FLOODPLAIN ANALYSIS AND MAPPING STANDARDS GUIDANCE DOCUMENT

Mecklenburg County Map Maintenance Initiative

Revision 1: March 2012

Flood Mitigation Program
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Version History

Original Document
The Mecklenburg County Floodplain Analysis and Mapping Standards Guidance Document (Standards Document) was first issued in July 2008 as part of the initial phase of the County's Map Maintenance initiative. The original document was developed by Dewberry & Davis, Inc. in coordination with Mecklenburg County Storm Water Services and Charlotte Storm Water Services. The initial document was developed prior to the any actual floodplain analysis and mapping production tasks associated with the Map Maintenance initiative.

Revision History

<u>This Revision (Revision 1)</u>
This revision (Revision 1) represents a significant revision to the original document. This revision is being issued to provide clarifications/updates to floodplain analysis and mapping standards, as well as, project logistics, based on experience from actual Map Maintenance projects that have been performed since the publication of the original document. In addition to clarifications/updates to floodplain and mapping analysis standards, there are significant revisions to structure, format, and content of the original document. At the time of writing this revision, three (3) Map Maintenance phases (known as Floodplain Mapping Services 2007 and 2008, and FY2010, respectively) are in the processes of being implemented. Floodplain analysis has been completed or nearly completed for all these phases. The Revision 1 document was prepared/updated by Michael Baker Engineering, Inc.

Acronyms and Abbreviations

BFE – Base Flood Elevation
CEA – Community Encroachment Area
CMSWS – Charlotte-Mecklenburg Storm Water Services
CLOMR – Conditional Letter of Map Revision
CRN – Charlotte Raingage Network
CTP – Cooperating Technical Partner
DEM – Digital Elevation Model
DFIRM – Digital Flood Insurance Rate Map
DUA – Dwelling Units per Acre
ETJ – Extraterritorial Jurisdiction
FDP – Floodlands Development Permit
FDT – Floodway Data Table
FEMA – Federal Emergency Management Agency
FHDT – Flood Hazard Data Table
FIS – Flood Insurance Study
G&S – FEMA Guidelines and Specifications for Flood Hazard Mapping Partners
IDF – Intensity-Duration-Frequency
LFD – Letter of Final Determination
LiDAR – Light Detection and Ranging
LOMR – Letter of Map Revision
MAS – Mapping Activity Statement
MIP – Mapping Information Platform
NCDENR – North Carolina Department of Environment and Natural Resources
NCDOT – North Carolina Department of Transportation
NCFMP – North Carolina Floodplain Mapping Program
NFIP – National Flood Insurance Program
NOAA – National Oceanic and Atmospheric Administration
NOAA HMR - National Oceanic and Atmospheric Administration Hydrometeorological Report
NRCS (formerly SCS) – National Resource Conservation Service (formerly known as Soil Conservation Service)
PMP – Probable Maximum Precipitation
RSC – Regional Service Center
ROW – Right-of-Way
SOMA – Summary of Map Actions
SSURGO - Soil Survey Geographic database
TR-55 – Technical Release 55 (Publication from NRCS (SCS))
USGS – United States Geological Survey
USGS SIR – United States Geological Survey Science Investigation Report
USGS WSP - United States Geological Survey Science Water Supply Paper

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1. Introduction

1.1. Purpose and Overview

The purpose of this document is to provide guidance to mapping contractors related to creating regulatory and other local floodplain mapping products in Mecklenburg County. The mapping standards and guidance contained in this document should be followed for floodplain mapping efforts associated with Charlotte-Mecklenburg Storm Water Services (CMSWS) Map Maintenance projects (further described later in this section). Deviations from these standard procedures must be documented and approved by the County.

This document provides local guidance and standards specific to Map Maintenance projects in Mecklenburg County. It is intended to be an additional resource to applicable Federal Emergency Management Agency (FEMA) and North Carolina Floodplain Mapping Program (NCFMP) guidelines and standards, as well as, requirements of any Mapping Activity Statement (MAS) agreements developed for specific Map Maintenance projects between FEMA and Mecklenburg County. A summary of the guidelines and standards described in this document is presented in Appendix A.

1.2. Value of Floodplain Mapping

Accurate flood hazard mapping is important to public health and safety in our community. Floodplain maps work in tandem with regulations to:

- Ensure safer construction for new or redeveloped buildings in/near floodplains
- Communicate the flood risk to current and potential floodplain property owners
- Determine where flood insurance is needed and properly rate the policies
- Assist with planning and prioritizing flood mitigation projects, like acquisitions

In an effort to protect public health and safety, the floodplain maps and regulations in Mecklenburg County focus on the current risk of flooding, as well as, the future risk. The floodplain maps and associated floodplain analysis provides valuable information as to flood risks under existing conditions, and future conditions based on anticipated/planned development in the County. The purpose of providing floodplain boundary mapping and other flood hazard information based on future conditions is to show these potential risks and assist in making better and more informed decisions today.

1.3. History of Floodplain Mapping in Mecklenburg County

The Mecklenburg County Flood Mitigation Program within Charlotte-Mecklenburg Storm Water Services (hereinafter referred to as CMSWS), through inter-local agreements, administers the National Flood Insurance Program (NFIP) throughout the County, which includes the City of Charlotte, the Towns of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, Pineville, and the unincorporated areas of Mecklenburg County. CMSWS maintains a progressive floodplain management program and is a pioneer in flood map modernization efforts. CMSWS initiated an unprecedented comprehensive effort to study and remap all of the FEMA-regulated floodplains in the County using custom GIS-based tools in 1997, and in 1999 became one of the earliest communities in the nation to enter what is now known as the Cooperating Technical Partners (CTP) program. Working with FEMA, Mecklenburg County became one of the first communities to have customized FEMA Digital Flood Insurance Rate Maps (DFIRMs), which became Effective in February 2004.

1.4. Map Maintenance

The County's DFIRMs from 2004 represented state-of-the-art technical and mapping information when they were developed and still provide a greater level of detail than found on FEMA mapping in most communities. However, the community is ever changing and the information and analysis the DFIRMs are based on is becoming quickly outdated. The County has experienced explosive growth in the 1990's and 2000's, resulting in numerous developments in floodplain areas, as well as, upland areas. In addition, there have been many projects (both private and County initiated) that impact floodplain mapping through modifications to streams or floodplain corridors (e.g. stream restoration, flood mitigation projects, stream crossings, etc.). In striving towards the goal of providing accurate mapping in a cost-effective manner to the community, CMSWS commenced a floodplain Map Maintenance initiative in 2007 (hereafter referred to as Map Maintenance). The goal of the Map Maintenance initiative is to verify and/or update floodplain mapping and other flood hazard information on a regular basis to ensure that it is reasonably accurate. The initiative will provide a standardized process to incorporate changes in the watersheds and streams, correct errors and deficiencies in the existing maps, and incorporate improved mapping data and methods.

2. Map Maintenance Administration/Workflow

2.1. Mapping Partner Roles/Responsibilities

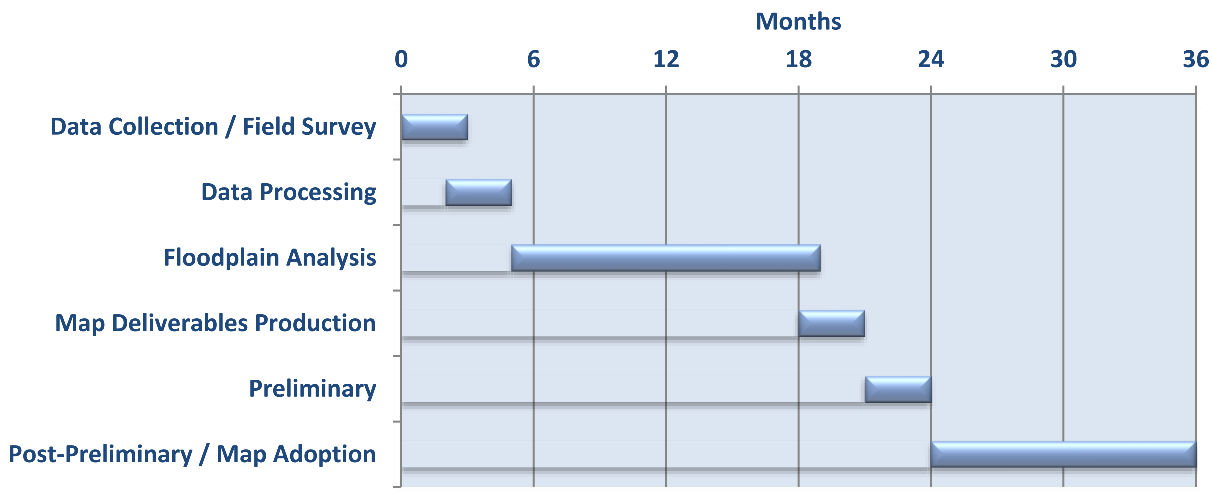
Map maintenance in Mecklenburg County involves a number of partners and stakeholders that are necessary for successful implementation of any given project. The table below lists the primary partners and their typical responsibilities. Additional and/or refined responsibilities may be defined in the MAS and/or the project specific scope of work.

Table 2-1. Mapping Partner Roles/Responsibilities Summary

Agency/Partner	Role	Responsibilities
Mecklenburg County	Overall Project/Program Manager	Manage/Direct Mapping and Independent QC Contractors. Lead coordination effort with mapping partners and other project stakeholders. Report to FEMA as required by MAS.
Mapping Contractor	Floodplain Analysis and Map Product Production	Conduct floodplain analysis, produce DFIRM map deliverables, and assist County with public involvement and map adoption as specified in project scope. Contracted with County.
Independent QC Contractor	Independent Quality Control	Conduct independent QC of technical floodplain analysis and mapping project per milestone submittals identified in project scope of work. Generally contracted with County.
NCFMP	State Coordinator	Coordinate analysis/mapping/adoption with adjacent counties, incorporation of map updates in State databases, and public/NFIP coordination during map adoption. Signing partner on MAS.
FEMA	Funding/Compliance Partner	Provide funding, compliance oversight, and Regional Service Center (RSC) support for as specified in the MAS.

2.2. Map Maintenance Workflow

The specific workflow and schedule for a given Map Maintenance project is dependent on a number of factors such as project size, complexity, and stakeholder process, and will likely vary from project to project. However, the overall process from start to finish will likely be 2.5 – 3.5 years. The chart below shows the anticipated general workflow/schedule for a typical Map Maintenance project.



3. Data Collection and Development Standards

This section provides guidance for identifying, obtaining, and processing available base data, as well as, guidelines for collecting field data to support the floodplain analysis and mapping.

3.1. Base/Supporting Data

A wide variety of base data is necessary to conduct floodplain analysis and mapping at the County watershed scale. A list of some of the relevant base data is provided in the table below.

Table 3-1. Potential Sources of Base/Supporting Data

Data Type	Source(s)	Estimated Update Frequency	Additional Notes
Effective Mapping Data	Mecklenburg County, NCFMP	As needed	Effective studies from 2009 are being updated through Map Maintenance initiative projects.
Aerial Photography	Mecklenburg County, NCFMP	Every 2 years	Current latest County aerials from 2011. NCFMP and others may capture aerials that may be applicable.
Topographic Data	Mecklenburg County, NCFMP	Every 5 years	Current latest LiDAR from 2007 from which County has produced 2’ contours and 20’ Digital Elevation Model (DEM). NCFMP also captures LiDAR that may be applicable.
Street Centerlines	Mecklenburg County	Continually	
Political Boundaries	Mecklenburg County	As needed	
Rainfall / Stream Gage Data	USGS, Mecklenburg County	Continually	Real-time storm rain/stage data for gages can be downloaded from internet for storms for 120 days previous. Contact USGS office for storms older than 120 days. Annual Water Reports, which can also be downloaded from internet, provide useful summary information.
Dam Information	NCDENR Dam Safety Program, Mecklenburg County	Every 1 – 2 years	Inventory of dams with basic location and physical characteristics information can be obtained from internet. As-built information, hydrologic/hydraulic information, and other detailed information may be available by contacting Dam Safety office.
Soils	Mecklenburg County, NRCS (SSURGO data)	As needed (sporadically)	Current latest digital soil information dated 2010 (SSURGO). Current latest soil survey report from 1980.
Parcels	Mecklenburg County	Continually	
Existing Land Use Data	City of Charlotte (Storm Water Services)	Continually	See Section 3.2 below for more detailed description.
Future Land Use Data	City of Charlotte (Planning Commission)	Every 6 months	Extends to ETJ. See Section 3.2 below for more detailed description.

Data Type	Source(s)	Estimated Update Frequency	Additional Notes
Building Footprints	Mecklenburg County	Every 1 – 2 years	
Impervious Surfaces	Mecklenburg County	See Additional Notes.	Comprehensive impervious surface layer developed in 2011. Individual residential and commercial impervious surfaces updated regularly (3 – 6 months) for billing purposes. Update frequency for comprehensive layer not established but expected to be every 1 – 2 years.
Drainage System Information	City of Charlotte (Storm Water Services)	Continually	City maintains a city-wide drainage system inventory in GIS. However, it is believed to be roughly 50% complete and has known accuracy limitations, so is recommended for general reference only.

Other base data will likely be necessary to support analysis and mapping effort. The Mapping Contractor shall coordinate with the County and other agencies as necessary, to identify and obtain the most appropriate data at the commencement of a given mapping project.

3.2. Land Use Processing

Land use is often used in floodplain analysis as an indirect indicator of the percent imperviousness of a watershed, which in turn has a significant effect on subsequent surface runoff and associated hydrologic peak flow calculations. The Effective DFIRMs include floodplain mapping based on both existing and future land use conditions. Information for obtaining/developing existing and future land use for Map Maintenance projects is described below.

3.2.1. Existing Land Use

The existing land use layer maintained by the CMSWS is to be used as the "basis" for the existing land use for Map Maintenance projects. In this layer, land use is classified under twelve (12) categories listed in the table below. This layer, which is regularly maintained/updated from aerial photography and development plans, is relatively detailed with boundaries generally being accurate to the acre level.

Table 3-2. Existing Land Use Classifications

Land Use Code	Land Use Category	Typical/Representative Land Uses
1	**Woods/Brush**	Woods, vegetated fields, etc.
2	**>2 Acre Residential & Open Space**	Farms, golf courses, fields, etc.
3	**0.5 to 2 Acre Residential**	Primarily large-lot single family residential
4	**0.25 to 0.5 Acre Residential**	Primarily medium-lot single family residential
5	**<0.25 Acre Residential**	Primarily small-lot single family residential, but includes condos/apartment complexes and similar
6	**Institutional**	Schools, hospitals, government offices, etc.
7	**Industrial – Light**	Warehouses, etc.

Land Use Code	Land Use Category	Typical/Representative Land Uses
8	**Industrial – Heavy**	Terminal transfer facilities, etc.
9	**Commercial – Light**	Office parks, hotels, multi-family > 6 DUA, apartments, etc.
10	**Commercial – Heavy**	Car parks, malls, etc.
11	**Water Bodies**	Usually ponds > 2 acres in size
12	**Transportation**	Right-of-ways (ROW) for major thoroughfare/interstates. Note that ROWs for smaller streets (e.g. collectors, thoroughfares, etc) are integrated with predominate adjacent land use.

Although the existing conditions land use layer is believed to be the best available data, additional verification and modification to the base information is necessary for use on Map Maintenance projects. This verification consists of the following general tasks:

- Identify and separate out non-detached multi-family (i.e. condos, apartments, etc.) parcels from Land use Code 5 and recode to Land Use Code 9.
- Identify and incorporate ROWs for smaller streets (residential, collector, arterial, etc.) into layer as Land Use Code 12.
- Conduct spot checks of land use with aerials, new development plan data, and other base layers to ensure land use is reasonably accurate/appropriate for use with hydrologic analysis.

In addition to these land use base edits, logistical/data processing edits to the existing land use layer are also necessary for consistency and documentation purposes. These logistical edits, as well as, more detailed instructions for processing existing land use are provided in Appendix B.

3.2.2. Future Land Use

The future land use layer developed by the Charlotte-Mecklenburg County Planning Department is to be used as the "basis" for the future land use for Map Maintenance projects. This layer is regularly maintained from zoning cases and district/area plans, and is believed to be the best available data at large scale. This future land use layer has approximately ninety (90) land use classifications groups. Unlike the existing land use data which is countywide, the future land use data only covers the City ETJ. As with the existing land use, additional verification and modification to the base information is necessary to ensure appropriateness for floodplain mapping and comparability with the existing land use. This verification consists of the following general tasks:

- Translate future land use categories to equivalent 12 existing land use categories. A translation table is provided in Appendix B.
- Create/Incorporate ROWs for all streets.
- Identify and update "no change" areas – these are areas that should not change between existing and future land use conditions as has been previously determined. In most cases information in the future land use layer will be overwritten with existing land use. Areas of no change include:
    - Effective floodplain areas
    - Park & Recreation properties
    - Catawba Land Conservancy properties
    - "Developed" residential properties
    - Cemeteries
    - Golf courses

    - Properties with R111 designation
- Develop future land use for areas outside of ETJ, if applicable. Potential data sources include the existing land use coverage, the 2015 land use file that was used for the current Effective mapping, aerial photographs, City/County zoning layers, land use information from other municipalities in the County, and others. Any land use created or derived from other sources will need to be translated and combined with the edited future land use within the ETJ to form a single comprehensive layer that covers the entire study area.

In addition to these land use base edits, logistical/data processing edits of the future land use layer are also necessary for consistency and documentation purposes. These logistical edits, as well as, more detailed instructions for processing future land use are provided in Appendix B.

3.3. Study Stream and Floodplain Development Verification

Floodplain mapping is largely based on a defined study stream and accuracy of data in the associated floodplain corridor. In a dynamic community such as Mecklenburg County, there is development and/or projects that can directly impact the study stream and/or floodplain corridor. One of the purposes of the Map Maintenance initiative is to capture changes that have occurred in the floodplain corridor and update the analysis appropriately. Guidelines for identifying and assessing necessary changes in the floodplain are summarized below.

3.3.1. Model Stream Alignment Verification

The Mapping Contractor will verify and/or update the alignment and extents for each study stream to be modeled in the Map Maintenance project. In general, the study stream should extend to the current Effective limits unless otherwise specified in the MAS or as directed by the County. In cases that the Effective streamline does not extend to the approximate one mile contributing drainage area, the Mapping Contractor shall coordinate with the County on the appropriate resolution (i.e. extend upstream, leave as is, etc.).

The stream alignment should be updated based on the latest aerials where the channel is visible (i.e. ensure streamline is within channel banks), as well as, field surveys, topographic information, and drainage inventory information as appropriate.

3.3.2. Stream Crossing Verification/Compilation

The Mapping Contractor shall identify and locate all stream crossings (e.g. culverts, bridges, dams, weirs, etc.) that are to be modeled in the given Map Maintenance project. Stream crossings shall be identified and located by reviewing the most recent aerials in conjunction with Effective HEC-RAS models. The Mapping Contractor or County (as determined by the specific scope of work) shall tabulate the spatial location (approximate centroid of where the structure crosses the stream) and related information about each structure, such that all known stream crossings should have a spatial point location and descriptive information. The list of items to tabulate for each stream crossing is provided in Appendix C. Crossings that are identified on the aerial photography and are in the Effective HEC-RAS models should be further verified as described directly below. Crossings that are identified, but not in Effective HEC-RAS models shall be flagged for new field survey (described following verification procedures).

Stream crossings identified in the above step that are in the Effective HEC-RAS models should be verified by making site visits to each structure (where feasible), verifying (or remeasuring) basic geometry/dimension and characteristics (e.g. material, end treatments, etc.). For structures where field verification is not feasible (e.g. lack of access, safety concerns, etc.), the Mapping Contractor shall obtain and review pertinent available information (e.g. as-builts) to verify structure information based on "best available data".

3.3.3. Floodplain Development Projects Evaluation

Mecklenburg County requires a local Floodlands Development Permit (FDP) for any development activity within the Effective floodplain limits. Further development activity or other projects within the FEMA or Community Encroachment Area floodways require hydraulic analysis and additional permitting through a "No-Impact" study or FEMA Map Revision (i.e. CLOMR or LOMR). These activities and projects can have a significant impact on hydraulic analysis and/or the mapping in the vicinity near the projects. The County maintains a database and filing system for FDP applications, and often will have supporting information for these projects (e.g. surveys, plans, models, etc.) that are submitted as part of the FDP process. The Mapping Contractor shall coordinate with the County to review, identify, and incorporate projects that have occurred in the floodplain areas since the Effective maps and/or otherwise impact floodplain analysis and mapping for the given Map Maintenance project.

3.4. Field Surveys

Although information from Effective models and new data sources is used where possible, field survey is needed to verify/update channel geometries and collect information for new or modified stream crossings/structures. Guidelines for identifying areas for field survey are provided below. The Mapping Contractor shall follow FEMA Data Capture Standards for actual field collection specifications (e.g. survey codes, photograph requirements, naming conventions, etc.), unless otherwise directed by the County.

3.4.1. Channel Cross Section Surveys

Channel cross section information refers to geometry and feature information that is collected for natural stream channels at selected locations along the study stream. This information is one of the key elements of hydraulic floodplain modeling as it is directly used to assess the flood carrying capacity of a channel. For the purposes of Map Maintenance projects, field data collection of cross section information is primarily used to supplement and/or verify information obtained from other sources such as countywide LiDAR and Effective hydraulic models – it is not intended to be solely sufficient to support hydraulic modeling described in later chapters.

The number and location of field survey cross sections should be estimated based on an assessment of the stream channel and immediate overbanks. Generally cross sections should be surveyed at a density and frequency necessary to pick up significant breaks in channel profile and geometry, as well as, provide reasonable "ground truthing" along the entire limits of the study stream. Based on previous projects and evaluations, collecting cross sections at an ***average*** spacing of 1,100 feet has shown to be a reasonable estimate for floodplain mapping projects in Mecklenburg County. Similarly, previous evaluations have also shown that LiDAR is reasonably accurate within the channel overbanks for wider, open streams, with relatively shallow base flow. Whereas, it is generally less accurate for narrower streams obscured by vegetation or with deeper base flow. From this, it is recommended that field data collection efforts be more concentrated on the narrower and more densely vegetated streams, and less concentrated on the wider streams in open areas. Though the overall average cross section field data collection spacing is one cross section every 1,100 feet, the actual locations for field data collection should be determined by the Mapping Contractor and CMSWS. The Mapping Contractor shall coordinate with the County on determine the final number and locations for field cross section surveys.

In an effort to optimize the balance of the amount of data collected, accuracy, and cost effectiveness of field data collection efforts, a limited "relative GPS" survey can be used to collect channel cross sections. The relative GPS channel survey involves the same (or very similar) channel measurements as a traditional survey, however, the measurements are tied to a non survey-grade reference (rather than a more precise survey-grade reference). In a relative GPS survey, the horizontal reference is generally obtained from a mapping-grade GPS unit, whereas, the vertical reference is obtained from available LiDAR information. Other horizontal and vertical reference sources that result in equal to or greater accuracy levels may be used if the aforementioned sources are not feasible or not available. Similar to full survey-grade survey, the reference point location should be off the top of bank (approximately 50' where feasible). In a relative GPS cross section, the coordinates and elevation of the remaining cross section points are calculated from offset distances and level readings relative to the reference point. These relative GPS surveys are most appropriate in open area areas with flatter overbanks where there is generally better confidence in GPS reception and LiDAR accuracy. As these methods are not as accurate as full surveys, they should be used to supplement full surveys and generally should account for less than half of all cross section surveys conducted for the Map Maintenance project. The Mapping Contractor shall use appropriate judgment to ensure GPS/LiDAR based measurements provide reasonable estimates of elevations in the channels. Furthermore, the County must approve the use relative GPS or any other simplified survey techniques prior to commencement of field surveys.

3.4.2. Stream Crossing Surveys

Stream crossing information refers to geometry and feature information that is collected for culvert, bridge, or dam/weir structures that cross a modeled stream. In general, utility crossings (e.g. sewer aerials) are not to be included, unless they are large enough or oriented such that they represent a significant obstruction to flow. Similar to natural cross sections, this information is a key element of hydraulic floodplain modeling as structures can have a significant impact on flooding conditions in a stream. For the purposes of the Map Maintenance projects, field data collection of stream crossing information is primarily used to supplement and/or verify information previously collected and used in the Effective studies. However, new field survey will be necessary for newer structure crossings that are not in the Effective studies and/or that have been significantly modified since the Effective studies.

The number and location of field survey stream crossings is dependent on the changes that have occurred along the given study streams for a specific Map Maintenance Project. Based on previous projects, stream crossing field surveys will only be needed on a relatively small number (generally 10 – 20%) of the total number of stream crossings to model. As a general rule of thumb, all stream crossing surveys should be conducted using full survey-grade procedures. However, non-survey grade field measurements may be acceptable in cases where the structure presents very minor obstructions (e.g. simple on-grade pedestrian bridges).

The Mapping Contractor shall coordinate with the County to determine the final number and locations for stream crossing surveys. Furthermore, the County must approve the use and application of non survey-grade approaches simple stream crossings.

4. Hydrologic Analysis Standards

This section provides guidance and standards for hydrologic analyses associated with floodplain modeling, as well as, for guidelines for documenting the analysis for review by the QC Contractor and/or the County. Hydrologic parameters and analyses not discussed below are left to the discretion of Mapping Contractor, but should be consistent with FEMA G&S and standard engineering practices, or as otherwise approved by the County.

4.1. Hydrologic Model Standards

A rainfall-runoff hydrologic model shall be developed to perform hydrologic analysis for Map Maintenance projects. Hydrologic model specifications and guidelines are presented in the subsections below.

4.1.1. Hydrologic Model

The Mapping Contractor shall use the latest version of HEC-HMS (HMS) for the Map Maintenance projects unless otherwise directed by the County. The current version at the time of this document update is Version 3.5. A separate HMS model should be developed for all areas/watersheds draining to a unique outlet (usually at the County Boundary), unless otherwise specified by the County. The models should contain the HMS "Basin Model", "Meteorologic Model", and "Control Specifications" components necessary to run the hydrologic storm simulations. The basin file elements should be georeferenced to State Plane coordinates to facilitate use of background images/GIS files for review. The model components should be named intuitively using a consistent nomenclature. Any temporary/intermediate components should be removed prior to submittal (i.e. HMS models should contain minimum components necessary to simulate required storms). The table below shows necessary model components for typical Map Maintenance project for hypothetical storm simulations for floodplain mapping. Additional components may be necessary for calibration storm event simulation.

Table 4-1. HMS Model Structure

HMS Model Component Types	Number of Components	Additional Notes
Basin Files	3	Separate basin files for existing and future land use condition. A third basin file necessary to develop "modified" discharges for the Community Encroachment Area floodway, is described in Section 5.
Meteorologic Models	8	Separate meteorologic files for each hypothetical storm simulation (as described in next subsection)
Control Specification	1	One control specification (simulation interval and duration) for all hypothetical storms

4.1.2. Hypothetical Storm Simulation

HMS meteorologic models shall be developed for the 50%, 20%, 10%, 4%, 2%, 1%, and 0.2% annual chance ,and the 1/3 Probable Maximum Precipitation (PMP) hypothetical storm events. The meteorologic models should use a 24-hr SCS Type II distribution with precipitation depths presented in the following table. The precipitation depths, which were determined in the initial Map Maintenance phase, were obtained from "NOAA dataset plus aggregated USGS site representing the CRN initial dataset" in USGS SIR 2006-5017 for the annual chance storms and from HMR-51 for the 1/3 PMP event.

Control specifications shall be developed to simulate the hypothetical storm events. The duration of the simulation should be set to capture the peak and the overall shape of the outflow hydrograph. A minimum 36-hr simulation is recommended. The time step should be set to adequately capture resolution of input data, the peak, and other inflections in the outflow hydrograph. A time step between 1 – 5 minutes will be appropriate. A 2-minute time step is recommended.

Table 4-2. Precipitation Depths for Hypothetical Storm Events

Hypothetical Storm Event	Precipitation Depth (inches)
50% Annual Chance (2-year)	3.06
20% Annual Chance (5-year)	4.08
10% Annual Chance (10-year)	4.80
4% Annual Chance (25-year)	5.76
2% Annual Chance (50-year)	6.51
1% Annual Chance (100-year)	7.29
0.2% Annual Chance (500-year)	9.23
1/3 PMP	13.5

4.2. Hydrologic Parameter Development

4.2.1. Subbasin Characteristics

Subbasins are areas that are used to sub-divide a watershed area into smaller hydrologic components in order to reflect more localized hydrologic patterns and ultimately to improve the accuracy of peak flows calculated along the study streams. SCS methodology shall be used for subbasin hydrology (i.e. Loss Method and Transform Method in HMS), unless otherwise approved by the County. Guidelines for subbasin development and hydrologic parameters are discussed in the subsections below.

4.2.1.1. Subbasin Delineation

Subbasins should be delineated such that they adequately capture the level of hydrologic response necessary for floodplain analysis, as well as, smaller-scale urban drainage at the "neighborhood" scale in more developed areas. Subbasin outlets should be defined at or near points of interest (e.g. stream confluences, roadway crossings, ponds, etc.), as well as, other locations as necessary. Generally speaking, subbasins should be smaller (typically less than 80 ac) in the developed headwater reaches and/or where there are more points of interest, and larger (often greater than 100 acres) along the study streams main stems (where the impact of an individual subbasin does not impact total flow) or in undeveloped areas with relatively uniform conditions. From sensitivity analysis and previous Map Maintenances phases, a median subbasin size in the 60 – 100 acre range is generally appropriate for Map Maintenance projects. Sizes of individual subbasins may vary more widely (typically 30 – 300 acres) depending upstream drainage area, urbanization, and drainage system characteristics. Subbasins may be generated using automated raster processing techniques (e.g. ArcHydro), however, adjustments may be necessary to adequately account for significant closed drainage systems, ponds, and/or other features that may not be captured in automated techniques, and to ensure there is proper connectivity between subbasins. In addition, it may be appropriate to merge subbasins created through automated processes (e.g. areas where there are multiple stream confluences in close proximity) to prevent from having very small subbasins (< 10 acres). Subbasin delineations at the outer edge of a given study watershed should be checked with boundaries developed for adjacent study watersheds. If multiple adjacent watersheds are being studied in a single map maintenance initiative, the Mapping Contractor(s) shall coordinate as necessary to ensure that watershed divides are reasonably consistent (i.e. no major gaps or overlaps) between study watersheds..

4.2.1.2. Time of Concentration / Lag Time

The Mapping Contractor shall use methodology outlined in TR-55 (Chapter 3) to calculate time of concentration (T_c)for each subbasin. This methodology entails determining a representative longest flowpath for each subbasin, segmenting the flow path by major flow regime, calculating travel times for each segment, and then summing all segment travel times to calculate the T_c for the subbasin. In addition the flow regimes presented in TR-55 (i.e. sheet flow, shallow flow, channel flow), flow through significant pipe systems and waterbodies should be considered in flowpath segmentation and subsequent travel time calculations. Given the large scale and magnitude of a typical Map Maintenance project and the inherent subjectivity in estimation, the Mapping Contractor may use simplified and/or automated methods to aide in the development of T_c calculations. Examples of such approximations/automations include assumed velocities for certain flow regimes (e.g. assume flow in pipes is 5 ft/s), use of GIS tools (e.g. ArcHydro) to automate development of longest flow paths and calculations of geometric properties (e.g. slope), and generalized assumptions for travel time calculation parameters (e.g. assumptions for Manning's n in sheet flow calculations). Results of automated methods should be checked and modified as appropriate to ensure they are reasonable as these methods can sometimes yield unreasonable results (e.g. flowpaths that are not representative of a subbasin, very high or low slopes that result in unrealistic travel time calculations, etc.). The Mapping Contractor is responsible for ensuring that they are justifiable and provide results that are appropriate/reasonable for the scale of the given Map Maintenance project. The Mapping Contractor should use the standard conversion of 0.6 * T_c to calculate the lag time (T_l). As T_c and T_l calculations are some of the more subjective and variable parameters in hydrology, the Mapping Contractor may consider adjustments to these parameters during hydrologic calibration, which is further discussed in Section 4.3.

4.2.1.3. Curve Number Development

The subbasin curve number (CN) can be estimated as a function of land use and soil type. Sources and procedures for manipulation of land use and soils data was described in Section 3. For Map Maintenance projects, CNs for each land use category and soil type are derived from a combination of average land use-percent impervious relationships that were calculated from a countywide impervious study/dataset (described in Section 3.1), as well as, values presented in TR-55. The land use-percent impervious relationships developed from the impervious study are presented in the following table. The increase in percent impervious for residential land use categories between existing and future conditions is to account for potential property improvements (e.g. accessory structures, patios, etc.) that increase the percent impervious of a property. It is noted that the values presented in the table below were generally rounded up slightly (i.e. 5% or less) from actual calculated countywide averages to account for the fact that the averages vary within individual watersheds.

Table 4-3. Estimated Percent Impervious by Land Use Category

Land Use Code	Description	Estimated Percent Impervious - Existing Conditions Land Use	Estimated Percent Impervious - Future Conditions Land Use
1	**Woods/brush**	1%	1%
2	**Open Space (golf courses, mining, fields)**	4%	4%
3	**> 1/2 acre to 2 acres residential**	12%	**16%**
4	**1/4 acre to 1/2 acre residential**	22%	**28%**
5	**< 1/4 acre residential**	34%	**42%**
6	**Institutional (schools, hospitals, government offices)**	45%	45%
7	**Light Industrial**	50%	50%
8	**Heavy Industrial**	50%	50%
9	**Light Commercial (office parks, hotels, multi-family)**	55%	55%
10	**Heavy Commercial (car parks, malls)**	75%	75%
11	**Water Bodies**	100%	100%
12	**Transportation (including right-of-ways)**	45%	45%

The CN for each combination of land use and soil type can be calculated using a weighted average between impervious versus pervious area. Impervious area is typically assigned a CN of 98. The CN for the remaining pervious area can be assigned from values in TR-55 for woods (Land Use Code 1 only) or open space (all other codes) assuming "good" ground cover conditions. Using these assumptions produces existing and future condition CNs as presented in the table below. Values in parentheses represent future condition CNs that differ from existing condition CNs. Unless noted as such, CNs are identical for existing and future conditions. This table should be used for Map Maintenance projects to determine the CN for each combination of land use category and NRCS hydrologic soil group.

Table 4-4. Calculated CNs by Land Use and Hydrologic Soil Group

Land Use Code	Description	Calculated CN Values By Hydrologic Soil Group						
		A	B	C	C/D	D	U	W
1	**Woods/brush**	31	55	70	74	77	70	98
2	**Open Space (golf courses, mining, fields)**	41	62	75	78	81	75	98
3	**> 1/2 acre to 2 acres residential**	46 (48)	65 (67)	77 (78)	80	82 (83)	77 (78)	98
4	**1/4 acre to 1/2 acre residential**	52 (56)	69 (71)	79 (81)	82 (83)	84 (85)	79 (81)	98 (98)
5	**< 1/4 acre residential**	59 (64)	74 (77)	82 (84)	84 (86)	86 (88)	82 (84)	98 (98)
6	**Institutional (schools, hospitals, government offices)**	66	78	85	86	88	85	98

Land Use Code	Description	Calculated CN Values By Hydrologic Soil Group						
		A	B	C	C/D	D	U	W
7	**Light Industrial**	69	80	86	88	89	86	98
8	**Heavy Industrial**	69	80	86	88	89	86	98
9	**Light Commercial (office parks, hotels, multi-family)**	71	81	87	89	90	87	98
10	**Heavy Commercial (car parks, malls)**	83	89	92	93	94	92	98
11	**Water Bodies**	98	98	98	98	98	98	98
12	**Transportation (including right-of-ways)**	66	78	85	86	88	85	98

Values in () represent future condition land use CNs where they differ from existing conditions land use CNs

The CN for each subbasin can be determined by calculating a weighted average CN of all the individual combinations of land use and soil type within the subbasin boundary. Subbasin CNs should be developed for both existing and future land use conditions to support existing and future condition floodplain analysis and mapping. It is noted that the CNs in the table above incorporate impervious areas, thus, a percent impervious value of "0" should be entered for each subbasin in the HMS model. Similarly, the initial abstraction (Ia) should be left blank in the HMS model to default to the value of (Ia = 0.2S) as described in the HMS User Guide.

As indicated above, the CNs presented in the table are based on countywide averages of percent impervious for each land use type. The impervious study also calculated average percent impervious values for each County watershed separately. In addition, the data layer itself provides a means to calculate the percent impervious for any given area. It is recommended that the Mapping Contractor use the impervious surface information to verify the reasonableness of calculated CNs. The Mapping Contractor may also use this and any other pertinent information to consider adjustments to CN numbers and/or associated parameters (%Impervious or Ia) if necessary during hydrologic calibration, which is further discussed in Section 4.3.

4.2.2. Hydrologic Routing

Hydrologic routing is often used in floodplain analysis to account for peak flow attenuation that occurs as a flood wave travels through a natural drainage system. In the context of the County Map Maintenance projects, routing specifically refers to routing of a flood wave through an open channel system (including culverts and bridges) (i.e. channel routing) or through storage areas such as in-line ponds or areas behind large embankments (i.e. storage routing). Guidelines for hydrologic routing are discussed in the subsections below.

4.2.2.1. Channel Routing

Channel routing occurs in floodplain areas where peak flows are attenuated as a result of water expanding and slowing down upon entering the floodplain. Channel routing is often accounted for through the use of hydrologic routing reaches, which route a hydrograph through a channel or pipe from one subbasin outlet to the next downstream subbasin outlet. Two general levels/approaches will likely apply for Map Maintenance projects. The Modified Puls method should be employed for reaches that are along modeled study streams in which detailed HEC-RAS modeling is being performed (as further described in Section 5). Storage-Outflow relationships should be developed in HEC-RAS for a family of discharges that covers the entire range in potential flows for modeled storms (i.e. 50% annual chance to 1/3 PMP events). It is recommended that the default initial condition of "Inflow=Outflow" be used. The number of subreaches should be estimated per guidance in the HMS Technical Reference manual or other appropriate reference. The Mapping Contractor may consider adjustments to the number of subreaches if necessary during hydrologic calibration, however, in general, adjustments should not be made to storage-outflow relationships during calibration since these are physically based and also are used in Community Encroachment Area analysis described in Section 5.5.

For channel routing upstream of study streams (i.e. no HEC-RAS models being developed), the Mapping Contractor may use a simplified method. It is recommended that Muskingum-Cunge 8-point routing or a similar method that utilizes at least some physically based parameters specific to the given routing reach (e.g. length, slope, roughness, etc.) be used (rather than a pure lag or empirical method). The Mapping Contractor should attempt to use a single method if possible. The method(s) and/or method parameters may be adjusted as appropriate during model calibration.

4.2.2.2. Storage Routing

Storage routing occurs when flow is impeded by a dam, embankment, or other feature and the structure (e.g. culvert pipe, weir, etc.) that allows water to pass through the feature does not have the capacity to pass the full natural flow. This causes the water to be "backed up" and stored behind the feature, thus reducing the peak flow. Storage routing is often accounted for through the use of storage elements in the HMS model, which route an input hydrograph through an outlet structure (e.g. spillway).

Storage routing is inherently incorporated in the Modified Puls method described for channel routing above, therefore, it should not be performed along study stream reaches where HEC-RAS model is being conducted, except for in-line ponds and locations with excessive backwater conditions (e.g. where backwater impacts a significant portion of the routing reach, upstream tributaries and/or other routing reaches). If excessive backwater conditions are identified, level-pool routing should be used. For storage areas where level-pool routing is used, the Mapping Contractor shall ensure that there is reasonable consistency (generally within 0.5 feet) between hydrologic level-pool elevations calculated in HEC-HMS versus hydraulic backwater elevations calculated in the HEC-RAS models (described in Section 5) through the in-line storage areas. However, as these excessive backwater conditions are not expected in most Map Maintenance projects, the Mapping Contractor shall coordinate with the County to ensure collective agreement on their use in individual cases.

Storage routing should also be considered for ponds/dams that are upstream of study streams that may have an appreciable impact on peak flows along study streams. Contributing drainage area, surface area, impoundment volume, hazard classification, multiple ponds in series, and location within watershed area are examples of factors that should be considered in assessing potential impact to flows on study streams. Generally, ponds with larger contributing drainage areas and impoundment volumes will tend to have the most significant impacts. A recommended threshold for screening ponds for potential consideration is to identify those that are greater than 0.5 acres in size with a contributing drainage area greater than 100 acres. Comparison with other hydrologic studies and/or calibration storm may also be used in final selection of ponds to consider for storage routing.

4.3. Hydrologic Calibration

Hydrologic calibration is the process of refining hydrologic model parameters based on comparisons of computed stream flow hydrographs with observed flow hydrographs from actual storms and/or estimated peak flows from previous studies. Guidelines for hydrologic calibration are discussed in the subsections below.

4.3.1. Storm Selection and Simulation Guidelines

There are a number of factors that should be considered when selecting storm events for calibration. Factors include storm characteristics such as precipitation depth, duration, and distribution (temporal and spatial), environmental conditions such as season and antecedent moisture conditions, as well as, other factors such as development changes in the watershed and confidence/completeness of gage data. The table below provides additional definition and considerations for these factors.

Table 4-5. Hydrologic Calibration Storm Selection Guidelines

Metric	Definition / Description	Additional Notes
Total Storm Precipitation Depth	Total amount of rainfall over defined storm period at a given rain gage	Hypothetical storm depths based on local IDF curve. USGS Water Reports, which provide daily rainfall totals for a given water year, are a good source to identify potential storm events of various magnitudes.
Total Storm Duration	Duration of defined storm period	Hypothetical storm events based on 24-hr storm duration
Spatial Precipitation Distribution	Variability of rainfall depths for a given storm as measured at different rain gages within watershed of interest	Hypothetical storm simulation generally assumes uniform rainfall over watershed area.
Temporal Precipitation Distribution	Pattern of rainfall at a given rain gage	Hypothetical storm (based on SCS Type 2 distribution) show balanced pattern (i.e. centered distribution)
Antecedent Moisture Conditions	Relates to level of moisture in ground prior to storm event	Hypothetical storms generally based on AMC 2 (i.e. “normal” condition)
Watershed Development	Relates to how much development has occurred in watershed since a given storm event	If calibrating to storms in a developing watershed, will need to consider more recent events, since hydrology patterns can change with development.

It is important to note that all these factors should be considered when selecting calibration storm events as they can all have a significant impact on the resultant hydrograph at a given stream gage. For example, two storms that have the same total depth can produce very different peak flows if the duration or distribution is different (e.g. one storm has very concentrated intense rainfall over shorter period of time and the other storm has slower rainfall that is spread over longer period of time).

In general, the more similarities that the calibration event shares with the target storm, the better. Long storms covering multiple days with multiple peaks, are often the most difficult to calibrate and thus should be avoided if possible/appropriate. If they are used, the Mapping Contractor should consider isolating sub-storms (i.e. portion of storm where rainfall/flow rises and then returns to near equilibrium), truncating storm simulation window, and adjusting other parameters (e.g. initial abstraction, etc.) as appropriate to account for the storm precipitation outside the truncated simulation time window. County Map Maintenance projects entail developing model simulations for a wide range storm magnitudes ranging from the 50% annual chance event to the 1/3 PMP event. The Mapping Contractor should try to calibrate to 2 – 3 storm events of varying magnitude if possible. However, since the %1 annual chance storm is the one used for development of floodplain and floodway boundaries, calibration storms with similar magnitude should be given precedence.

4.3.2. Calibration Parameters

As indicated previously, several of the parameters in hydrologic analysis are candidates for adjustments during calibration. The decision of which parameters to adjust and the type of adjustments are dependent on a number of factors including the nature of discrepancy between simulated versus observed values (e.g. peak, timing, shape, etc.), the subjectivity/variability of input parameters, and variability of watershed responses. The following table lists typical parameters considered for calibration and guidelines/recommendations for Map Maintenance projects.

Table 4-6. Typical Hydrologic Calibration Parameters

Calibration Parameter	Affects	Notes / Considerations	Potential Adjustment Approaches
Time of Concentration / Lag Time	Timing / Peak	One of the more subjective parameters. Adjustments can be made to adjust overall timing or focused on specific streams alter timing at confluences.	***Level 1 – Travel Time Parameter Adjustments:*** Adjust subjective/assumed longest flowpath travel time parameters within allowable ranges (e.g. lower or increase assumed Manning's n values on sheet flow, adjust assumed velocities for ponds, pipes, adjust slopes, etc.) to either increase or decrease total Tc based on comparison with observed timing. Adjustments to sheet flow segments generally have the biggest potential impact on overall Tc. ***Level 2 – Overall Tc / Tlag Adjustments:*** Apply adjustment to standard Tc to Tlag conversion (i.e. Tlag = 0.6Tc).
Initial Abstraction	Volume / Peak	Empirical formula that is somewhat subjective. Changes to initial abstraction generally has bigger impact on smaller storms.	Apply adjustment to standard Ia calculation (i.e. Ia = 0.2*S).

Calibration Parameter	Affects	Notes / Considerations	Potential Adjustment Approaches
Curve Number	Volume / Peak	Less subjective than others but can have significant impact on volume. Soil type and antecedent moisture condition generally have significant impact on CN. In addition %impervious used to develop CN assumes all is directly connected. Thus, may consider adjustments to account for these.	***Level 1 – Specific %Impervious Adjustments:*** Adjust CNs based on actual impervious surface data (if deviates from default Countywide averages). ***Level 2 – Land Use/Soil-Specific CN Adjustments:*** Apply adjustments to specific land use and/or soil categories where there is reason to believe published values are high. For example, if basin has significant "C" soils CNs are much higher, so may be appropriate to reduce. ***Level 3 – Overall CN Adjustments:*** Apply more global adjustment to CNs. In most cases would expect adjust to be within 4+/- raw CN points.
Channel Routing – Headwater Reaches	Peak / Timing	Often parameters for headwater routing reaches are approximated and generalized.	Depending on methodology can adjust input parameters (e.g. Manning's n value, section geometry, and/or energy slopes for Muskingum-Cunge 8-Point sections). Recommend assigning minimum and maximum thresholds for parameters estimated from general GIS data (e.g. energy slopes).
Channel Routing – Study Reaches	Peak / Timing	Less subjective as data extracted from HEC-RAS. Should ensure that cross sections reasonably capture back water areas otherwise will underestimate storage.	Adjust number of subreaches for Modified Puls. Generally lower numbers increase attenuation.
Pond Routing	Peak / Timing	If have large ponds and/or many small ponds can have significant impact on hydrologic response.	Can use calibration as a factor in decision in which ponds to incorporate into model.
Precipitation Assignments	Timing / Peak	Can have impact if significant spatial distribution in precipitation between gages.	Considering altering approach for assigning calibration storm precipitation to subbasins (e.g. Thiessen, isohyetal, etc.)

The Mapping Contractor should review initial uncalibrated hydrology results to first assess the level and type of calibration that is necessary, and then evaluate which parameters are most appropriate to make adjustments. Sensitivity analysis (i.e. artificially changing parameters individuals to assess impact on hydrologic response) can be helpful in initially identifying calibration parameters and associated level of adjustments. Final calibration should generally be based on physical information/justification when possible. Global changes to hydrologic parameters should be used with caution, but can be acceptable for variables that are more subjective (e.g. adjusting Manning's n values for sheet flow in subbasin lag calculation for different grass cover types). However, adjusted parameters should stay within the range of generally accepted values for a given physical condition.

4.3.3. Calibration Targets

In an ideal scenario, the calibration storm simulation would produce a runoff hydrograph that mimics the observed hydrograph at a given stream gage. As indicated above, there are many factors that can affect the hydrologic response, thus it is not practical in most cases to expect a theoretical model to precisely predict an observed hydrograph. However, suggested metrics and associated targets are recommended in the following table.

Table 4-7. Hydrologic Calibration Targets

Parameter	Precedence	Additional Notes
Peak Flow	1	Match within 10% of observed is preferred, but up to 20% can be considered reasonable. If beyond 20%, verify parameters and document discrepancies. If multiple gages along study stream, final calibration should also consider pattern of correlation (e.g. all high, all low, mixed)
General Hydrograph Shape	2	General shape of simulated hydrograph should be generally consistent with observed hydrograph (capture major patterns). Simulated hydrographs are often more angular/variable, but general pattern should be similar.
Time to Peak	3	Match within 30 minutes of observed is preferred, but up to 1 hr can be considered reasonable. If beyond 1 hr, verify parameters and document discrepancies. If multiple gages along study stream, final calibration should also consider pattern of correlation (e.g. all fast, all slow, mixed).
Total Runoff Volume	4	Match within 15% of observed is preferred, but up to 30% can be considered reasonable. If beyond 30%, verify parameters and document discrepancies. If multiple gages along study stream, final calibration should also consider pattern of correlation (e.g. all fast, all slow, mixed). Simulated often start and return to zero outflow faster than observed flows.

4.4. Hydrology Report Guidelines

The Mapping Contractor shall prepare a document summarizing the hydrologic analysis. The document should include appropriate text, tables, and figures, as well as, supporting digital data as necessary to qualitatively and quantitatively convey the approaches, input parameter data, calibration efforts, and hydrologic results with comparisons to previous studies/methodologies. The specific content and format may vary depending on Map Maintenance project, however, common/recommended elements to be included in the hydrologic submittal are listed below.

- Brief narrative providing overview of study (i.e. watershed(s) being studied, nature of update, model version used, etc.)
- Text describing hydrologic methodology and approach for developing all input parameters (e.g., Tc, CNs, headwater channel routings, etc.). Description of methodology and/or input parameters that are taken directly from this Standards Document (e.g. precipitation depths, CN lookup table, etc) can simply reference the Standard Document. More detailed documentation

should be provided where methods or values deviate from standard engineering practice and/or guidelines in this Standards Document.

- Text and/or tables providing statistical summaries (e.g. count, minimum, maximum, average, median, total, etc. as applicable) of major input parameters to convey characteristics specific to study watershed. Parameters for individual hydrologic component (i.e. subbasin, reach, etc.) can be included as appendices and/or referenced in summary tables in HMS models.
- Tables showing correlation between HEC-RAS cross sections (i.e. bounding cross section stations) and hydrologic routing reaches used in determining storage-outflow relationship for Modified Puls channel routing.
- Text and/or tables describing ponds considered for storage routing and basic characteristics (e.g. surface area, drainage area, source of data, etc.) of those that were included in the modeling.
- List of all precipitation and stream flow gages within study area watershed.
- Text and/or tabular description of storms events considered for hydrologic calibration including storm total precipitation depth, storm duration, and other descriptive statistics that may be pertinent.
- Figure(s) showing overall watershed with study streams, gages, major roads, and other major features of interest (e.g. Thiessen polygons for rain gages, etc.)
- Text providing description of general calibration methodology/approach including items such storm selection precipitation assignment methods, and similar.
- Text providing description and justification of adjustments made to hydrologic parameters in individual or multiple calibration storm models.
- Figures and/or tables comparing simulated versus observed hydrograph characteristics for calibration storm events. It is recommended to also provide graphs of rainfall hyetographs as well.
- Text providing description of adjustments made to hypothetical design storm models resulting from calibration of actual storm events.
- Tables providing comparisons of calibrated hypothetical flows to Effective and regression flows, along with text summarizing comparison patterns and believed reasoning for significant deviations .
- GIS files of subbasins, hydrostreams (stream network showing subbasin connectivity), longest flow paths, curve number, model stream lines, hydraulic cross sections (for reference on Modified Puls channel routing reaches), and similar.
- HMS models files and other digital supporting files as pertinent.

5. Hydraulic Analysis Standards

This section provides guidance and standards for hydraulic analyses associated with floodplain modeling, as well as, for guidelines for documenting the analysis for review by the QC Contractor and/or the County. Hydraulic parameters and analyses not discussed below are left to the discretion of Mapping Contractor, but should be consistent with FEMA G&S and standard engineering practices, or as otherwise approved by the County.

5.1. Hydraulic Model Standards

A hydraulic model shall be developed to perform hydraulic analysis for Map Maintenance projects. Hydraulic model specifications and guidelines are presented in the subsections below.

5.1.1. Model

The Mapping Contractor shall conduct steady-state analysis using the latest version of HEC-RAS (RAS), unless otherwise directed/allowed by the County. The current version at the time of this document update is version 4.1.0. A separate RAS model should be developed for each study stream, unless otherwise specified by the County. The RAS models should contain the "Geometry", "Flow", and "Plan" elements necessary to run the hydraulic models as described below. The model components in the geometry files should be georeferenced to State Plane coordinates to facilitate use of background images/GIS files for review. The table below shows necessary model components for typical Map Maintenance project for hypothetical storm simulations. Guidelines for creating each of the RAS component types is described later in this section. Additional components may be necessary for calibration storm event simulation.

Table 5-1. RAS Model Components for Hypothetical Storm Simulation

RAS Model Component Types	Number of Components	Notes
Geometry Files	2	One geometry file to represent existing/current study stream geometry. A second geometry file necessary to develop a "potential floodplain fill" scenario for the Community Encroachment Area floodway, is described later in this section.
Flow Files	3 - 4	One flow file that contains all existing and future land use condition hypothetical storm event peak flows and two flow files for floodway runs. May be appropriate to have additional flow file with more general family of discharges that was used to obtain storage-outflow information for Modified Puls channel routing along study streams (previously described in Section 4.2)
Plan Files	3 – 4	Three required plans for natural floodplain, FEMA (0.5' surcharge) floodway, and Community Encroachment Area (0.1' surcharge) floodway. The plans should be labeled as "Floodplain", "FEMA Floodway", and "Community Floodway", respectively. The "Floodplain" plan should include all hypothetical events. Model may also include an additional plan for the Modified Puls run.

5.1.2. Model Simulation

Water surface profiles shall be developed for the eight (8) hypothetical storm events simulated in the HMS models as described in Section 4.1. In addition, floodway runs for the FEMA (0.5' surcharge) and Community Encroachment Area (0.1' surcharge) floodways shall be developed as described later in this section. All models should be run assuming a subcritical flow regime with default settings and calculation tolerances unless specifically justified.

5.2. Hydraulic Geometry and Parameter Development

Hydraulic geometry stored in RAS geometry files define the geometry and physical characteristics of the channel and floodplain corridor. Guidelines for hydraulic geometry development are discussed in the subsections below.

5.2.1. Cross Section Placement and Geometry

5.2.1.1. General Cross Section Placement

Hydraulic model cross sections should be placed as necessary to adequately represent the channel and floodplain corridor for floodplain analysis and mapping. Placement is a function of stream size, slope, uniformity of cross section shape, structure crossing (i.e. roadways, dams, etc.) locations, and drainage characteristics. Cross sections shall be placed at representative locations along a stream reach and at locations where changes occur in discharge, slope, shape, roughness etc. Cross sections will generally have tighter spacing for areas with more abrupt changes and structure crossings, and looser spacing for flatter, uniform areas with fewer structures. For Map Maintenance projects, an overall average cross section spacing should generally be in the 200 – 400 foot range. Spacing between individual cross section can vary considerably more, but it is recommended that it not exceed 800 feet, except in situations such as flat areas with very high sinuosity streams. The most upstream cross section is to be at the designated upstream study limits (generally same as Effective study). For tributaries draining to other study streams, the downstream most tributary cross section should be placed within the FEMA floodway of the receiving stream where possible to facilitate floodplain/floodway mapping transitions at confluences.

5.2.1.2. Cross Section Placement Around Stream Crossings

Four (4) hydraulic model cross sections (referred to as sections "1", "2", "3", and "4") should be placed around stream crossings per guidance in the HEC-RAS Technical Reference manual (RAS Manual). As indicated in the RAS Manual, the bounding cross sections (i.e. "2", and "3") should be close to, but off the structure and/or associated crossing itself (i.e. generally should not include embankment, wingwalls, etc.). These bounding cross sections are usually placed at the toe of the crossing embankment, if present. Complex road networks with curving streams and numerous crossing and/or other atypical situations (e.g. drainage channel entering main channel at crossing, very high embankments, etc.) may warrant exceptions to typical practices based on prudent engineering judgment.

5.2.1.3. Cross Section Geometry

Cross section geometries, (i.e. station-elevation takeoffs, channel banks stations, etc.) should be built from the best available source(s) of ground surface data. As indicated in Section 3, field survey is used to capture the channel and immediate overbank at selected locations along the study stream. Similarly, as-built survey data from completed projects along the floodplain corridor (e.g. stream restoration projects) should be used if applicable/available. LiDAR or other similar larger-scale terrain data will likely need to be used to supplement field survey/as-built data to capture the full extent of the floodplain. For modeled cross sections where no field survey/as-built data is available, channel geometries should be estimated from the closest upstream/downstream survey geometry (e.g. width, depth, shape, etc), aerials, contour mapping, and/or other pertinent information. As development of cross section geometries will likely involve integration of multiple data sources and data interpolation, the Mapping Contractor should check the cross section plots and stream profile in RAS to ensure that the cross section geometry is reasonable (i.e. no big "spikes", unrealistic transitions, etc.).

5.2.2. Cross Section Parameters

Cross section parameters define the hydraulic characteristics of the cross section. Guidelines for cross section parameter development is discussed in the subsections below.

5.2.2.1. Channel Bank Stations

Channel bank stations define the limits of the channel along the cross section. The assignment of bank stations is significant in hydraulic modeling as it impacts hydraulic conveyance calculations (i.e. channel conveyance is calculated separately overbanks), and can impact the assignment of encroachment stations in floodway analysis and mapping (described in later sections). For Map Maintenance projects, channel banks should be assigned based on hydraulic and physical characteristics that separate the channel from the overbanks such as defined ground slope breaks, vegetation, and ground/channel bed materials. It is noted that assignment of channel banks stations for floodplain analysis may differ from those that would be assigned from a geomorphic assessment conducted for stream classification and/or restoration project. For example, the assigned bank stations for floodplain analysis may be significantly higher/wider than those assigned in a geomorphic analysis for an incised stream.

Channel banks can vary considerably along a stream as they are impacted by changing terrain, development/improvement impacts (e.g. stream crossings, stream projects, etc.), and changes in drainage area/flow characteristics. At locations where field channel survey is available in the vicinity of the hydraulic cross section, channel bank stations should be assigned based on consideration of bank locations noted in the survey and engineering judgment. At locations where no field channel survey is available in the vicinity, bank stations should be assigned based on natural slope break points depicted in existing County mapping (e.g. LiDAR). All estimated bank stationing should be checked with field channel survey information (e.g. compare channel widths) along the same channel and/or with other available data (e.g. aerial photography) to ensure bank stationing estimates are reasonable.

5.2.2.2. Reach Lengths

Downstream reach lengths represent the distance from a given cross section to the next downstream cross section. Channel reach lengths are the distance between cross sections along stream centerline, and should match the difference in cross section stations. Overbank flowpath lines for the left and right overbanks should be created in GIS and then used to calculate overbank reach lengths between cross sections. The overbank flowpath lines should be drawn to represent the approximate flowpath of potential flood flows through the overbank within the general stream valley corridor. The placement of overbank flowpath lines is somewhat subjective and relatively small fluctuations in reach lengths generally do not have a significant impact on resulting water surface elevations. However, in most cases the overbank flowpaths should be drawn within the 1% chance annual floodplain – approximately 1/4 – 3/4 the distance from the channel to the edge of the floodplain is typical

5.2.2.3. Channel/Floodplain Roughness, Obstruction, and Sinuosity Parameters

The roughness, level of obstruction, and sinuosity of the channel and valley affect the amount of resistance and associated conveyance properties of a cross section. The primary hydraulic cross section parameter to represent these resistance characteristics is the Manning's n coefficient. Manning's n values should be generally assigned for the channel and overbanks from values provided in the RAS Manual or similar published references (e.g. Chow, USGS, etc.) based on land cover information (e.g. field visits, photos, aerial images, etc.). However, they should also consider urban obstructions/modifications such as buildings, stream restoration projects, aerial utility crossings, and/or other items that impact roughness, but may not be explicit in published values. Incorporating buildings will likely be the most common urban impact to be considered in floodplain analysis for Map Maintenance projects. In "typical" situations where there are often numerous buildings within the floodplain (e.g. residential developments, commercial districts, etc.), the Mapping Contractor should adjust Manning's n values using guidelines presented in the table below.

Table 5-2. Building Obstruction Manning's n Categories

Building Obstruction Level	Adjusted Manning's n	Condition
Low	0.05 - 0.07	Scattered buildings in floodplain with low to medium natural ground roughness (e.g. 0.035 – 0.05)
Medium	0.08 - 0.12	Typical residential subdivision in floodplain with low to medium natural ground roughness
High	0.15 - 0.20	High density buildings in floodplain

In situations where there are few but very large buildings that by themselves comprise a significant obstruction of the floodplain area (e.g. a large industrial/warehouse building in a narrow floodplain area), the Mapping Contractor should consider the use of blocked obstructions to model the building. However, the use of blocked obstructions should be used very sparingly and only for exaggerated cases due to the manual and localized nature of this method.

Impacts for other urban obstructions/impacts such as stream restoration, utility crossings, and/or similar should be incorporated into the Manning's n values if deemed to be appreciable (e.g. the potential impact is measurable and would result in a change beyond outside range of inherent subjectivity). The mapping consultant shall use the Cowan equation, or similar methodology, to account for these secondary urban obstructions impacts. USGS WSP-2339 (1989), which can be downloaded from the internet, provides guidance and additional references for application of the Cowan equation. For example, to account for a stream restoration project it may be appropriate to adjust Manning's n to account for added sinuosity, vegetation, and/or obstructions from in-stream structures.

A single Manning's n value may be used to represent the channel for any given cross section. Manning's n values for the left and right overbanks should be horizontally distributed (i.e. use 'Horizontal Variation in n Values' in RAS) to reflect significant variations in surface roughness along the cross section. Land use/cover GIS data may be used to expedite development of overbank n values, however, the Mapping Contractor will likely have to edit/modify these automated values to ensure they adequately reflect roughness conditions in the floodplain corridor. As guidance for Manning's n assignments are often in provided in ranges of values, the Mapping Contractor may consider adjustments to Manning's n during hydraulic calibration, which is discussed later in this section.

5.2.2.4. Contraction/Expansion Coefficients

The Mapping Contractor shall assign contraction and expansion coefficients per the RAS Manual. Typically, contraction and expansion coefficients should be left at default values of 0.1 and 0.3, respectively, for natural cross sections, and increased to 0.3 and 0.5 for the two immediate upstream and one immediate downstream cross sections around significant stream crossings (i.e. sections "2", "3", and "4" as described in the RAS Manual). The Mapping Contractor may consider adjustments to these default contraction and expansions coefficients during hydraulic calibration.

5.2.2.5. Ineffective Flow Areas

The assignment of ineffective flow can have a significant impact on computed water surface elevations, as well as, the assignment of encroachment stations during floodway analysis. The Mapping Contractor shall assign ineffective flow areas where flow is not actively being conveyed (i.e. has velocity close to zero) per the RAS Manual. For natural cross sections, ineffective flow areas should be considered where there are continuous high ground/ridges along the overbanks that would prevent active flow on the landward side of the ridge (more typical case), or in significant backwater areas (e.g. channel valley "flares out" and then constricts - less typical case). The associated ineffective stations should correlate with the approximate high point of the ridge or point in the floodplain where flow becomes ineffective. Ineffectives should be added at the two immediate bounding cross sections around stream crossings (e.g. sections "2" and "3") per RAS Manual guidance. Generally, using approximate 1:1 contraction ratios and 1.5:1 expansion ratios are reasonable assumptions for estimating ineffective stations near stream crossings. Ineffective elevations should be set where significant overtopping would occur (i.e. minimum top of road or slightly higher). Elevations on the downstream side should be adjusted as necessary during the modeling process to ensure continuity of flow between the upstream and downstream sections (i.e. if flow is effective on the upstream side it should be effective on the downstream side, and vice versa). The Mapping Contractor may consider adjustments to these initial ineffective assignments during hydraulic calibration.

5.2.3. Modeling Stream Crossings/Structures

Stream crossings and their associated structures such as culverts, bridges, and dams obstruct the natural flow of flood waters and thus can have a significant impact on flood elevations. Guidelines for identifying stream crossings to be considered for inclusion into hydraulic models was presented earlier in Section 3. Guidelines for modeling stream crossings and associated structures are provided below.

5.2.3.1. Identifying Source Information for Stream Crossings/Bridges

Similar to natural cross sections, information for stream crossings may come from a combination of several sources. The table below lists the primary sources applicable to Map Maintenance projects in order of precedence. As indicated in the table, although new field survey is the source of top precedence, it is often limited to a relatively small proportion of all modeled crossings.

Table 5-3. Sources of Information for Stream Crossings

Precedence	Source	Applicability/Availability Notes
1	New field survey Collected for project	Best source as is collected specifically for floodplain mapping using appropriate data capture standards. Typically accounts for relatively small percentage of total stream crossings as often limited to newer or modified crossing structures.
2	As-Built Data	Generally available from NCDOT (Division 10 office) for interstate and State roads. May also be available for local municipal and/or private development projects.
3	Effective Models	Is often source for majority of stream crossings. Should be used for structure information (e.g. type, size, inverts, etc.) and immediate channel geometry on bounding cross section. Generally, Mapping Contractor should lay out new immediate bounding cross sections and input structure at appropriate station along new cross section.
4	Field Estimations	Relates to non survey-grade field measurements (e.g. bridge decks, railing heights, etc). Should only be used for minor structures such as on grade pedestrian bridges or other structures that are not expected to have significant impact and/or where better survey is not available.

As with natural cross sections, LiDAR or other similar larger-scale terrain data will likely need to be used to supplement source data above for stream crossing inputs.

5.2.3.2. Crossing Structure Hydraulic Parameters

Hydraulic structure parameters (e.g. Manning's n values, entrance and exit loss coefficients, drag coefficients, etc.) for structures (culverts, bridges, and weirs) should follow guidance in the RAS Manual. Culverts should generally be modeled as unobstructed. For bridges, it is recommended that the bridge modeling approach generally be set as the higher of energy and momentum solutions for low flow, and pressure/weir solutions for high flow, using RAS default coefficient values, unless specific reason otherwise. The Mapping Contractor may consider adjustments to these parameters during hydraulic calibration.

5.2.3.3. Crossing Deck/Roadway Hydraulic Parameters

Deck/Roadway geometries (i.e. station-elevation takeoffs) should represent the highest cross section along the deck/roadway where flood waters would need to rise before "spilling over" and continuing downstream. This is often the center of the roadway (at the crown), but may be at the edge or even off the road depending on topography and road/deck characteristics. Similar to cross section geometries, deck/roadway geometries should be built from the best available source(s) of survey/ground surface data. If there are guard rails present that present direct or likely obstruction to flow (e.g. solid rails, or rails that block a significant portion of open area), they should be incorporated into the deck/roadway (i.e. showing rail as part of geometry). Inclusion of minimally obstructive rails (e.g. tube railings, etc.) is left to the discretion of the Mapping Contractor. Deck/Roadway parameters for "Distance" and "Width" should be based on measurements from the upstream side of the bridge deck or roadway to the next upstream cross section, and the width of deck/roadway itself. Embankment side slopes (not used in computations) can be left at 1. It is recommended that default values of "Broad Crested" for weir shape and 2.6 for the weir coefficient be used unless justified otherwise. The Mapping Contractor may consider adjustments to these parameters during hydraulic calibration.

5.2.3.4. Modeling Complex Systems/Structures

As Mecklenburg County is a largely urbanized area, there are numerous areas where the natural stream network has been piped in or otherwise significantly altered to accommodate development. Some of these alterations result in complex systems/structures that may be atypical, and/or stretch the limits for modeling in RAS. Examples of complex systems/structures that are likely to be encountered on Map Maintenance projects include long pipe systems with multiple junctions and/or pipe transitions that can extend under large developments or interstate interchange systems, and multiple study streams converging at one or more stream crossings. The Mapping Contractor should identify potential complex systems and evaluate analyses necessary to verify or adjust RAS analysis techniques to ensure that hydraulic analysis and results are reasonable. This evaluation should entail comparison with Effective analysis and results at a minimum, but may also include sensitivity analyses within RAS, and/or development and comparison with other models/methodologies. For example, in the case of modeling an extended closed pipe system that has multiple pipe size/characteristic changes, it may be appropriate for the Mapping Contractor to assess the difference in results between assuming the smaller (or more conservative) pipe characteristics for the whole system versus assuming the larger (less conservative) characteristics. If the difference in results was relatively minor, then simply using the more conservative approach could be appropriate. If the difference was significant, then it may be necessary to insert additional tightly spaced cross sections to represent/model the junctions and/or use an independent method more appropriate for analysis of closed systems (e.g. Hydraulic Grade Line calculations, SWMM, etc.) to calculate flood elevations. The results of the independent analysis would then be used to adjust parameters in the RAS model. The Mapping Contractor shall identify potential complex modeling systems and coordinate with the County on the preferred analysis approach and resolution for modeling.

5.3. Flow File Development

Peak flows developed in the hydrologic analysis for each of the simulated storm events are entered in RAS flow files to define the maximum amount of flow that is passing through the floodplain corridor under a given simulated storm event. Guidelines for hydraulic flow file development are discussed in the subsections below.

5.3.1. Flow Change Locations

Peak flows from HMS models for all flow loading/reporting points (i.e. junctions and/or routing reaches) along study streams should be considered for potential input into RAS as flow changes. Flow change points with minor changes (i.e. <10% change in 1% annual chance storm) from the next upstream flow change can be removed if deemed appropriate. However, at a minimum, flow changes should be specified at the upstream end of each study stream and just downstream of confluences of other studied (i.e. modeled) tributaries regardless of change. Similarly, it is recommended that intermediate flow changes be used such that distance between flow changes not exceed two miles. The Mapping Contractor shall associate the flow change location in RAS (i.e. based on cross section station) to a specific HMS loading/report element ID. Typically the HMS loading/reporting point should be assigned to a cross section within the same subbasin at a location deemed appropriate based on engineering judgment to maintain continuity of flow at stream crossings (i.e. have same flow immediately upstream and downstream) and to account for localized drainage characteristics within the subbasin. The Mapping Contractor may consider adjustments to flow change location assignments for calibration of actual storm events (particularly smaller events) since these storms may exhibit different flow distribution characteristics than the hypothetical 1% annual chance storm.

5.3.2. Boundary Conditions

The Mapping Contractor shall use normal depth with a specified starting slope as a downstream boundary condition for all models and flow profiles (including all tributary models), except where there is an Effective study for a given study stream that continues across the County boundary. In this case, the computed water surface elevation from the Effective study in the adjacent County (in some cases may be a County in South Carolina) should be used as a "known" water surface elevation to set the boundary condition, where possible/appropriate. It is noted that flows developed in Mecklenburg Map Maintenance projects may differ significantly from those used in adjacent county studies due to difference hydrologic analysis methods, thus there may be situations where the known water surface is not appropriate to use as a boundary condition. Similarly, Mecklenburg County Map Maintenance projects will generally include several more flow profiles (e.g. 50%, 20% annual chance storms) than studies in adjacent counties. Normal depth can be used in both of these cases of significant flow disparities or "unmatched" flow profiles between different Effective studies at the County boundary.

The slopes for models/profiles using normal depth boundary conditions can be estimated from channel inverts, upstream model segments, or other engineering data as appropriate. The Mapping Contractor may need to adjust starting slopes for individual flow profiles to ensure that that the water surface profiles do not cross between the various flow profiles.

5.4. Hydraulic Calibration

Hydraulic calibration is the process of refining hydraulic model parameters based on comparisons of computed flood elevations with measured elevations from actual storms and/or estimated elevations from previous studies. In general, hydraulic calibration should be performed for the same storm events and/or Effective studies that were used in hydrologic calibration (discussed previously). However, there may be additional direct or indirect information such as property owner testimonies, insurance claims, and similar, that may also be considered to help ensure flood stages computed in the models are reasonable with actual conditions. Guidelines for hydraulic calibration are discussed below.

5.4.1. Calibration Parameters

As indicated in previous subsections many of the hydraulic parameters can be considered for adjustment during hydraulic calibration. Recommendations/Guidelines for adjustments to parameters typically considered for hydraulic calibration are provided in the following table.

Table 5-4. Typical Hydraulic Calibration Parameters

Calibration Parameter	Calibration Implementation Comments
Flow Assignment	Although not often considered as a hydraulic calibration parameter, flow assignments and/or flow change locations can be evaluated/refined specific to a calibration storm event. If calibrated hydrology is noticeably different than observed flows (e.g. > 10%), then consider adjusting flows to match observed flows in hydraulic calibration. Also, flow change locations are often generalized based on the 1% annual chance storm, which may "miss" variations in smaller storms. Adding flow change locations that may have been discarded initially may improve hydraulic calibration.
Manning's n	Often preferred calibration parameter as adjustments can be applied to channel and/or overbank locally or globally based on calibration need. Adjustments should stay within published ranges and as close as possible to "typical" values used by Mapping Contractor on other study streams.
Ineffective Flow	Most applicable near structures (i.e. Sections "2" and "3). Relatively mild adjustments can be made to ineffective stations/elevations based on refinement to contraction/expansion assumptions near structures. These adjustments can sometimes have quite noticeable impacts to computed water surface elevations. Can also be applied selectively to natural cross sections with backwater areas and/or ridges on the overbanks.
Contraction/Expansion	Best applied locally to cross sections that have atypical transitions between cross sections (e.g. near "pinch points"). Generally only mild adjustments (i.e. +/- 0.2) to recommended values are justifiable.
Structure Parameters	Applicable to single or multiple structures. Can adjust entrance/exit coefficients, Manning's n values, and others within published tolerances.

In general, parameters that simply constitute a refinement of modeling (e.g. flow change location assignments) or that are more subjective and/or have a wider range of acceptable values (e.g. Manning's n) should be considered for calibration first. As the hydraulic response of parameters to adjustments can vary significantly, it is recommended that informal sensitivity analysis be conducted to assess and help guide the calibration process. As with hydrologic calibration, the adjustment/refinement of hydraulic parameters for calibration should generally be based on physical information when possible. Global changes to hydraulic parameters can be used with caution for variables that are more subjective (e.g. using 0.06 instead of 0.05 for overbank Manning's n values to represent a low density of buildings in the floodplain). However, in all cases adjusted parameters should stay within the range of generally accepted values for a given physical condition.

5.4.2. Calibration Targets

As indicated above, the Mapping Contractor should perform hydraulic calibration to ensure computed flood stages in the models are reasonable given past flood events and/or previous studies. The following table provides general guidelines/recommendations for calibration targets. However, it is noted that there are many variable storm-specific factors that can impact the hydraulic (and hydrologic) response of a stream system. Thus, a given model that has good correlation or has a consistent tendency (e.g. generally higher/lower than observed data) with one storm may not have as good calibration, or the opposite tendency, on a different storm. In addition, hypothetical storm events used for floodplain mapping are often very different from individual calibration storms, thus, this should also be considered in assessing calibration results.

Table 5-5. Hydraulic Calibration Targets

Condition	Precedence	Calibration Targets / Notes
Calibration along Streams near Gages with Historical Flow and Stage Data	1 (Gage measured paired flows and stages at one or more locations)	Match flood elevation within 0.5'+/- preferred, but up to 1' considered reasonable. If outside 1', verify parameters and document discrepancies. If multiple gages along study stream, final calibration should also consider pattern of correlation (e.g. all high, all low, mixed).
Calibration at High Water Marks along Streams with Historical Flow Gage Data	2 (Field estimated stage, gage-extrapolated or storm modeled flow at one or more locations)	Preferred targets same as above if feasible. However, since more uncertainty in flow and elevations estimates, up to 1.5' considered reasonable. If outside 1.5', verify parameters and document discrepancies.
Calibration at High Water Marks along Streams without Historical Flow Gage Data	3 (Field estimated stage, frequency estimated flow at one or more locations)	Preferred targets same as above if feasible. However, since more uncertainty in flow estimates, up to 2' considered reasonable. If outside 2', verify parameters and document discrepancies.
Calibration along Streams with No Historic Flow or Stage Data	4 (No field data. Comparisons with Effective and/or other studies only)	No preferred targets since, as new studies may have many changes from Effective studies. However, evaluate major discrepancies greater than 3' and adjust/or justify as appropriate.

In addition to comparisons with historic storm events and previous studies, the Mapping Contractor should check the final calibrated models for instabilities (e.g. locations where model defaults to critical depths, crossing water surface elevation profiles, etc.), and make adjustments as necessary to stabilize the models.

5.5. Floodway Analysis

The floodway represents the portion of a channel or other watercourse and the adjacent land area that should be reserved/maintained in order to carry the base flood without increasing flood elevations by more than a specified maximum tolerance. In most communities, there is one floodway that is based on a maximum 1-foot surcharge tolerance. However, there are two floodways on the DFIRMs for Mecklenburg County with non-standard surcharge limits – the FEMA floodway and the Community Encroachment Area (CEA) floodway, which are described below.

5.5.1. FEMA Floodway

The FEMA floodway is the floodway recognized by FEMA. For Map Maintenance projects, the FEMA floodway shall be modeled based on a 0.5-foot maximum surcharge (rather than the typical 1-foot surcharge) based on the FEMA base flood (i.e. the 1% annual chance existing conditions discharges).

5.5.2. Community Encroachment Area

The CEA floodway is an additional floodway that is adopted and regulated at the local level. The CEA floodway shall be determined using a 0.1-foot maximum surcharge based on a "modified" 1% annual chance existing conditions discharge. This "modified" discharge accounts for loss of floodplain storage associated with potential fill to the FEMA encroachments (as developed in the previous subsection). The process to calculate the "modified" discharge is detailed in the step-by-step approach that follows. It is important to note that the CEA floodway ***is not*** related to the Community 1% annual chance floodplain (shown as shaded Zone X for most streams in Mecklenburg County). The Community floodplain is based on ***future land use conditions*** hydrology, whereas the "modified" discharge used in the CEA floodway is based on ***existing land use conditions*** hydrology.

Calculation of 'Modified' 1% Annual Chance Discharges

1) Create a new "floodplain fringe fill" RAS geometry
   Create a new RAS geometry file that shows the floodplain fringe (i.e. area outside the FEMA Floodway) as being filled or otherwise blocked off along the entire length of study stream. The potential fill can be implemented in RAS as levees, blocked obstructions, ground fill, or similar, however, it must block off all area such that there is no flow or storage beyond the limits of the FEMA floodway. Thus, the height of the "fill" must be set higher than the highest calculated elevation used in storage-discharge curves described in Step 2. It is important to note that the Mapping Contractor shall use the FEMA floodway limits developed in the previous subsection to set the "fill" limits, **not** the encroachments from the Effective study that is being updated.
2) Run family of discharges through floodplain fringe fill geometry
   Create a new RAS plan file and run family of discharges that was developed for Modified Puls channel routing (described in Section 4) through floodplain fringe fill geometry developed in Step 1 above.
3) Extract storage-outflow relationships based on floodplain fringe fill for updated hydrologic channel routing
   Extract updated storage-outflow relationships from RAS run in Step 2 for hydrologic channel routing reaches using Modified Puls methodology in HMS.
4) Create a new "floodplain fringe fill" HMS basin file
   Copy existing conditions basin file in HMS to a new basin file and update storage-discharge curves for Modified Puls routing reaches based on information compiled in Step 3.
5) Run "floodplain fringe fill" HMS basin file to calculate "modified" 1% annual flow
   Run updated model from Step 4 to create "modified" 1% annual chance existing conditions discharges. These "modified" discharges will be used in determining the CEA floodways.

Once the "modified" discharge has been developed, the Mapping Contractor shall develop a RAS flow file for the CEA floodway and input the "modified" discharge for both the natural 100-yr and the floodway flow profiles. The Mapping Contractor shall then create a plan file for the CEA floodway (named "Community Floodway") and perform the CEA floodway analysis based on a 0.1 ft surcharge. It is anticipated that the "modified" discharge will be equal to or greater than the base 1% annual discharge due to accounting for loss of storage in the floodplain fringe area. Similarly, the CEA floodway encroachments/boundary should always be as wide or wider than the FEMA floodway boundary. If the processes described above result in either one of these conditions not being met, then the Mapping Contractor shall adjust the calculated "modified" flow and/or the CEA floodway analysis to ensure the above conditions are met.

5.5.3. Floodway Analysis Guidelines and Considerations

Analysis for both floodways should utilize Method 4 with the "equal conveyance reduction" option to initially set encroachment stations. The use of channel bank offsets is left to the discretion of the Mapping Contractors, however, use of a small (< 5') bank offset is suggested. The target surcharges may then be revised and/or converted to Method 1 to finalize encroachment stations as necessary. For Map Maintenance projects a 0.04 contingency is allowed for all surcharge limits, resulting in a minimum allowable surcharge of -0.04 for both floodways and maximum allowable surcharges of 0.54 and 0.14', for the FEMA and CEA floodways, respectively. The following conditions/checks should be considered in finalizing the floodway analysis:

- The surcharges should be within allowable limits as described above.
- Encroachment stations should always be placed at or outside of the channel banks.
- The final respective floodway analysis should be "optimized" (i.e. reasonably close to maximum surcharge at majority of cross sections).
- Floodway encroachments should generally be placed within active conveyance zones (i.e. should not be placed where flow is ineffective).
- Floodway boundary should generally have smooth transitions along the study stream with gradual variations in top width between adjacent cross sections, where possible.
- Flows, flow changes, and boundary conditions are consistent between non-floodway runs and floodway runs.

As indicated above, both FEMA and CEA floodways are based on existing land use conditions hydrology. For clarity, the table below summarizes the flow profiles to be used with the various floodplain/floodway mapping elements for Map Maintenance .

Table 5-6. Flood Hazard Mapping Features and Corresponding Hydrologic Discharges

Mapping Feature	Source of Hydrologic Discharges
FEMA 1% Annual Chance Floodplain	Existing land use conditions 1% annual chance discharges
FEMA Floodway	Existing land use conditions 1% annual chance discharges
Community Encroachment Area Floodway	'Modified' existing land use conditions 1% annual chance discharges
Community 1% Annual Chance Floodplain	Future land use conditions 1% annual chance discharges

5.6. Hydraulic Report Guidelines

The Mapping Contractor shall prepare a document summarizing the hydraulic analysis. Similar to the hydrologic report, the document should include appropriate text, tables, figures, supporting digital data as necessary convey the approaches, assumptions, and results of the hydraulic analysis. The specific content and format may vary depending on Map Maintenance project, however common/recommended elements to be included in the submittal are listed below.

- Brief narrative providing overview of study (i.e. study stream(s) being studied, nature of update, model version used, etc.)

- Text describing hydraulic methodology and approach for developing all input parameters (e.g., Manning's n, etc.). Description of methodology and/or input parameters that are taken directly from this Standards Document can simply reference the Standard Document. More detailed documentation should be provided where methods or values deviate from standard engineering practice and/or guidelines in this Standards Document.
- Text and/or tables providing statistical summaries (e.g. count, minimum, maximum, average, median, total, etc. as applicable) of major input parameters to convey characteristics specific to study streams (e.g. Manning's n ranges, etc.). Parameters for individual hydraulics components (i.e. structure information at stream crossings.) can be included as appendices and/or referenced directly in RAS models.
- Tables showing correlation between RAS flow changes and HMS element IDs.
- Text and/or tabular description of hydraulic calibration data such as stage gages and high water marks.
- Figure(s) showing study streams, gages, major roads, and other major features of interest.
- Text providing description of general calibration methodology/approach.
- Text providing description and justification of adjustments made to hydraulic parameters in individual or multiple calibration storm models.
- Tables comparing simulated calculated flood elevations versus observed/measured flood elevations.
- Text providing description of adjustments made to hypothetical design storm models resulting from calibration of actual storm events.
- Tables comparing calibrated flood elevations to Effective elevations at representative locations along each study stream. Areas with significant (>3') differences should be explained.
- Text describing FEMA and CEA floodway analysis with tables comparing modified 1% annual discharge used for CEA floodway versus standard 1% annual discharge used for FEMA floodway.
- GIS files of model study streams, cross sections, stream crossing structures, overland flow paths, floodplain and floodway boundaries, and similar files pertinent to the hydraulic analysis.
- Updated HMS models with "floodplain fringe fill" models.
- RAS models and other digital files as pertinent.

6. Floodplain / Floodway Mapping and Enhanced Mapping Product Standards

This section provides local guidance and standards for floodplain and floodway boundary mapping that will ultimately be used to create the boundaries shown on the DFIRMs, as well as, generation of enhanced mapping products that will be used locally. These guidelines are intended to be supplemental in nature, thus boundary mapping should be consistent with FEMA and NCFMP guidelines, as well as, standard engineering practice.

6.1. Floodplain Boundaries

The Mapping Contractor shall create floodplain boundaries for the FEMA 1% annual chance floodplain and the Community 1% annual floodplain, unless otherwise directed by the County. The floodplain boundaries should be mapped using the same base topographic dataset that was used in the hydraulic analysis, however, there may be situations where it may be appropriate/necessary to incorporate additional topographic/site information and/or adjust mapping accordingly. The table below lists local standards and guidelines for floodplain boundary mapping. The use of automated techniques mapping is acceptable as long as the following guidelines can be met.

Table 6-1. Floodplain Boundary Mapping Guidelines

Floodplain Mapping Condition	Guidelines/Requirements
Limits of Floodplain Boundaries	FEMA 1% Annual Chance Floodplain Boundary should be clipped/truncated at most upstream hydraulic cross section at upper limit of study stream. Boundary should be mapped to natural backwater elevation along all other unmodeled tributaries. Community 1% Annual Chance Floodplain Boundary should be mapped to natural backwater elevation for both upper limit of study stream and unmodeled tributaries.
General Floodplain Boundary Shape	Boundaries for both floodplains should be consistent with the underlying topographic data, however they should be reasonably smooth and contiguous (i.e. not overly jagged/"blocky"). Discontinuous areas should generally be removed except at stream crossings with high embankments or similar. Similarly, small (< 1,000 sq ft+/-) "islands" in the floodplain should be removed.
Mapping at Stream Crossings	Overtopping For stream crossings where the structure/embankment is overtopped, floodplain mapping should be continuous across the structure/embankment. Non-Overtopping For culvert, dams, or similar structures where structure/embankment is not overtopped, the floodplain should not be mapped across the crossing (i.e. boundary is discontinuous). For bridges, the floodplain should be mapped over the structure (i.e. boundary is continuous).

Floodplain Mapping Condition	Guidelines/Requirements
Consistency with RAS Models	Floodplain boundary mapping should be consistent with RAS model results at modeled cross sections (e.g. top widths within 10%, overtopping/non-overtopping consistent between RAS profile and mapping, etc.).
Mapping near Modeled Tributary Confluences	Floodplain mapping near confluences of individual study streams should be merged together based on governing (i.e. higher) elevation of the individual stream floodplains.
FEMA versus Community Floodplain Boundary	The FEMA 1% annual chance floodplain boundary should always be inside (or equal to) the Community 1% annual chance floodplain boundary.

6.2. Floodway Boundaries

The Mapping Contractor shall create floodway boundaries for the FEMA and CEA floodways, unless otherwise directed by the County. The floodway boundaries should be mapped from connecting defined encroachment stations at each hydraulic cross section, with smooth continuous segments based on interpolated floodway widths, floodplain corridor terrain, aerials, and other base data as necessary. Straight line connections between known floodway encroachments are generally not acceptable. The table below lists local standards and guidelines for floodway boundary mapping.

Table 6-2. Floodway Boundary Mapping Guidelines

Floodway Mapping Condition	Guidelines/Requirements
Limits of Floodplain Boundaries	Boundaries for both floodways should be clipped/truncated at most upstream hydraulic cross section at upper limit of study stream (same as FEMA floodplain).
General Floodway Boundary Shape	Boundaries for both floodplains should be smooth and continuous and consistent floodplain corridor. In general, there should be no “islands” or discontinuities in floodways.
Mapping at Stream Crossings	Floodways should be mapped continuously through all stream crossings, whether floodplain is continuous or not (i.e. structure/embankment in not overtopped). In general, floodway boundary should be mapped based on connecting respective encroachment stations at bounding cross sections with straight (or near straight) line. However, floodway boundary should be within floodplain boundary where floodplain boundary is continuous. If stream crossing entails a longer closed pipe system with bends (or similar), the floodway mapping should following the alignment of the pipe at a width close to that of the pipe system. This may result in more angular floodways than normal.
Floodway Mapping Around Buildings	As a general rule of thumb, if less than 50% of the building falls within an initial floodway boundary delineation, the boundary should be modified to generally exclude the whole building, otherwise the initial floodway boundary should remain unmodified (i.e. through a 50% or more of the building).
Consistency with RAS Models	Floodway boundary mapping should be consistent with RAS model results at modeled cross sections (e.g. top widths within 25’, etc.).

Floodway Mapping Condition	Guidelines/Requirements
Mapping near Modeled Tributary Confluences	Floodway mapping near confluences of individual study streams should be merged together based on governing (i.e. wider) width of the individual stream floodplains.
FEMA versus Community Encroachment Boundary	The FEMA floodway boundary should always be inside (or equal to) the Community Encroachment floodway boundary.

6.3. Enhanced Risk Mapping Products

In addition to the traditional floodplain and floodway boundaries that are shown on DFIRM panels, several additional enhanced risk mapping products are being developed for Map Maintenance projects. Anticipated enhanced map products for Map Maintenance projects include floodplain depth rasters and velocity rasters. Descriptions and guidelines for developing these products are provided below.

6.3.1. Depth Rasters

Depth rasters store the depth of flood water over the natural ground surface for a given storm event. The information is stored in GIS-based rasters (i.e. equally sized cells) that cover the floodprone area in the channel corridor. The depth value of a given cell is calculated by subtracting the difference between the modeled flood elevation for a given storm event and the ground elevation at that same location. Depth raster should be created for all modeled storm events being developed for the Map Maintenance project, unless otherwise directed by the County. General guidelines for the development of depth rasters in the table below should be used unless otherwise directed by the County.

Table 6-3. Depth Raster Guidelines

Depth Raster Characteristics	Guidelines/Requirements
Data Format	ESRI GRID format (single band)
Cell Size	10’ x 10’ cell size
Spatial Extents	A single continuous depth grid should be created for all interconnected study streams within a watershed. The depth grid should at least cover the extents of flooding for a given storm event.
Mapping near Modeled Tributary Confluences	Depth raster values near confluences of individual study streams should be continuous and account for backwater (i.e. be based on the governing (i.e. higher) depth of the individual streams).

As the depth raster is a raster product, editing/refining of the resultant dataset is not expected, however, the Mapping Contractor is responsible for preparing input data such that the depth raster is reasonably accurate and contains no discontinuities, “waterfalls” , “jumps”, or other significant artificial anomalies. These issues can occur near tributary confluences if backwater is not accounted for properly. In addition to the depth raster, the Mapping Contractor shall also develop and provide a single ground surface raster that has same cell size and a consistent cell alignment with depth.

6.3.2. Velocity Rasters

Velocity rasters store the velocity of flood water at a given location in GIS-based rasters that cover the floodprone area in the channel corridor. The velocity value of a given cell is derived from RAS channel, left overbank, and right overbank velocity results. Velocity rasters shall use the same specifications as depth rasters as presented above, using the higher of the computed velocities around confluences.

7. Map Product Standards

This section provides standards and guidelines for the development of map products – DFIRM panels, DFIRM database (DFIRM DB), and the Flood Insurance Study (FIS). Mapping standards not discussed below should be consistent with appropriate FEMA and/or NCFMP guidelines and specifications. A list of anticipated applicable FEMA and NCFMP guidelines is provided below. It is noted that at the time of writing of this document, the NCFMP is transitioning to a new map product approach/format. This new format, referred to as Digital Display Environment (D2E), is an all digital database-driven environment. The Mapping Contractor shall confirm the latest guidelines and standards to use prior to development of map products.

DFIRM Database References

- NCFMP DFIRM Database Dictionary (May 2008).
- FEMA G&S, Appendix L: Guidance for Preparing Draft Digital Data and DFIRM Database.

DFIRM Mapping References

- NCFMP Graphical Specifications for Floodplain Mapping Contractors, Sections NC.1 through NC.11. (November 2007).
- FEMA G&S, Appendix C: Guidance for Riverine Flooding Analysis and Mapping, Sections C.6, C.7.2, and C.8.
- FEMA G&S, Appendix E: Guidance for Shallow Flooding Analysis and Mapping, Sections E.1 through E.5.
- FEMA G&S, Appendix K: Format and Specifications for Flood Insurance Rate Maps, Sections K.1 through K.2.

FIS References

- NCFMP Graphical Specifications for Floodplain Mapping Contractors, Section NC.12. Dated November 2007.
- For other specifications, FEMA G&S, Appendix J: Format and Specifications for Flood Insurance Study Reports. Sections J.1 through J.5.

7.1. Unique Local Map Product Characteristics

Mecklenburg County has a unique format for map products. This format, first implemented in the map products that became Effective in 2009, is based on the NCFMP format with several local modifications as outlined in the following table. The Mapping Contractor shall produce map products using this same unique format for Map Maintenance projects unless otherwise directed by the County.

Table 7-1. Unique Local Map Product Characteristics

Map Product/Feature	Unique Characteristics
Floodplain Mapping (applies to DFIRM, DFIRM DB, and FIS)	Future land use condition 1% annual chance storm is used for all shaded Zone X mapping in Mecklenburg County with exception of the Catawba River system, which uses the standard 0.2% annual chance storm (based on existing land use conditions). The future land use condition 1% annual chance storm is also shown on the flood profiles in the FIS.

Map Product/Feature	Unique Characteristics
Floodway Mapping (applies to DFIRM, DFIRM DB, and FIS)	Mecklenburg County has two floodways. The FEMA floodway is based on a more restrictive 0.5' surcharge (rather than typical 1'). In addition, a second Community Encroachment Area floodway based on a 0.1' surcharge using a modified flow that accounts for potential fill in the floodplain, is also mapped.
Mixed DFIRM Base Mapping (applies to DFIRMs)	Base mapping for areas within Mecklenburg County use vector-based base mapping (e.g. street edges, building footprints, etc. on clear background). For DFIRM panels along County boundary, areas in adjacent NC counties are mapped using NCFMP black and white aerial photo base mapping, resulting in "mixed base" DFIRMs.
DFIRM Flood Hazard Data Table (applies to DFIRMs)	Flood Hazard Data Table (FHDT) on DFIRMs contains additional elevations and stream offsets for the future land use conditions 1% annual chance storm and CEA floodway, respectively (in addition to information in standard NCFMP FHDTs).
DFIRM Border (applies to DFIRMs)	Mecklenburg County DFIRMs contain additional items (e.g. CMSWS logo, contacts, and reference in notes; additional legend items for additional floodplain/floodway features and benchmarks, etc.).

7.2. DFIRM Database

The Mapping Contractor shall obtain a copy of the latest Effective DFIRM database from the County and update it with any new information associated with the Map Maintenance project. In addition to updating flood hazard information (e.g. floodplain/floodway boundaries, BFEs, etc.), the Mapping Contractor should replace/update base mapping (e.g. streets, buildings footprints, political boundaries, etc.) on any revised panels with the most current data obtained from the County. For all impacted data layers/tables, the Mapping Contractor shall merge the updated features with unrevised features to form a single comprehensive Countywide layer for each respective feature type. In the case of floodplain/floodway boundaries, the merged data layers should be seamless and integrate backwater or other floodplain characteristics as necessary. Furthermore, the Mapping Contractor shall ensure proper topology is established per applicable NCFMP/FEMA guidelines. Gaps currently exist between the limit of study within Mecklenburg County and the limit of study within contiguous counties for various streams that flow in and out of Mecklenburg County. The Mapping Contractor shall identify any gaps that may impact the given Map Maintenance project and coordinate with the County and NCFMP to resolve or determine path for future resolution (e.g. addressed in future NCFMP Map Maintenance revision).

An additional aspect of merging effective and new flood hazard information is the process of identifying all Effective LOMRs and determining if they are still valid or superseded by the revision. LOMRs on non-restudied streams will still be valid and should be incorporated into DFIRMs and the FIS report. Any LOMRs on restudied streams will be superseded by the new analysis and should not be incorporated into the DFIRMs and FIS Report.

In addition to the NCFMP format database, a DFIRM database in standard FEMA format may be required for submission to FEMA when the information is submitted for Preliminary. The Mapping Contractor shall develop a Countywide DFIRM database in standard FEMA format if required. Conversion tools may be available from the County or NCFMP to assist in the conversion process.

7.3. DFIRM Panels

Once all of the Effective and new data is merged in the DFIRM database, the Mapping Contractor shall develop revised DFIRMs for the panels that are impacted by the Map Maintenance project (including the Index panel) using appropriate NCFMP/FEMA mapping specifications. New floodplain hazard/mapping information (e.g. BFEs, FHDTs, cross sections, annotation, etc.) should be used to replace/update Effective information for all restudied streams. The Mapping Contractor shall coordinate with the County to obtain the DFIRM panel and index templates (i.e. ArcMap MXD files or equivalent) in order to maintain consistency and facilitate DFIRM production.

7.4. FIS

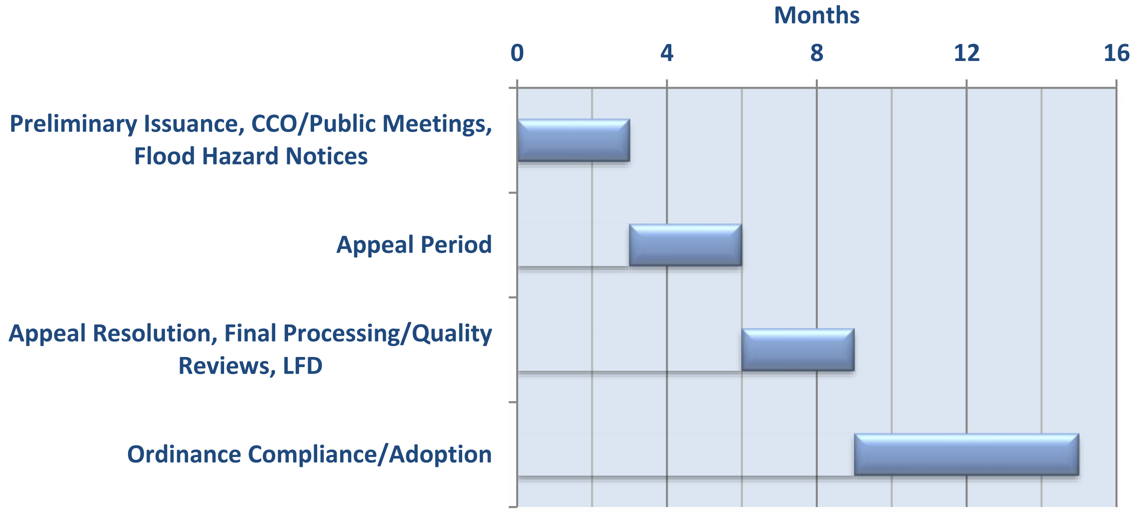
The FIS Report must be updated to merge Effective and new flood hazard information as part of each Map Maintenance project. The current Effective FIS has five volumes, with narrative text in Volume 1, Floodway Data Tables (FDTs) in Volume 2, and profiles in Volumes 3 - 5. The Mapping Contractor shall coordinate with the County to obtain an editable version (i.e. Microsoft Word and AutoCAD) of the latest FIS text and profiles. The Mapping Contractor shall update any portions that are impacted by the Map Maintenance project. Anticipated sections/elements of the FIS that will likely need to be updated are listed in the table below, however, the Map Contractor should review all sections/elements to determine if additional modifications are appropriate.

Table 7-2. Typical FIS Changes

FIS Section/Element	Unique Characteristics
Introductory Pages (Cover, Table of Contents, Notes, etc.)	Update Effective dates, page references, and similar.
Table of Flooding Sources	Update study limits and stream lengths as appropriate.
Letters of Map Revisions	Update table with new LOMRs since previous FIS issuance.
Hydrologic Analysis (Section 5.1)	Add new subsection titled "Revised Analyses for this FIS" or similar with date and add narrative of updated hydrologic analysis. Any approaches/methods that are different from hydrologic analysis text already in FIS will need to be documented. Update "Summary of Discharges" table (and "Summary of Stillwater Elevations" if applicable).
Hydraulic Analysis (Section 5.2)	Add new subsection titled "Revised Analyses for this FIS" or similar with date and add narrative of updated hydraulic analysis. Any approaches/methods that are different from hydrologic analysis text already in FIS will need to be documented. Update "Roughness Coefficients" table.
Base Map (Section 6.2)	Update base map reference sources and date.
Map Revision History (Section 7.5)	Update revision dates.
Authority and Acknowledgments (Section 8.1)	Update text and tables with dates and Map Contractor information.
Floodway Data Tables (Volume 2)	Update flood hazard information for any restudied streams.
Flood Profiles (Volumes 3 – 5)	Update/Replace flood profiles and associated data (i.e. stream crossing information) for any restudies streams. In general, profiles should be recreated at same scale as previous Effective profiles.

8. Preliminary / Post-Preliminary / Map Adoption

This section provides general anticipated logistics for the Preliminary, Post-Preliminary, and Map Adoption processes prior to the Map Maintenance updates becoming Effective. The graph below shows general typical timelines for this final stage of implementing Map Maintenance projects.



The Map Contractor shall assist the County with the issuance of Preliminary map products and subsequent FEMA processes. General anticipated Mapping Contractor involvement is outlined below, however, the specific involvement in each of the tasks listed will be determined by the scope of work for the given Map Maintenance project.

8.1. Issuance of Preliminary Map Products

The Mapping Contractor will submit map products to the County for final review. A preliminary Summary of Map Actions (SOMA), prepared by the Mapping Contractor, will be included with the Preliminary map products. The SOMA includes pertinent information of all Letters of Map Change (LOMC) located on the panels that are undergoing revision that will help the community with the validation of such LOMCs to maintain the FIRM. The Mapping Contractor shall then coordinate with the County to upload necessary information and data to the Mapping Information Platform (MIP) and assist with the release of notifications to County officials and the community about the issuance of Preliminary map products for public review. The Mapping Contractor may also need to coordinate with the NCFMP and adjacent county/state agencies for panels along the County border.

8.2. Post-Preliminary and Map Adoption

Once the Preliminary map products are issued for public review, the Mapping Contractor will assist the County with public meetings, preparation and release of required flood hazard determination news, as well as, its publication on FEMA's website for public review. This process is required to start the corresponding appeal period. The Mapping Contractor will assist with evaluating and preparing a resolution of appeals per the scope for the given Map Maintenance project. Once appeals and protests are resolved, the Mapping Contractor will coordinate with the County for preparation and submission of FIRM products for final reviews to assure that any necessary revisions comply with applicable standards. The Mapping Contractor will prepare and coordinate the issuance of the Final SOMA and Letter(s) of

Final Determination (LFD) to start the 6-month compliance period, and the preparation and submission of final FIRM products for public distribution.

References

National Oceanic and Atmospheric Administration (NOAA) / United States Army Corps of Engineers (USACE). Hydrometerological Report No. 51. Probable Maximum Precipitation Estimates, United States East of the 105th Meridian. 1978 (Reprinted 1980)

Soil Conservation Service (SCS) (now NRCS). Technical Release 55, Urban Hydrology for Small Watersheds. 1986

USACE. HEC-RAS River Analysis System Hydraulic Reference Manual. 2010 (or latest edition)

USACE. Hydrologic Modeling System HEC-HMS Technical Reference Manual. 2000 (or latest edition)

United States Geological Survey (USGS). WSP-2339, Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. 1990

USGS. SIR 2006-5017, Frequency of Annual Maximum Precipitation in the City of Charlotte and Mecklenburg County, North Carolina, through 2004. 2006

Appendix A –

Analysis and Mapping Standards Summary Table

Analysis and Mapping Standards Summary Table

Mecklenburg County Map Maintenance
March 2012

Item / Feature	Guidelines / Standards	Document Reference
	DATA COLLECTION / PROCESSING	
Base Data (aerials, LiDAR, streets, etc.)	Obtain and/or coordinate with County to obtain latest data for base mapping	Section 3.1
Existing Land Use	Use layer maintained by CMSWS as base layer. Verify and update based on aerials and development plan. Modify by adding ROWs and separating non-detached multi-family.	Section 3.2.1 and Appendix A
Future Land Use	Use layer maintained by C-M Planning Dept as base layer. Translate to existing land use codes, create ROWs, modify "no change" areas, and develop for areas outside ETJ (if necessary).	Section 3.2.2 and Appendix A
Study Streams	Use Effective streams as base. Verify and/or update alignment based on latest aerials, survey, or similar data.	Section 3.3.1
Study Stream Crossings	Review latest aerials, Effective models, and other pertinent data to locate and attribute all stream crossings to be modeled and flag crossings where field surveys are necessary.	Section 3.3.2 and Appendix B
Floodplain Development Projects	Coordinate with County to identify projects with study area floodplains (through permit tracking) and evaluate need to incorporate into modeling/mapping.	Section 3.3.3
Field Survey - Channel Cross Sections	Identify locations for channel cross section survey using approximate 1,100 ft average spacing. Coordinate with County on location and number. May use combination of survey-grade and non-survey grade techniques. Use FEMA Data Capture Standards for field measurements/coding.	Section 3.4.1
Field Survey - Stream Crossings	Survey new/modified stream crossings identified in verification process. Generally use survey-grade except for minor crossings with minimal impacts. Use FEMA Data Capture Standards for field measurements/coding.	Section 3.4.2
	HYDROLOGIC ANALYSIS	
Hydrologic Model	Latest version of HEC-HMS, with appropriate basin files, meterologic models, and control specifications.	Section 4.1.1
Hypothetical Storm Simulation	Run 50%, 20%, 10%, 4%, 2%, 1%, and 0.2% annual chance, and the 1/3 PMP with 24-hr SCS Type 2 simulation using total depths specified, and following SCS methodology.	Section 4.1.2

Item / Feature	Guidelines / Standards	Document Reference
Subbasin Delineation	Delineate as appropriate for modeling. Anticipated median size in watershed between 60 – 100 ac, but individual size can range more widely (typically 30 – 300 acres). Generally smaller in urbanized headwater basins and large in rural basins or along study stream where relative impact of subbasin is less on flow in study stream.	Section 4.2.1.1
Time of Concentration / Lag Time	Use general TR-55 methodology. Simplifications acceptable. Use standard conversion of 0.6*Tc to calculate lag time. However, Tc and Tlag parameters subject to adjustment during calibration.	Section 4.2.1.2
Curve Number	Develop from underlying land use and soil using lookup table provided. CNs provided account for %impervious so enter as zero. Should verify by independently calculating %impervious from impervious surface dataset. CN subject to adjustment during calibration	Section 4.2.1.3
Initial Abstraction	Use standard Ia = 02.S, however subject to adjustment during calibration	Section 4.2.1.3
Channel Routing	Use Modified for channel routing along study stream reaches, obtaining storage-discharge information from HEC-RAS models. For channel routing in non-study stream headwater reaches can use simplified method. Channel routing subject to adjustment during calibration.	Section 4.2.2.1
Storage/Pond Routing	Consider headwater ponds greater than 0.5 acres with drainage area greater than 100s for pond/storage routing. Add based on engineering adjustment. Do no model ponds/storage areas along study stream (since accounted for in Modified Puls routing) unless has excessive backwater condition. Storage routing subject to adjustment during calibration – generally decision to include or exclude routing is means of calibration.	Section 4.2.2.2
Hydrologic Calibration	Identify 2 – 3 appropriate storms (preferably similar characteristics as hypothetical storm with higher end and lower end magnitudes). Calibrate parameters as discussed in document. Preferred correlations are: within 10% peak, 30 minutes time to peak, and 15% volume. However, matches outside these tolerances are acceptable with appropriate justification.	Section 4.3
Hydrology Report / Submittals	Include narrative, text, tables, models, and other supporting information as outlined.	Section 4.4
HYDRAULIC ANALYSIS		
Hydraulic Model	Latest version of HEC-RAS, with appropriate geometry, flow, and plan files.	Section 5.1.1
Hypothetical Storm Simulation	Run for same 8 hypothetical storms as run for hydrology, plus 2 (FEMA and Community Encroachment Area) floodway runs. Use default settings.	Section 5.1.2
Hydraulic Cross Section Location	Locate/Align as appropriate for modeling. Generally overall spacing between 200 – 400', not to exceed 800'. Put four cross sections around significant stream crossings per RAS Manual.	Section 5.2.1
Cross Section Channel Banks	Assigned from survey, topo, and/or aerials as appropriate.	Section 5.2.2.1

Item / Feature	Guidelines / Standards	Document Reference
Reach Lengths	Center reach length should be equal to difference in stationing. Left and right overbanks should be based on digitized lines that approximate flowpath of flood flows – typically ¼ - ¾ distance from channel to edge of floodplain.	Section 5.2.2.2
Roughness Coefficients	Manning's n based on standard published values. Use horizontal variation in overbanks. Manning's n values should be adjusted to consider impact from development (e.g. buildings, etc.) or projects in stream (e.g. stream restoration) where applicable. Roughness coefficients subject to adjustment during calibration.	Section 5.2.2.3
Blocked Obstructions	Generally not to be used except in limited cases where large buildings comprise significant obstruction to floodplain area. Incorporate obstructions in most cases with adjustment to Manning's n values.	Section 5.2.2.3
Contraction Expansion Coefficients	Use default 0.1 and 0.3 for natural cross sections, and 0.3 and 0.5 for two immediate upstream and one immediate downstream cross section. Coefficients subject to adjustment during calibration.	Section 5.2.2.4
Ineffective Flow Areas	Use at structures per RAS Manual. Assumptions of 1:1 for contraction and 1.5:1 for expansion in setting horizontal stations generally reasonable. Elevations should be set near minimum overtopping elevation. Ineffectives at natural cross sections generally limited to cross sections with continuous high ground/ridges or significant backwater areas.	Section 5.2.2.5
Stream Crossings / Structures	Follow general RAS Manual procedures/standards. Information for most structure will likely be obtained from Effective models. For complex structures/systems may need to adjust standard techniques and compare with other methods/models as appropriate.	Section 5.2.3
Flow Changes	Consider all HMS flow loading points along study stream as potential. May remove changes with change in flow <10%. However, at a minimum, flow changes should be specified at the upstream end of each study stream and just downstream of confluences of other studied (i.e. modeled) tributaries regardless of change. Recommend maximum distance between flow changes (regardless of %change) of 2 miles.	Section 5.3.1
Boundary Conditions	Use normal depth with estimate starting slope for all models/profiles except where there is an Effective study for a given study stream that continues across the County boundary. For this case use known elevation.	Section 5.3.2
Hydraulic Calibration	Calibrate to same storms considered for hydrologic calibration. Calibrate parameters as discussed in document. A preferred correlation is within 0.5', however, up to 2' can be considered reasonable where calibration data is available, and up to 3' for comparison to Effective. Provide justification for deviations outside tolerance.	Section 5.4
FEMA Floodway	0.5' surcharge using base 1% annual chance discharge. 0.04 allowance on min/max surcharges.	Section 5.5.1
CEA Floodway	0.1' surcharge using "modified" 1% annual chance discharge. 0.04 allowance on min/max surcharges.	Section 5.5.2

Item / Feature	Guidelines / Standards	Document Reference
Hydraulic Report / Submittals	Include narrative, text, tables, models, and other supporting information as outlined.	Section 5.6
	MAPPING	
Floodplain Boundaries	Create floodplain boundaries for FEMA (existing conditions) and Community (future conditions) 1% annual storm. See report for boundary standards	Section 6.1
Floodway Boundaries	Create floodway boundaries for FEMA (base discharge) and CEA (modified discharge) floodways.	Section 6.2
Depth Rasters	Seamless layer of 10' x 10' cells that account for backwater near tributaries	Section 6.3.1
Velocity Rasters	Seamless layer of 10' x 10' cells that have use governing velocities near tributaries	Section 6.3.2
	MAP PRODUCTS	
DFIRM Database	Seamless countywide database that is compliant with NCFMP/FEMA guidelines (where applicable), however, that account for local characteristics.	Section 7.2
DFIRMs	Uses same format as Effective maps from 2009 (mixed-base).	Section 7.3
FIS	Updated/Added sections/components to form seamless document.	Section 7.4

Appendix B –

Land Use Processing Instructions

Existing and Future Conditions Land Use Processing Guidelines

Mecklenburg County Map Maintenance
December 2011

Overview: Instructions for processing base existing and future conditions land use layers for hydrologic analysis in Map Maintenance Projects.

<u>Existing Land Use</u>

Background: The base existing conditions land use layer to be used for this project is a county-wide layer developed/maintained by CMSWS (City- Administrative/GIS Services Division – contact Keri Shearer). The layer is regularly maintained from aerial photography and development plans. The layer is relatively detailed with boundaries being generally accurate to the acre level. Polygons of same land use classification have been merged (e.g. polygons are not at parcel level), so "typical" size is 20 acres or less. Contiguous wooded area polygons can be considerably larger. Conversely, larger parcels (e.g. schools, parks, etc.) have been subdivided by actual land cover even though on one parcel (e.g. large wooded and open space areas are coded separately from built-upon areas). Streets (except for major thoroughfares, and included in predominate adjacent land use (e.g. streets in residential neighborhoods are coded as residential rather than being broken out separately as streets). Land use is classified under 12 categories under the numeric 'LUSECODE' attribute as described below:

LUSECODE	Description	Notes
1	Woods/Brush	Woods, vegetated fields, etc.
2	>2 Acre Residential & Open Space	Farms, golf courses, fields, etc.
3	0.5 to 2 Acre Residential	Primarily single family residential
4	0.25 to 0.5 Acre Residential	Primarily single family residential
5	<0.25 Acre Residential	Primarily single family residential, but includes condos/apartment complexes and similar
6	Institutional	Schools, hospitals, government offices, etc.
7	Industrial – Light	Warehouses, etc.
8	Industrial – Heavy	Terminal transfer, etc.
9	Commercial – Light	Office parks, hotels, multi-family > 6 DUA, apartments, etc.
10	Commercial – Heavy	Car parks, malls, etc.
11	Water Bodies	Usually ponds > 2 acres in size
12	Transportation	Right-of-way for major thoroughfare/interstates. Does not include arterial/collector streets – those are integrated with predominate adjacent land use.

Processing Instructions for Application to Floodplain Analysis:

1. Obtain latest layer from CMSWS (City)

2. Clip land use to study area clip boundary (usually set to be 500'+/- beyond preliminary study watershed boundaries).
3. Manipulate attribute fields to result in database design below. Populate 'LUCodeOrg', 'LUCode', 'LUSource', and 'DateCrrnt' fields. Initially calc 'LUCode' = 'LUCodeOrg'; LUSource' = "City SWS"; and 'DateCrrnt' equal to date file received/updated from City.

Field Name	Data Type	Description
LUCodeOrg	Number (Integer)	Original LUSECODE as Assigned by City SWS
LUCode	Number (Integer)	Final LUSECODE for Floodplain Mapping
LUDesc	Text (50 char width)	Land Use Code Full Text Description
LUSource	Text (20 char width)	Source of Final Land Use Code Designation
DateCrrnt	Date	Date Current of Land Use Code (i.e. Last Updated/Modified)
Notes	Text (100 char width)	Notes Related to Land Use Modifications
PctImpv	Number (Integer)	Assumed/Estimated Percent Impervious

4. Separate out true multi-family residential properties (non-detached, complex type buildings) classified as LUCode = 5 and recode to them to LUCode = 9 (i.e. Commercial – Light) . Recommended process for doing this is outlined below:
   - Using most tax parcels layers, select features that are identified as condominiums, town houses, or apartments using the following statement below in ArcMap. Export selected features to a separate feature class.

     "cdeBuildin" in ('04', '06', '09', '60', '61', '63')

     (Note: This should give similar results to "DescProper" in ('Condominium', 'Multi-Family'), but that may selection set may also include nursing home and assisted living parcels.)

   - Select 'LUCode' = 5 (i.e. <0.25 residential properties).
   - Using 'Select by Location' functions, select from currently selected features that intersect exported . Save selection as a temporary separate feature class.
   - Review resultant land use features with aerials in background. Update LUCode where appropriate for non-detached condo/townhouse/apt complexes – keep LUCodeORG the same. In some cases, may need to edit landuseEX_working boundaries. Update LUSource, DateCrrnt, and Notes.

     NOTE: DO NOT simply update all land use polygons that intersect condo/townhouse/apt parcels without reviewing them, as the layer boundaries may have small overlaps/gaps, so the selection by location procedure will likely select some polygons that you do not want to change.
5. Create and "burn in" right-of-ways (ROW)
   - Using clipped ***future*** land use layer, create closed polygons for ROW areas (i.e. the future land use layer does include polygons for many right-of ways – there are gaps in the GIS layer) and populate them as LUCode = 12.
   - Select newly created ROW polygons and export to a separate feature class. If study area is within future land use limits add and populate land use attributes (in table above). If study limits extends outside of limits of future land use layer, will have to create ROW for those portions using similar process with parcels layer.

- Update/Replace polygons in existing land use ("input features") with ROW polygons ("update features"). Populate fields in resulting new feature class (i.e. Source, DateCrrnt, Notes, LuCodeORG, etc.).

6. Conduct land use accuracy spot checks
    - Obtain "Preliminary Plans" layer from County GIS showing development areas (sometime past and future) and verify land use depicts development that has occurred. Update land use as appropriate and populate notes column. Generally if aerials show site is cleared and roads are built, ok to depict as developed.
    - Identify cemeteries greater by than 1 ac and confirm they are shown as open space. Can use parcels layer to help identify cemeteries by selecting 'ParLegalDe' Like '%CEMETERY'%'. Update land use as appropriate and populate notes column.
7. Conduct database integrity/consistency checks
    - Make sure that attributes are fully populated:
        i. 'LUCode' - All polygons are populated with values from 1 – 12
        ii. 'LUCodeORG' - All polygons are populated with 1 – 12 (for polygons in original City land use layer) or -9999 for ROWs or new created polygons outside City layer.
        iii. 'LUSource' - All polygons are populated. Typically large majority of polygons will have source of 'City SWS' (i.e. unedited polygons). Generally speaking, any polygons where LuCode <> LuCodeORG should have source of "Baker" or potentially hyphenated name. Values should be standardized as well so only have minimum (generally 2 – 4) unique source names across dataset.
        iv. 'DateCrrnt' - All polygons are populated. Typically large majority of polygons will have date from source of City SWS polygons. Anything edited should have date after that. Make sure no bogus dates.
        v. 'Notes' – Any polygons that have been edited (i.e. LuCode <> LuCodeORG) should have a note (e.g. ROW updates, aerial update, etc.). Non-edited polygons will typically have blank or null. Values should be standardized so have minimum number of unique notes (would generally expect < 10 unique notes).
        vi. 'ORIG_FID' – All polygons should be populated with number greater than zero or -9999 for new on non-applicable polygons.
    - Conduct geometry cleaning and topology checks:
        i. Use GIS to confirm that there are no gaps or overlaps in data.
        ii. Not essential, but recommend to converting any multi-part polygons to single part.
        iii. Not essential, but recommend merging sliver polygons (generally <0.1 acres or smaller).

<u>Future Land Use</u>

Background: The future land use layer developed by the Charlotte-Mecklenburg County Planning Department is to be used as the "basis" for the future land use on the Project. This layer is believed to be the best available data at large scale. The future land use is a compilation of land use sources/decisions listed below. Sources are listed are listed in order from lower to higher precedence (i.e. items lower in the list supersede those above it).

- District plans – largest scale and most general land use plan adopted by City Council. 7 district plans cover City ETJ.

- Area plans – more detailed City Council adopted land use plans that encompass several neighborhoods (generally 1 – 5 sq mi area). Area plans are developed and adopted to update district plans for specific areas as needed. They are not necessarily contiguous and do not cover entire ETJ.
- Approved rezoning cases – parcel level land use updates based on Council approved rezoning.
- FEMA floodplain areas – areas within Effective FEMA 100-yr floodplain boundaries. All areas in this category have been classified as greenway/open space.

Area plans and rezoning cases have relatively high level of public involvement while district plans (originally developed in the early to mid 1990's) had limited public involvement/approval. The future land use layer is categorized into multiple (can be as many as ninety) groups.

Processing Instructions for Application to Floodplain Analysis:

1. Obtain latest layer from C-M Planning Commission
2. Clip land use to study area clip boundary (usually set to be 500'+/- beyond preliminary study watershed boundaries).
3. Manipulate attribute fields to include fields below and populated accordingly.

Field Name	Data Type	Description
District	Text (10 char width)	General Planning District
PlanName	Text (50 char width)	Name of Adopted Plan
AdoptDate	Date	Adoption Date of Plan
AdoptType	Text (14 char width)	Type of Adoption (i.e. District, Area, Rezoning, etc.)
PropLuseCd	Text (25 char width)	Adopted Proposed Land Use Code
PropLuseTx	Text (75 char width)	Adopted Proposed Land Use Full Text
Density	Number (Double)	General Density for Residential Component
ZoneDes	Text (15 char width)	Zoning Designation (for Rezonings only)
RezoneDate	Date	Rezoning Date Approval (
LUCodeOrg	Number (Integer)	Original LUSECODE as Assigned by City SWS
LUCode	Number (Integer)	Final LUSECODE for Floodplain Mapping
LUDesc	Text (50 char width)	Land Use Code Full Text Description
LUSource	Text (20 char width)	Source of Final Land Use Code Designation
DateCrrnt	Date	Date Current of Land Use Code (i.e. Last Updated/Modified)
Notes	Text (100 char width)	Notes Related to Land Use Modifications
PctImpv	Number (Integer)	Assumed/Estimated Percent Impervious

4. Convert future land use categories to "equivalent" existing land use categories using translation table at back of this document. If any non-matches, assign translation.
5. Create/Incorporate ROW polygons
    - Follow steps described in existing land use development – can either create by closing boundaries or integrating ROWs that were previously created
6. Identify and create "No Change" area polygons. These are areas that based on previous discussions and land use task force meeting that are to be assumed should not change in the

future. The current process will be to overwrite the future land use with the existing land use in these areas (or otherwise verify they are already similar/same). Note that some areas may meet more than one "no change" classification (e.g. park area in floodplain).

- Identify polygons in base future land use layer altered from being in floodplain
    i. Select polygons with 'AdoptType' = "FEMA" (i.e. most of these should have a 'PrpLuseCd' of "GREENWAY" or "WATER").
    ii. Export these polygons to a new temporary layer.
    iii. Add a field called 'AreaType' (String, 100) and calc as "FEMA"
- Identify Park & Rec properties
    i. Obtain latest Park & Rec properties from County GIS - these should include parks, greenways, nature preserves, public golf courses, etc.)
    ii. Select properties in study area and export to new temporary layer.
    iii. Add a field called 'AreaType' (String, 100) and calc as "Park Properties"
- Identify Catawba Land Conservancy properties
    i. Obtain latest Catawba Land Conservancy (CLC) properties from CLC or County GIS.
    ii. Select properties in study area and export to new temporary layer.
    iii. Add a field called 'AreaType' (String, 100) and calc as "Catawba Land Conservancy"
- Identify developed residential properties
    i. Select developed properties from working existing land use layer using general expression below. This captures multi-use residential that had been recoded as part of steps above, in addition to established neighborhoods. 'LUCode' in (3,4,5) OR ('LUCode' = 9 AND 'LUCodeOrg' = 5).

        NOTE: If there are lots of non-contiguous properties with 'LuCode' = 3 (i.e. are not really neighborhoods, consider removing from selection as these may be more likely to be developed).
- Identify developed residential properties
    i. Select developed properties from working existing land use layer using general expression below. This captures multi-use residential that had been recoded as part of steps above, in addition to established neighborhoods. 'LUCode' in (3,4,5) OR ('LUCode' = 9 AND 'LUCodeOrg' = 5).
    ii. Select properties in study area and export to new temporary layer.
    iii. Add a field called 'AreaType' (String, 100) and calc as "Developed Residential"
- Identify cemetery properties
    i. Export cemeteries as previously identified during existing conditions land use processing and export to new temporary layer.
    ii. Add a field called 'AreaType' (String, 100) and calc as "Cemetery"
- Identify golf course properties
    i. Identify golf courses. Can use parcels to aide by selecting 'Neighborh' = "GOLF COURSES".
    ii. Select properties in study area and export to new temporary layer.
    iii. Add a field called 'AreaType' (String, 100) and calc as "Golf Course"
- Identify R111 properties:
    i. Select parcels with 'LandUseCod' = "R111" that are >1 acre
    ii. Export to new temporary layer.
    iii. Add a field called 'AreaType' (String, 100) and calc as "R111 Properties"

- Identify and separate out any additional "no change" areas as agreed upon by County, land use task force, or similar.
- Combine all individual "no change" layers into one layer.
    i. Use 'Union' command in ArcToolbox to append/intersect individual layers (need ArcInfo license to be able to do more than 2 at one time). The union will create a new layer with 'AreaType' and multiple AreaType deviations (e.g. AreaType1) since the field exist in all individual "no change" layers.
    ii. Combine/Clean-up attribute fields such that it is easy to tell all underlying "no change" areas in attribute. One approach is to update original 'AreaType' field to include all "no change" descriptions. This can be done by series of attribute selections and field calculations in ArcMap. Polygons with multiple underlying no change designations should be concatenated separated by semi-colons (e.g. "FEMA; Golf Course; Park Properties").
    iii. The resulting final layer should have all "no change" areas boundaries and applicable "no change" designations. No other attributes are necessary.

7. Clip working existing land use with combined "no change" layer.
8. Use 'Update' function in ArcToolbox under 'Analysis Tools/Overlay' (need ArcInfo license) to update/replace polygons in future land use ("input features") with existing land use in "no change" areas.
9. Conduct database integrity/consistency checks similar to as described for existing land use.
10. Create future land use for any study area that is outside of limits of base future land use mapping (i.e. outside ETJ). Any newly created areas will need to have same data format/assumptions and merged with base layer to form single comprehensive future land use for study area. Potential data sources include existing land use coverage, the 2015 land use file that was used for the current Effective mapping, aerial photographs, City/County zoning layers, land use information from other municipalities in the County, and others. The mapping contractor shall coordinate with CMSWS to assess the most appropriate data source for developing future land use beyond the City ETJ.

Future Land Use Translation Table

Future Land Use Code (PropLuseCd)	Future Land Use Code Description (PropLuseTx)	Translated Land Use Code (LUCode)	Translated Land Use Description (LUDesc)
GREENWAY	GREENWAY	2	>2 Acre Residential & Open Space
IND1	INDUSTRIAL	8	Industrial - Heavy
IND2	INDUSTRIAL - LIGHT	7	Industrial - Light
IND3	INDUSTRIAL - HEAVY	8	Industrial - Heavy
INST	INSTITUTIONAL	6	Institutional
INST_CH	INSTITUTIONAL_CHURCH	6	Institutional
INST_MED	INSTITUTIONAL_MEDICAL	6	Institutional
MF	MULTI-FAMILY	9	Commercial - Light
MF12	MULTI-FAMILY <= 12 DUA	9	Commercial - Light
MF17	MULTI-FAMILY <= 17 DUA	9	Commercial - Light
MF22	MULTI-FAMILY <= 22 DUA	9	Commercial - Light
MF25	MULTI-FAMILY <= 25 DUA	9	Commercial - Light
MF8	MULTI-FAMILY <= 8 DUA	9	Commercial - Light
MFGT25	MULTI-FAMILY > 25 DUA	9	Commercial - Light
MH	MOBILE HOME	3	0.5 to 2 Acre Residential
MIX1	SINGLE FAMILY/MULTI-FAMILY	9	Commercial - Light
MIX10	SINGLE FAMILY/MULTI-FAMILY/INSTITUTIONAL/OFFICE/RETAIL	9	Commercial - Light
MIX11	MULTI-FAMILY/OFFICE	9	Commercial - Light
MIX12	MULTI-FAMILY/LIMITED RETAIL	9	Commercial - Light
MIX13	MULTI-FAMILY/RETAIL	9	Commercial - Light
MIX14	MULTI-FAMILY/UTILITY	9	Commercial - Light
MIX15	OFFICE/INDUSTRIAL-WAREHOUSE-DISTRIBUTION	7	Industrial - Light
MIX16	MULTI-FAMILY/OFFICE/RETAIL	9	Commercial - Light
MIX17	RESEARCH/OFFICE/RETAIL	7	Industrial - Light
MIX18	INSTITUTIONAL/PARK	6	Institutional
MIX19	OFFICE/RETAIL	9	Commercial - Light
MIX2	SINGLE FAMILY/OFFICE	9	Commercial - Light
MIX20	OFFICE/INDUSTRIAL	7	Industrial - Light
MIX21	MULTI-FAMILY/GREENWAY	3	0.5 to 2 Acre Residential
MIX22	MULTI-FAMILY/RESEARCH	9	Commercial - Light
MIX23	MULTI-FAMILY/OPEN SPACE	3	0.5 to 2 Acre Residential
MIX24	MULTI-FAMILY > 12 /OFFICE/RETAIL	9	Commercial - Light
MIX25	MULTI-FAMILY > 12 /OFFICE/RETAIL/INDUSTRIAL	9	Commercial - Light
MIX26	OFFICE/RETAIL/INDUSTRIAL-WAREHOUSE-	9	Commercial - Light

Future Land Use Code (PropLuseCd)	Future Land Use Code Description (PropLuseTx)	Translated Land Use Code (LUCode)	Translated Land Use Description (LUDesc)
	DISTRIBUTION		
MIX27	SINGLE FAMILY/MULTI-FAMILY/INSTITUTIONAL/OFFICE	9	Commercial - Light
MIX28	MULTI-FAMILY/INSTITUTIONAL/OFFICE/RETAIL	9	Commercial - Light
MIX29	MULTI-FAMILY/INSTITUTIONAL/OFFICE	9	Commercial - Light
MIX3	SINGLE FAMILY/MULTI-FAMILY <= 8 DUA	9	Commercial - Light
MIX30	INSTITUTIONAL/OFFICE/RETAIL	9	Commercial - Light
MIX33	INSTITUTIONAL/OFFICE	9	Commercial - Light
MIX34	OFFICE/WAREHOUSE	7	Industrial - Light
MIX35	OFFICE/RETAIL/LIGHT INDUSTRIAL	7	Industrial - Light
MIX36	INSTITUTIONAL/RETAIL	9	Commercial - Light
MIX4	SINGLE FAMILY/MULTI-FAMILY/OFFICE	9	Commercial - Light
MIX5	SINGLE FAMILY/MULTI-FAMILY/INSTITUTIONAL	9	Commercial - Light
MIX6	SINGLE FAMILY/MULTI-FAMILY/RETAIL	9	Commercial - Light
MIX7	SINGLE FAMILY/OFFICE/RETAIL	9	Commercial - Light
MIX8	SINGLE FAMILY/MULTI-FAMILY/RESEARCH/RETAIL	9	Commercial - Light
MIX9	SINGLE FAMILY/MULTI-FAMILY/OFFICE/RETAIL	9	Commercial - Light
N/A	N/A	9	Commercial - Light
OFFICE1	OFFICE	9	Commercial - Light
OFFICE2	OFFICE/BUSINESS PARK	9	Commercial - Light
OFFICE3	OFFICE/BUSINESS PARK/RESEARCH	9	Commercial - Light
OFFICE4	OFFICE/BUSINESS PARK/LIGHT INDUSTRIAL	9	Commercial - Light
OFFICE5	OFFICE/BUSINESS PARK/INDUSTRIAL	9	Commercial - Light
OPSPACE	PARK/OPEN SPACE	2	>2 Acre Residential & Open Space
PARKING	PARKING	12	Transportation
PRIVREC	PRIVATE RECREATION	2	>2 Acre Residential & Open Space
RES_OFF	RESIDENTIAL/OFFICE	5	<0.25 Acre Residential
RES_OFF_RETAIL	RESIDENTIAL/OFFICE/RETAIL	9	Commercial - Light
RES_RETAIL	RESIDENTIAL/RETAIL	9	Commercial - Light
RES12_OFF	RESIDENTIAL <= 12 DUA/OFFICE	9	Commercial - Light
RES22_OFF	RESIDENTIAL/OFFICE	9	Commercial - Light
RESEARCH	RESEARCH	9	Commercial - Light
RESID	RESIDENTIAL	4	0.25 to 0.5 Acre Residential
RESID12	RESIDENTIAL <= 12 DUA	9	Commercial - Light

Future Land Use Code (PropLuseCd)	Future Land Use Code Description (PropLuseTx)	Translated Land Use Code (LUCode)	Translated Land Use Description (LUDesc)
RESID17	RESIDENTIAL <= 17 DUA	9	Commercial - Light
RESID22	RESIDENTIAL <= 22 DUA	9	Commercial - Light
RESID4	RESIDENTIAL <= 4 DUA	4	0.25 to 0.5 Acre Residential
RESID5	RESIDENTIAL <= 5 DUA	4	0.25 to 0.5 Acre Residential
RESID6	RESIDENTIAL <= 6 DUA	9	Commercial - Light
RESID8	RESIDENTIAL <= 8 DUA	9	Commercial - Light
RESIDGT22	RESIDENTIAL > 22 DUA	9	Commercial - Light
RETAIL	RETAIL	10	Commercial - Heavy
SF1	SINGLE FAMILY <= 1 DUA	3	0.5 to 2 Acre Residential
SF3	SINGLE FAMILY <= 3 DUA	4	0.25 to 0.5 Acre Residential
SF4	SINGLE FAMILY <= 4 DUA	4	0.25 to 0.5 Acre Residential
SF5	SINGLE FAMILY <= 5 DUA	5	<0.25 Acre Residential
SF6	SINGLE FAMILY <= 6 DUA	5	<0.25 Acre Residential
SF8	SINGLE FAMILY <= 8 DUA	9	Commercial - Light
TOD-E	TRANSIT ORIENTED DEVELOPMENT - EMPLOYMENT	10	Commercial - Heavy
TOD-M	TRANSIT ORIENTED DEVELOPMENT - MIXED	10	Commercial - Heavy
TOD-R	TRANSIT ORIENTED DEVELOPMENT - RESIDENTIAL	10	Commercial - Heavy
UTIL	UTILITY	7	Industrial - Light
WARE	WAREHOUSE/DISTRIBUTION	8	Industrial - Heavy
WATER	WATER	11	Water Bodies

Appendix C –

Sample Data Collection for Stream Crossings

Stream Crossing Verification Items

Mecklenburg County Map Maintenance

The Mapping Contractor shall develop a spreadsheet or database to monitor and verify data collection for stream crossings. The table below lists field names (i.e. spreadsheet columns) that should be populated for each stream crossing.

FIELD NAME	FORMAT	DESCRIPTION
XING_ID	[Text]	Unique ID assigned to stream crossing
WSHD_NAME	[Text]	Watershed Name
STRM_NAME	[Text]	Stream Name
STRM_STA	[Integer]	Stream Station (ft) from downstream using new/revised stream line shapefile
EFFSTRM_STA	[Integer]	Stream Station (ft) from downstream using old/effective stream line shapefile
XING_DESC	[Text]	Description of stream crossing location
STR_TYPE	[Text]	Crossing/structure type
STR_DESC	[Text]	crossing/structure description
PUB_OR_PRVT?	[PUB/PRVT]	Is this a private/public structure. Most crossings are public but there are a few driveway culverts/bridges on private property which are privately owned.
IN_EFFMODL?	[Y/N]	Was structure/crossing part of Countywide effective mapping study undertaken in 1999-2004. All new structures between 1999-2004 will not be in the last effective study
EFF_AGREE?	[Y/N]	Is structure/crossing description, dimensions etc in agreement with field observations
AERL_AGREE?	[Y/N]	Is structure/crossing description, dimensions etc in agreement with aerial photograph
IS_FLD_VRFD?	[Y/N]	Is structure/crossing field verified
TO_FULL_SRVY?	[Y/N]	Is structure/crossing flagged for full survey
NOTES	[Text]	Notes, comments
DATASOURCE	[Text]	Data source

FIELD NAME	FORMAT	DESCRIPTION
FINALIZED	[Y/N]	Final QA/QC of structure completed?
PHOTO_DSC	[Text]	Photo - Looking downtream at the downstream stream channel
PHOTO_DSF	[Text]	Photo - Looking upstream at the downstream culvert/bridge face
PHOTO_USC	[Text]	Photo - Looking upstream at the upstream stream channel
PHOTO_USF	[Text]	Photo - Looking downtream at the upstream culvert/bridge face
OLD-PHOTO_ID	[Text]	Hyperlink to old photo of existing stream crossing scanned from 1999-2004 mapping study
SKETCH_ID	[Text]	Hyperlink to old survey sketch of existing stream crossing scanned from 1999-2004 mapping study