AGREEMENT BETWEEN THE DEPARTMENT OF THE ARMY AND THE METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY, TENNESSEE FOR THE PROVISION OF CERTAIN TECHNICAL ASSISTANCE

THIS AGREEMENT is entered into this _____ day of _May_____, _2025___, by and between the Department of the Army (hereinafter the "Government"), represented by the District Commander for Nashville District (hereinafter the "District Commander") and the Metropolitan Government of Nashville and Davidson County, Tennessee (hereinafter the "Non-Federal Sponsor"), represented by the Mayor of Metropolitan Government of Nashville and Davidson County .

WITNESSETH, THAT:

WHEREAS, Section 22 of the Water Resources Development Act of 1974, as amended (42 U.S.C. 1962d-16), authorizes the Secretary of the Army to provide technical assistance related to the management of State water resources (hereinafter "Technical Assistance") to a State or non-Federal interest working with a State and to establish and collect fees for the purpose of recovering 50 percent of the costs of such assistance except that Secretary may accept and expend non-Federal funds provided that are in excess of such fee; and

WHEREAS, the Government and the Non-Federal Sponsor have the full authority and capability to perform in accordance with the terms of this Agreement.

NOW, THEREFORE, the parties agree as follows:

1. The Government shall provide Technical Assistance in accordance with the attached Scope of Work, and any modifications thereto, that specifies the scope, cost, and schedule for activities and tasks. In carrying out its obligations under this Agreement, the Non-Federal Sponsor shall comply with all the requirements of applicable Federal laws and implementing regulations, including but not limited to, if applicable, Section 601 of the Civil Rights Act of 1964, as amended (42 U.S.C. 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto; the Age Discrimination Act of 1975 (42 U.S.C. 6102); and the Rehabilitation Act of 1973, as amended (29 U.S.C. 794), and Army Regulation 600-7 issued pursuant thereto.

2. The Non-Federal Sponsor shall provide 50 percent of the costs of providing the Technical Assistance in accordance with the provisions of this paragraph. As of the effective date of this Agreement, the costs of providing the Technical Assistance are projected to be $800,000.00, with the Government's share of such costs projected to be $400,000.00 and the Non-Federal Sponsor's share of such costs projected to be $400,000.00.

a. No later than 15 calendar days after the effective date of this Agreement, the Non-Federal Sponsor shall provide the full amount of its share of costs by delivering a check payable to "FAO, USAED, Nashville (H3)" to the District Commander or by providing an Electronic Funds Transfer of such required funds in accordance with procedures established by the Government.

b. If the Government determines at any time that additional funds are needed from the Non-Federal Sponsor to cover the Non-Federal Sponsor's costs of the Technical Assistance, the Government shall provide the Non-Federal Sponsor with written notice of the amount of additional funds required. Within 60 calendar days of such notice, the Non-Federal Sponsor shall provide the Government with the full amount of such additional funds.

c. Following completion or termination of the Technical Assistance and resolution of any relevant claims and appeals, the Government shall conduct a final accounting and furnish the Non-Federal Sponsor with the written results of such final accounting. Should the final accounting determine that additional funds are required from the Non-Federal Sponsor, the Non-Federal Sponsor, within 60 calendar days of written notice from the Government, shall provide the Government with the full amount of such additional funds by delivering a check payable to "FAO, USAED, Nashville (H3) " to the District Commander, or by providing an Electronic Funds Transfer of such required funds in accordance with procedures established by the Government. Should the final accounting determine that the Non-Federal Sponsor has provided funds in excess of its required amount, the Government shall refund any remaining unobligated amount. Such final accounting does not limit the Non-Federal Sponsor's responsibility to pay its share of costs, including contract claims or any other liability that may become known after the final accounting.

3. To the extent practicable and in accordance with Federal laws, regulations, and policies, the Government shall afford the Non-Federal Sponsor the opportunity to review and comment on contract solicitations prior to the Government's issuance of such solicitations; proposed contract modifications, including change orders; and contract claims prior to resolution thereof. Ultimately, the contents of solicitations, award of contracts, execution of contract modifications, and resolution of contract claims shall be exclusively within the control of the Government.

4. In addition to its required cost share, the Non-Federal Sponsor may determine that it is in its best interests to provide additional funds for the Technical Assistance. Additional funds provided under this paragraph and obligated by the Government are not included in calculating the Non-Federal Sponsor's required cost share and are not eligible for credit or repayment.

5. The Non-Federal Sponsor shall not use Federal program funds to meet any of its obligations under this Agreement unless the Federal agency providing the funds verifies in writing that the funds are authorized to be used for the provision of the Technical Assistance. Federal program funds are those funds provided by a Federal agency, plus any non-Federal contribution required as a matching share therefor.

6. Upon 30 calendar days written notice to the other party, either party may elect, without penalty, to suspend or terminate the provision of Technical Assistance under this Agreement. Any suspension or termination shall not relieve the parties of liability for any obligation incurred.

7. The parties agree to use their best efforts to resolve any dispute in an informal fashion through consultation and communication. If the parties cannot resolve the dispute through negotiation, they may agree to a mutually acceptable method of non-binding alternative dispute resolution with a qualified third party acceptable to the parties. Each party shall pay an equal

share of any costs for the services provided by such a third party as such costs are incurred. The existence of a dispute shall not excuse the parties from performance pursuant to this Agreement.

8. To the extent permitted under applicable Federal laws and regulations, the Government shall allow the Non-Federal Sponsor to inspect books, records, documents, or other evidence pertaining to costs and expenses maintained by the Government, or at the Non-Federal Sponsor's request, provide to the Non-Federal Sponsor or independent auditors any such information necessary to enable an audit of the Non-Federal Sponsor's activities under this Agreement. The Non-Federal Sponsor shall pay the costs of non-Federal audits without reimbursement or credit by the Government.

9. In the exercise of their respective rights and obligations under this Agreement, the Government and the Non-Federal Sponsor each act in an independent capacity, and neither is to be considered the officer, agent, or employee of the other. Neither party shall provide, without the consent of the other party, any contractor with a release that waives or purports to waive any rights a party may have to seek relief or redress against that contractor.

10. Any notice, request, demand, or other communication required or permitted to be given under this Agreement shall be deemed to have been duly given if in writing and delivered personally or mailed by registered or certified mail, with return receipt, as shown below. A party may change the recipient or address to which such communications are to be directed by giving written notice to the other party in the manner provided in this paragraph.

If to the Non-Federal Sponsor:
Mayor of Nashville and Davidson County
Office of the Mayor
1 Public Square, Suite 100
Nashville, TN 37201

If to the Government:
District Engineer
US Army Corps of Engineers
Nashville District
110 9th Avenue South, Room A-405
Nashville, TN 37203

11. To the extent permitted by the laws governing each party, the parties agree to maintain the confidentiality of exchanged information when requested to do so by the providing party.

12. Nothing in this Agreement is intended, nor may be construed, to create any rights, confer any benefits, or relieve any liability, of any kind whatsoever in any third person not a party to this Agreement.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement, which shall become effective upon the date it is signed by the District Commander.

DEPARTMENT OF THE ARMY

BY: _____
Robert W. Green
Lieutenant Colonel, U.S. Army
District Commander

DATE: _____

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY

BY: _____
Freddie O'Connell
Mayor
Metro Nashville and Davidson County, TN

DATE: _____

NON-FEDERAL SPONSOR'S
SELF-CERTIFICATION OF FINANCIAL CAPABILITY
FOR AGREEMENTS

I, Jenneen Reed, do hereby certify that I am the Finance Director of the Metropolitan Government of Nashville and Davidson County, Tennessee (the "Non-Federal Sponsor"); that I am aware of the financial obligations of the Non-Federal Sponsor for the Metro Nashville Flood Preparedness Phase 8; and that the Non-Federal Sponsor has the financial capability to satisfy the Non-Federal Sponsor's obligations under the Metro Nashville Flood Preparedness Phase 8 PAS Agreement.

IN WITNESS WHEREOF, I have made and executed this certification this_____day of April, 2025.

BY: Signed by: Jenneen Reed/mjw 62377A2A8742469... _____

TITLE: Director, Department of Finance

DATE: 4/21/2025

CERTIFICATION REGARDING LOBBYING

The undersigned certifies, to the best of his or her knowledge and belief that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by 31 U.S.C. 1352. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

_____

Freddie O'Connell
Mayor, Nashville and Davidson County, Tennessee

DATE: _____

CERTIFICATE OF AUTHORITY

I, Wallace Dietz, do hereby certify that I am the principal legal officer for the Metropolitan Government of Nashville and Davidson County, Tennessee, that the Metropolitan Government of Nashville and Davidson County, Tennessee is a legally constituted public body with full authority and legal capability to perform the terms of the Agreement between the Department of the Army and the Metropolitan Government of Nashville and Davidson County, Tennessee in connection with the Metro Nashville Flood Preparedness Phase 8, and to pay damages, if necessary, in the event of the failure to perform in accordance with the terms of this Agreement, as required by Section 221 of Public Law 91-611, as amended (42 U.S.C. 1962d-5b), and that the person who executed this Agreement on behalf of the Metropolitan Government of Nashville and Davidson County, Tennessee acted within his statutory authority.

IN WITNESS WHEREOF, I have made and executed this certification this 22nd day of April 20 25.

Signed by:
Wallace Dietz
14180CBFF5E4432...

Wallace Dietz
Director of Law
Nashville and Davidson County, Tennessee

U.S. ARMY CORPS OF ENGINEERS
SCOPE OF WORK
FOR
METRO NASHVILLE FLOOD PREPAREDNESS (NFP)
PHASE 8

CUMBERLAND RIVER FLOODPLAIN STORAGE ANALYSIS AND HARPETH RIVER TRIBUTARY HYDRAULIC MODELING

November 05, 2024

Introduction. This scope covers additional work to be performed by the Nashville District (LRN) of the US Army Corps of Engineers (USACE) for calendar years 2025 thru 2027 and build upon studies and investigations completed in support of flood preparedness in Metro Nashville, Davidson County, Tennessee. On March 11, 2024, Metro Water Services provided a letter of intent requesting additional planning assistance from the USACE Nashville District. This letter allows the district to request new start funding for the Nashville Flood Preparedness efforts. Current NFP Phase 7 work underway to be completed in fiscal year 2025 includes updating statistical and hydrologic models from previous NFP efforts and developing Steady Flow HEC-RAS model for the Cheatham Reservoir, Cumberland River miles 148.7 to 216.2. This scope of work expands on the current phase to include completion of 1-Dimesional (1-D) unsteady flow 100-yr floodplain storage analysis for the Cheatham Reservoir, development of 2-Dimensional (2-D) HEC-RAS hydraulic model for Cumberland River mile 186 to 194 through downtown Nashville, and updating 1-D HEC-RAS hydraulic models for 26 miles of Harpeth River tributary streams including South Harpeth River, Highway 100 Tributary, and Poplar, East Fork, Little East Fork, Flat, Trace, and Buffalo Creeks.

Purpose. Metro Nashville has a current ordinance which requires the first floor of residential structures built in floodway fringe along any stream to be at least four foot above the base flood elevation and non-residential structures to be at least one foot above the base flood elevation. Development in the floodway is strictly prohibited unless analysis is provided demonstrating the encroachments will not result in any increase in base flood elevations. Another ordinance requires any alterations in the floodway fringe that result in filling or elimination of floodplain storage shall provide compensation storage capacity. Dredging or cut volumes below the elevation of the two-year storm event are not included in the compensating storage capacity. Metro Water Services currently receives numerous permit request for development in the floodway fringe and is concerned about the effects of filling the floodway fringe to the floodway. There office has requested USACE assistance in determining possible impacts to flood heights. In addition, USACE wants to determine if filling in the floodway fringe impacts the current operations of reservoirs within the Cumberland River Basin.

Previous Studies.

1996 Cumberland River Floodplain Storage Analysis. The Nashville District (LRN) conducted an unsteady flow (U-NET) analysis for the Cumberland River Cheatham Reservoir to determine the cumulative effects of complete filling of the floodway fringe. This study was performed following the 1995 FIS Update modeling completed by LRN. The term "cumulative" refers to calculation of increase in water surface profiles due to change in both floodway conveyance and the peak discharge. Normal calculation procedures used in steady flow modeling, such as steady flow HEC-RAS, only account for changes in floodplain conveyance. They do not account for changes in peak discharge due to the loss of floodplain storage. Unsteady flow computer modeling process was used to define the cumulative effects for this study. The results of this study also identified possible areas which are impacted greater than the FEMA one foot surcharge criteria. Fill in the floodway fringe along these critically impacted areas would require compensation storage. The study concluded that under normal conditions, the Cumberland River from below Old Hickory Dam to Cheatham Dam, is a navigation reservoir (flat) with normal level pool elevation of 385 ft. Under flood conditions, much of the available natural floodplain storage is occupied by reservoir water to elevation 408 ft. For floods in the magnitude of the 100-yr flood, the reach of the Cumberland River from Old Hickory Dam (Mile 216.2) to Mile 197.2 (near Opryland Hotel) responds similar to 'natural' river conditions (sloped) with little reservoir effects. Consequently, the unsteady floodway analysis indicated in order to maintain the FEMA floodway criteria, there is a need for compensation storage requirements along most of the 'natural' stream, above the influence of backwater and reservoir effects, to account for significant overbank storage eliminated by encroachments. Results from the Floodway analysis concluded that compensation storage would be required for fill in the entire floodway fringe to the floodway from mile 197.2 to 216.2. From mile 148.7 (Cheatham Dam) to 197.2, compensation storage would not be required. These combined conditions resulted in increases in base flood elevations equal or less than one foot.

2021 Cumberland River (East Bank) Floodplain Conveyance Analysis. The Cumberland River through downtown Nashville is experiencing significant re-development. The May 2010 flood was devastating to Metro Nashville area resulting in over $2 Billion in flood damages. Figure 1 shows historical flooding from the March 1975 and May 2010 floods along the Cumberland River East Bank. The proposed River North development along the East Bank is shown in Figure 2.

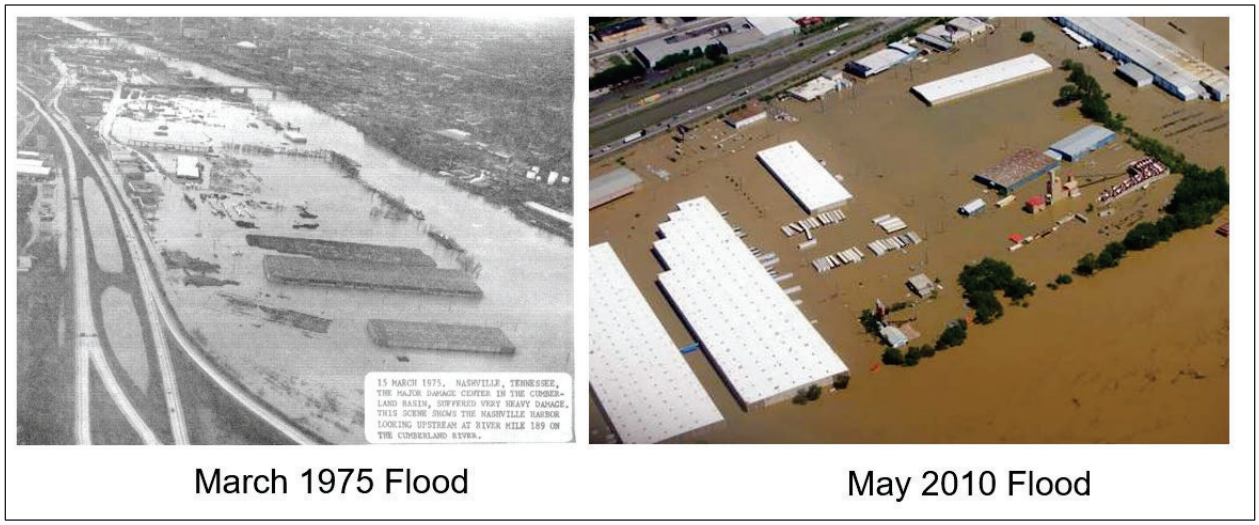


Figure 1. Cumberland River Nashville - East Bank Flooding

Figure 2. River North Proposed Development Along East Bank

In 2021, USACE performed hydraulic modeling analysis for Metro to evaluate the impacts of placement of fill along the East Bank and the conceptual plan to raise major roadways. The 2021 analysis included the evaluation of the removal of most of the flood fringe flow conveyance (Floodway plus 50 ft buffer) along the East Bank for the 100-yr and 500-yr frequency floods. The 2021 analysis concluded that the steady flow hydraulic model was not very sensitive to removal of flood fringe flow conveyance along the East Bank. The East Bank flood fringe conveyed less

than 1% of the 100yr flow and less that 2% of the 500yr flow based on 1-D steady flow hydraulic modeling. The proposed roadway raises had no impact to the 100-yr or 500-yr BFEs. Removal of the entire East Bank flood fringe plus 50 feet buffer conveyance showed minimal impacts with a 0.01 ft and 0.03 increase in the 100-yr and 500yr BFE, respectively.

Current Study.

Cumberland River Flow Frequency Statistical Analysis and Hydraulic Modeling. The Cumberland River Cheatham Reservoir flow frequency statistical analysis and 1-D steady flow hydraulic (HEC-RAS) model are currently being updated as part of current Metro Nashville Flood Preparedness PAS Phase 7 agreement to be completed in Fiscal Year 2025. The District Quality Control (DQC) review for the Cumberland River Flow Frequency Analysis was completed in May 2024. Agency Technical Review (ATR) is scheduled for completion in July 2024. The updated study includes an additional 119 years of historic peak data not included in the previous flow frequency analyses. All historic unregulated peak flow data were transformed to fully regulated annual peaks and combined with regulated period (1948 – 2024) extending the Bulletin 17C analyses historic period to 231 years. Flow frequency analysis techniques have changed in recent years where statistical software and methodologies have improved with greater emphasis on extending the period of record by incorporating all available historic data. H&H modeling has also improved to better calculate peak flow values from historical stage data and changes between without and with regulation. Cumberland River Cheatham reservoir FEMA effective and 2024 revised preliminary 2-, 10-, and 100-yr flow frequency discharges are shown in Table 1. Revised preliminary steady flow HEC-RAS model with updated flow frequency discharges indicate an increase in 100-yr base flood elevations in downtown Nashville of 2.5 feet when compared to the effective FIS.

Table 1. Cumberland River Revised Flow Frequency Discharges (1000 cfs)

2-yr		
Gage Location	**FEMA Effective FIS**	**Revised**
	2022	**2024**
Old Hickory Dam	58	99
Nashville Gage	93	102
Cheatham Dam	92	125
10-yr		
Gage Location	**FEMA Effective FIS**	**Revised**
	2022	**2024**
Old Hickory Dam	115	134
Nashville Gage	115	136
Cheatham Dam	140	170
100-yr		
Gage Location	**FEMA Effective FIS**	**Revised**
	2022	**2024**
Old Hickory Dam	198	173
Nashville Gage	155	174
Cheatham Dam	208	214

Task 1. Cumberland River Cheatham Reservoir 100-yr Floodplain Storage Analysis.

Task 1 includes development of 1-D unsteady flow models and performing a 100-yr floodplain storage analysis for the Cheatham Reservoir for the purpose of modeling overbank storage eliminated from the flood fringe, the portion of the floodplain outside the floodway. The models will also be used to develop a modified floodway encroachment scenario consisting of fill in the entire flood fringe with compensation storage required only in sensitive reaches. It is expected that increases in 100-yr flow frequency discharges will result in different floodway conditions than effective FEMA FIS especially along sensitive reaches. The goal of this study is to evaluate the unsteady flow floodplain storage using similar approach to 1996 study described above. The revised 2024 HEC-RAS model geometry for the Cheatham Reservoir is shown as Figure 3.

The 2024 model includes approximately 300 cross-sections representing the main stem channel and floodplain overbanks of the Cumberland River, 15 bridge crossings, and 20 storage areas representing tributary backwater (storage areas) adjacent to main channel. The model has been calibrated using both 1-D steady and unsteady flow analyses. The March 1975 and May 2010, two largest floods of regulation period (1948 to present), will be evaluated further to verify the model's ability to reproduce observed conditions at gaged locations and highwater marks. Both steady and unsteady flow geometries will be identical except for slight differences in manning's n roughness coefficients. The following tasks will be included as part of the 100-yr floodplain storage analysis.

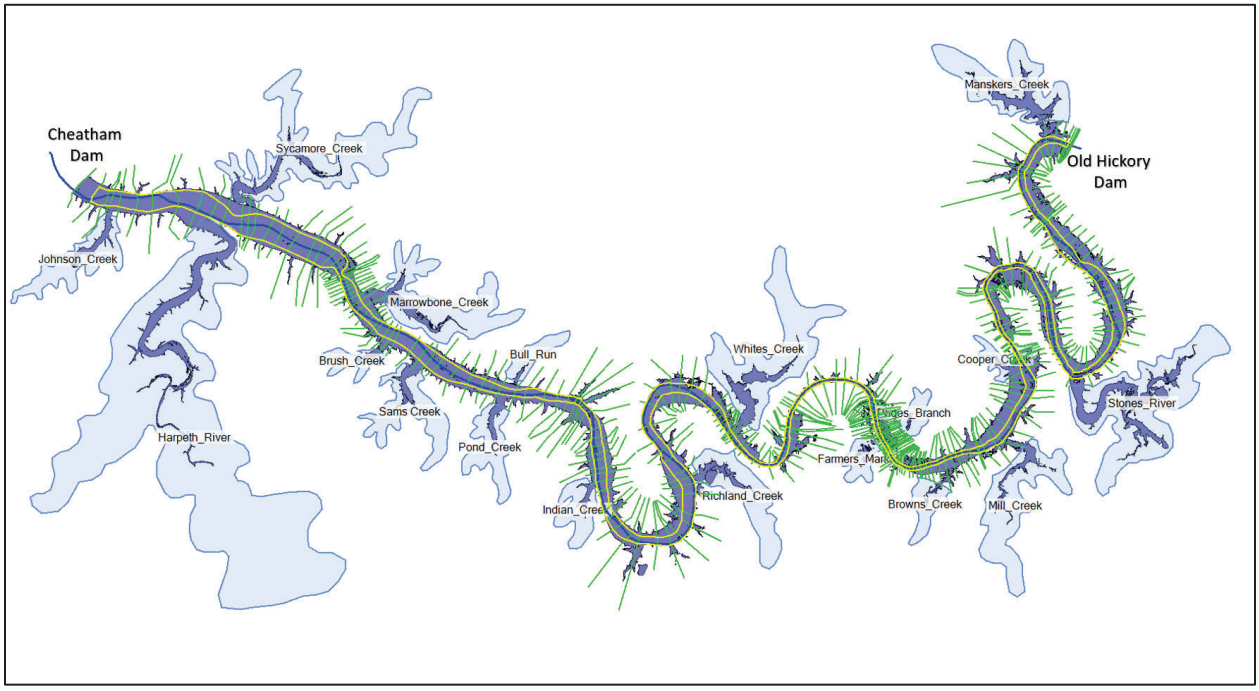


Figure 3. 2024 Cumberland River Cheatham Reservoir HEC-RAS Model

1.1. Develop 100-yr Unsteady Flow Boundary Conditions. Steady flow simulations used in flood insurance studies are based on the assumptions of gradually varying steady peak flow. Unsteady flow models require flow/stage hydrographs (varies with time) boundary conditions. The Cheatham Pool unsteady flow modeling runs include Old Hickory Dam

(upstream), Cheatham Dam (downstream) and multiple lateral and uniform lateral inflow hydrograph boundary conditions. The 1996 floodplain storage analysis adopted the March 1975 flood hydrographs developed from observed LRN Water Management data and calibrated models as its 100-yr boundary conditions. The 1975 flood was the maximum regulated flood of record and approximately the same as the 100-yr regulated flood at the time of the study. The assumptions were since the development of the 100-yr flood hydrographs was hypothetical, it was determined that hydrographs calibrated to reproduce a real event such as the 1975 flood would provide much more reliable conclusions. 100-yr flood hydrograph boundary conditions will be developed in a similar manner for this study using results from calibrated models combined with observed records. The March 1975 and May 2010 flow hydrographs at Old Hickory Dam, Nashville Gage, and Cheatham Dam are shown in Figure 4. The observed and simulated data for the May 2010 flood event is more comprehensive and detailed than May 1975 flood event including recent model calibration to main stem and tributary flow hydrographs and highwater marks. Both 1975 and 2010 floods will be taken into consideration when developing 100-yr flood event boundary conditions for the unsteady flow analysis.

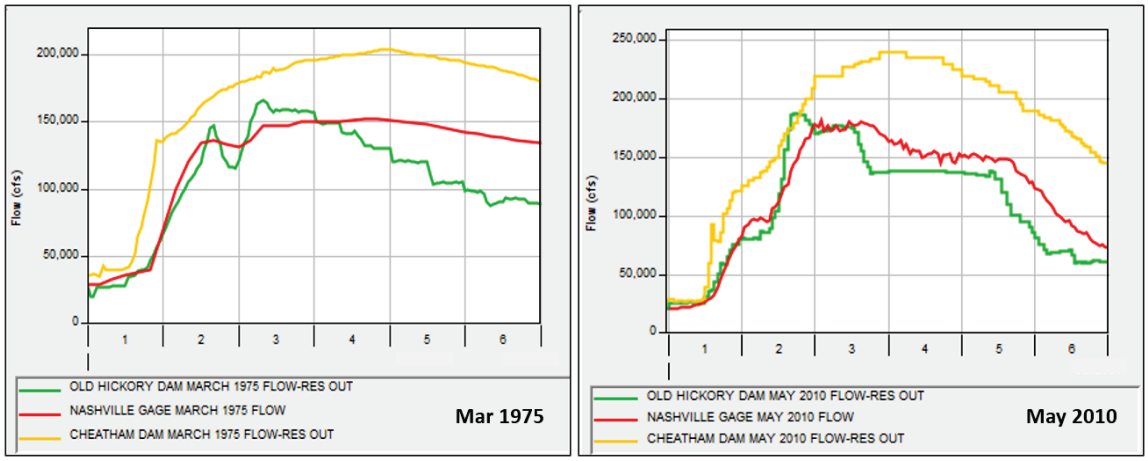


Figure 4. March 1975 and May 2010 Flood Hydrographs

1.2. Develop Existing Conditions 1-D 100-yr Unsteady Flow Model Geometry. The 100-yr unsteady flow model geometry will be identical to updated steady flow model geometry shown in Figure 3. Updated unsteady models will be calibrated to adequately reproduce observed floods. To verify the accuracy of the unsteady flow model, the 100-yr water surface profiles will be compared to the final steady flow modeling results. Unsteady flow roughness coefficient and boundary conditions will be adjusted to produce 100-yr unsteady maximum water surface profiles similar to steady flow modeling results to establish a base unsteady flow base flood condition.

1.3. Perform 100-yr Unsteady Flow Modeling Runs (Floodplain Storage Analysis). Three unsteady flow modeling runs will be performed for this study and are listed below with descriptions.

a. Existing (Base) Conditions

1. No Floodway Encroachment
2. 2025 Updated Existing Conditions Geometry
3. 100-yr unsteady flow boundary conditions
4. Water surface elevations computed using the unsteady flow model.

b. **Plan A. 100-yr Unsteady Flow Floodway Encroachment Analysis.** Plan A will demonstrate the cumulative impacts of filling in the floodway fringe and provide useful information for Metro when reviewing floodplain variances and placement of critical infrastructure and major developments within the floodplain.

1. 2025 Floodway Encroachments. No flow or storage of flood waters will be permitted on the left side of the left encroachment station or on the right side of the right encroachment station, simulating walls on either side of the channel and fill in the entire floodway fringe with no compensation storage.
2. No encroachment will be applied to tributary backwater (storage areas).
3. 100-yr unsteady flow boundary conditions
4. Water surface elevations computed using the unsteady flow model.
5. Resulting increases in base flood elevations greater than one foot.

c. **Plan B. 100-yr Unsteady Flow 'Modified' Floodway Encroachment Analysis.** Figure 5 shows the percentage of channel vs. overbank flow in the updated 100-yr steady flow model. Very similar to the 2021 floodplain conveyance analysis described above, the Nashville downtown corridor between Metro Center Levee (Mile 186), East Bank (Mile 190) and West Bank (Mile 192) conveys less than two percent of the total Cumberland River 100-yr discharge in the overbanks. The floodplain overbanks along downtown corridor includes older commercial developments placed on fill and bridges above the 100-yr profile spanning the entire floodplain with little encroachment between top of channel banks. Floodplain areas along the Cumberland upstream from Nashville like Shelby Bottoms (Mile 195) and Hermitage Golf Course (Mile 208) represent more natural floodplain conditions and convey more overbank flow and storage where loss in flood fringe will have more impact on base flood elevations and increasing flows downstream. Loss of flood fringe storage downstream from Nashville including Cheatham County may also result in higher flood profiles and peak discharges upstream into Davidson County.

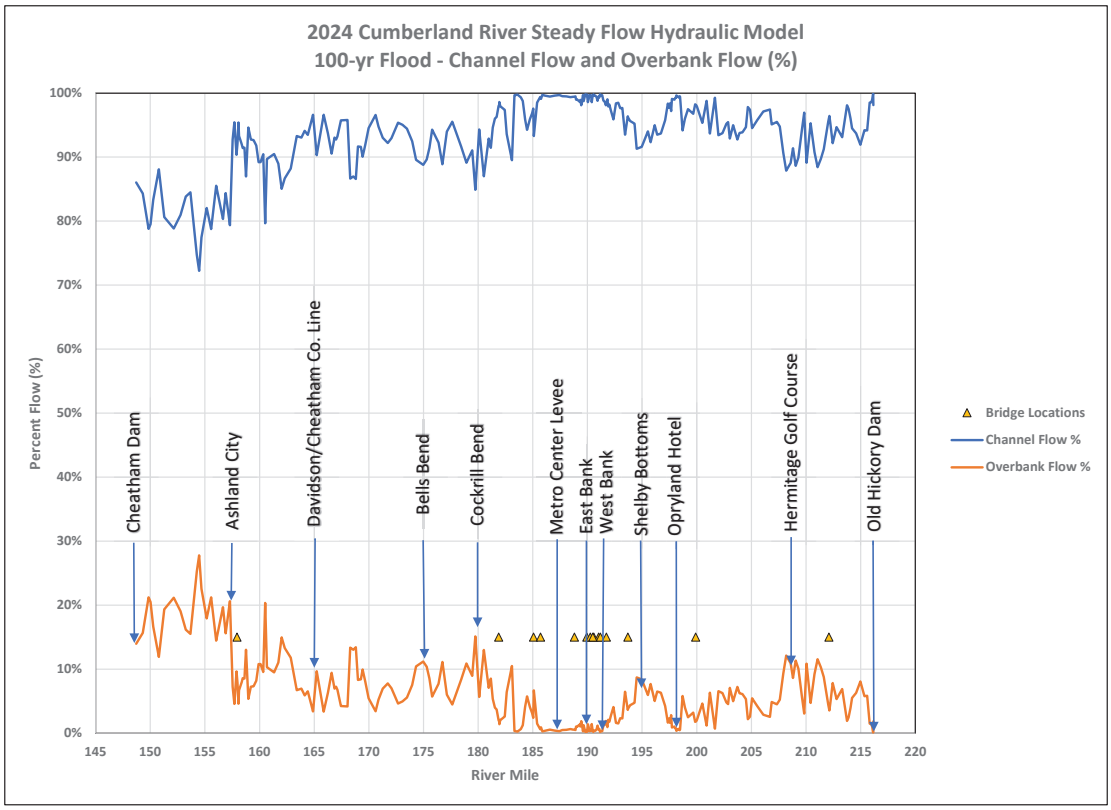


Figure 5. 100-yr – Cumberland River Channel and Overbank Flow (%)

Plan B will include evaluation of loss of floodplain storage within individual sub-reaches (and reach combinations) within the Cheatham Reservoir. Figure 6 shows individual sub-reaches for Plan B analysis. The 1996 study concluded compensation storage was required for fill in the floodway fringe between mile 216.2 (Old Hickory Dam) to mile 148.7 (Opryland Hotel) in order to pass the 100-year flood with an increase in base flood elevations equal to or less than one foot. The 1996 base flood profile was also 2-3 feet lower than revised preliminary 100-yr base flood profiles. Numerous systematic unsteady 100-yr floodway encroachment runs will be performed to evaluate revised base flood profile sensitivity to loss of floodplain storage and include developing a 'Modified' floodway boundary where all increases in base flood elevations are equal to or less than one foot.

1. Modified Floodway Encroachments
2. No encroachment will be applied to tributary backwater (storage areas).
3. 100-yr unsteady flow boundary conditions
4. Water surface elevations computed using the unsteady flow model.
5. All increases in base flood elevations equal to or less than one foot (Target).

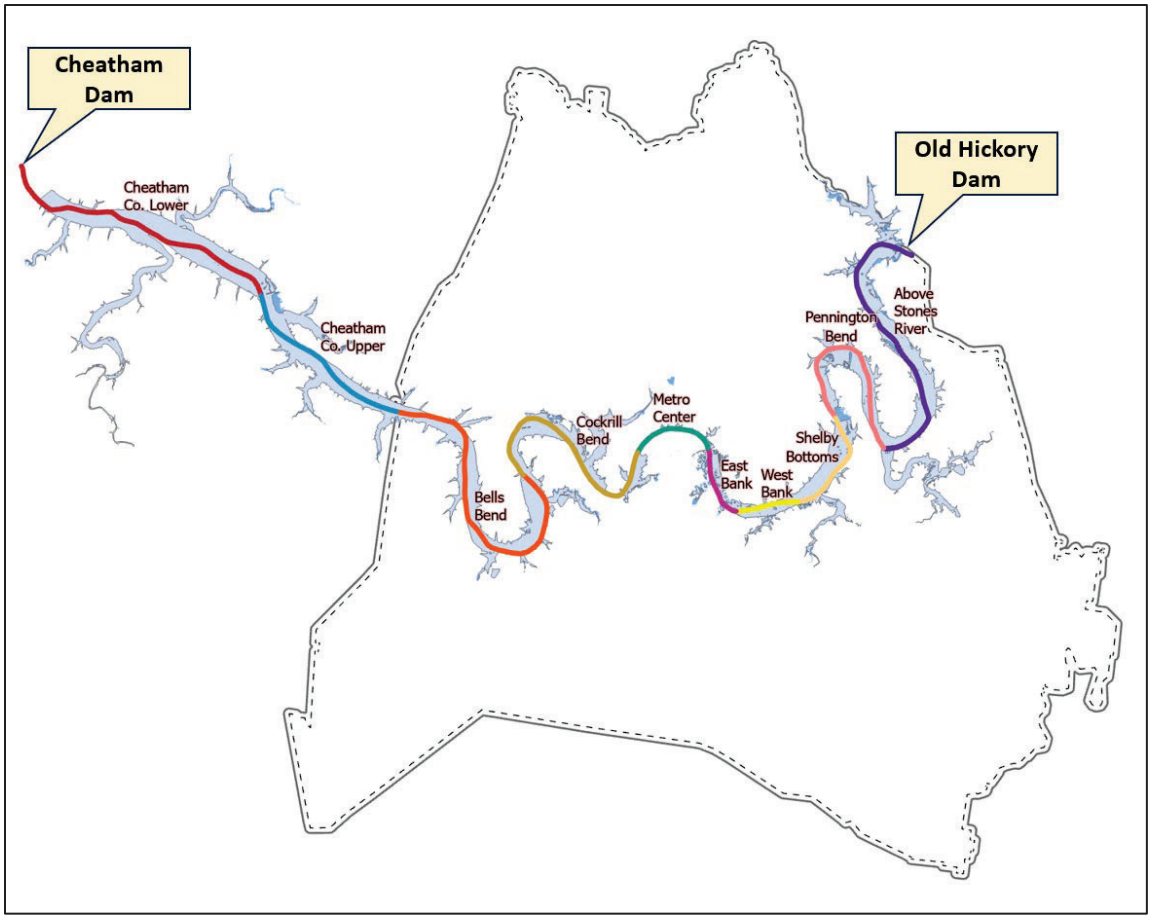


Figure 6. Floodplain Storage Analysis Sub-reaches

1.4. Develop 1-D Unsteady Flow Inundation Mapping Products. Inundation, cross-section, and floodway boundary GIS layers will be created from unsteady flow analyses results. Plan A will provide a worst-case scenario where entire floodway fringe is filled to floodway boundary. Plan B floodway boundaries will include a 'Modified' floodway to maintain increases in base flood elevations to less than one foot. Both products can be used by Metro to evaluate proposed plans for developments like River North and demonstrate the value of providing floodplain storage along the Cheatham Reservoir. Metro can also use these products to be more conservative for placement of critical infrastructure and protection of lives and property. For example, Metro has multiple water and wastewater facilities within the Cheatham Reservoir where they may want to protect critical components (water treatment, power stations, and access routes) to higher base flood elevations based on loss of flood fringe storage. The preliminary steady flow modeling results do indicate an average 2.5 ft increase in base flood elevations where current critical infrastructure, and access and evacuation routes may be compromised. The 'Modified' floodway will also identify floodplain areas to preserve in a more natural state to safely pass the base flood.

Task 2. Develop 2-Dimensional (2-D) HEC-RAS Model for Cumberland River Mile 186 to 194. Task 2 includes the development of a 100-yr flood event 2-D HEC-RAS model for eight river miles of the Cumberland River between miles 186 and 194 including Metro Center Levee and the East and West Banks in downtown Nashville shown in Figure 7.

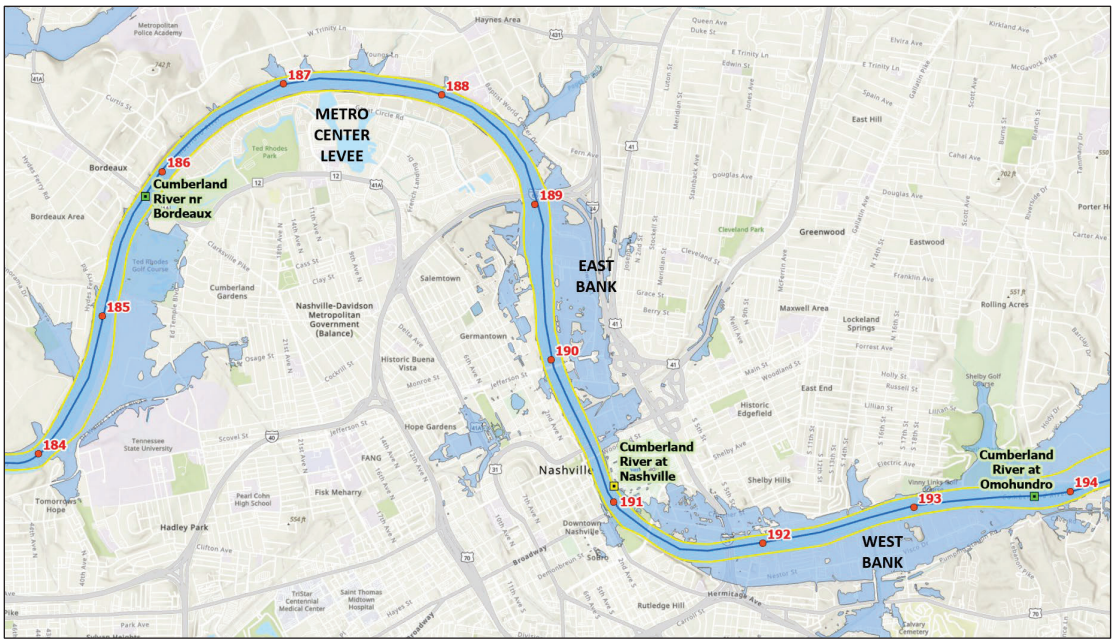


Figure 7. Cumberland River 2-D Hydraulic Modeling Extents

1-D modeling requires knowledge of the flow paths before laying out the model cross sections. If the flow path of the water is not fully known for all events, then 2-D modeling will be more accurate. If the flow path changes during an event, 2-D models can handle this, and 1-D cannot. The 2-Dimensional model will provide more accurate modeling of water movement across the surface and around obstructions (buildings) than 1-D (or cross-section based) flood modeling as shown in Figure 8.

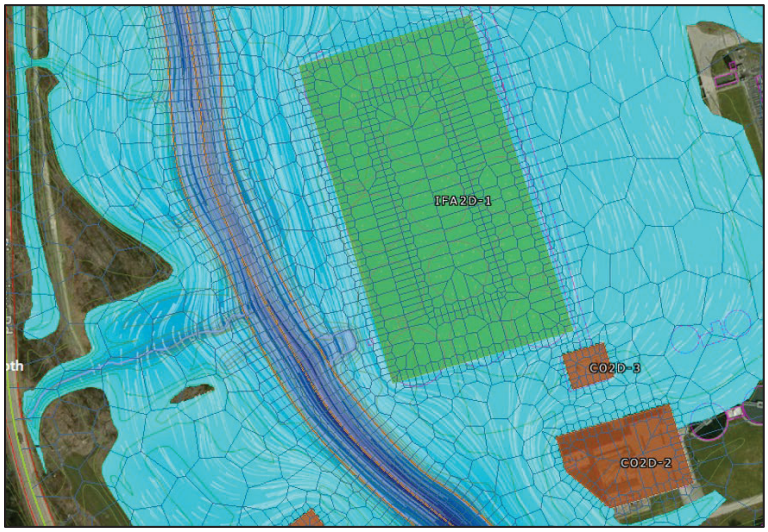


Figure 8. 2-Dimensional (2-D) Model Terrain

The 2-D model will be used to evaluate the 100-yr flood event for existing and proposed development conditions along the Nashville downtown East Bank (Mile 189 to 194) of the Cumberland River. Proposed East Bank development currently includes the Tennessee Performing Arts Center (TPAC), River North, Oracle America Campus, and the new Tennessee Titans Stadium. LRN has developed all regulatory models for Metro since the establishment of the National Flood Insurance Program in 1968 and works very closely with Metro on major developments impacting base flood elevations. In addition, USACE needs to determine if filling in the floodway fringe impacts the current operations of the Cheatham Reservoir. The existing East Bank development is mostly commercial and industrial built prior to 1968 and experienced significant flooding during the March 1975 and May 2010 flood events. Figure 9 shows the May 2010 flooding and current proposed redevelopment extents along the East Bank. In the past, Metro has requested USACE hydraulic modeling assistance to evaluation of raising roadways (also shown in Figure 9) to allow safe access and egress during significant flooding event. Metro is currently considering raising major roadways and other critical infrastructure to the May 2010 plus 2 feet for planning purposes and awaiting results from current Phase 7 PAS study. Figure 10 shows a concept rendering of proposed East Bank development looking upstream with new Titans Stadium on left.

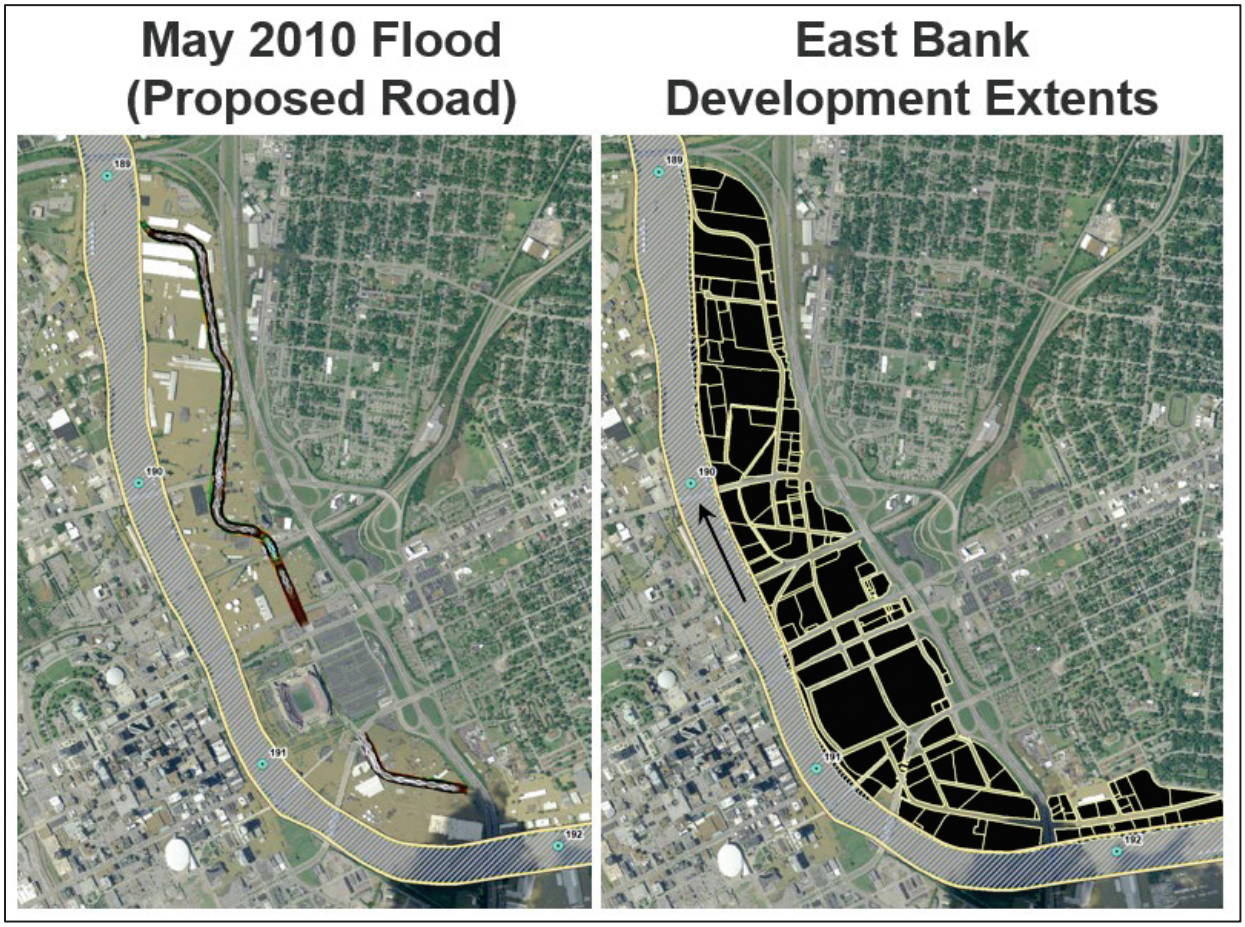


Figure 9. East Bank – May 2010 Flood and Proposed Development Extents.

Figure 10. East Bank Development Concept - Looking Upstream

Existing and proposed complex urban areas along the East and West banks necessitates the need for 2-D modeling. The 2-D model will define flow movement more accurately into and out of the existing East and West Banks through downtown Nashville. The 2-D model will to be used to evaluate re-development of downtown floodplain corridor in the future. The 2-D model may reveal adverse impacts to flooding conditions but identify separate overbank flow paths in addition to the main channel and floodway. Metro can use 2-D modeling results to enhance communication with stakeholders to develop more resilient developments in the future minimizing adverse impacts.

Task 3. Update Harpeth River Tributary Stream HEC-RAS Hydraulic Models. Task 3 includes updating HEC-RAS hydraulic models for 26 miles of Harpeth River tributary streams including South Harpeth River, Highway 100 Tributary, and Poplar, East Fork, Little East Fork, Flat, Trace, and Buffalo Creeks.

Background. The Current NFP Phase 7 includes comprehensive review and update of hydrologic models and flow statistics to determine existing conditions flood risk to critical infrastructure and private property and prioritize streams for consideration for future hydraulic modeling updates. Figure 11 shows the Metro Davidson County FEMA Flood Insurance Study (FIS) streams. There are currently 140 streams (approximately 450 stream miles) with FEMA detailed studies (Zone AE) including three USACE projects; Cheatham Reservoir, Old Hickory Dam and Reservoir, and J. Percy Priest Dam and Reservoir. Cumberland River major tributary streams include the Stones and Harpeth Rivers, and Mill, Richland, Whites, Browns and Mansker, and Sycamore Creeks. Smaller tributary streams include streams with one square mile or greater drainage area. All of Davidson County models were completed by the Nashville district between 2011 and 2019 as part of Planning Assistance to States (PAS) studies Phases 2 through 6.

Current work includes development of new HEC-HMS models for watersheds where Metro local studies and USGS regression equation were used in the past to develop FEMA regulatory discharges. Figure 12 shows the new and revised Phase 7 HEC-HMS subbasin delineation for previous NFP Phase 2 streams. New models were developed for Whites, Browns, Richland, and Sevenmile Creeks, Sorghum, Whittemore and Franklin Branches, and eight Harpeth River tributaries; South Harpeth River, Highway 100 Tributary, and Poplar, Flat, Trace, Buffalo, Little East Fork, and East Fork Creek. The remaining Phase 2 streams required only minor updates to hydrologic parameters and software versions. HMS models from Phases 3 through 6 required only software version updates.

Phase 7 hydrologic models were calibrated to observed streamflow records and Bulletin 17C flow frequency statistics to establish average hydrologic parameters and antecedent moisture conditions (AMCs). Contributing Drainage Area vs. Flow relationships were developed to compare revised Phase 7 hydrologic modeling and Bulletin 17C statistical results to effective FIS discharges and USGS regional regression equations. The graphical trendline function in Microsoft Excel was used to developed power regression equations for 17 stream gage locations with contributing drainage areas less than 100 square miles. The 2-, 10-, and 100-yr flow frequency regression curves are shown in Figure 13. Updated Phase 7 HMS results trend above revised Bulletin 17C and below effective FIS results, indicating current regulatory flows are still conservative when compared to observed flow frequency statistics. HA3 USGS regression equations matched reasonably well to Bulletin 17C for the 2-yr and 10-yr flood events for drainage areas less than 30 square miles and lower for larger drainage areas. HA3 uses different equations for drainage area greater than 30 square miles. HA2 USGS regression equations were significantly lower that Bulletin 17C over the full range of flow frequency events. USGS equations were published in year 2000, prior to May 2010 flood of record for all streams within the Nashville area. Several floods in the Metro area have matched or exceeded May 2010 flood, notably the August 2013 flood in Madison along Ewing, Gibson and Cooper Creeks and March 2021 flood along Sevenmile and McCrory Creeks.

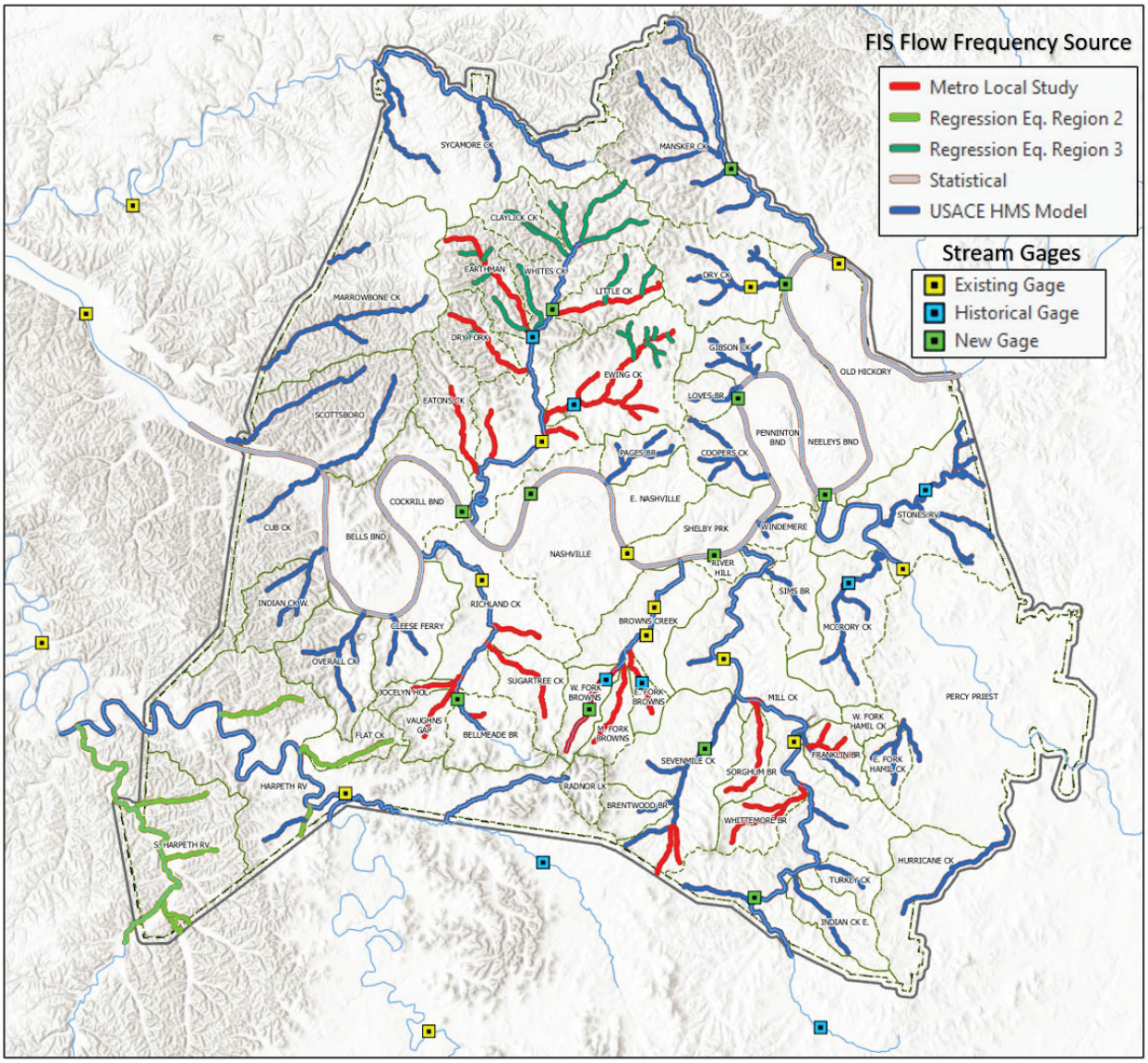


Figure 11: Metro Davidson County FEMA FIS Streams

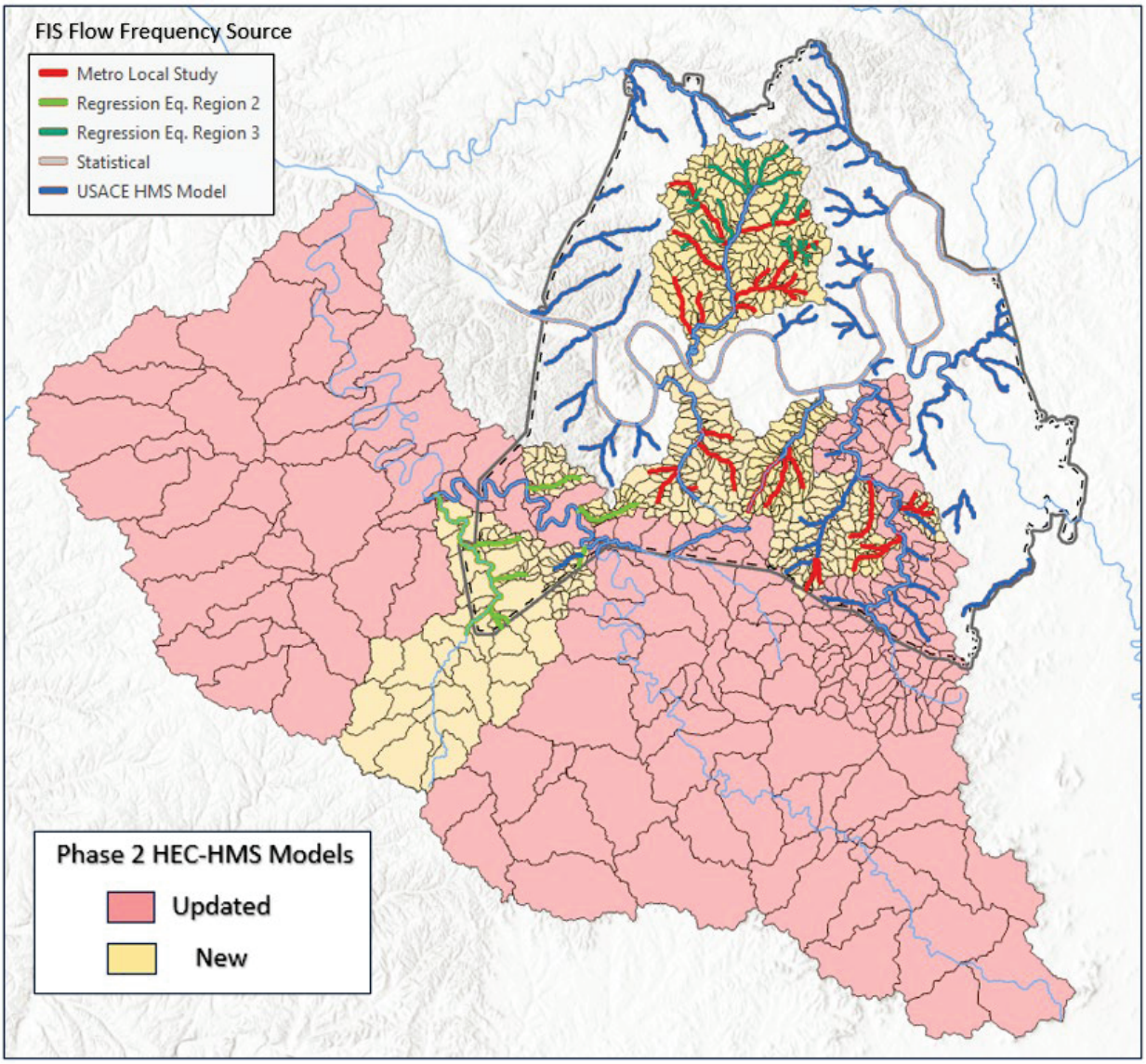
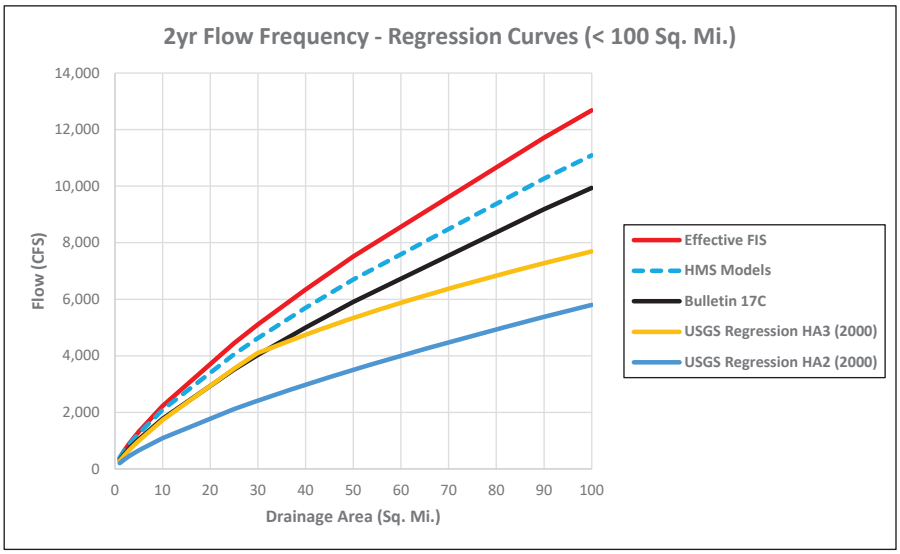
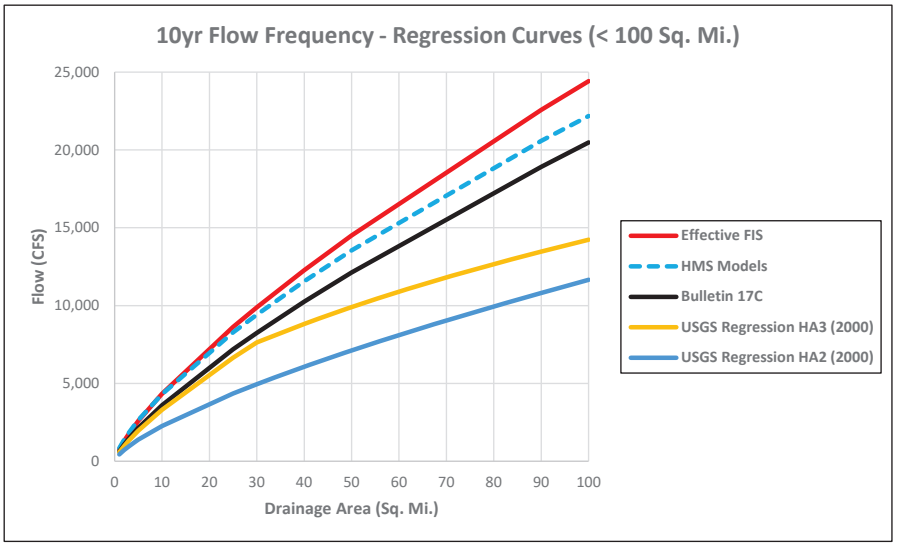


Figure 12. Metro NFP Phase 2 HEC-HMS Modeling Updates





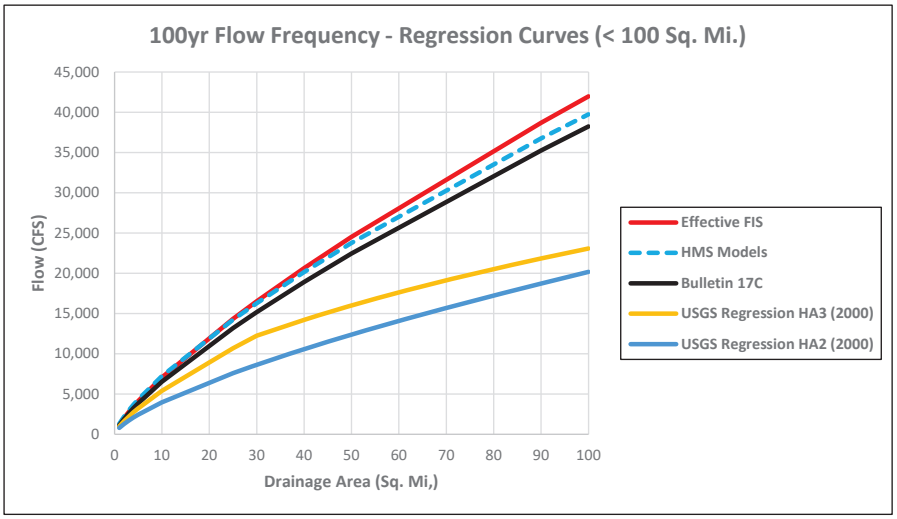


Figure 13. Flow Frequency Regression Curves (DA < 100 Sq. Mi.)

Revised HMS Modeling flow frequency discharges for basins that previously used USGS regression equations are trending much higher especially at the 100-yr flood event, the baseline flood used for FEMA floodplain regulation. Streams where USGS regression equations were adopted in the past also revealed the largest increases in water surface profiles. Phase 7 included updating RAS models to version 6.4.1. Revised Phase 7 frequency event discharges were input into updated RAS models to evaluate changes in water surface profiles. Revised HMS model frequency discharges for Harpeth River tributaries and Whites Creek headwater streams were sometimes double when compared to USGS Regression equations. Comparison between Phase 7 HMS and Effective FIS frequency flow (ratio) and average water surface elevation (BFE) differences for the 2-, 10-, and 100-yr frequency events are shown in Table 2 for the Harpeth River Watershed. All Streams with a 100yr BFE Change Category of >1.0 ft Increase or >2.0 ft Increase used USGS regression equations to establish the effective FIS discharges.

Table 2. Harpeth River Watershed. Phase 7 vs. Effective FIS - Flow and BFE Comparison

Harpeth River Watershed										
Metro NFP Phase	Stream Name	Drainage Area	HEC-RAS Stream Miles	Average Flow Change (Ratio)			Avg WSEL (BFE) Difference (Feet)			100YR BFE Change Category
		(Sq. Miles)	(Miles)	2YR	10YR	100yr	2YR	10YR	100yr	(Feet)
Phase 2	Harpeth River	865.68	62.29	1.06	1.01	1.00	0.3	0.1	0.2	< 1.0 ft Increase
Phase 2	Little Harpeth River	46.43	2.21	0.72	0.96	1.03	-1.1	-0.1	0.1	< 1.0 ft Increase
Phase 2	Otter Creek	6.81	4.86	0.80	1.05	1.13	-0.4	0.1	0.3	< 1.0 ft Increase
Phase 2	Hwy 100 Trib	1.45	1.92	1.15	1.41	1.46	0.5	1.4	1.9	> 1.0 ft Increase
Phase 2	South Harpeth River	80.92	11.01	1.26	1.33	1.53	1.0	1.3	2.5	> 2.0 ft Increase
Phase 2	Poplar Creek	3.11	2.58	1.39	1.80	1.72	0.7	2.2	2.3	> 2.0 ft Increase
Phase 2	Little East Fork Creek	4.20	0.83	2.12	2.02	1.86	2.3	3.0	3.6	> 2.0 ft Increase
Phase 2	Flat Creek	3.22	3.74	1.94	2.04	1.87	1.0	1.9	2.8	> 2.0 ft Increase
Phase 2	Trace Creek	6.68	1.02	1.90	2.16	2.16	1.7	3.3	4.4	> 2.0 ft Increase
Phase 2	East Fork Creek	12.88	1.51	2.19	2.17	2.24	2.5	2.5	2.3	> 2.0 ft Increase
Phase 2	Buffalo Creek	5.64	3.05	1.66	2.24	2.32	0.3	1.1	1.6	> 1.0 ft Increase

Task 3 Scope. Tasks 3 scope includes updating 26 miles of HEC-RAS hydraulic models for Harpeth River tributary streams including South Harpeth River, Highway 100 Tributary, and Poplar, East Fork, Little East Fork, Flat, Trace, and Buffalo Creeks located in southwest Davidson County shown in Figure 14. Existing hydraulic models were developed by USACE and A/E contractors as part of Phase 2 and completed in 2012. The models were developed using ArcGIS software HEC-GeoRAS extension and HEC-RAS version 4.1 and updated to version 6.4.1 as part of Phase 7. Hydraulic model geometry was developed from 2011 LiDAR terrain data, field reconnaissance, and GPS survey of 64 bridges. Metro Nashville is developing very rapidly where floodplain modeling needs to be updated at least once every 10 years. The existing 2012 models provide modeling and documentation to leverage for this study. New lidar terrain data was collected in both 2016 and 2022. At the time of the Phase 2 study, known issues were found with the 2011 LiDAR data set, specifically the 2009 Geoid correction. The geoid is a model of global mean sea level used to measure precise ground surface elevations. It was discovered a reference point used for geoid correction was incorrect and shifted terrain when compared to previous Geoid 2003 as shown in Figure 15. The largest errors were found in the southern portion of Davidson County. Figure 16 shows a comparison between 2011and 2022 LiDAR for Flat Creek tributary HEC-RAS geometry. The following tasks will be completed for Task 3.

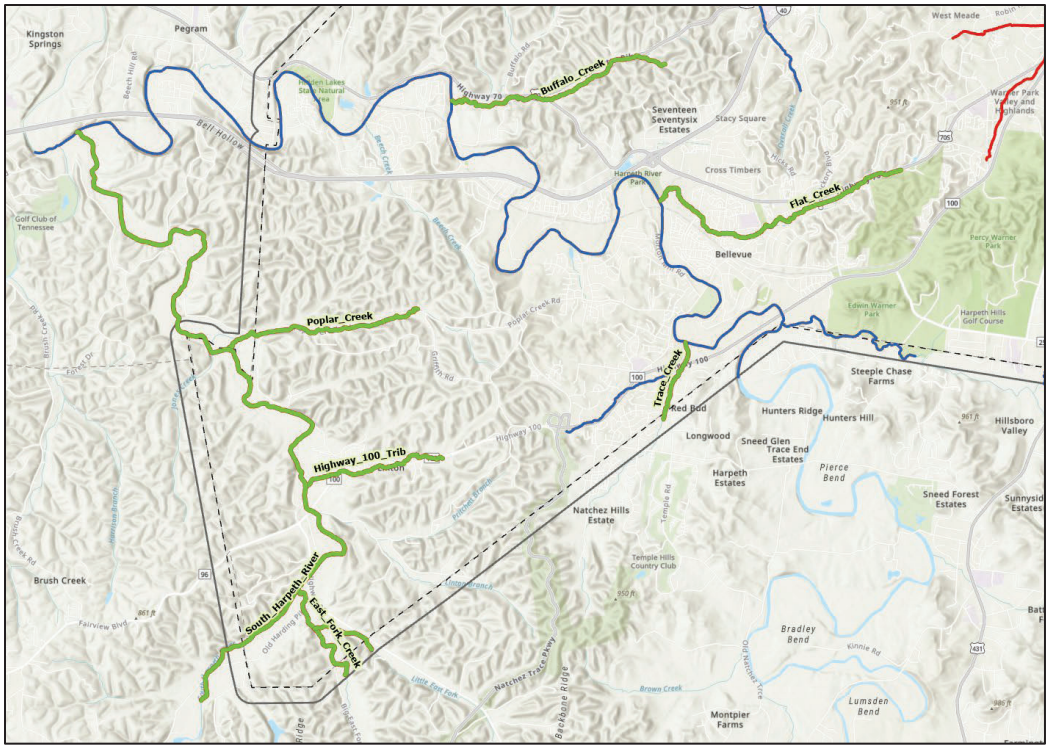


Figure 14. Harpeth River Tributary Stream HEC-RAS Models

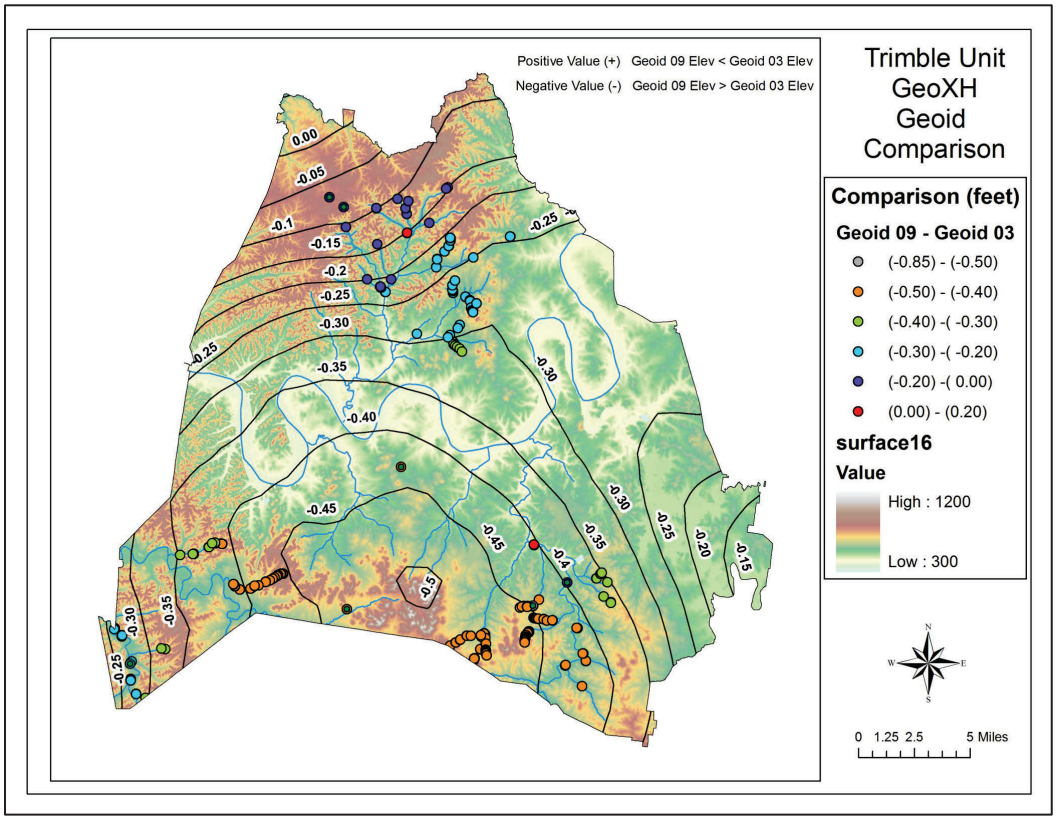


Figure 15: Trible Unit GeoXH Geoid Comparison

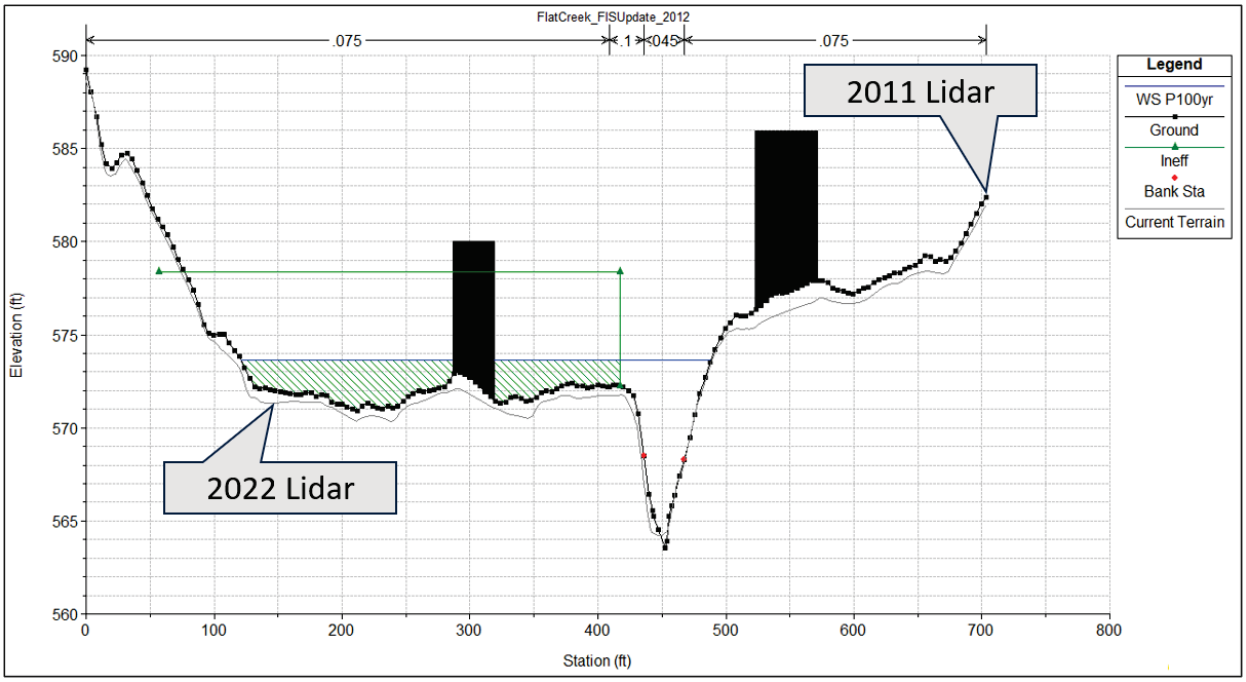


Figure 16. Flat Creek Cross-Section – LiDAR Terrain Differences

3.1. Update HEC-RAS Model Geometry. 1-Dimensional HEC-RAS model geometry will be updated using latest version of HEC-RAS software and State of Tennessee 2022 LiDAR terrain dataset. Field reconnaissance and GPS survey will be performed for all hydraulic structures (bridges). Channel thalweg and spot elevations will be surveyed to verify bathymetry and accuracy of the LiDAR data. Additional cross-sections will be added for new developments, model stability, and improve flood profile accuracy.

3.2. Calibrate Hydrologic and Hydraulic Models. Detailed hydrologic models (HEC-HMS) were created for Harpeth River tributary streams within Davidson County as part of Phase 7. Stream flow records were not available for hydrologic model calibration along these streams. The tributary HMS models will be updated to include the May 2010 meteorological model (precipitation data) developed from gridded rainfall and available precipitation gages. May 2010 highwater marks were collected and surveyed for the Harpeth, South Harpeth, and Little Harpeth Rivers. The Little Harpeth River also includes HEC-HMS and HEC-RAS models developed in 2016 by USACE for Williamson County, TN. FEMA and Metro Nashville collected flood depth information for residential structures following the record May 2010 flood. GPS survey will be performed to collect additional finished floor and highwater mark information along smaller tributary streams where residential flooding was reported. Hydrologic parameters will be updated in the Little Harpeth River HMS model to be consistent with Davidson County (Metro) tributary modeling techniques. HEC-HMS May 2010 Flood Event simulations will be performed for all study basins to develop May 2010 peak flows discharges for input into hydraulic models. Computed May 2010 HEC-RAS peak flow water surface profiles will be compared to available highwater marks. Further

adjustments will be made to both HEC-HMS and HEC-RAS modeling parameters to improve model calibration.

3.3. Perform Existing Conditions Hydrologic Analysis. HEC-HMS model calibration to flow frequency analysis (Bulletin 17C) was performed for multiple streams within Davidson and surrounding counties as part of current Phase 7. Additional HMS model calibration will be performed using the updated Little Harpeth River HMS model and Little Harpeth River at Granny White Pike Flow Frequency Analysis to refine hydrologic parameters (initial deficit and constant loss rates) for flood frequency discharge estimates. Flood frequency discharges will be computed in HEC-HMS for each sub-basin and at points of interest for the following annual percent chance Exceedence events: 50% (2-year), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) and 0.2% (500-year).

3.4. Perform Existing Conditions Hydraulic Analysis. Flood frequency profiles and inundation boundaries will be computed for each study stream for the following eight annual percent chance Exceedence events: 50% (2-year), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) and 0.2% (500-year).

3.5. Perform 100-yr Floodway Encroachment Analysis. An existing conditions floodway will be developed for the 1% (100-year) annual percent chance exceedence event. Floodway encroachment stations will not be changed at existing cross-sections where possible based on current flood insurance studies. It is expected since revised HEC-HMS discharges are much larger than adopted USGS regression equations, the floodway will be larger. Along stream reaches where effective floodway widths are inadequate, the basis of equal conveyance reduction from each side of the floodplain will be applied.

3.6. Prepare Hydrologic and Hydraulic Data and Documentation: Study data will be compiled in a manner suitable for submission to the Metro, Davidson County, TN and FEMA. FEMA will utilize the hydrologic and hydraulic models and documentation report as leverage data to develop floodplain and floodway mapping extents, as well as profiles for inclusion in the FIS report. Revised analyses may be used at City's discretion to augment regulatory data in circumstances where the new information is more conservative that the effective FIS.

Task 4. District Quality Control (DQC) Reviews. The purpose of the technical reviews is to assure the integrity and accuracy of the technical products produced. A DQC team (from LRN) will be identified to ensure that products completed correctly, engineering assumptions, concepts and analyses are valid and comply with accepted USACE and industry standards; that the customer's needs will be met; and that products and deliverables comply with U.S. laws, regulations, and existing public policy. The DQC team will review the final products.

Task 5. Cost and Schedule. The cost estimate and cost-share amounts are displayed in Table 3 and include approximately 15% contingency. The schedule is dependent on receipt of federal and local sponsor funds, as well as identifying the USACE resources to perform the work. USACE may leverage their Architect-Engineering (A-E) contracts to complete components of this work as needed. This work will be conducted over an approximately 2-year (24 month) time frame, pending receipt of funding. Non-federal funds must be in balance with federal funds (matching 50/50 funds available) for funds to be executed. A more detailed cost estimate is shown in Table 4 including sub-tasks and planning and contracting branch support. Preliminary schedule for H&H technical tasks is shown as Table 5.

Table 3. Cost-Share Estimate

Task	Total Cost	USACE	Metro Nashville Non-Federal Sponsor
Task 1. Cheatham Reservoir 100-yr Floodplain Storage Analysis	$200,000	$100,000	$100,000
Task 2. Develop 2-D Model for Downtown Nashville (Mile 186 to 194)	$200,000	$100,000	$100,000
Task 3. Update Harpeth River Tributary HEC-RAS Models	$400,000	$200,000	$200,000
Total	**$800,000**	**$400,000**	**$400,000**

* The budget in this table is an estimate based on availability and quality of existing data

Table 4. Detailed Cost Estimate

Metro Nashville Flood Preparedness (NFP) Phase 8 Tasks	Cost ($) Combined One Scope
Task 1. Cumberland River Cheatham Reservoir 100-yr Floodplain Storage Analysis.	$200,000
1.1. Develop 100-yr Unsteady Flow Boundary Conditions.	$25,000
1.2. Develop Existing Conditions 1-D 100-yr Unsteady Flow Model Geometry.	$21,000
1.3. Perform 100-yr Unsteady Flow Modeling Runs (Floodplain Storage Analysis).	$100,000
1.4. Develop 1-D Unsteady Flow Inundation Mapping Products.	$15,000
1.5. District Quality Control (DQC) Review	$15,000
1.6. Communication and Coordination	$10,000
1.7. Planning/Project Management (PPM)	$14,000
Task 2. Develop 2-Dimensional (2-D) HEC-RAS Model for Cumberland River Mile 186 to 194.	$200,000
2.1. Data Collection and Verification.	$15,000
2.2. Develop Existing and Proposed Conditions 2-D Model Geometry.	$75,000
2.3. Develop Boundary Conditions and Calibrate Models.	$10,000
2.4. Perform Existing and Proposed Conditions 100-yr Hydraulic Analysis.	$45,000
2.5. Develop 1-D Unsteady Flow Inundation Mapping Products.	$15,000
2.6. District Quality Control (DQC) Review	$15,000
2.7. Communication and Coordination	$10,000
1.7. Planning/Project Management (PPM)	$15,000
Task 3. Update Harpeth River Tributary Stream HEC-RAS Hydraulic Models.	$400,000
3.1. Update HEC-RAS Model Geometry.	$107,000
3.2. Calibrate Hydrologic and Hydraulic Models.	$20,000
3.3. Perform Existing Conditions Hydrologic Analysis.	$36,000
3.4. Perform Existing Conditions Hydraulic Analysis.	$24,000
3.5. Perform 100-yr Floodway Encroachment Analysis.	$35,000
3.6. Prepare Hydrologic and Hydraulic Data and Documentation.	$31,000
3.7. District Quality Control (DQC) Review	$31,000
3.8. Communication and Coordination	$12,000
1.7. Planning/Project Management (PPM)	$37,000
3.10. Contracting	$67,000
NFP Phase 8 Total	$800,000

Table 5. Preliminary Schedule

Metro Nashville Flood Preparedness (NFP) Phase 8 Tasks	Year 1 Quarter				Year 2 Quarter			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Task 1. Cumberland River Cheatham Reservoir 100-yr Floodplain Storage Analysis.								
1.1. Develop 100-yr Unsteady Flow Boundary Conditions								
1.2. Develop Existing Conditions 1-D 100-yr Unsteady Flow Model Geometry.								
1.3. Perform 100-yr Unsteady Flow Modeling Runs (Floodplain Storage Analysis).								
1.4. Develop 1-D Unsteady Flow Inundation Mapping Products.								
1.5. District Quality Control (DQC) Review								
Task 2. Develop 2-Dimensional (2-D) HEC-RAS Model for Cumberland River Mile 186 to 194.								
2.1. Data Collection and Verification								
2.2. Develop Existing and Proposed Conditions 2-D Model Geometry								
2.3. Develop Boundary Conditions and Calibrate Models								
2.4. Perform Existing and Proposed Conditions 100-yr Hydraulic Analysis								
2.5. Develop 1-D Unsteady Flow Inundation Mapping Products								
2.6. District Quality Control (DQC) Review								
Task 3. Update Harpeth River Tributary Stream HEC-RAS Hydraulic Models.								
3.1. Update HEC-RAS Model Geometry.								
3.2. Calibrate Hydrologic and Hydraulic Models.								
3.3. Perform Existing Conditions Hydrologic Analysis.								
3.4. Perform Existing Conditions Hydraulic Analysis.								
3.5. Perform 100-yr Floodway Encroachment Analysis.								
3.6. Prepare Hydrologic and Hydraulic Data and Documentation.								
3.7. District Quality Control (DQC) Review								