz 1986, 1988; Shankman and Drake 1990; Shankman and Kortright 1994).

Since Bald Cypress and Water Tupelo need to be frequently inundated to outcompete other bottomland woody species for space and resources, this suggests that they need to be inundated frequently. In this suitability assessment, the extent of the 2-year flood represents the likely maximum extent of the potential Bald Cypress and Water Tupelo habitat due to the minimum frequency of flood inundation needed for the aquatic woody species to thrive. Bald Cypress and Water Tupelo cannot survive in deep water or constant flowing water. Hence, the extent for the 0.28 cubic meters per second flow, which represents the discharge condition that is too wet for Bald Cypress and Water Tupelo to regenerate. The 0.28 cubic meter per second FDG was subtracted from the 2-year FDG to generate a map to show the potential suitable areas for Bald Cypress and Water Tupelo regeneration using the tools in ArcMap.
Furthermore, there are other areas within the Cypress Creek Watershed that are unsuitable for Bald Cypress and Water Tupelo regeneration due to frequent or continual inundation and land use. The following land use regions from the 2011 National Land Cover Database of Illinois were removed from the flood inundation layer calculated above: open water, developed (open space, low intensity, medium intensity, or high intensity), barren, planted and cultivated (pasture, hay, or cultivated crops), deciduous forest, (dominated by 5-meter trees and 20 or more % coverage) and evergreen forest (dominated by 5-meter trees and 20 or more % coverage). The final layer generated after the removal of unsuitable land cover types is the potential habitat for Bald Cypress and Water Tupelo along the study reach.

3.11 POTENTIAL FLOODED HABITAT COMPARED TO HYDROGEO MORPHIC DATA

In ArcGIS, the layer of Bald Cypress and Water Tupelo potential habitat was overlaid onto the HGM layer generated by Heitmeyer and Mangan (2012) by decreasing opacity to allow the HGM layer characteristics to show while still defining the extents of potential Bald Cypress and Water Tupelo habitat. The potential habitat area estimated in this study was then compared to the HGM layer for the lower Cypress Creek study reach in order to determine if both assessments indicate the same Bald Cypress and Water Tupelo regeneration areas or if the assessments reveal different locations for Bald Cypress and Water Tupelo regeneration. In ArcGIS using the toolbox tool to convert rasters, the HGM layer and all FDGs raster layers were converted to polygon layers to calculate total potential habitat area for each study.
CHAPTER 4

RESULTS

4.1 DISCHARGES FOR THE RETURN PERIOD OF INTEREST

Discharges for the selected return periods were generated using the U.S. Geological Survey’s StreamStats software. These discharges along the lower Cypress Creek ranged from 55 cms for a 2-year return period above Adds Branch and up to 157 cms for the 25-year return period near the confluence with the Cache River. The flow frequency for Adds Branch ranged from 28 cms for the 2-year return period up to 72 cms for the 25-year return period (Table 4.1).

Table 4.1 USGS StreamStats for selected return periods along Cypress Creek and Adds Branch in cms.

<table>
<thead>
<tr>
<th></th>
<th>2-Year</th>
<th>5-Year</th>
<th>10-Year</th>
<th>20-Year</th>
<th>25-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cypress Creek, Before Adds Branch</td>
<td>55.22</td>
<td>84.38</td>
<td>105.34</td>
<td>144.08</td>
<td>153.76</td>
</tr>
<tr>
<td>Adds Branch Tributary</td>
<td>27.84</td>
<td>44.17</td>
<td>56.35</td>
<td>68.81</td>
<td>71.92</td>
</tr>
<tr>
<td>Confluence with the Cache River</td>
<td>68.53</td>
<td>102.5</td>
<td>126.29</td>
<td>150.76</td>
<td>156.88</td>
</tr>
</tbody>
</table>

4.2 CYPRESS CREEK HYDROGRAPHS

The unit hydrographs were generated for the three boundary condition locations for the hydraulic model for the return periods of interest. The estimated time to peak discharge was approximately 40 minutes for each location. Similarly, the length of the unit hydrograph at each location was approximately 100 minutes. Figure 4.1 is the unit hydrograph for the upstream boundary near Cypress Creek Road, Figure 4.2 is the
unity hydrograph for the inflow boundary at Adds Branch, and Figure 4.3 is the unit hydrograph for the downstream boundary near the confluence with the Cache River.

Figure 4.1 The unit hydrograph for selected return periods of Cypress Creek upstream of Adds Branch.
Figure 4.2 The unit hydrograph for the selected return periods at the Adds Branch confluence with Cypress Creek.

Figure 4.3 The unit hydrograph for the selected return periods for Cypress Creek at the confluence with the Cache River.
4.3 HYDRAULIC MODELING RESULTS

The results of the Cypress Creek HEC-RAS model were water surface elevations (WSELs) for each modeled cross-section and are identified for each cross section (Appendix A). Figure 4.4 shows the WSELs profile along the lower Cypress Creek study area for the return periods of interest. Review of the hydraulic modeling results revealed, first, WSELs increase with discharge as the return period decreases. Second, the WSELs decrease in the downstream direction, from a high of 109.5 m for the 20-year return period to a low of 103.7 m for the 2-year return period as the elevation of the stream channel decreases toward the confluence with the Cache River. Lastly, at the beginning of the model, the channel WSELs for the 2-year flood are great than the 5-year flood in a specific number of case. Higher WSELs of the 2-year flood can be attributed by substantial backwater flooding from channel constriction preventing flow from moving downstream.
Figure 4.4 Modeled water surface profile for the lower Cypress Creek study reach.
4.4 SENSITIVITY ASSESSMENT

For the purpose of testing sensitivity of the Cypress Creek HEC-RAS model, eight total scenarios were modeled to assess the uncertainty in the selection of the roughness coefficient, Manning’s $n$, and discharges. According to the hydraulic modeling literature, these model parameters were expected generally have the largest sensitivity and consequently the most substantial impacts on the predicted WSELs (Dyhouse et al. 2003). For this sensitivity assessment, both parameters were increased and decreased by 20% for model runs using the unit hydrographs for the 2-year through the 20-year return periods. For this assessment, minimum difference, maximum difference, and average difference between the WSELs for the actual conditions and the sensitivity scenarios were calculated for the 2-year and 20-year return periods (Table 4.2, Table 4.3).

Channel Manning’s $n$ was increased to 0.048 and decreased to 0.032, holding all other parameters constant, to assess sensitivity of this parameter on the predicted WSELs. Table 4.2 summarizes sensitivity analysis results. Appendix C and D contain the results of the roughness parameter sensitivity analyses. These changes in Manning’s $n$ resulted in differences in WSELs between the model of actual conditions and these sensitivity analyses scenarios of 0.0 to ± 0.15 m with an average difference of approximately 0.05 m. The majority of the WSELs fall into the 86.87 percentile, where they are one standard deviation away from the mean. The WSELs from the 20-year event Manning’s $n$ 20% decrease are the only results that demonstrate 90.9% of the WSELs are one standard deviation away from the mean. The measures of skewness, the asymmetry of the data distribution, and kurtosis, the steepness of the data
distribution, evaluated the WSELs for the four sensitivity trials of Manning’s $n$ and the results are listed in Table 4.2. All skewness measures are greater than zero, which signifies that the data lean towards positive numbers. The kurtosis measures exemplify that the farther from zero, the steeper the distribution curve or heavier the tails are when moving from the 2-year Manning’s $n$ decrease to the 2-year Manning’s $n$ increase. These results suggest that the hydraulic model is relatively sensitive to Manning’s $n$ at the beginning and at the end of the hydraulic model (Appendix D, Appendix E). This observation is consistent with the hydraulic modeling literature (Dyhouse et al. 2003).

Overall, the small relative changes in WSELs suggest the model is only modestly sensitive (within ± 0.15 m) to changes in Manning’s $n$.

Table 4.2 Statistics on the WSELs for the four Manning’s $n$ sensitivity trials.

<table>
<thead>
<tr>
<th></th>
<th>2-Year Decrease</th>
<th>2-Year Increase</th>
<th>20-Year Decrease</th>
<th>20-Year Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. Difference in WSEL (m)</td>
<td>0</td>
<td>0.006</td>
<td>0</td>
<td>0.003</td>
</tr>
<tr>
<td>Max. Difference in WSEL (m)</td>
<td>0.149</td>
<td>0.113</td>
<td>0.140</td>
<td>0.122</td>
</tr>
<tr>
<td>Avg. Difference in WSEL (m)</td>
<td>0.046</td>
<td>0.052</td>
<td>0.049</td>
<td>0.052</td>
</tr>
<tr>
<td>Avg. % Change in WSEL</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Min. WSEL (m)</td>
<td>103.70</td>
<td>103.69</td>
<td>104.93</td>
<td>104.92</td>
</tr>
<tr>
<td>Max. WSEL (m)</td>
<td>108.77</td>
<td>108.98</td>
<td>109.27</td>
<td>109.52</td>
</tr>
<tr>
<td>Avg. WSEL (m)</td>
<td>104.86</td>
<td>104.92</td>
<td>105.57</td>
<td>105.65</td>
</tr>
<tr>
<td>Std. of WSEL (m)</td>
<td>1.40</td>
<td>4.61</td>
<td>3.74</td>
<td>3.83</td>
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<tr>
<td>% of WSELs within 1 Std.</td>
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<td>86.87</td>
<td>90.9</td>
<td>86.87</td>
</tr>
<tr>
<td>Remaining % of WSELs within 2 or more Std.</td>
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<td>9.1</td>
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<tr>
<td>Skewness</td>
<td>1.53</td>
<td>1.70</td>
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<td>2.46</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>1.42</td>
<td>2.11</td>
<td>4.44</td>
<td>5.03</td>
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</table>

Discharge values for the 2-year and 20-year return periods were increased and decreased by 20%. Table 4.3 summarizes the results for the discharge sensitivity analyses and the detailed result of these analyses can be found in Appendices G and
H. These changes in discharge values resulted in differences in WSELs between the model of actual conditions and these sensitivity analyses scenarios of 0.0 to ± 0.5 m with an average difference of approximately 0.2 m. Across all scenarios, 86.8% of the WSELs were within one standard deviation of the mean. The remaining 13.13% of the WSELs were within two more standard deviations from the mean. Similarly, to Manning’s $n$, the 13.13% of the WSELs that were within two or more standard deviations from the mean were located at the start of the Cypress Creek HEC-RAS model. Skewness and kurtosis were also calculated for the four trail peak discharge WSELs and are displayed in Table 4.3 Similarly, to Manning’s $n$ results, skewness for peak discharge variable change shows a tendency of the data distribution to be positive. Kurtosis for the discharge sensitivity trial results indicate either that the data is heavily tailed or that the distribution of the data is steep. These results suggest that the hydraulic model is relatively sensitive to changes in discharge and is most sensitive at the beginning and at the end of the hydraulic model (Appendix I, Appendix J). This observation is consistent with the hydraulic modeling literature (Dyhouse et al. 2003). Overall, the small relative changes in WSELs suggest the model is only modestly sensitive (within ± 0.5 m) to these magnitude changes in discharge.
Table 4.3 Statistics on the WSELs for the four peak discharge sensitivity trials.

<table>
<thead>
<tr>
<th></th>
<th>2-Year Decrease</th>
<th>2-Year Increase</th>
<th>20-Year Decrease</th>
<th>20-Year Increase</th>
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<td>Avg. Difference in WSEL (m)</td>
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<td>0.33</td>
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<tr>
<td>Avg. % Change in WSEL (m)</td>
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<td>Min. WSEL (m)</td>
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<td>Max. WSEL (m)</td>
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<td>108.98</td>
<td>109.26</td>
<td>109.53</td>
</tr>
<tr>
<td>Avg. WSEL (m)</td>
<td>104.81</td>
<td>104.97</td>
<td>105.50</td>
<td>105.71</td>
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<tr>
<td>Std. of WSEL (m)</td>
<td>1.42</td>
<td>1.38</td>
<td>1.16</td>
<td>1.15</td>
</tr>
<tr>
<td>% of WSELs within 1 Std.</td>
<td>86.87</td>
<td>86.87</td>
<td>86.87</td>
<td>86.87</td>
</tr>
<tr>
<td>Remaining % of WSELs within 2 or more Std.</td>
<td>13.13</td>
<td>13.13</td>
<td>13.13</td>
<td>13.13</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.51</td>
<td>1.73</td>
<td>2.34</td>
<td>2.48</td>
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<tr>
<td>Kurtosis</td>
<td>1.43</td>
<td>2.17</td>
<td>4.45</td>
<td>5.13</td>
</tr>
</tbody>
</table>

4.5 INUNDATION MAPPING

Figure 4.5 shows the extent of inundation for high to moderate frequency floods with the 2-year, 5-year, and 20-year return periods. Using the inundation extent for the 2-year flood as a proxy of connectivity between Cypress Creek and its floodplain suggest the areas with the greatest connectivity are found along the northern and southern most sub-reaches of the study, sub-reach one and two. The 2-year flow event was selected as a proxy for connectivity because the 5-year and 2-year flood represent the discharge condition in which the streams in this climatic setting overflow their banks and inundate their floodplain (Ward et al. 2015). The second sub-reach located in the vicinity of Hickory Bottoms had more topographic diversity and consequently a relatively more complex mosaic of inundation. The impact of straightening and deepening the channel along portions of the study reach for improvement of floodplain drainage appears to have had only a localized impact on connectivity between lower Cypress Creek and its floodplain. These impacts are represented by the relatively lower
frequency inundated areas immediately adjacent to the creek channel. The most noticeable area of this phenomena is the vicinity of Cypress Creek Road and downstream of Hickory Bottoms (sub reach one and three).

Figure 4.5 The extent of inundation for the 2-year, 5-year, 10-year, and 20-year return periods. The extent of inundation are labeled in blue color and incrementally change to a darker shade as the return period increases. Cypress Creek is mapped as the yellow line and the red line is the extent of the study area.
4.6 POTENTIAL FLOODED HABITAT AND COMPARISON TO HGM STUDY

Using the suitability criteria for the Bald Cypress and Water Tupelo habitat, 289 hectares of habitat were identified. The majority of suitable habitat is located in the northern portion of the study area. However, substantial areas of habitat can be found along the meandering portions of Cypress Creek between Hickory Bottoms and Quarry Road (Figure 4.6).

Figure 4.6 Potential habitat for Bald Cypress and Water Tupelo.

Figure 4.7 shows an overlay of the hydrogeomorphic data from the HGM study with the potential habitat results from this assessment. The dark gray shaded area represents the potential Bald Cypress and Water Tupelo habitat of this study while the light blue area, identified as Cypress-Tupelo Swamp, represents the HGM results. Both studies indicate there are potential areas suitable for Bald Cypress and Water Tupelo
regeneration in the northern section of the study for approximately 19 hecatres. Nonetheless, this comparison also shows substantial disagreement in the location of this habitat.

The Cypress-Tupelo swamp indicated in the HGM study is located on private land or private land adjacent to federal and state agency boundaries, which would likely complicate any restoration efforts in these areas. This study however, considers the possible land availability, the boundary range, and the most relevant factors (current hydrologic and hydraulic conditions), when determining possible Bald Cypress and Water Tupelo habitat suitability.
Figure 4.7 The potential habitat of the Bald Cypress and Water Tupelo in this study and Mangan and Heitmeyer (2012).
CHAPTER 5

DISCUSSION

5.1 RESEARCH FINDINGS

The historic land use distribution of the Cypress Creek Watershed greatly differs from the current 2011 National Land Cover Dataset. This is evident by comparing Figure 1.1 and 1.2. Prior to settlement, the lower Cypress Creek study area was mainly covered by bottomland forests. However, current land use conditions demonstrate strong post-settlement activities such as agriculture and municipal development. Today, agriculture comprises 54%, the largest percentage, of the watershed’s land use. In addition to land use changes, channel alterations, such as straightening and deepening, to the Cypress Creek channel have reduced floodplain connectivity by drying out the floodplains for agricultural production. Thus, human settlement in the Cypress Creek watershed has caused land use changes and channel alterations that have drastically reduced the availability of floodplain habitats for Bald Cypress and Water Tupelo to less than 5% where bottomland forests once covered 90% of the watershed.

The hydrologic and hydraulic assessments of Cypress Creek demonstrate two differing types of floodplain connectivity. These areas have relatively lower and higher connectivity to the floodplain. The reaches with lower floodplain connectivity are located in the vicinity of Hickory Bottoms Management Unit in sub-reach two (Figure 4.5). Low floodplain connectivity is indicated by no floodplain inundation for the 2-year flood event along this sub reach. While sub-reach two contain pools, riffles, and runs, like an unaltered channel, it has experienced substantial incision due to upstream and downstream channelization. As such, it is in stage five of Simon and Hupp’s (1986)
channel evolution model where the channel has widened and is creating a new floodplain within the new wider channel. In addition the floodplain along this sub-reach also contains relatively high natural topographic relief compared to the northern and southern sub-reaches resulting in less areas being inundated when creek flows exceed the channel banks. Due to relatively lower floodplain connectivity in the Hickory Bottoms Management Unit area, potential Bald Cypress and Water Tupelo regeneration habitat is minimal and constrained to the inside and along the edges of the Cypress Creek channel (Figure 4.7).

The areas with the greatest floodplain connectivity are along the northernmost and southernmost sub-reaches of the lower Cypress Creek study reach. The extent of inundation for the 2-year discharge extends across most of the floodplain (Figure 4.5). The channel along these sub-reaches has been straightened and entrenched due to human influences for the purposes of agriculture and are in stage three of Simons and Hupp (1986) channel evolution due to significant channel slumping and collapse of vegetation. In Figure 4.5, it is evident by the extent of flood inundation that the modification of sub-reach one and three through channel straightening has not inhibited inundation reaching the floodplain, evidently no matter how small (2-year return period) or large (20-year return period) the flood. Usually during stage three of Simons and Hupp’s (1986) channel evolution model, the connectivity between the stream and their floodplain is reduced. However, it seems despite the morphological changes along these lower Cypress Creek sub-reaches, the channel in this area is still highly connected to the extremely low-gradient floodplain in these areas. Despite channelization and straightening along these sub-reaches, the relatively erosion
resistant clays in the channel may impede large incision, which contributes to the relatively higher floodplain connectivity in these sub-reaches. Given the high connectivity along these sub-reaches, these areas have the most substantial potential habitat for Bald Cypress and Water Tupelo regeneration.

In addition, the northern sub-reaches and its associated floodplain have the greatest potential for habitat regeneration because of its conservation status. The southern sub-reach is less suitable for Bald Cypress and Water Tupelo habitat because of its adjacent agricultural land use. These potential suitable habitats can be attributed to the channel modifications that created stream instability and high floodplain connectivity. It is interesting to note that the most potential habitat of Bald Cypress and Water Tupelo is found where the reaches have been modified, not where there is a more natural channel form.

Comparing estimates of habitat suitability for Bald Cypress and Water Tupelo between this study and Heitmeyer and Mangan (2012) show substantial differences in estimates of suitable habitat areas (Figure 4.7). Both studies show some overlap in suitable habitat areas within the northern sub-reach and a few small areas along the southern sub-reach of lower Cypress Creek. This indicates that both studies in these locations meet the criteria for potential Bald Cypress and Water tupelo habitat, which are the necessary flooding extents and the pre-settlement vegetative community physiographic characteristics. Conflicts do occur for the remaining larger portions of the study area. Conflicting potential habitat results can be attributed to each study's methodology and parameters on generating Bald Cypress and Water Tupelo habitat. This study's northernmost sub-reach exemplified the best inundation potential, the
necessary criteria for Bald Cypress and Water Tupelo regeneration and survival, within CCNWR’s boundaries (Brugam et al. 2007; Conner and Flynn 1989; DuBarry 1963; Keim and Amos 2012; Mattoon 1916; Middleton 1995, 1999; Ningchuan et al. 2002; Schneider and Sharitz 1986, 1988; Shankman and Drake 1990; Shankman and Kortright 1994). Heitmeyer and Mangan’s (2012) remaining Cypress-Tupelo habitat between the Hickory Bottoms Unit area and Quarry Road is not within the current CCNWR’s boundaries and cannot be managed by the USFWS for habitat and species regeneration.

The uppermost sub-reach of the lower Cypress Creek study area is the best option for stream restoration and to increase suitable habitat for Bald Cypress and Water Tupelo. This sub-reach of lower Cypress Creek falls within CCNWR management boundaries and this study indicated that potential habitat is available under current hydrologic and hydraulic conditions. Stream restoration could include current hydraulic conditions by keeping cross-sectional area and discharge the same, however changing the channel banks to a stable, meandering length through abandoned historic channels. Historic, meandering abandoned channels exist to the east of the Cypress Creek channel in the Hickory Bottoms Unit above the bridge. In addition, older Bald Cypress species can be found in and near these historic meandering channel.
Figure 5.1 Sub-reach 1 with the greatest potential for Bald Cypress and Water Tupelo habitat.

5.2 SENSITIVITY RESULTS

Sensitivity analyses concluded two areas of model uncertainty and one where the model was relatively sensitive. All eight sensitivity trials on Manning’s $n$ and peak discharges demonstrated uncertainty at the beginning and the end of the model through graphical analysis and a larger percent difference in WSELs (Appendix B, Appendix C, Appendix D, Appendix E, Appendix F). Uncertainty could have resulted due the following factors: ineffectual flow areas in the model, significant changes in slope or channel elevation, the entrenchment and straightening of the channel, or simply due to boundary conditions (Dyhouse et al. 2003). Despite the visual and calculated percent
change uncertainty, statistical results showed that at least 86.87% of WSELs were one standard deviation from the mean WSEL.

The hydraulic model was modestly sensitive in the middle reaches of the study for changes in Manning’s $n$ and discharge. This is demonstrated by minimal graphical and percent changes (Appendix G, Appendix H, Appendix I, Appendix J, Appendix K). Due to relatively sensitive model parameters, Manning’s $n$ and discharge, WSELs could be exaggerated by small incremental changes in parameters. The sensitivity in this area could be attributed to the change in channel depth, width, and sub-reach length because the channel length, width, and depth parameters were fixed and the geomorphology of the middle reaches greatly differs from the boundary sub-reaches.

5.3 LIMITATIONS

The limitations of the Cypress Creek hydrologic assessment and hydraulic model include an absence of long-term historical hydrologic data, scarce observations of discharge and stage, simplified sources of flow, channel geometry out of accuracy bounds, placement of ineffectual flow areas, and the exclusion of bridges from the model. Due to the remote location and being ungagged, Cypress Creek has no long-term record of hydrologic data. The absence of hydrologic data presented a limitation when attempting to develop flood frequencies. The U.S. Geological Survey’s StreamStats application estimates discharges for the selected return periods through regression analysis. The regression based discharge estimates were larger in comparison to estimates calculated from measured channel geometry. Comparing the regression verses channel geometry calculated estimated discharges of the return periods evaluated in this study, regression based discharges were up to an order of
magnitude larger. This comparison suggests there may be substantial uncertainty about the StreamStats peak discharge estimates for this region. Since Cypress Creek is an ungauged stream, the region’s sample of streams was used for regression analysis to calculate peak discharges. Differences in stream statistics and basin characteristics from the regional sample of streams and Cypress Creek can create flow estimate errors (USGS 2016). To properly assess the uncertainty of Cypress Creek discharge requires a continuous monitoring station over a significant period of time to gather a historical discharge record.

Observation of discharge were limited for Cypress Creek. Attempts at gathering discharge measurements during the summer months were impeded by unusually dry hydrologic conditions resulting in very low channel flows. On several occasions the flows were so anemic, the pygmy current meter was unable to register the stream’s weak velocity (<0.2 m/sec). On the other hand, secondary attempts in November and December provided better discharge measurement calculations due to the wetter hydrologic conditions; nevertheless, Hickory Bottoms was the only accessible entry point due to high-water levels during this period. Since collection of discharge and stage observations were limited, we performed a sensitivity analysis on Manning’s n and discharge to assess the impact of model parameters selection on WSELs estimates.

The sources of flow were simplified for the Cypress Creek model due to data availability and scope of work within the CCNWR boundaries because access to privately held lands was not possible. Cypress Creek and Adds Branch are the only sources of flow used for the hydraulic model. Other flow inputs such as back flooding from the Cache River, groundwater sources, and other minor tributaries were not
accounted for in the model. Due to the flat topography and low slope of the Cypress Creek Watershed, the water table of the Cypress Creek’s floodplain would not be greatly influenced by additional flow inputs. In addition, stage level data for the confluence of Cypress Creek and the Cache River is non-existent, which is why a normal depth approach was used to simulate the stage level using frictional slope at the end of the hydraulic model.

Satellite strength was sometimes reduced due to dense vegetation cover and steep channel banks. This caused some elevation data collected to exceed the desired accuracy bounds of this study. While in most cases these channel elevation points were excluded from being used to develop the hydraulic model, in some instances, channel elevations which exceeded the desired accuracy bounds were used because they were necessary to realistically define the channel cross section. The use of the elevation data which exceeded desired accuracy bounds adds additional uncertainty in the modeling results. Because the uncertainty in the elevation data is likely random it is difficult to assess this type of uncertainty on the modeled WSELs. However, the elevation data used in this modeling effort was substantially more accurate than the other sources of elevation data, such as the 1:24,000 topographic maps and the channel elevations of the obtained LiDAR, and these surveyed elevations represents the best available information at this time.

Ineffectual flow areas were placed along the northern sub reach to alleviate the issue of the floodplain conveying flood water before the creek channel reached above bankfull stage. Due to man-made trenching of this portion of lower Cypress Creek and subsequent channel aggradation, there where areas of the floodplain at a lower
elevation than portions of the creek channel. Given the assumptions of the hydraulic model, the areas with the lowest elevation will fill first, resulting in floodwater being conveyed through the floodplain instead of the channel resulting in an unrealistic WSELS. To address this issue in the 1-D hydraulic model, ineffectual flow areas were employed to no allow the floodplain to convey floodwater until the elevation of the water in the channel exceeds bankfull conditions.

Bridges were not included in the lower Cypress Creek hydraulic model. While bridges can locally impact WSELS immediately upstream and downstream of the bridge, excluding these structures are not expected to add substantial amounts of uncertainty to the model results. This is because two of the bridges are located near the upstream and downstream boundaries of the model away from the main area of interest. The third bridge, Hickory Bottom Bridge, spans the entire stream channel without any piers interacting with the flow except for discharges above bankfull.

5.4 FUTURE RESEARCH

Future research of the Cypress Creek Watershed can be categorized into three groups, hydrologic observations, channel geomorphology, and collecting population information on the bald cypress and water tupelo species.

Hydrologic observations of Cypress Creek for future research include continuous monitoring of the creek's WSELS and precipitation. In addition, discharges can be measured at the WSEL monitoring level locations to develop rating elevations to estimate creek discharges. This data can be then used to develop more realistic flow frequencies to inform hydrological and other water level related analyses.
Channel geomorphology knowledge can be strengthened by assembling cross-sectional elevation and width data for main reaches of Cypress Creek with a level and elevation rod. Due to the remote location of Cypress Creek and weak signal strength of a GPS unit inside a channel, an eye or automatic level and elevation rod are best used to generate detailed cross sections of Cypress Creek. If a GPS unit must be used, creation of a base station is advised to increase accuracy of elevation data in the survey in addition to collecting elevation points for longer than 10 seconds.

To further examine possible regeneration locations and the current population extents of the Bald Cypress and Water Tupelo, a population density survey is necessary in the Cypress Creek Watershed. Though the CCNWR is conducting a forest inventory study currently, their survey is not explicit in determining the population density of Bald Cypress and Water Tupelo. Thus, while the CCNWR forest inventory study will reveal possible presence of Bald Cypress and Water Tupelo in the individual survey quadrants, it will not gather the total species number and geographical location of the groves. Understanding species location will provide more context for restoration and the regeneration possibilities.

5.5 CONCLUSION

The results of this study are of a great importance to the wetlands of the CCNWR and the Cache River Watershed. The Cypress Creek Wetlands are listed as UNESCO and RAMSAR’s “Wetland of International Importance”. Wetland preservation and regeneration is crucial to the survival of Bald Cypress and Water Tupelo species in southern Illinois. This is because these aquatic woody species require specific hydrologic conditions to regenerate. This study helps the USFWS focus their CCNWR
Habitat Management Plan initiatives to a specific area within the refuge that possess the hydrologic and hydraulic conditions that are most suitable for Bald Cypress and Water Tupelo regeneration.

The hydrologic analysis and hydraulic modeling of Cypress Creek performed in this study has provided an assessment of the flood inundation extents for five return periods, the areas of high and low floodplain connectivity, and areas with hydrologic and hydraulic conditions suitable for regeneration of Bald Cypress and Water Tupelo. In general, the portion of Cypress Creek which has relatively good hydrologic connectivity and therefore, many of the areas suitable for reforestation of Bald Cypress and Water Tupelo, are located within the CCNWR between Cypress Creek Road and the Hickory Bottoms Management Unit. Within this area, there are 289 ha of floodplain which have hydrologic and hydraulic conditions for reforestation of Bald Cypress and Water Tupelo.

Comparison of the potential areas suitable for Bald Cypress and Water Tupelo habitat between this study and HGM show poor agreement (<6.6% overlap). The difference in potential Bald Cypress and Water Tupelo habitat between this study and the HGM assessment are attributed to this study's use of hydrologic and hydraulic relevant factors that reflect current conditions along the reach of interest compared to the HGM parameters. The HGM parameters are more reflective of the historic conditions, which are substantially different both hydrologically (i.e. land cover change impacts of runoff) and geomorphically (shape and length of the creek channel) than present day conditions along Cypress Creek.
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APPENDICES
APPENDIX A

THE WSEL RESULTS BY THE CYPRESS CREEK HYDRAULIC MODEL FOR THE FOUR EXCEEDANCE PROBABILITIES AND THEIR 99 CROSS SECTIONS

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APPENDIX B

THE WSEL RESULTS BY THE CYPRESS CREEK HYDRAULIC MODEL FOR THE SENSITIVITY TRIAL ON THE VARIABLE MANNING’S N AND THE 2-YEAR AND 20-YEAR EXCEEDANCE PROBABILITIES

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APPENDIX C

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### APPENDIX D

THE WSELS ABSOLUTE DIFFERENCES AND PERCENT CHANGE FOR
THE 20-YEAR AND 20-YEAR 20% INCREASE AND DECREASE IN MANNING’S N

RELATIVE TO THE ORIGINAL 20-YEAR WSELS

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APPENDIX E

THE WSELS OF THE MANNING’S N SENSITIVITY TRIAL FOR EACH CROSS SECTION AND THE 2-YEAR EXCEEDANCE PROBABILITY
APPENDIX F

THE WSELS OF THE MANNING’S N SENSITIVITY TRIAL FOR EACH CROSS SECTION AND THE 20-YEAR EXCEEDANCE PROBABILITY
APPENDIX G

THE WSEL RESULTS BY THE CYPRUS CREEK HYDRAULIC MODEL FOR
THE SENSITIVITY TRIAL ON THE VARIABLE PEAK DISCHARGE AND THE 2-YEAR
AND 20-YEAR EXCEEDANCE PROBABILITIES

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APPENDIX H

THE WSELS ABSOLUTE DIFFERENCES AND PERCENT CHANGE FOR

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THE ORIGINAL 2-YEAR WSEL

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APPENDIX I

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APPENDIX J

THE WSELS OF THE PEAK DISCHARGE SENSITIVITY TRIAL FOR EACH CROSS SECTION AND THE 2-YEAR EXCEEDANCE PROBABILITY
APPENDIX K

THE WSELS OF THE PEAK DISCHARGE SENSITIVITY TRIAL FOR EACH CROSS SECTION AND THE 20-YEAR EXCEEDANCE PROBABILITY
VITA

Graduate School
Southern Illinois University

Tara Gracer
taragracer@gmail.com

Illinois Wesleyan University
Bachelor of Arts, Economics, 2013
Bachelor of Arts, Environment Studies, 2013

Special Honors and Awards:
   Alumni Scholarship Award, 2009
   Leadership Award, National Society of Leadership and Success, 2012

Thesis Paper Title:
A Hydrologic and Hydraulic Assessment of Cypress Creek for the Identification of the Potential Habitat for the Bald Cypress and Water Tupelo

Major Professor: Dr. Jonathan W. Remo

Publications:

