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

THIS AGREEMENT is entered into this ___ day of August, 2022, 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 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.

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 $1,035,123, with the Government's share of such costs projected to be $517,562 and the Non-Federal Sponsor's share of such costs projected to be $517,562.

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 District (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 provision 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. Should the final accounting determine that the Non-Federal Sponsor has provided funds in excess of its required amount, the Government shall refund the excess amount, subject to the availability of funds. 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. 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.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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 certified mail, with return receipt, as shown below. A party may change the recipient or address for such communications 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

9. 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.

10. 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: ____________________________
LTC Joe Sahl, PMP
Lieutenant Colonel, U.S. Army
District Commander

DATE: ____________________________

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY, TENNESSEE

BY: ____________________________
John Cooper
Mayor
Nashville and Davidson County, Tennessee

DATE: ____________________________

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

I, Kelly Flannery, do hereby certify that I am the Finance Director of the Metropolitan Government of Nashville and Davidson County (the "Non-Federal Sponsor"); that I am aware of the financial obligations of the Non-Federal Sponsor for the Metro Nashville Flood Preparedness Phase 7 Planning Assistance to States; and that the Non-Federal Sponsor has the financial capability to satisfy the Non-Federal Sponsor's obligations under the Project Partnership Agreement between the Department of the Army and the Metropolitan Government of Nashville and Davidson County for the Metro Nashville Flood Preparedness Phase 7 Planning Assistance to States Agreement.

IN WITNESS WHEREOF, I have made and executed this certification this 3rd day of August, 2022.

BY: DocuSigned by: Kelly Flannery
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TITLE: Director of Finance

DATE: 8/3/2022

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.

____
John Cooper
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 7, 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 3rd day of August 20 22.

DocuSigned by:
Wallace Dietz
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Wallace Dietz
Director, Department of Law
Nashville and Davidson County, Tennessee

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
110 NINTH AVENUE SOUTH, ROOM A410
NASHVILLE TN 37203

REPLY TO

Project Planning Branch July 27, 2022

Metropolitan Nashville and Davidson County
Metro Water Services
800 Second Avenue South
Nashville, TN 37210

Dear Mr. Palko:

This letter is in reference to the new phase for the flood preparedness study conducted in partnership between the Metro Nashville (Metro) and the U.S. Army Corps of Engineers, Nashville District (USACE). The project is being conducted under the USACE Planning Assistance to States Program (PAS). Following execution of the PAS cost share agreement between Metro and USACE, this letter is for the use of your office to make official request of payment in the amount of $173,000 for the new phase 7 of the Metro Nashville Flood Preparedness PAS study. This payment would constitute the first installment of Metro's share of funds for this project in accordance with the pending cost share agreement currently in review with Metro.

Additional funds would be requested at regular intervals to ensure Metro remains in balance with federal funding allocated to the project. At this time, the expected payment interval would occur in three installments to match fiscal cycles. Installment two, amount, $172,000, after July 1, 2023. Installment three, amount, $172,000, after July 1, 2024. By this method, payment across the three fiscal cycles would then reach the total amount of $517,000 in 2024.

We appreciate the opportunity to continue our efforts in Nashville. If you have any questions regarding this request, please contact Plan Formulation Section Chief, Tom Herbert, at (615) 736-7194 or by email at Thomas.Herbert@usace.army.mil.

Sincerely,

CARRINGTON.CRAIG.D.1259431480
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Craig D. Carrington,
Chief, Plan Formulation Section

U.S. ARMY CORPS OF ENGINEERS
SCOPE OF WORK
FOR
METRO NASHVILLE FLOOD PREPAREDNESS (NFP)
PHASE 7

Purpose and Background: This scope covers additional work to be performed by the Nashville District (LRN) of the US Army Corps of Engineers (USACE) for calendar years 2022 thru 2024 and build upon studies and investigations completed in support of flood preparedness in Metro Nashville, Davidson County Tennessee. This scope of work intends to generally progress the flood preparedness efforts completed through cooperation among Metro Nashville-Davidson County (Metro), LRN USACE, the US Geologic Survey (USGS), the National Weather Service (NWS), and the Federal Emergency Management Agency (FEMA).

Tasks and Subtasks:

TASK 1. Update Flood Frequency Analysis. Statistical Software Package (HEC-SSP) Bulletin 17C Analysis. The current effective FIS was developed over the past decade to include Bulletin 17B annual peak discharge statistical analysis for gages with a period of record of 30 years or greater. The effective FIS hydrologic models were calibrated to flood frequency discharge curves that included the period of record up to the May 2010 flood event. Several significant flooding events have occurred since May 2010. Frequency curves will be updated using Bulletin 17C analysis for current period of record. USGS “Guidelines for Determining Flood Flow Frequency Bulletin 17C” was released in May 2019. A particularly important innovation in these new guidelines is the elimination of the need, implicit in application of Bulletin 17B, that all annual peaks be either point-value flow estimates, or upper bounds on historical flows, or on low flows and zero flows. With new statistical and computational procedures, these Guidelines employ a new comprehensive data framework; flood data are now generalized as “interval estimates” that incorporate both standard point-value flood observations, as well as upper bound, lower bounds, or simple interval estimates describing the value of the peak flood in each year. A Bulletin 17C analysis will be performed on stream gages listed in Table 1. The flood frequency statistics are the baseline for all FIS modeling throughout Davidson County. Most gages listed in Table 1 include peak annual records up to current year. Annual peak records for the missing records will be extended beyond 2010 utilizing hydrologic models and highwater mark data where available. Several gages will also require evaluation of rating curves to update and extend period of record. The results of this analysis will be compared to current effective FIS discharges and other USACE studies to identify changes and trends in the flood frequency discharge curves. Bulletin 17C writeup will be included in the hydrologic and hydraulic analysis report.

Table 1. Bulletin 17C Flood Frequency Analysis

NUM	Stream	Gage Location	Drainage Area
1	Cumberland River	Old Hickory Tailwater	11,673
2	Cumberland River	Nashville Gage	12,856
3	Cumberland River	Cheatham Dam	14,163
4	Harpeth River	At Franklin	176.0
5	Harpeth River	At Bellevue	409.0
6	Harpeth River	Near Kingston Springs	667.0
7	Little Harpeth River	Granny White Pike	22.0
8	Mill Creek	Woodbine	93.4
9	Mill Creek	Near Antioch	64.0
10	Mill Creek	Near Nolensville	40.5
11	Mill Creek	At Nolensville	12.0
12	Sevenmile Creek	At Blackman Rd	12.2
13	Richland Creek	At Charlotte Pk	24.3
14	Sugartree Creek	at YMCA	1.5
15	Browns Creek	At Fairgrounds/Factory St.	13.2
16	WF Browns Creek	At Gen. Bates Dr.	3.3
17	Whites Creek	Near Bordeaux	51.6
18	Ewing Creek	At Knight Rd	13.3

TASK 2. Future Buildout Analysis for Cumberland River Tributary Streams: This section summarizes subtasks related to providing Metro with updated existing and future frequency discharges and floodplain boundaries for Flood Insurance Study (FIS) study streams within Davidson County not affected by the flood regulation of Cumberland and Stones River.

2.1. Update HEC-HMS Models. The hydrologic models for the FIS study area were developed over the last decade using different versions of HEC-HMS software. USACE has developed multiple versions of the models for different studies (FIS, RTS, Section 205, etc.). There are currently 24 tributary watersheds with HMS models and listed in Table 2. The first step will be updating to the latest version of HEC-HMS. In the past, this was typically a straightforward process where minor changes will be required to run the models. Advancements in GIS interface and frequency storm development may require additional steps. Updated models will be used to perform flood event model calibrations for existing conditions and flood frequency analysis at gaged locations and estimation of existing and future conditions discharges.

Table 2: Tributary HEC-HMS Models

NUM	Watershed	NUM	Watershed
1	Mill Creek	13	Overall Creek
2	Browns Creek	14	Pages Branch
3	Whites Creek	15	Windemere Branch
4	Richland Creek	16	Dry Creek
5	Harpeth River	17	Cub Creek
6	McCroroy Creek	18	Gizzards Branch
7	Stoners Creek	19	Bull Run
8	Coopers Creek	20	Manskers Creek
9	Davidson Branch	21	Sulphur Creek
10	Gibson Creek	22	Marrowbone Creek
11	Indian Creek	23	Sycamore Creek
12	Loves Branch	24	Little Harpeth

In the early NFP phases (Phases 1 and 2) of the FIS update work, computed HMS Flood frequency flows were compared to the 2001 effective Davidson County FIS and stormwater management studies (Metro Local Studies) shown in Figure 1. These local studies completed in the early 1990s included detailed hydrologic (HEC-1) models which were the basis for FEMA regulatory discharges prior to 2010. Local studies were available for the several of the major tributary basins and compared reasonably well to updated flood frequency curves in the headwater regions of major basins and provided more detail than later USACE HMS models. For this reason, FIS frequency discharges were unchanged for multiple Metro Local Study streams. Tennessee regional regression equations were also used to estimate flood frequency flows for Zone A streams without published local studies or detailed HMS models.

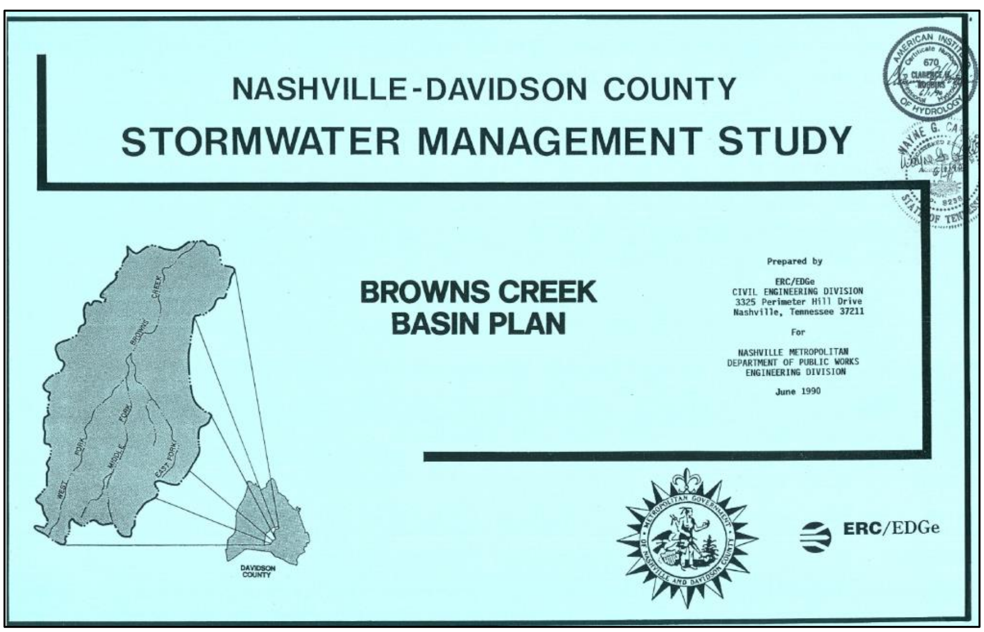

Figure 1. Metro Local Studies

Figure 2 shows the source of adopted discharges for FIS updates since 2010 for Davidson County. NFP phases 3 thru 6 included the development of more detailed HMS and RAS models for the remainder of the Metro FIS study streams. The primary goal of the FIS updates was to establish detailed studies (FEMA Zone AE) for all streams with a contributing drainage area of one square mile or greater. All USACE HMS (Blue), Regression (Green) include eight flood frequency profiles (2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year). The Metro Local Studies (Red) include only the 2-, 10-, and 100-year profiles because they were adopted from past local studies. Moving forward, the goal is to establish eight frequency profiles for all Metro streams. The hydrologic models for Metro local study and regression equation streams will be updated or developed to sufficient level of detail to compute HEC-RAS discharges and eight frequency profiles.

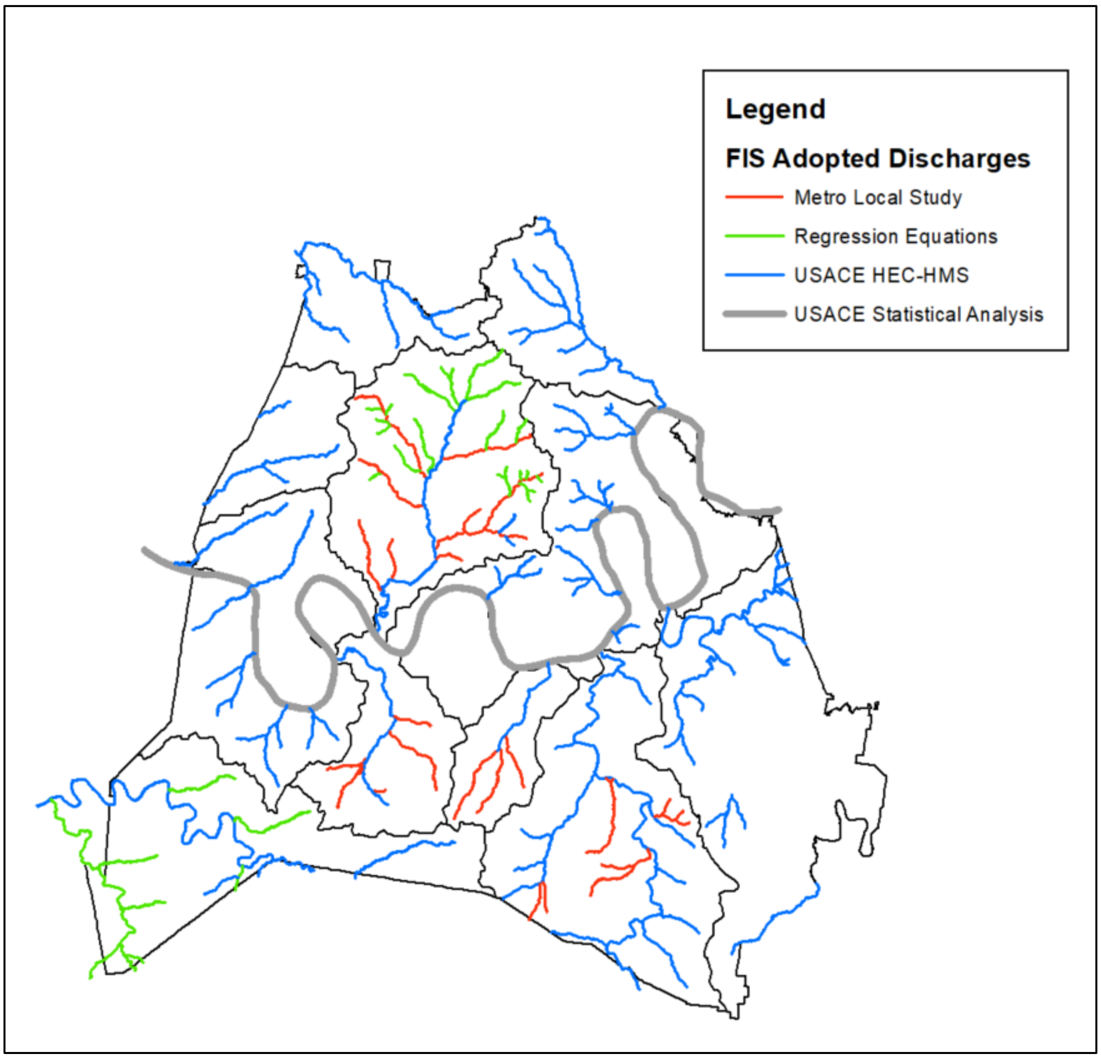

Figure 2. Metro FIS Streams Adopted Discharges

2.2. Calibrate Hydrologic Models to Recent Flooding Events. The current FIS studies were derived from hydrologic model calibration up to and including the May 2010 flood event. Flood event calibration was mostly available for stream gages located in the lower third of major tributary basins. Multiple precipitation and streamflow gages have been installed by the

USGS since May 2010 in support of the Metro Situational Awareness for Flooding Events (SAFE) program to improve flood preparedness for the region. Most new gages are in the upper third or headwater region of major tributary basins to increase flood warning times, improve evacuation planning, and provide better data to define rainfall-runoff characteristics. Flood event calibration will be performed for several recent and historic flooding events for all gages to update hydrologic modeling parameters (i.e., antecedent moisture conditions, soil infiltration rates, connected imperious area, timing, storage, etc.). Flood event calibration will be performed on gages within Mill, Browns, Whites, Richland, Dry and Manskers Creek and Harpeth River watersheds. New DHS gages will also be considered for event calibration as their data become available.

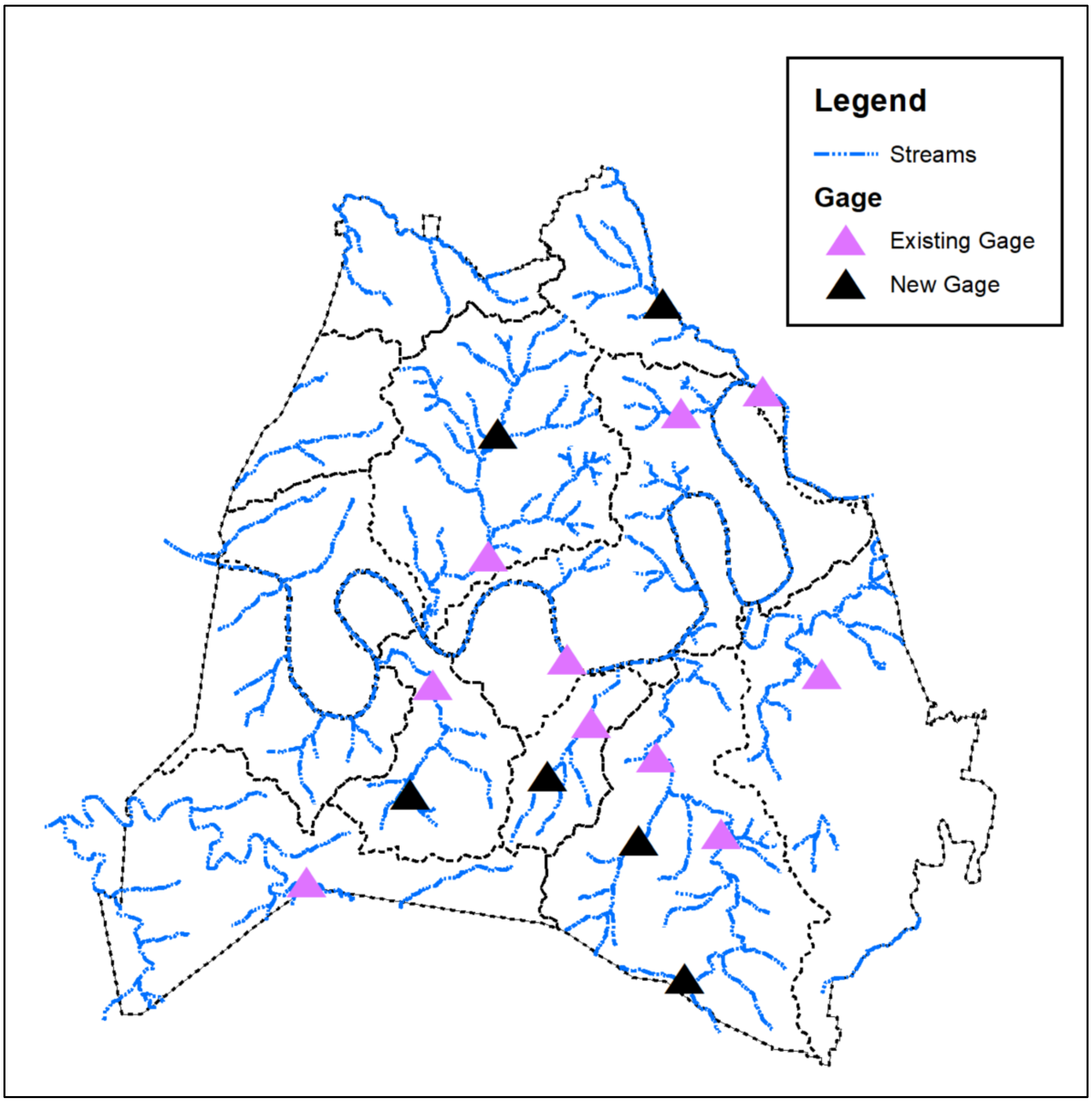

Figure 3. Metro/Davidson County Stream Gages

2.3. Compare Recent Significant Precipitation Events to NOAA Atlas 14. Flood Frequency storms are developed from NOAA Atlas 14 precipitation frequency estimates for the United States. The current Atlas 14 estimates were last updated in 2004. Multiple storm events within the Nashville area since 2004 have resulted in floods greater than a 100-year flood event. The May 2010 event produced record rainfall and flooding for the middle Tennessee region while other events (August 2013, August 2017, and March 2021) were localized to the Metro area. Significant rainfall observations since 2004 will be compared to 100-yr Atlas 14 precipitation frequency estimates. Precipitation records will be obtained from real-time Metro SCADA, USGS, USACE gage locations and the NWS gridded rainfall data and compared to Atlas 14 precipitation depth-duration curves. Recent flood event precipitation data will be taken into consideration when developing hypothetical storms for existing and future conditions.

2.4. Compute Existing Conditions Flood Frequency Discharges. Flow frequency curves computed in Task 1 will be used as a guide to update existing conditions frequency event discharges. Initial deficit (loss) will be adjusted to calibrate peak HMS flood frequency discharges to Bulletin 17C flow frequency curves. Regional loss parameters will be applied to un-gaged basins. For example, loss parameters from Mill Creek calibration would be applied to adjacent Hurricane Creek. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year flood frequency discharges will be computed for all HEC-RAS flow change points in FIS models. Since HMS models are being calibrated to multiple updated flow-frequency curves, changes to hypothetical storm (Atlas 14) precipitation may not be as critical for determination of existing conditions discharges.

2.5. GIS Analysis of Greater Nashville Regional Council (GNRC) Demographic Forecast Database. The GNRC has developed demographic forecast models for Davidson County and surrounding counties as shown in Figure 4. 2017 and 2045 demographic forecast GIS data obtained from Metro will be used to develop future imperviousness for FIS study watersheds. GIS techniques will be applied to compute the base year 2017 percent imperviousness for each parcel within the GNRC dataset. 2017 density (household, employment, population, etc.) will be compared to existing imperviousness to develop relationship tables to estimate future (2045) imperviousness. An example application for Turkey Creek within the Mill Creek basin is illustrated in Figure 5. The white X identifies a parcel where population density increases from 0 – 100 to 1000 – 1500 people per square mile over the 28-year analysis period. The 2017 relationship table computed an average imperviousness of 10 percent for 0 – 100 p/sq. mi. and 26 percent for 100 – 1000 p/sq. mi. population categories. An area-weighted imperviousness will be computed for each subbasin using this approach. For this example, the 2017 and 2045 subbasin weighted imperviousness was computed to be 11 percent and 23 percent, respectively. This analysis will be performed for all HEC-HMS basin models used to develop FIS flood frequency discharges.

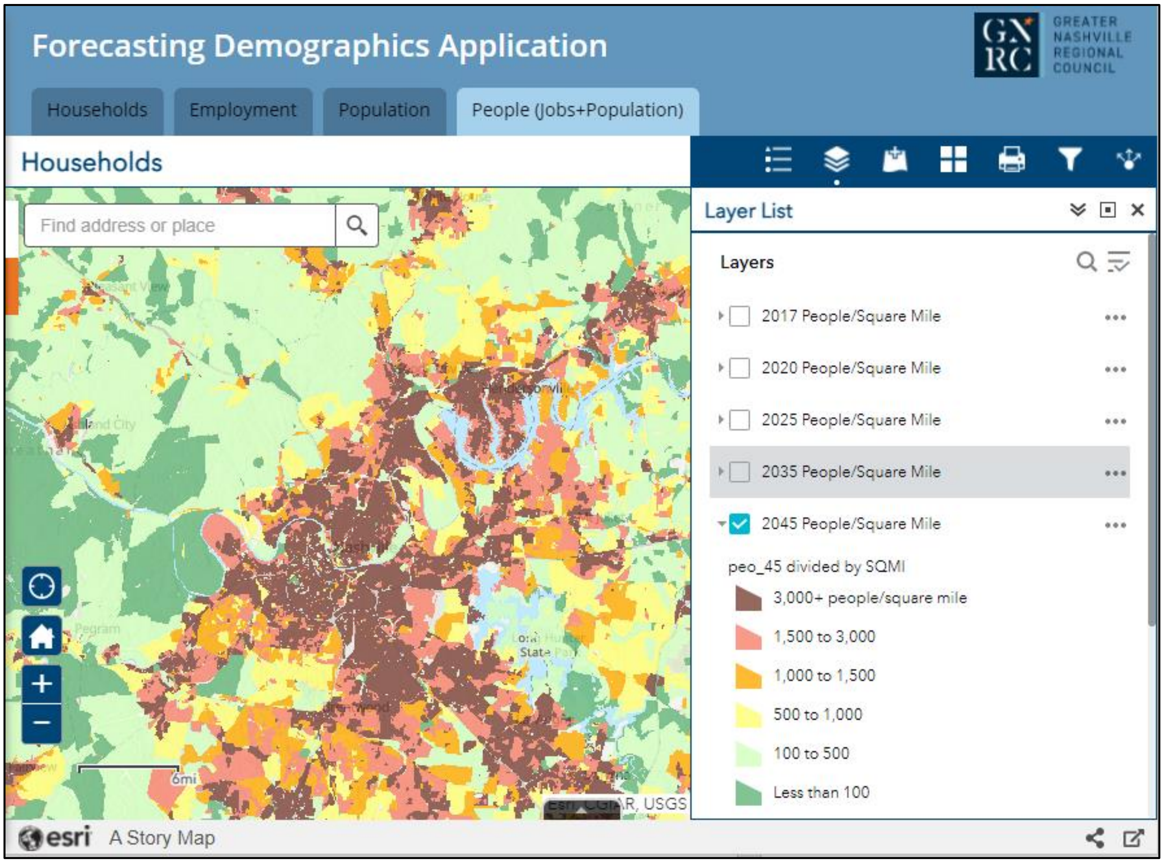

Figure 4. GNRC Demographic Forecast Data
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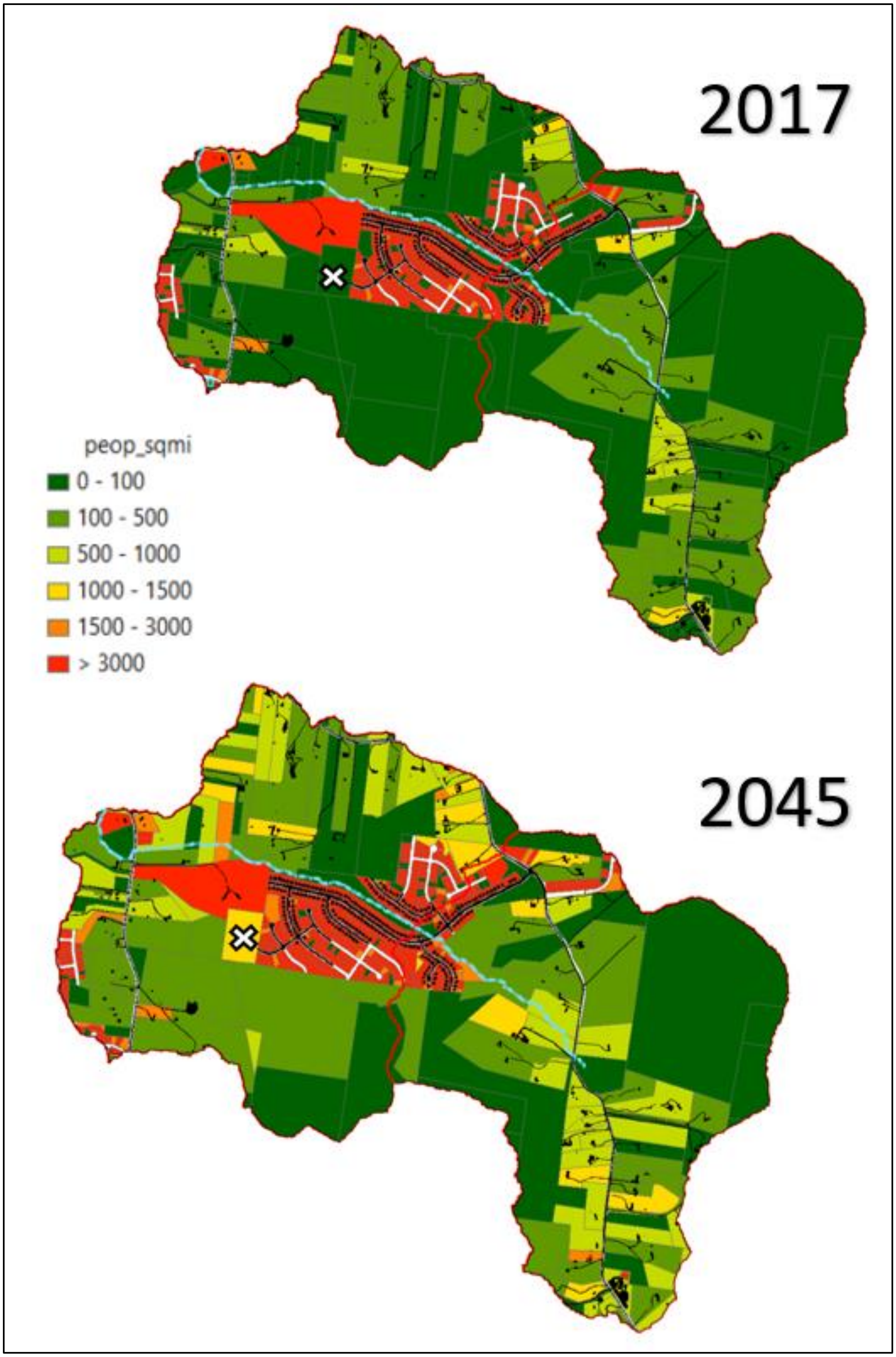

Figure 5. Turkey Creek Future Impervious Estimation

2.6. Estimation of Future Buildout Hydrologic Parameters. The Clark unit hydrograph method is used to transform rainfall to runoff in HEC-HMS models. The Clark method requires two parameters to calculate the unit hydrograph for each subbasin: Tc, the time of concentration, and R, a storage coefficient. In general terms, these parameters are shaping parameters for the runoff hydrograph of individual subbasins. Tc and R coefficients are estimated using GIS techniques and adjusted during storm event calibration. Historic imagery and GIS data will be used to evaluate watersheds where significant development has occurred. For future buildout conditions, time of concentration (Tc) will require some adjustment to reflect changes in velocity of overland flow and channel flow based on changes in surface conditions and stormwater drainage improvements. Clark storage coefficient (R) will also be adjusted to reflect loss of storage due to filling low lying areas and depressions, and drainage systems improvements. Figure 6 is an example of a Mill Creek subbasin where significant development occurred between 1998 and 2014. Clark parameters will be adjusted for subbasins with future imperviousness increasing by more than 10 percent to reflect flashier (urbanized) runoff response.

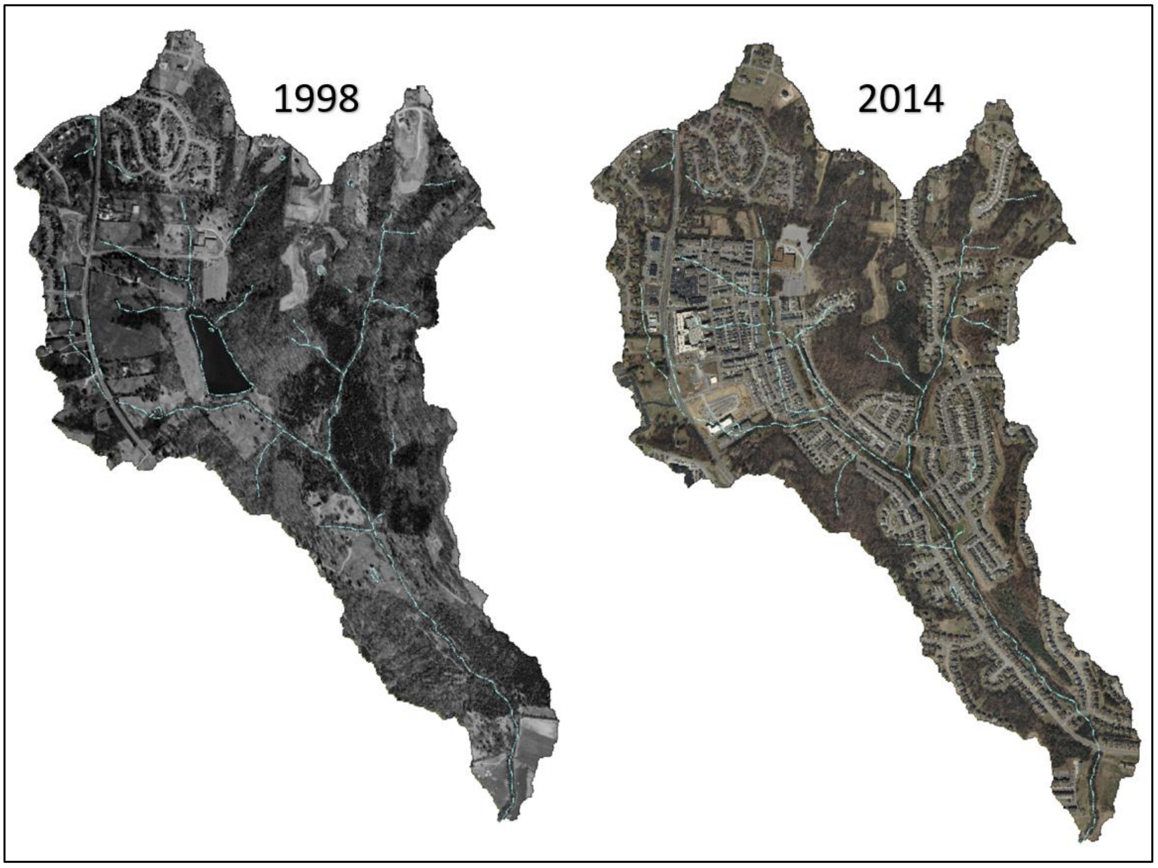

Figure 6. Mill Creek Subbasin 1998-2014 Development

2.7. Climate Change Considerations. The Cumberland River Section 205 Report included qualitative analysis to estimate the impacts from Climate Change. Engineering Construction Bulletin (ECB) 2018-14 requires that potential impacts to climate change be qualitatively analyzed for the study areas on USACE projects. NOAA released a National Environmental Satellite, Data, and Information Services (NESDIS) report in 2013 that assessed climate trends and scenarios for the Southeastern United States (Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, 2013). In this report, projections predict that in the region of the study area, drought conditions will be more severe but large precipitation events will become more intense over the next 50 years, with high uncertainty. The report also states that the frequency of extreme precipitation events has been increasing across the Southeast region, particularly of the past two decades. NOAA also released State Climate Summaries in 2017. For Tennessee, the summary states that the number and intensity of extreme heat and precipitation events are projected to increase in the future. In 2015, USACE released a report titled "Recent U.S. Climate Change and Hydrology Literature Applicable to U.S. Army Corps of Engineers Missions". The study area falls in the Ohio Region 5 for this report. This report states that while projections of precipitation are less certain than other models, most studies project increases (in the range of 5%-15% annual precipitation increase for the study region). The report also states that conclusions are split about streamflow trends, however most authors indicated an upward trend in streamflow for the region than not. In the Cumberland Section 205 study, the summary of future climate projections findings states that most projections tend toward more intense and frequent storm events than the recent past. To account for the increase of storm intensity, the upper 90% confidence band of the Atlas 14 frequency precipitation depths was used in the Cumberland 205 study for the future conditions to address the climate preparedness and resilience of the project. This equated to an increase in frequency precipitation depths on average of 10%. The use of the upper confidence band of the Atlas 14 depths was also contributed by the fact that the last update of depths from NOAA Atlas 14 were in 2004 and in the study area, multiple major rainfall events have been recorded since 2004. The Climate Hydrology Assessment Tool (CHAT) was also used to help quantify the future conditions flows. An example of the USACE Climate Assessment Tool is shown in Figure 7. Figure 7 shows the projected trendline from 2017 looking back 50 years to 1967 and looking forward 50 years to 2067. In the Section 205 study, this future increase in flow was then compared to the existing conditions water year and a percent increase was determined for the future condition. This percent increase was then applied to the current calibrated frequency flows at the gage for a comparison of future without project (FWOP) flows per frequency event (Figure 8). While these values were not used directly to change the future flows of the study streams, it was used as a qualitative visual comparison to determine if the future flows were in the reasonable range of flows as the climate tool predicts. This study will expand upon the Cumberland River Section 205 study by updating the Richland, Browns and Whites Creek analysis and adding the Mill Creek and Harpeth River gages to the analysis.

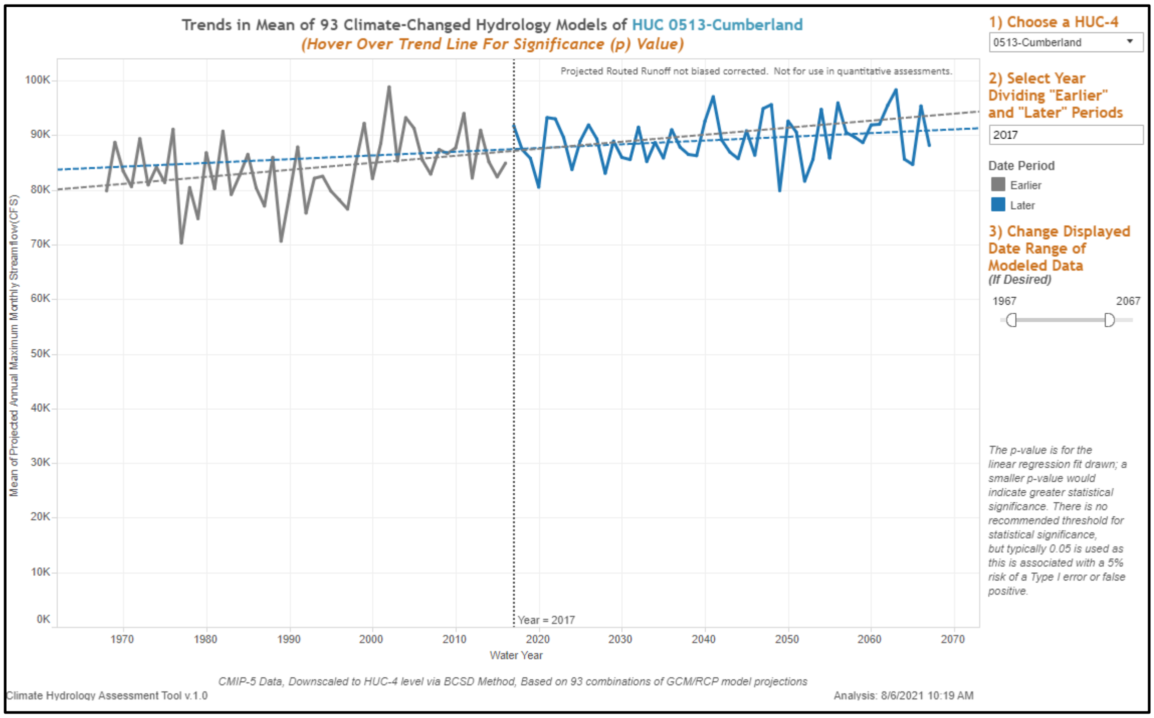

Figure 7. Mean Projected Annual Maximum Monthly Streamflow

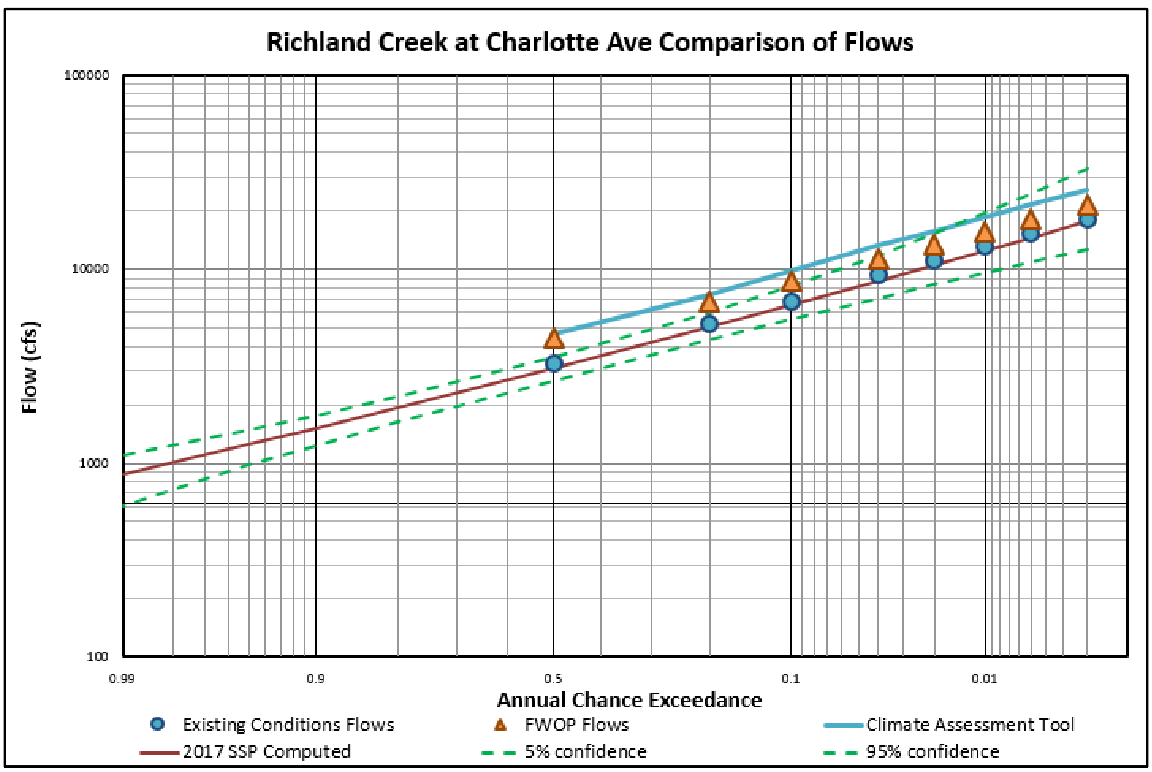

Figure 8. Richland Creek Climate Change Assessment

2.8. Compute Future Conditions Flood Frequency Discharges. 2045 subbasin imperviousness and Clark parameters will be applied to HMS basin models to compute future conditions discharges. Initial and constant loss rates will be the same as those used in existing conditions runs. Comparison of recent storm event rainfall to Atlas 14 will help with determination of upper bounds assumptions for future conditions frequency precipitation estimates. The 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year flood frequency discharges will be computed for all HEC-RAS flow change points in FIS models.

2.9. Update Steady Flow (1-D) HEC-RAS FIS Models. There are 138 different HEC-RAS models (approximately 450 stream miles) listed in Tables 3 and 4. The majority of the existing FIS models were developed in HEC-RAS version 4.1. Phase 6 also included updating all RAS models to version 5.0.7 and reorganizing by major watersheds. No major updates to model geometry will be performed for this study. HEC-RAS models will be updated to include the effective FIS, existing (2017) and 2045 future buildout profile runs for all FIS study streams. Floodways will not be updated for this study. The models will be organized with one LiDAR terrain file used by all models to visualize inundation, water surface grids, and depth grids for FIS, existing, and future conditions.

Table 3. HEC-RAS Models

NUM	Stream	Watershed	Length (mi)	NUM	Stream	Watershed	Length (mi)
1	Cumberland River	Cumberland River	51.0	32	Whites Creek	Whites Creek	12.8
2	Stones River	Stones River	6.9	33	Whites Creek Trib	Whites Creek	1.2
3	Collins Creek	Mill Creek	1.4	34	Drake Branch	Whites Creek	1.7
4	Franklin Branch	Mill Creek	2.7	35	Ewing Creek	Whites Creek	4.2
5	Franklin Branch Tributary 1	Mill Creek	1.7	36	Ewing Creek Trib 1	Whites Creek	1.0
6	Franklin Branch Tributary 2	Mill Creek	0.8	37	Ewing Creek Trib 2	Whites Creek	0.5
7	Franklin Branch Tributary 3	Mill Creek	0.5	38	Bear Hollow Branch	Whites Creek	0.7
8	Holt Creek	Mill Creek	2.5	39	Carney Creek	Whites Creek	0.7
9	Indian Creek	Mill Creek	3.3	40	Claylick Creek	Whites Creek	0.3
10	Mill Creek	Mill Creek	21.8	41	Crocker Springs Branch	Whites Creek	2.0
11	Sevenmile Creek	Mill Creek	7.0	42	Crocker Springs Branch Trib	Whites Creek	0.5
12	Sevenmile Creek Tributary 1	Mill Creek	1.8	43	Cummings Branch	Whites Creek	2.8
13	Sevenmile Creek Tributary 2	Mill Creek	1.3	44	Dry Fork Creek	Whites Creek	3.7
14	Sims Branch	Mill Creek	2.1	45	Earthman Fork	Whites Creek	5.0
15	Sorghum Branch	Mill Creek	3.7	46	Earthman Fork Trib 2	Whites Creek	0.7
16	Turkey Creek	Mill Creek	1.8	47	Earthman Fork Trib 3	Whites Creek	0.6
17	Whittemore Branch	Mill Creek	3.5	48	Earthman Fork Trib 4	Whites Creek	0.5
18	Whittemore Branch Tributrary	Mill Creek	1.3	49	Eatons Creek	Whites Creek	3.4
19	Glenrose Tributary	Mill Creek	0.9	50	Johnson Hollow Creek	Whites Creek	1.6
20	Brentwood Branch	Mill Creek	1.4	51	Little Creek	Whites Creek	3.9
21	Barrywood Branch	Mill Creek	1.3	52	Little Creek Trib 1	Whites Creek	1.8
22	Browns Creek	Browns Creek	4.4	53	Little Creek Trib 2	Whites Creek	1.1
23	East Fork Browns Creek	Browns Creek	2.3	54	North Fork Ewing Creek	Whites Creek	3.6
24	Middle Fork Browns Creek	Browns Creek	3.0	55	North Fork Ewing Creek Trib 1_7	Whites Creek	0.9
25	West Fork Browns Creek	Browns Creek	3.6	56	North Fork Ewing Creek Trib 2	Whites Creek	1.3
26	Richland Creek	Richland Creek	9.5	57	North Fork Ewing Creek Trib 3	Whites Creek	0.4
27	Sugartree Creek	Richland Creek	3.5	58	North Fork Ewing Creek Trib 4	Whites Creek	0.4
28	Belle Meade Branch	Richland Creek	0.6	59	North Fork Ewing Creek Trib 5	Whites Creek	0.3
29	Jocelyn Hollow	Richland Creek	1.5	60	North Fork Ewing Creek Trib 6	Whites Creek	0.3
30	Trib to Richland Creek	Richland Creek	1.5	61	North Fork Ewing Creek Trib 8	Whites Creek	0.3
31	Vaughns Gap Branch	Richland Creek	2.0	62	Shaw Branch	Whites Creek	2.7
				63	Trantham Creek	Whites Creek	2.7
				64	Vhoins Branch	Whites Creek	1.2

Table 4. HEC-RAS Models (Continued)

NUM	Stream	Watershed	Length (mi)	NUM	Stream	Watershed	Length (mi)
65	Harpeth River	Harpeth River	62.3	103	Pages Branch	Pages Branch	2.5
66	Buffalo Creek	Harpeth River	3.0	104	Pages Branch Tribs	Pages Branch	1.1
67	East Fork Creek	Harpeth River	1.5	105	Pages Branch Tribs	Pages Branch	0.8
68	Flat Creek	Harpeth River	3.7	106	Cumberland Local Tribs	Windemere	1.1
69	Hwy 100 Trib	Harpeth River	1.9	107	Cumberland Local Tribs	Windemere	0.4
70	Little East Fork Creek	Harpeth River	0.8	108	Dry Creek	Dry Creek	3.8
71	Little Harpeth River	Harpeth River	2.2	109	Apple Valley Branch	Dry Creek	1.1
72	Otter Creek	Harpeth River	4.9	110	Woods Lake Branch	Dry Creek	1.7
73	Poplar Creek	Harpeth River	2.6	111	Cub Creek	Cub Creek	3.6
74	South Harpeth River	Harpeth River	11.0	112	Gizzards Branch	Gizzards Branch	1.7
75	Trace Creek	Harpeth River	1.0	113	Gizzards Branch Trib 1	Gizzards Branch	0.2
76	Stonemeade Branch	Harpeth River	1.6	114	Gizzards Branch Trib 2	Gizzards Branch	0.2
77	McCrory Creek	McCrory Creek	5.9	115	E F Hamilton Creek Trib 1	JPP Reservoir	1.0
78	Elm Hill Tributary	McCrory Creek	1.4	116	E F Hamilton Creek Trib 2	JPP Reservoir	1.4
79	Pulley Branch	McCrory Creek	1.4	117	East Fork Hamilton Creek	JPP Reservoir	2.2
80	Stoners Creek	Stoners Creek	5.6	118	Hurricane Creek	JPP Reservoir	3.7
81	Dry Fork	Stoners Creek	2.9	119	West Branch Hurricane Creek	JPP Reservoir	1.3
82	Dry Fork Trib 1	Stoners Creek	2.5	120	Bull Run	Bull Run	5.9
83	Dry Fork Trib 2	Stoners Creek	0.4	121	Bakers Fork	Manskers Creek	3.8
84	Scotts Creek	Stoners Creek	0.9	122	Bakers Fork Trib	Manskers Creek	2.2
85	Scotts Creek Trib	Stoners Creek	0.7	123	Lumsley Fork	Manskers Creek	1.4
86	Scotts Hollow	Stoners Creek	0.9	124	Mansker Creek	Manskers Creek	10.7
87	Cooper Creek	Coopers Creek	3.6	125	Mansker Creek Trib 1	Manskers Creek	1.7
88	Cooper Creek Tribs	Coopers Creek	1.0	126	Mansker Creek Trib 2	Manskers Creek	0.7
89	Cooper Creek Tribs	Coopers Creek	0.9	127	Walkers Creek	Manskers Creek	3.2
90	Davidson Branch	Davidson Branch	1.7	128	Walkers Creek Trib	Manskers Creek	0.7
91	Ewin Branch	Davidson Branch	1.5	129	Sulphur Creek	Sulphur Creek	4.6
92	Gibson Creek	Gibson Creek	1.7	130	Little Marrowbone Creek	Marrowbone Creek	6.3
93	Gibson Creek Tribs	Gibson Creek	1.0	131	Little Marrowbone Creek Trib	Marrowbone Creek	1.3
94	Gibson Creek Tribs	Gibson Creek	0.2	132	Marrowbone Creek	Marrowbone Creek	1.5
95	Gibson Creek Tribs	Gibson Creek	0.9	133	Long Creek	Sycamore Creek	5.0
96	Gibson Creek Tribs	Gibson Creek	0.6	134	Long Creek Trib	Sycamore Creek	1.2
97	Indian Creek	Indian Creek	3.1	135	South Fork Sycamore Creek	Sycamore Creek	6.9
98	Indian Creek Trib	Indian Creek	1.6	136	South Fork Sycamore Creek Trib	Sycamore Creek	2.1
99	Loves Branch	Loves Branch	1.8	137	Sulphur Branch	Sycamore Creek	2.9
100	Overall Creek	Overall Creek	3.8	138	Sycamore Creek	Sycamore Creek	2.0
101	Trib 1 to Overall Creek	Overall Creek	1.0				
102	Overall Creek Trib 2	Overall Creek	1.3				

2.10. Organize Modeling Data and GIS Data. This work does not include delivery of models to FEMA for FIS update. The primary purpose of this work is to establish existing conditions and future conditions frequency discharges based on updated models, flow frequency curves and GNRC demographic forecast. The revised existing and future conditions analyses will be different than effective FIS. The models and supporting GIS data will be organized for Metro Water Services as follows:

Model and GIS Data Deliverables (Geodatabase)

- Hydrologic (HEC-HMS) models organized by major watersheds.
- Hydraulic (HEC-RAS) models organized by major watersheds with one terrain for all.
- Point shapefile - hydraulic model flow distribution locations for effective FIS, existing (2017) and future (2045) conditions. Points layer will include attribute data that identifies frequency flows and HEC-RAS flow change points.
- GIS Inundation layers – inundation boundary, depth grid and water surface grid for eight existing and future conditions profiles.
- XS Shapefile - cross-sections and detailed study streams attributed with analysis results. Cross-Sections will include effective, existing and future water surface elevations and HEC-RAS cross-section stationing.

2.11. Develop Hydrologic and Hydraulic Report. Detailed H&H report will be developed to document methodology, assumptions, analysis, and results. Recommendations on future studies and path forward for FIS updates will also be provided.

TASK 3. Cumberland River Future Conditions Analysis. This task included the evaluation of the Cumberland River watershed and system of Dams to evaluate potential future flow scenarios along the Cumberland River mainstem through Davidson County. This task is currently under development by Nashville District Water Resources Section. Multiple factors impact the operations of the USACE dams upstream from Nashville, TN. The goal of this task is to better define the flood risk along the Cumberland River and assist Metro with managing those risk into the future. The current regulatory 100-yr floodplain is based on statistical analysis of peak streamflow records (Task 1). The latest hydrologic and hydraulic software will be used to evaluate "what if" storm scenarios for the region. For example, Metro Nashville recently requested USACE evaluate potential flooding if the August 2021 Waverly Storm fell over Davidson County. Results showed that the Waverly storm could result in 100-yr level of flooding along the Cumberland River and greater that 500-yr flooding along major tributary streams. The upstream dams are part of the ageing critical infrastructure built 75 years ago. USACE Dam Safety guidelines often require operational changes to mitigate risk such as dam failure by requiring Interim Risk Reduction Measures (IRRM) at these ageing projects. Another "What if" scenario may be performing H&H analysis for period of record with risk reduction measures in place to estimate the increased flood risk which would allow metro to make risk-based decisions about placement of critical infrastructure in the floodplain.

TASK 4. HEC-RTS Training and Technology Transfer. This section refers to the Hydrologic Engineering Center's Real-Time Simulation software (HEC-RTS) and capability transfer from LRN to the local and federal agencies. To accomplish this task, items such as webinars, in-person trainings, RTS model simulations, and H&H technical guidance need to be completed. Coordination with the sponsors will be done to ensure that Metro-Nashville needs, and interests are met. Specific subtasks are described below.

4.1. Live Webinars and Demonstrations. This task contains the continuation of the HEC-RTS webinar series. An introduction webinar into HEC-RTS and a basic demonstration of the software has been given to Metro in November 2021. Additional webinars on the H&H applications within HEC-RTS and real-life scenario demonstrations that it is used for will be performed. The goal of the webinars and demonstrations is to give the sponsors the awareness and understanding of what HEC-RTS is and the benefits of using it.

4.2. Technology Transfer. The transfer of the HEC-RTS software and Metro-Nashville watershed models will take place after the webinars. The goal of this task is to install and test the application on Metro-Nashville staff computers. LRN will directly work with the staff to ensure the successful installation. Once complete, the software will be ready for Metro's use. Also, LRN will provide RTS user guides and specific Metro model guidance documents.

4.3. In-Person Training and Workshops. This task is aimed to provide Metro with in-person training and hands-on workshops with HEC-RTS. LRN will lead and collaborate with the chosen Metro-Nashville staff through presentations and practice with the Metro models. The workshops will contain step-by-step instructions for attendees to follow when practicing RTS.

4.4. Coordinated Model Forecasts. Additional practice and experience with HEC-RTS is needed frequently for the benefit of the modelers and the model. Weekly coordination with Metro staff to run model forecasts will be scheduled. LRN will also complete forecast runs and be available for technical guidance and troubleshooting. If needed, summary calls will be available to conclude the day's forecasts and clear up questions. The goal of this task is to give the Metro modeler's the confidence and ability to complete critical forecast runs during storm events.

4.5. Technical Guidance. LRN will be available any time to answer questions, provide guidance, and troubleshoot issues that the modelers have when running HEC-RTS. Recommendations on HEC-RTS and the Metro watershed models will be available when requested.

TASK 5. HEC-RTS MODELING. Through Phase Six, real-time forecasting capabilities have been developed using the HEC-RTS software for eight watersheds in Davidson County. These include: Mill, Browns, Richland, Whites, Manskers, Marrowbone, Dry Creeks, and Harpeth River. The models provide real-time flood forecasts that contain inundation mapping, Metro SAFE levels, and flood categories. The following subtasks are aimed to improve the accuracy and reliability of HEC-RTS.

5.1. Additional Gages. Metro-Nashville has communicated the possibility for additional data collection gages at critical locations in the local area. Gages are a key piece of HEC-RTS models as they are used to inform the current hydrologic state of the stream and watershed. LRN will gives recommendations on the locations where the gages will be most effective for the models and forecasts. Once the gages are functional, the team will incorporate them into the model which will increase the confidence and coverage of HEC-RTS.

5.2. Individual Model Upgrades and Fixes. LRN will perform detailed reviews on each of the eight watershed models. The goal will be to find any inconsistencies or issues with both the accuracy and functionality of the models and resolve these items. Examples of these could be: script errors, gage rating curve inconsistency, and base model problems. These fixes will create very accurate and reliable models for real-time forecasting.

5.3. Additional Rainfall Sources (Gridded Rainfall). The current watershed models use observed gage rainfall data and National Weather Service (NWS) Quantitative Precipitation Forecasts (QPF) to complete forecasts. Gridded rainfall like Multi-Radar Multi-Sensor (MRMS) Quantitative Precipitation Estimation (QPE) and NOAA High-Resolution Rapid Refresh (HRRR) data will be examined by LRN for its effectiveness with the models. This would provide multiple sources of data which would provide a way to review the data and a backup plan for acquiring data.

5.4. HEC Software Updates. The H&H software applications within HEC-RTS go through updates frequently and at separate times. The HEC software updates are usually done to fix bugs, increase the functionality, and keep up with current guidance. A HEC-RTS update is expected to occur soon. This new product will be analyzed and tested with the Metro models to determine the applicability of the upgrade. If it is concluded that it would be beneficial to update to this version, coordination with Metro will be completed to effectively upgrade.

TASK 6. H&H Modeling Support. This task includes aiding Metro on complicated H&H model reviews and evaluation of floodplain management scenarios. Over the past 12 years since the May 2010 flood event, the Nashville district has developed all the hydrologic and hydraulic models for Metro/Davidson County in support of FEMA FIS and other flood damage reduction studies (PAS, GI, Section 205, etc.). Metro watershed advisors and leadership often call upon USACE staff to assist with challenging model review for new developments. Metro Planning also request our modeling support on alternative analysis for larger developments such as East Bank of the Cumberland River.

Cost and Schedule: The Phase 7 scope is estimated at $1,035,123. Although the schedule is dependent on receipt of federal and Metro funds, it is anticipated that this work will begin in the 4th quarter of calendar year 2022 to be completed in 36 months, three calendar years. Estimated costs are displayed below in Table 5. Cost shared (50%/50%) are presented in Table 6. Preliminary Schedule is included as Table 7.

Table 5. Nashville Flood Preparedness Phase 7 Cost Estimate.

Task	Description	Cost ($)
TASK 1	Update Flood Frequency Analysis	$73,200
TASK 2	Future Buildout Analysis for Cumberland River Tributary Streams	$488,665
2.1	Update HEC-HMS Models	$101,800
2.2	Calibrate Hydrologic Models to Recent Flooding Events	$57,000
2.3	Compare Recent Significant Precipitation Events to NOAA Atlas 14	$17,500
2.4	Compute Existing Conditions Flood Frequency Discharges	$86,800
2.5	GIS Analysis of GNRC Demographic Forecast Database	$43,700
2.6	Estimation of Future Buildout Hydrologic Parameters	$20,000
2.7	Climate Change Considerations	$15,000
2.8	Compute Future Conditions Flood Frequency Discharges	$47,200
2.9	Update Steady Flow (1-D) HEC-RAS FIS Models	$65,265
2.10	Organize Modeling Data and GIS Data	$14,400
2.11	Develop Hydrologic and Hydraulic Report	$20,000
TASK 3	Cumberland River Future Conditions	$150,000
TASK 4	HEC-RTS Training and Technology Transfer	$48,208
4.1	Live Webinar and Demostrations	$7,320
4.2	Technlogy Transfer	$1,028
4.3	In-Person Training and Workshops	$7,540
4.4	Coordinated Model Forecast	$5,120
4.5	Technical Guidance	$27,200
TASK 5	HEC-RTS Modeling	$20,834
5.1	Additional Gages	$1,952
5.2	Individual Model Updates and Fixes	$9,892
5.3	Additional Rainfall Sources	$3,404
5.4	HEC Software Updates	$5,586
TASK 6	H&H Modeling Support	$30,000
6.1	Plan/Development Review	$15,000
6.2	Planning Assistance	$15,000
H&H	SUM	$810,907
	Mentoring and Review (10%)	$81,091
	Supervisors (5%)	$40,545
	Total	$932,543
PPM	Project Management (10%)	$93,254
	Supervisors (1%)	$9,325
	Total	$102,580
	NPF Phase 7 Total	$1,035,123

Table 6. Cost Shared Between USACE and Metro Nashville Partner.

Task	Description	Total	USACE	Metro Nashville
		Cost ($)	Contribution ($)	
TASK 1	Update Flood Frequency Analysis	$73,200	$36,600	$36,600
TASK 2	Future Buildout Analysis for Cumberland River Tributary Streams	$488,665	$244,333	$244,333
TASK 3	Cumberland River Future Conditions	$150,000	$75,000	$75,000
TASK 4	HEC-RTS Training and Technology Transfer	$48,208	$24,104	$24,104
TASK 5	HEC-RTS Modeling	$20,834	$10,417	$10,417
TASK 6	H&H Modeling Support	$30,000	$15,000	$15,000
H&H Branch	Mentoring and Review	$81,091	$40,545	$40,545
	Supervisors	$40,545	$20,273	$20,273
PPM	Planning/Project Management	$102,580	$51,290	$51,290
	NPF Phase 7 Total	$1,035,123	$517,562	$517,562

Table 7. Nashville Flood Preparedness Phase 7 Preliminary Schedule

Task	Description	FY22 (Quarter)				FY23 (Quarter)				FY24 (Quarter)				FY25 (Quarter)			
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
TASK 1	**Update Flood Frequency Analysis**				■	■											
TASK 2	**Future Buildout Analysis for Cumberland River Tributary Streams**																
2.1	Update HEC-HMS Models					■	■	■	■								
2.2	Calibrate Hydrologic Models to Recent Flooding Events							■	■								
2.3	Compare Recent Significant Precipitation Events to NOAA Atlas 14									■							
2.4	Compute Existing Conditions Flood Frequency Discharges										■	■					
2.5	GIS Analysis of GNRC Demographic Forecast Database							■	■								
2.6	Estimation of Future Buildout Hydrologic Parameters											■	■				
2.7	Climate Change Considerations									■							
2.8	Compute Future Conditions Flood Frequency Discharges												■	■			
2.9	Update Steady Flow (1-D) HEC-RAS FIS Models													■	■		
2.10	Organize Modeling Data and GIS Data														■		
2.11	Develop Hydrologic and Hydraulic Report															■	■
TASK 3	**Cumberland River Future Conditions**									■	■	■					
TASK 4	**HEC-RTS Training and Technology Transfer**																
4.1	Live Webinar and Demostrations					■											
4.2	Technlogy Transfer					■	■										
4.3	In-Person Training and Workshops						■										
4.4	Coordinated Model Forecast						■	■									
4.5	Technical Guidance							■									
TASK 5	**HEC-RTS Modeling**																
5.1	Additional Gages								■	■							
5.2	Individual Model Updates and Fixes								■	■							
5.3	Additional Rainfall Sources								■	■							
5.4	HEC Software Updates								■	■							
TASK 6	**H&H Modeling Support**																
6.1	Plan/Development Review				■	■	■	■	■	■	■	■	■	■	■	■	■
6.2	Planning Assistance				■	■	■	■	■	■	■	■	■	■	■	■	■

ORIGINAL

METROPOLITAN COUNTY COUNCIL

Resolution No. ______________

A resolution approving an agreement between the United States Department of the Army and the Metropolitan Government of Nashville and Davidson County for Phase 7 of the Flood Preparedness Study in Davidson County, Tennessee.

Introduced ______________________

Amended ______________________

Adopted ______________________

Approved ______________________

By ______________________________
Metropolitan Mayor