CHAPTER 3: WATER QUANTITY

The proper management of stormwater runoff is one of the primary objectives of the Town's Stormwater Program. This includes direct management and maintenance of the drainage system within the Town-owned/maintained property and right-of-ways (ROWs), as well as, regulatory, design standards, and policy controls associated with controlling stormwater runoff, providing appropriate levels of service for safety and drainage system function, and protecting loss of life and property from flood damages. This chapter provides a summary of information and data reviewed for this master plan, as well as, a discussion of the drainage system characteristics, flooding and water quantity related issues, and a review and comparison of program policies with other communities.

A. Data Collection

A multitude of data and information was used in conducting the master plan quantity analysis. This included large-scale (i.e. Town-wide) general mapping data sets, previous studies, and stormwater specific data sets. In addition, new survey information was collected in the TCAP area to support the flood risk assessment. The table below summaries data used during the project, followed by a more detailed description of the survey information collected for the project.

Table 3.1 – Summary of Data/Information Sources

Data / Information Type	Source(s)	Description / Application to Master Plan Process
General Base Mapping	Town of Cary, Wake County	Includes aerial photography, planimetrics, parcels, streets, streams, impervious surfaces, land use, political/planning boundaries, and similar layers. Used for all master plan assessments.
Topographic / Elevation Data	Town of Cary, NCFMP	Includes contour mapping and aerial-based LiDAR data. Contour data were used for general mapping. LiDAR data were used to construct terrain models for water quantity and risk assessment.
Drainage System Inventory	Town of Cary	Comprehensive inventory of open and closed system. Used in infrastructure evaluation.
Drainage Reports and Work Order Databases	Town of Cary	Databases of drainage reports and work orders with records dating back to December 2001. Used in inventory, risk, and water quantity assessments.
Floodplain Analyses and Mapping Data	FEMA, Town of Cary	Includes floodplain mapping and associated Flood Insurance Study report for areas along FEMA mapped streams; floodplain mapping, hydraulic analyses and reports associated with Walnut Creek, Swift

		Creek, and Coles Branch within TCAP area associated with a 2006 stormwater study.
Previous Stormwater Related Studies	Town of Cary	Included previous stormwater related studies initiated by the Town from 1993, 2005, and 2006, as well as studies done for several private development projects. Used in water quantity assessment and potential improvements.
Mobile LiDAR	New Survey	Ground-based mobile LiDAR was collected along roadways within the TCAP areas for this project. Used in the risk assessment, as well as, visualization/mapping. See detailed description below.

Mobile LiDAR Data Collection

Figure 3.1 Mobile LiDAR Unit

Light Detection And Ranging (LiDAR) is an optical remote sensing technology that uses rapid laser pulses (up to 400,000 pulses per second) to measure the distance and other properties of a target. LiDAR devices can be integrated with Global Positioning System (GPS) receivers and attached to a moving platform such an airplane, truck, or boat to quickly capture very detailed feature and elevation information that can be mapped to real world coordinate systems. LiDAR collected from airplanes (i.e. aerial-based LiDAR) has become a very popular for topographic (i.e. elevation) mapping of large-scale areas. Ground-based mobile LiDAR (i.e. LiDAR collected from a ground vehicle) expands the amount of information that can be obtained as it collects ground-level perspectives/dimensions (i.e., looking left, right, up, down) rather than simply looking down from above as in the case of aerial-based LiDAR.

A mobile truck unit was used to capture ground-based LiDAR and imagery within the vicinity of the TCAP area. Multiple survey passes were performed along each accessible roadway in the study area and supplemented GPS data with existing survey information (e.g. storm sewer inlet/rim elevations) to ensure complete and accurate coverage.

In addition to providing detailed elevation and imagery in the roadway corridors, the LiDAR data was also processed to determine finished floor elevations (FFEs) of nearly 700 building structures within the vicinity of mapped floodplains in the study area. The use of mobile LiDAR mitigated the need for right of entry while ensuring completeness of information. The mobile LiDAR truck has two sensors (as shown in graphic above), which is especially important in the determinations of FFEs, as it enables effective laser shots on target when differing obstructions are encountered (parked cars, shrubbery, trees, mailboxes, people, etc.), and/or for when the front door is recessed from the façade of the building.

Figure 3.2 Example Building FFEs and Photo Collected Along Walnut Creek

B. Evaluation of Existing Drainage System

The drainage system within the Town Planning Boundary consists of a network of interconnected streams, ponds, ditches, and closed system structures (e.g. pipes, inlets, etc.). The majority of the Town is in the Neuse River Basin with large-scale drainage flowing northeast toward Lake Crabtree, or to the southeast to Swift Creek, Walnut Creek, and Middle Creek. The western portion of the Town is located in the Cape Fear Basin and drains to the west/southwest towards Jordan Lake. Large-scale drainage patterns and FEMA mapped floodplains are shown in the graphic below.

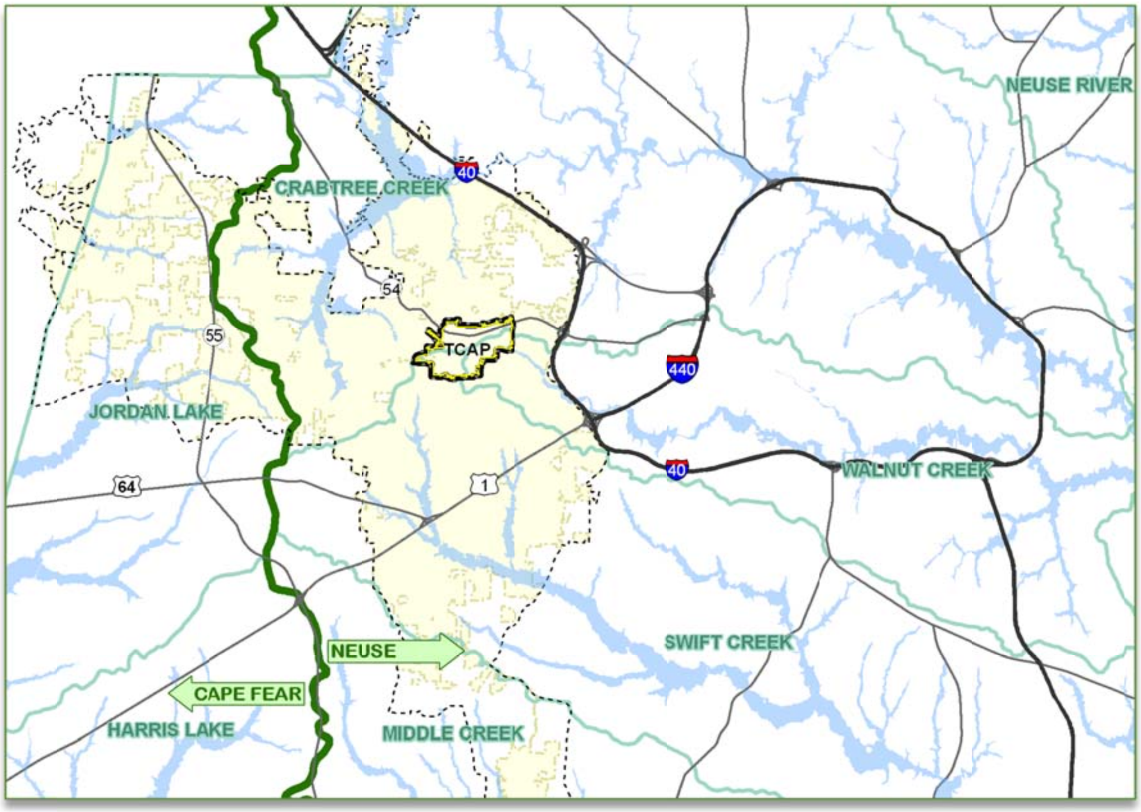


Figure 3.3 Large-Scale Drainage Patterns and FEMA Mapped Floodplains

Large-Scale Drainage System

For the purposes of this study, the large-scale drainage system is generally considered to be areas with mapped floodplain boundaries. The large majority of floodplain mapping is associated with the Effective FEMA Flood Insurance Study, which generally maps areas with contributing drainage areas of one square mile and larger. There are approximately 34 FEMA streams with mapped floodplains totaling an estimated 66 miles in length within the Town planning limits. The 2006 TCAP study developed approximately four additional miles of floodplain mapping along Swift, Walnut, and Coles Branch, upstream of existing FEMA mapping. Also, approximately one mile of floodplain mapping was developed along Panther Creek (immediately upstream of the FEMA mapping boundary) in the Northeast Creek watershed. This mapping was conducted in association with the Highcroft Village subdivision and is mentioned as part of the development flood studies below. The table below summarizes floodplain mapping from the FEMA and TCAP studies by sub basin/watershed.

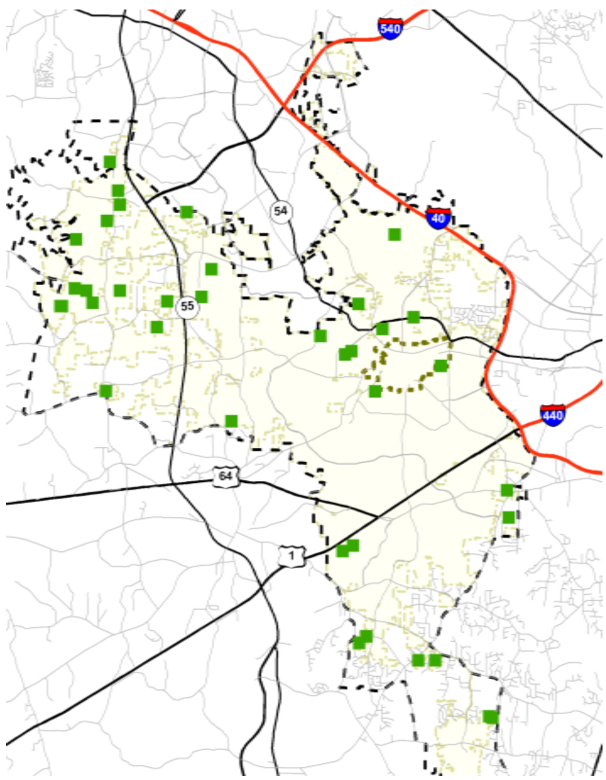
Table 3.2 – Summary of FEMA and Town Floodplain Mapping within Planning Boundary

Watershed	FEMA Mapping Stream Miles	Town Mapping Stream Miles
Lake Benson-Swift Creek	0.0	0.0
Lake Wheeler-Swift Creek	17.8	1.4
Middle Crabtree Creek	0.0	0.0
New Hope River-B Everett Jordan Lake	0.0	0.0
Northeast Creek	4.8	0.9
Upper Crabtree Creek	25.3	1.5
Upper Middle Creek	5.0	0.0
Walnut Creek	2.0	1.3
White Oak Creek	11.4	0.0
Totals	66.3	5.1

In addition to the floodplain mapping listed above, the Town of Cary requires a flood study and an associated floodplain boundary as part of its development ordinances for projects that drain 50 acres or more. A review of records provided by the Town indicates there have been approximately 37 private flood studies associated with development projects. The following general observations are made from the review of the development flood studies:

- The studies were dated between 1997 and 2008, with the majority (29 of 37) of them being done in the past 10 years (i.e. since 2002).
- Only one study (Highcroft Village subdivision) has mapped floodplain boundaries that were available in digital format. All other floodplain boundaries and their respective drainage basins have not been digitized.
- Twenty-two (22) of the studies had a hard copy floodplain boundary mapped.

Figure 3.4 Development Related Flood Study Locations



- Digital hydraulic models (e.g. HEC-RAS) were only on file for five of the flood studies.

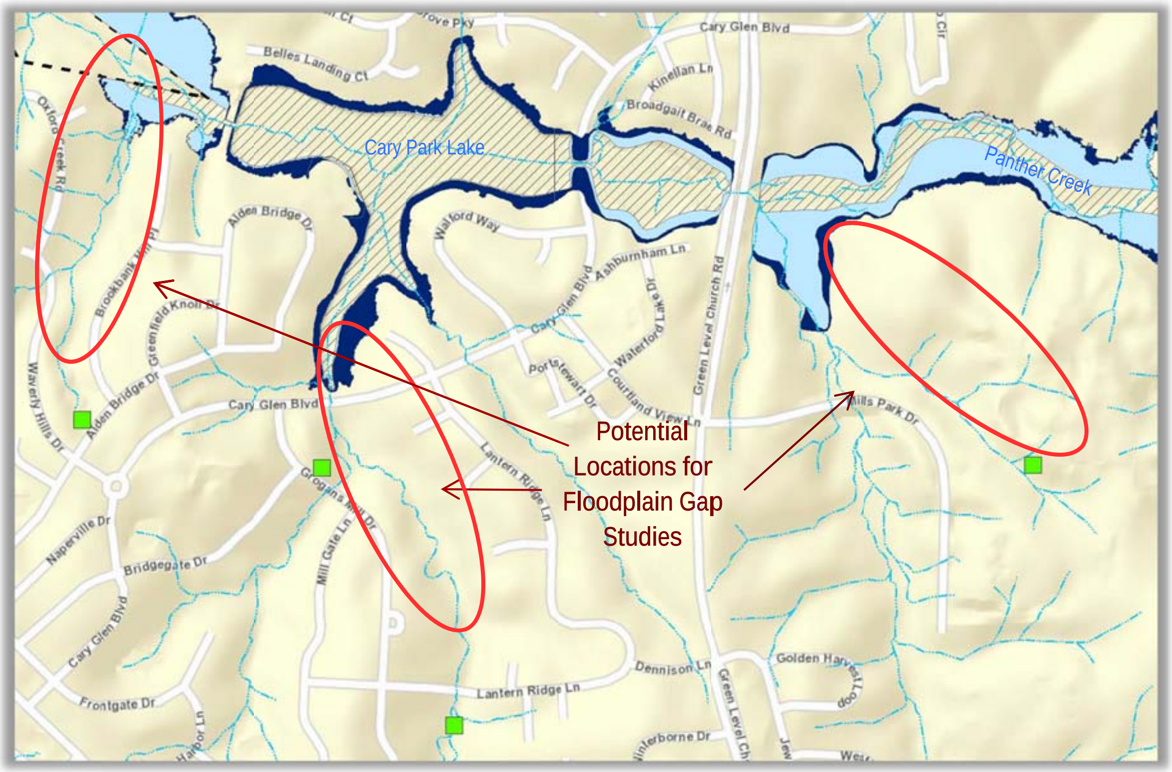
A more detailed text summary and a map showing the locations with all available digital floodplain boundaries are included in Appendix A.

Floodplain Mapping Gap Analysis

As will be discussed in Section E of this chapter, there can be significant flood risk outside of the FEMA mapped floodplains. A significant percentage (as high as 50%) of flood insurance claims within Cary and other cities in the Piedmont region of North Carolina are outside of the mapped floodplains. This point is further reinforced by the TCAP study which identified significant flood hazard risk to properties and roadway upstream of the FEMA floodplains. Requiring flood studies for local projects draining 50 acres or more helps minimize potential loss from flooding for a particular development project. However, combining this development project flood hazard information with FEMA studies provides an excellent opportunity to not only extend and better communicate flood hazard information, but also provide a more holistic and consistent approach for regulation of development upstream of FEMA floodplains. As FEMA studies typically begin where the contributing drainage area is one square mile (640 acres), there is usually a "gap" in available flood information and mapping between the development studies and the FEMA floodplains. If supplemental analyses were conducted to "connect" these gaps, it would provide continuous flood hazard mapping and information for improved risk communication, mitigation planning, as well as a "base" model that could be used to assess impacts and update flood hazard changes from future developments along the stream corridor.

An analysis was conducted to identify the availability/usability of data from the private flood studies mentioned above in conjunction with the other available floodplain mapping for master planning purposes. Because there are 37 flood study sites all over the Town, it would require significant resources and time to conduct the necessary analysis to "connect" the existing FEMA and private development flood study information. As a means of prioritization, proximity of development flood study sites in relation to existing FEMA floodplains could be used to identify where resources could be applied most effectively. For example, there is a relatively high clustering of development sites that drain to Cary Park Lake and Panthers Creek in the northwest area of Town. The graphic below shows these development sites and existing areas that could be analyzed to provide floodplain mapping connectivity. Other locations, such as Hatchet Grove Tributary near Louis Stephens Drive and Camp Branch near Holly Springs Road, have multiple flood studies in relatively close proximity to existing floodplain mapping. Other factors that could be considered in prioritizing supplemental flood studies include the amount of developed properties between a development flood study and the FEMA floodplain, and synergy with other existing public projects in the stream corridor (e.g. stream restoration project). The Town has already extended floodplain information through the TCAP study and the study along Panthers Branch. By conducting additional flood studies to "connect" the existing FEMA mapped floodplain with private development information, the Town will establish a continuity of flood risk assessment throughout the Town Planning Boundary.

Figure 3.5 Clusters of Development Flood Studies Draining to Panther Creek



Localized (Small-Scale) Drainage System

For the purposes of this study, the localized drainage system is generally considered to be all stormwater drainage infrastructure features as well as smaller creeks and streams (without an associated flood study). The Town of Cary has a comprehensive inventory of the drainage system which was used in the evaluations and analysis of the localized drainage system in this master plan. The existing stormwater drainage system is discussed in more detail below.

Review of Stormwater Inventory

As part of the National Pollution Discharge Elimination System (NPDES) Phase II requirement, and the Town of Cary's desire to meet / exceed its stormwater management responsibilities, the Town commissioned an inventory of its stormwater conveyance networks. Phases 1 and 2 of this effort were completed by Dewberry & Davis, Inc. (Dewberry) between 2002 and 2005. Phases 3 and 4 were completed by Withers & Ravenel in 2008 and 2010. No new stormwater inventory information was collected as part of this Master Plan effort.

The resulting stormwater network inventory identified approximately 530+ miles of pipe systems and culverts, approximately 300+ miles of creeks and streams, and over 39,000 mapped structures (e.g. inlets, junction boxes, outlets) within the Town's planning limits. The structures have fields for type of feature (yard inlet, curb inlet, pipe outlet, etc.), top and invert elevations, identification numbers, as well as some photographs. The databases contain fields for pipe size, material, length, identification number, connecting manholes (by ID, where present), and some photographs.

The Dewberry and Withers & Ravenel geodatabases contain additional information on specific types of structures, including condition, ownership for point structures (entries include Town, Private, NCDOT, or unknown), invert and top elevations, connectivity with adjacent pipes or structures, dimensions, flow (presence, as well as odor and color), obstruction, and comments, which typically explain condition and obstruction if less than ideal. The condition and ownership fields add particular value because they show which parts of the conveyance system potentially need maintenance or replacement, and which are within the Town's ROW. This is potentially helpful for planning capital improvements and maintenance programs.

Table 3.3 provides a summary of these "localized" drainage features by watershed area and location within the study area (e.g. Town Planning Limits, Town Municipal Limits, and TCAP Area Limits).

Table 3.3 – Summary of Localized Drainage System

Watershed	Town Planning Boundary			Town Municipal Limits			TCAP Area Limits		
	Pipe Length (mi)	*Stream Length (mi)*	*Structures (no.)*	*Pipe Length (mi)*	*Stream Length (mi)*	*Structures (no.)*	*Pipe Length (mi)*	*Stream Length (mi)*	*Structures (no.)*
Lake Benson-Swift Creek	5.7	0.57	386	5.1	0.57	362	N/A	N/A	N/A
Lake Wheeler-Swift Creek	162.7	81.2	11,847	162.7	73.2	11,706	5.4	1.4	461
Middle Crabtree Creek	25.0	7.3	1,772	22.7	3.6	1,632	0.7	0.05	49
New Hope River-B Everett Jordan Lake	2.8	2.8	226	2.8	2.5	226	N/A	N/A	N/A
Northeast Creek	65.2	57.7	4,945	62.6	38.5	4,839	N/A	N/A	N/A
Upper Crabtree Creek	179.0	92.9	13,688	176.4	89	13,566	6.2	2.5	527
Upper Middle Creek	19.3	15.9	1,354	18.5	5.6	1,301	N/A	N/A	N/A
Walnut Creek	30.8	11.3	1,896	30.1	10.9	1,892	4.7	1.4	367
White Oak Creek	44.1	36.1	3,279	42.5	19.5	3,209	N/A	N/A	N/A
Totals	535	306	39,393	523	243	38,733	17	5.4	1,404

An analysis of the stormwater system as a whole shows that of the more than 39,000 structures, more than one-third are combination inlets. Curb inlets and grate/yard inlets account for 18% each, while catch basins and manholes are the fewest at 3% of the total system. Combination inlets have a grate at ground level and a larger open vertical inlet, while curb inlets only have a large open vertical inlet. Table 3.4 provides a more detailed summary of the more prevalent structures in the system. A list of structure types (including descriptions and example photos) created for the Town of Cary Stormwater Infrastructure Inventory Project is located in Appendix A.

Table 3.4 – Summary of Stormwater Infrastructure Structure Type

Structure Type	Owner (System)	Number of Features	Percent of Structure Type (%)	Percent of All Structures (%)
Combination Inlet	Town	9180	60	30
	Other (i.e. Private, NCDOT, unknown)	6089	40	20
Curb Inlet	Town	4776	68	16
	Other (i.e. Private, NCDOT, unknown)	2199	32	7
Grate / Yard Inlet	Town	1596	23	5
	Other (i.e. Private, NCDOT, unknown)	5423	77	18
Manhole	Town	421	32	1
	Other (i.e. Private, NCDOT, unknown)	907	68	3

Two of the attributes within the inventory identify ownership of the structures, as well as the condition of the structures and pipes. Infrastructure ownership is categorized as either Town, Private, NCDOT, or not applicable. These fields add particular value because they show which parts of the conveyance system potentially need maintenance or replacement, and which parts of the system are the within the Town's right-of-way. Of the approximately 39,000 structures, approximately 2.7% are listed as "Inaccessible". Therefore, the condition of these structures is unknown. Of the approximately 38,000 remaining structures that have a condition listed, approximately 86% are listed as "Good", approximately 3.6% are listed as "Fair", and approximately 0.8% are listed as "Poor". A figure highlighting the pipe network based on pipe condition is shown in Appendix A.

In addition to pipe condition, the age of individual pipes within the system can be useful when identifying areas of a stormwater drainage system that potentially have the greatest need for maintenance or repair. Since this information does not currently exist in the Town of Cary stormwater inventory database, two methods were developed to assess the age of different stormwater structures.

The first method essentially involved assigning an approximate year that a given stormwater element was constructed based on the age of nearby building(s) as a surrogate for the date when nearby stormwater structures were built. A key limitation to this method is the assumption that the building dates coincide with the dates of nearby stormwater conveyance features. Some examples of when this will not be true include areas where the stormwater system has been improved through Capital Improvement Projects (CIP) and parcels along major roads that may have been constructed well before the adjacent buildings.

The second method for dating stormwater infrastructure features involved assigning an estimated age based on the average age of the subdivision where the infrastructure is located. Drainage features located outside of defined subdivisions are assigned an age from their adjoining drainage feature. A key limitation to this method is the assumption that the age of drainage features located between subdivisions closely matches the age of the features located within the subdivisions themselves.

A more detailed description of these methods, along with figures depicting the estimated age of stormwater infrastructure within the Town's stormwater system using both methods, is located in Appendix A.

An assessment of the Town's infrastructure including age and potential capacity / sufficiency conflicts is provided in Section 3C – Infrastructure Assessment.

C. Infrastructure Assessment

The previous section provided an evaluation of the existing drainage system within the Town of Cary planning limits. This section provides an overall assessment of the existing stormwater infrastructure. Several parameters were considered when assessing the Town's stormwater infrastructure. These parameters included:

- Age of the infrastructure components
- Bridge / culvert crossing Level of Service (LOS) analysis
- Infrastructure capacity / sufficiency (i.e. locations where pipe sizes decrease moving downstream)
- Databases of requests/complaints and maintenance related to stormwater conveyance system problems
- Pipe condition (assessed during stormwater inventory effort)

By evaluating the items listed above, the Town's stormwater conveyance system was assessed to identify areas with the highest probable need for maintenance and/or improvement.

Infrastructure Age

Some of the more common pipe materials used for stormwater infrastructure include Corrugated Metal Pipe (CMP), Corrugated Plastic Pipe (CPP or HDPE), and Reinforced Concrete Pipe (RCP). The typical life expectancy ranges based on manufacturer estimates for these common pipe materials is shown in the table below. However, the actual life span for any stormwater pipe will vary based on several factors including, but not limited to, pipe material, pipe installation, flow conditions and water quality, and chemical composition of the surrounding soil in which the pipe is placed.

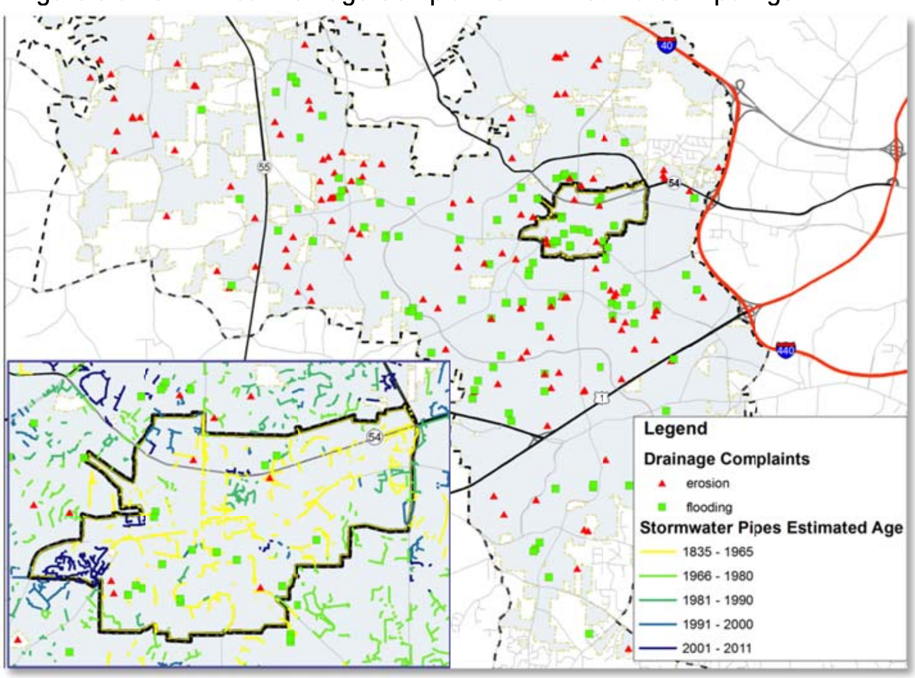
Table 3.5 – Typical Stormwater Pipe Life Expectancy

Pipe Material	Typical Life Expectancy (Years)
Corrugated Metal (CMP)	25 - 50
Corrugated Plastic (CPP or HDPE)	40 – 60
Reinforced Concrete (RCP)	50 - 80

An infrastructure age analysis on the Town of Cary stormwater inventory database indicates that approximately 22 miles (4%) of the total pipe length within the Town of Cary Planning Boundary are more than 50 years old. Any CMP segment that is in this age range will most likely need inspection and repair or replacement soon. Conversely, approximately 350 miles (67%) of the existing pipe infrastructure was constructed after 1990 making them less than 25 years old.

Within the TCAP area, the age estimation method discussed in Section 3B indicates that approximately 5 miles of pipe was constructed prior to 1965. However, it should be noted that this age estimate does not account for any stormwater infrastructure maintenance or improvement projects that may have occurred since the original land development. A figure showing the location of these pipes (highlighted in yellow) along with a point layer of drainage reports is shown below.

Figure 3.6 TCAP Area Drainage Complaints with Estimated Pipe Age



The value of the age of infrastructure data is that it aids in identifying potential areas of concern for maintenance and capital improvement needs when coupled with other data such as the Stormwater Citizen Request Database and the PWUT Work Order Database. This also provides a predictive tool for identifying potential future problem areas as the infrastructure ages further.

Roadway Crossing Level of Service (LOS) Analysis

Roadway crossings with significant flooding depth during the 100-yr storm event (hot spots) were identified from floodplain mapping data and associated flood profile information presented in the Flood Insurance Study (FIS) for Wake County (Effective Date May 2, 2006), as well as, from the 2006 TCAP study. The performance level of service (LOS) and 100-year overtopping depths were evaluated for the 20 roadway crossings in the TCAP study area and 74 roadway crossings identified in the FEMA studies.

The crossings in the TCAP study area are cross-street drainage, thus the defined LOS is a 25-yr storm (i.e. able to pass the 25-yr storm without overtopping). Of the 20 crossings located in the TCAP study area, only two meet the 25-yr LOS. For the 74 crossings in the FEMA mapped floodplains, the desired LOS is the 100-yr storm. The evaluation indicates that 41 of the 74 crossings located within the FEMA floodplain meet their desired LOS. The tables below summarize the LOS evaluations for crossings within the TCAP and FEMA floodplains.

Table 3.6 – Roadways/Stream Crossings Level of Service Summary

Area	Meets LOS	Does Not Meet LOS	Total Crossings	Percent Meeting LOS
TCAP Study Area (25-yr LOS)	2	18	20	10%
FEMA Floodplain Area (100-yr LOS)	41	33	74	55%
Totals	43	51	94	45%

Table 3.7 – FEMA Roadways/Stream Crossings Level of Service by Study Stream

Study Stream	Level of Service				Subtotals
	<=10-yr	50-yr	<100-yr	>=100-yr	
Bachelor Branch			3	1	4
Black Creek Tributary A				4	4
Briar Creek	2			2	4
Basin 28, Stream 8	2			1	3
Coles Branch			1	2	3
Crabtree Creek				6	6
Hatchery Grove Tributary			1	1	2
Kit Creek				2	2

Study Stream	Level of Service				Subtotals
	<=10-yr	*50-yr*	*<100-yr*	*>=100-yr*	
Little Briar Creek	2				2
Lens Branch	1	1	1	2	5
Morris Branch	2	1		1	4
Morris Branch Tributary	1				1
Panther Creek	2			1	3
Straight Branch	1			2	3
Swift Creek	1	1		6	8
Swift Creek Tributary 7	2		1	5	8
Turkey Creek			1	1	2
Turkey Creek Tributary			3		3
White Oak Creek			2	2	4
Walnut Creek	1			2	3
Totals	17	3	13	41	74
	DOES NOT MEET LEVEL OF SERVICE STANDARD			MEETS LEVEL OF SERVICE STANDARD	

Table 3.8 – TCAP Roadways/Stream Crossings Level of Service by Study Stream

Study Stream	Level of Service				Subtotals
	<2-yr	*2-yr*	*10-yr*	*>=25-yr*	
Coles Branch	1	1	1	2	5
Swift Creek Tributary 7	5	1			6
Walnut Creek	2	6			8
Walnut Creek Tributary			1		1
Totals	8	8	2	2	20
	DOES NOT MEET LEVEL OF SERVICE STANDARD			*MEETS LEVEL OF SERVICE STANDARD*	

It is noted that the Town has a higher LOS standard by requiring that all roadway crossings in the FEMA floodplain accommodate the 100-yr storm. A 100-yr LOS is often specified just for interstates or major thoroughfares. Therefore, when prioritizing those roadway crossings with the highest need for improvement, one should consider factors such as:

1. Is the road a secondary road that currently provides at least a 25-yr level of service? If so, it would have a lower priority.
2. Is the road the only access point for residences along the road? If so, it would have a higher priority.

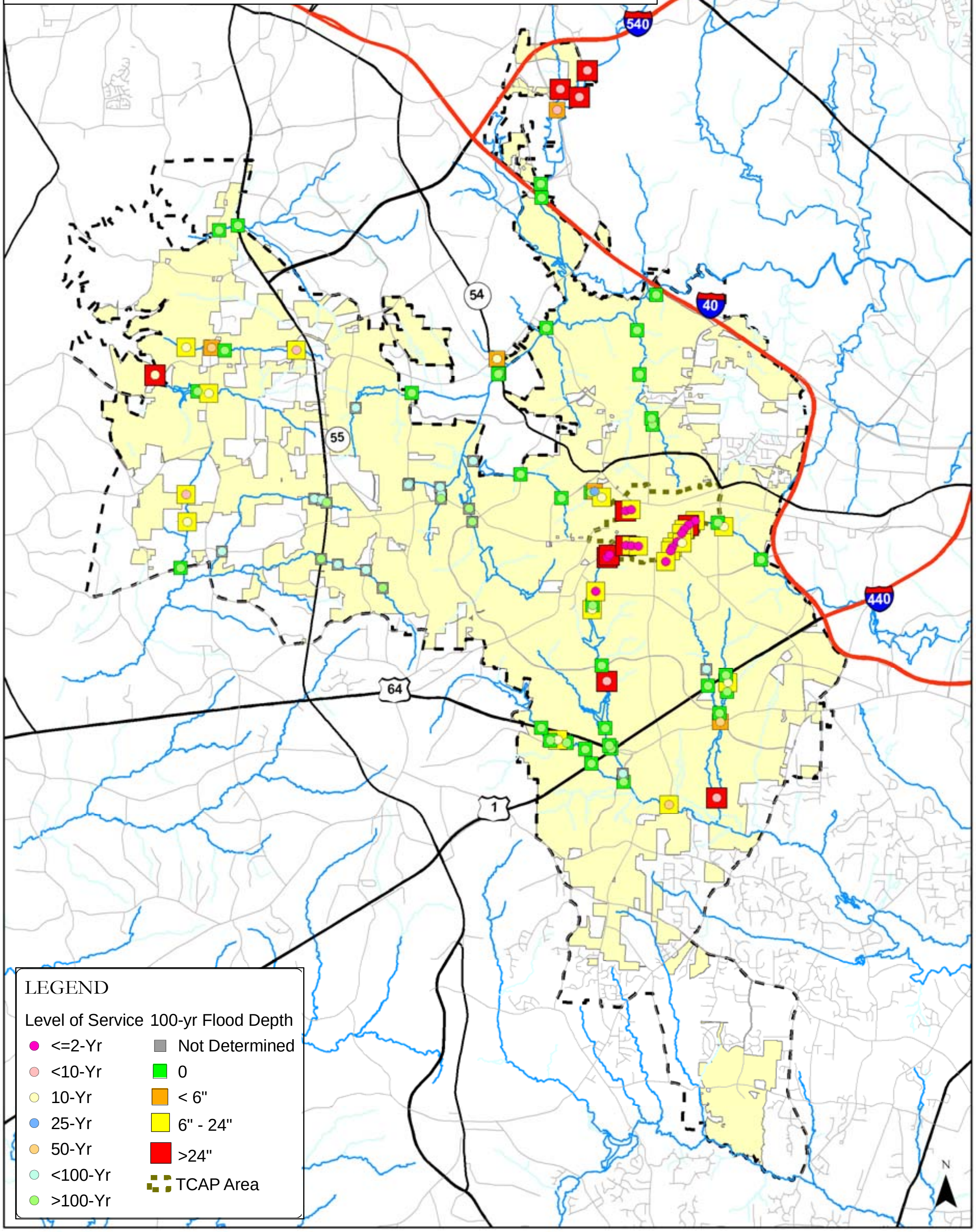
In addition to LOS, overtopping depth is useful in identifying those crossings that have the greatest need for improvement or replacement. Generally, travel becomes unsafe in passenger vehicles once the roadway flooding depth reaches six (6) inches or more. Travel becomes dangerous for all vehicles (including emergency vehicles) once roadway flooding depth reaches 12 inches or more. Table 3.9 below illustrates that of the 74 crossings that do not meet their desired 100-yr LOS, only 16 (22%) are predicted to have a 100-yr roadway flooding depth of greater than 6 inches. Additionally, only 11 (15%) have a flooding depth of greater than 12 inches. Conversely, within the TCAP study area, 18 out of 20 (90%) of the roadway crossings are predicted to have roadway flooding of greater than 6 inches during the 100-yr storm, and 15 out of 20 (75%) are predicted to have a roadway flooding depth greater than 12 inches.

Table 3.9 – Percent of Roadway Crossings Exceeding Depth Thresholds

	% Depth > 6"	% Depth > 12"
TCAP Study Area	90	75
FEMA Floodplain Area	22	15

Figure 3.7 provides a graphic overview of the LOS and roadway overtopping depth evaluation throughout the Town of Cary planning boundary.

Figure 3.7 Roadway Level of Service and 100-yr Overtopping Depth



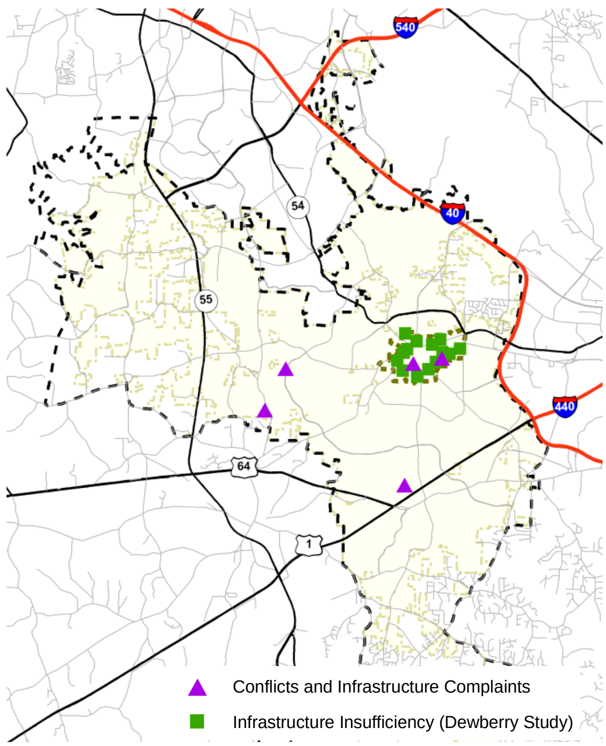
Infrastructure Capacity / Sufficiency Analysis

In order to assess the capacity and sufficiency of the stormwater drainage system infrastructure, stormwater conveyances with a potential sizing conflict were identified (see Appendix A). Two sources were used to identify capacity shortcomings in the stormwater conveyance system infrastructure: 1) locations where pipe size decreases in combination with problem notifications, and 2) flooding due to conveyance insufficiencies identified through hydraulic model studies.

As part of the master plan, five instances were identified where pipe diameters decreased moving downstream in the conveyance system in the same vicinity where the Town of Cary's Public Works Utility Department (PWUT) work order database or the stormwater report database included an identified problem. These areas are also known as "neck downs." To identify neck downs, the databases were reviewed to find locations where the pipe size decreased moving downstream. The PWUT reporting indicates that the neck downs are indeed causing flooding and/or stormwater blockages. The seven identified locations of conflicts and infrastructure complaints are shown in purple in the graphic below.

In addition to analyzing the Town's databases, hydraulic grade line (HGL) analyses were completed on the TCAP's existing stormwater systems with 10-acre drainage areas that serve as tributaries to Walnut Creek, Coles Branch, and Swift Creek Tributary 7. The lines modeled were chosen to assure that the primary conveyances of the stormwater system are properly sized. Existing and ultimate build-out conditions within the TCAP area were modeled as separate scenarios for each drainage system. The hydraulic grade line analysis highlighted areas that are at flood risk in the existing and future condition models due to conveyance insufficiencies. Chapter 4 of the TCAP hydraulic study by Dewberry modeled existing and future conditions for open and closed drainage systems in the TCAP area. This study identified 14 areas with the potential for street and structure flooding due to infrastructure insufficiencies. These small-scale drainage areas (shown in green in the graphic above) are located upstream of the mapped TCAP floodplain and outside of the LiDAR study.

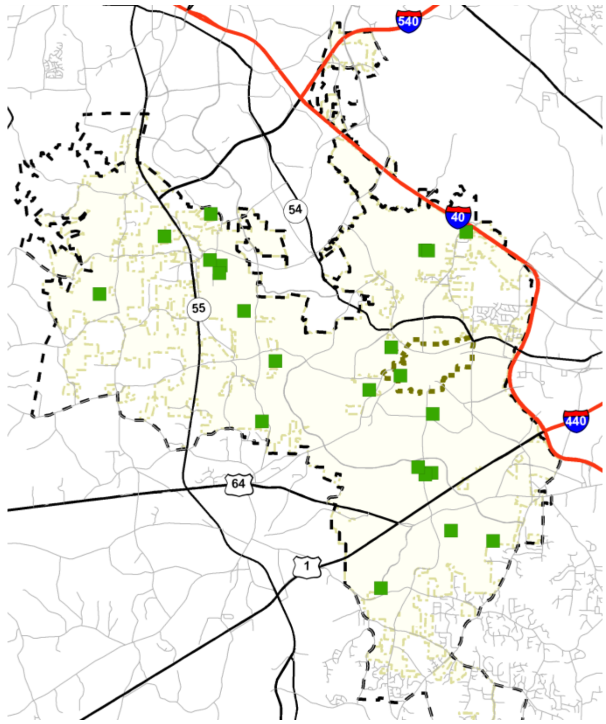
Figure 3.8 Potential Infrastructure Insufficiency and "Neck Down" Locations



Insufficiencies Identified by Town Databases

Additional sources for identifying conveyance infrastructure problem areas are the Town's PWUT work order database and the stormwater complaint database. The work order database shows when, where, and what fixes were completed by PWUT staff on the stormwater conveyance system. The Stormwater Citizen Request Database contains calls from the public about stormwater problems, many of which are maintenance-related or on private property (see Section 3D). However, the databases identified 22 problem areas that are likely the result of infrastructure insufficiencies. The listed causes of these problem areas include failures (10; e.g., broken pipes, improper construction, etc.), sinkholes (7), clogs (4), and flooding (1). The locations of these problem areas are shown in the graphic.

Figure 3.9 Potential Infrastructure Insufficiency Locations Identified via Town of Cary databases



Pipe Condition

In the conveyance inventories conducted by Dewberry and Withers & Ravenel (see Section 3B), 78 pipes, which sum to 5,594 linear feet, were identified as being in 'Poor' condition. This is a subjective determination but it indicates that an infrastructure problem may exist. There are also 936 pipes in Fair condition which sum to 75,144 linear feet and 30,375 pipes totaling 2,577,450 feet in Good condition.

In an attempt to determine pipe ownership, Baker assigned ownership to each pipe segment using a street centerline layer with an ownership attribute and methodology similar to that used to estimate pipe age as mentioned earlier and described in Appendix A. Based on this analysis within the ROW, 19,899 of the 35,398 pipe segments were assigned ownership. Of the 19,899 pipe segments with ownership, approximately 15,084 (74%) belong to the Town of Cary, while approximately 3, 682 (21%) belong to the State. The remaining belongs to Private or Other. Of the 15,084 pipe segments owned by the Town, approximately 31 (0.2%) are categorized as "Poor", while approximately 486 (3%) are categorized as "Fair", and approximately 13,919 (92 %) are categorized as "Good". The remainder was unrated.

Summary

Using numerous data sources and methods, potential stormwater infrastructure insufficiencies have been identified. Some of the more prevalent findings are listed below:

- The greatest concentration of stormwater pipes that are estimated to be greater than 50 years old are located in the TCAP area.
- The TCAP area has the greatest concentration (90%) of roadway / stream crossings that currently do not meet the desired level of service (i.e. 25-year).
- The TCAP area has a significant number (14) of locations that have the potential for street and / or structure flooding due to infrastructure insufficiencies (i.e. undersized pipes, culverts, etc.).
- Approximately 76% of the pipes that could be assigned ownership belong to the Town of Cary, and of those, more than 92% are categorized as "Good" condition based on previous inventories.

Taken as a whole, the infrastructure assessment provides the Town with a better understanding of those areas with the greatest stormwater needs, and the means to quantify the cost of improving the stormwater conveyance system function. This will be done in Chapter 6.

D. Flood Risk Assessment

Risk based assessment is the process of identifying the potential for an event or situation to adversely impact a given subject area or item. In context of a stormwater master plan, risk is generally associated with risk of flooding to buildings/property and roadways. In this case, flooding (e.g. flood waters in buildings or overtopping roadways) is the event; and damage and/or loss of function is the impact. Flood risks associated with roadways are included with the infrastructure assessment in Section 3C, thus, this section focuses on flood risk assessment associated with buildings and property.

Risk can be quantified by evaluating the probability that the event will occur along with the magnitude or consequence of the event happening. Most flood studies entail computing flood elevations for a range of design storm events (e.g. 2-, 10-, 100-yr storms). Each design storm event has a statistical probability associated with it. Statistical probabilities associated with common design storm events are presented in the table below. For example, if a building is within the 100-yr floodplain (i.e. typical FEMA or Town mapped floodplain), it has a 1% chance of flooding in any given year, a 10% chance of a given 10-year period, and a 26% over a 30-year (i.e. typical life of mortgage) period.

Table 3.10 – Percent Chance of Flooding for Typical Design Storms

Design Storm Event	% Chance of Flooding in a Given Year	% Chance of Flooding over a 10-Year Period	% Chance of Flooding over a 30-Year Period
2-yr	50%	> 99%	> 99%
10-yr	10%	65%	96%
25-yr	4%	34%	71%
50-yr	2%	18%	45%
100-yr	1%	10%	26%
500-yr	0%	2%	6%

The computed flood elevations associated with each of these storm events can be compared with physical elevations of building features (e.g. finished floor, crawl space, etc.) to determine the occurrence and magnitude (i.e. depth) of flooding in a given event. By considering both the probability and the impact/consequence, flood risks can be quantified and thus be used to rank and prioritize buildings and properties. The subsections below describe the approach that was used to conduct the flood risk based assessment for buildings and properties within the Town Planning Boundary.

Floodprone Building Identification

The risk assessment for this master plan focused on floodprone areas associated with larger-scale drainage areas, in which flood hazard information is available. Smaller-scale areas were not included as there is generally not detailed flood hazard information available, and these areas are more susceptible to "flashy" storm events, clogged pipes, and other very localized conditions. To identify buildings to be considered in the flood risk assessment, available building footprints and floodplain mapping layers were analyzed using GIS. Building footprints obtained from the Town were supplemented and verified with a draft building footprints layer that was obtained from the NCFMP for Wake County. Floodplain mapping was obtained from FEMA and from the 2006 TCAP study described in previous sections.

Building footprints that were within or in immediate proximity to mapped floodplains were considered to be "floodprone" and were thus included in the risk assessment. Based on GIS analysis, 842 building footprints were within mapped floodplain areas and an additional 77 were in immediate proximity, resulting in 919 buildings that were identified for consideration. These floodprone building footprints were analyzed with floodplain mapping, tax parcels, and terrain data to attribute each building with basic property information (e.g. address, PIN, land classification, building value, etc.), flood hazard (e.g. flooding source, location in floodplain, etc.), and elevation information (e.g. lowest and highest ground elevations at footprint).

The focus of this risk assessment is on primary or finished structures, rather than accessory structures (e.g. sheds, garages, etc.). As this classification information was not included in the base building footprint data, primary buildings were identified based on the assumption that building footprints with less than 800 square feet area are accessory. These initial accessory assignments were adjusted manually if noted during the risk assessment process. Of the identified floodprone buildings, 113 were identified as accessory structures and thus removed from further consideration in the risk assessment. The table below shows counts of accessory versus primary buildings in the vicinity of mapped floodplain areas.

Table 3.11 – Floodprone Building Summary by Building Classification and Floodplain Source

Floodplain Source	No. of Primary Structures	No. of Accessory Structures	Subtotals
FEMA Floodplains	628	67	*695*
TCAP Area Floodplains	178	46	*224*
Totals	806	113	919

Flood Risk Overview

Of the 806 primary buildings listed above, 743 were identified as being within a mapped floodplain area, and were thus evaluated for potential flood risk. The other 63 were in close proximity, but were outside the floodplain. A broad-level analysis was first performed on all of these buildings to characterize and assess the general magnitude of flood risk within the Town area. Items considered in this broad analysis included, location of the building within the floodplain, land use, and value of the buildings. The location of the building within a floodplain can give an indication of relative risk. One characteristic of flood risk that can be obtained from floodplain mapping is whether or not the building is completely surrounded by the floodplain or if only a portion of the building touches the floodplain. Buildings in which floodplain mapping only touches a portion of the building may be subject to flooding of the structure and/or amenities. Buildings that are completely surrounded by the floodplain not only have an increased potential for structure related flooding, but also have issues of lack of ingress and egress for inhabitants and emergency personnel, as well as increased susceptibility of damage to the structure from flood waters that surround the structure. The area of the floodplain which is often recognized as the most dangerous is the floodway, which is delineated on FEMA mapped streams that are based on detailed studies. The floodway is typically located in the central portion of the floodplain that carries the majority of flood flow and subject to higher flood flow velocities. The table below provides counts of primary buildings

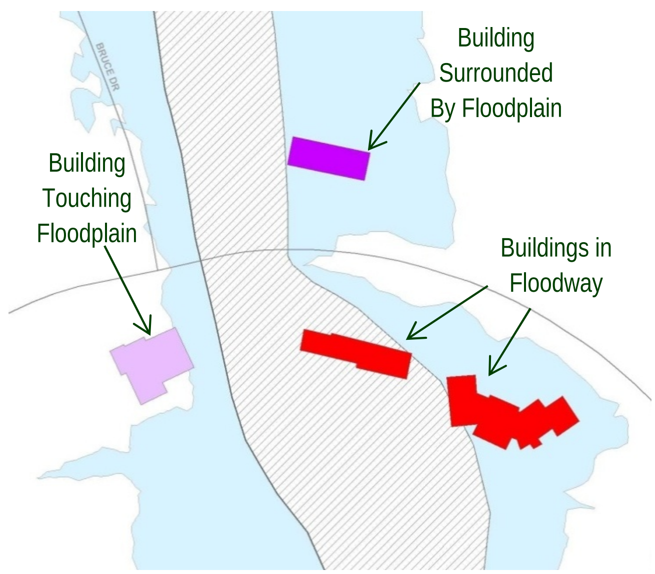


Figure 3.10 Example of Building Location in Floodplain

within each of these locations along with total building values estimated from available tax parcel data. It is noted that the damages only include estimated values of the buildings themselves. The estimate does not include the potential value of building contents, which is often estimated at 30% to 100% of the building value depending on building use and type. The building values are provided to give a sense of the potential for damages, however, it is not meant to imply actual damage that would occur in a flood.

Table 3.11 – Primary Floodprone Building Value by Location in the Floodplain

Location in Floodplain	No. of Primary Buildings	Approx. Building Value ($millions)
Within Mapped Floodway	46	$41
Surrounded by Mapped Floodplain	224	$73
Touches a Mapped Floodplain	473	$252
Totals	743	$366

There are three types of mapped floodplains used in the study: the 100- and 500-year floodplains based on existing land use conditions, and the 100-year floodplain based on predicted future land use conditions. The 100-year future conditions mapping typically has higher flood elevations than the existing condition. The Town regulates to the 100-yr future floodplain in areas that are mapped to ensure that buildings and developments are built such that they will not incur flooding as the area develops. The TCAP area streams have only a 100-year existing conditions land use mapped floodplain, whereas, the FEMA streams have the 100-year existing land use conditions floodplain as well as either a 500-year floodplain or the 100-year future conditions floodplain, depending on the individual stream. Table 3.12 below presents primary floodprone buildings by floodplain designation.

Table 3.12 – Primary Floodprone Building Value by Floodplain Designation

Floodplain Designation	No. of Primary Buildings	Approx. Building Value ($millions)
100-yr Floodplain (Existing Conditions)	462	$173
100-yr Floodplain (Future Conditions)	86	$60
500-yr Floodplain	195	$132
Totals	743	$366

In addition to location within the floodplain, the use of the building and property can be a factor in the level and type of flood risk. For example, there may be higher potential for personal injury or damage to vehicles for residential buildings (especially multi-family buildings) as floods can happen during the night while people are unaware and unprepared to act. Similarly, flooding at critical facilities (e.g. hospitals, utility plants, etc.) may disrupt services that can adversely impact thousands of people. Flooding at commercial and industrial properties, while often not affecting people directly, can result in significant damages and/or other economic hardships from lost production to business income.

Single-family residential homes account for the large majority (over 80%) of all primary floodprone buildings within the study area, however, there are a number of multi-family, commercial, industrial, and institutional structures as well. No critical facilities were identified as being in the mapped floodplains. The table below presents primary floodprone buildings by land use classification.

Table 3.13 – Primary Floodprone Building Value by Land Classification

Land Classification	No. of Primary Buildings	Percent of Total (by No. of Buildings)	Approx. Building Value ($millions)
Single Family Residential	602	81%	$153
Commercial	29	4%	$91
Golf Course	15	2%	$87
Other	17	2%	$18
Apartment/Condo/Townhouse	15	2%	$7
Manufactured Home Park	65	9%	$10
Totals	743	100%	$366

Flood Risk Approach

The subsection above provides an overall perspective of the magnitude of potential flood risk to building structures with the Town planning limits. As is shown in the tables, there are hundreds of buildings that are potentially at risk of flooding. The next step in the flood risk assessment is to further refine and evaluate the level of risk such that it can be quantified and thus be used to aid in prioritizing for mitigation planning. As indicated previously, there are two general sets of floodplain information – (1) FEMA information and (2) information from the 2006 TCAP study. The NCFMP is currently conducting a detailed risk assessment for buildings within the FEMA mapped floodplains as part of their Integrated Hazard Risk Management (IHRM) initiative. More information on the IHRM program can be found at http://www.ncihrm.com/Home. It is anticipated that the results of the IHRM analysis will be available by the end of 2012. The information will be available on the internet via the NCFMP' s Flood Risk Information System (FRIS) website, which is currently in development. As the risk assessment currently underway by the NCFMP will address buildings in the FEMA floodplain, the risk assessment for this master plan focuses on the floodprone areas delineated for the TCAP study. The master plan risk assessment will extend flood risk assessment upstream of the FEMA streams using similar analysis being conducted by the NCFMP.

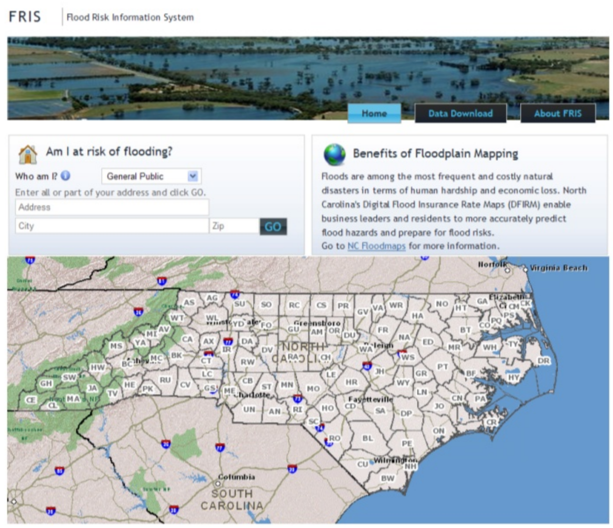


Figure 3.11 *Prototype of NCFMP FRIS Website*

TCAP Area Flood Risk Evaluation

As indicated previously, there are 178 primary buildings that are within or in close proximity to the 100-yr floodplains that were developed for the 2006 TCAP study. In addition to the mapped floodplain boundary itself, hydraulic models developed for the study were obtained. These models provide flood elevations along each of the study streams for a range of storm events including the 10-, 25-, 50-, and 100-yr events. Having flood elevations over a range of events allows one to assess the likelihood and magnitude of flooding at the buildings by comparing the flood elevations with building and adjacent ground elevations. As part of the mobile LiDAR collection described previously, finished floor elevations (FFEs) were obtained for approximately 160 of the 178 buildings. FFEs for the remaining 18 buildings, which could not be determined due to obstructions (e.g. trees, cars, etc.), were estimated from ground data adjacent to each building, building/foundation type, and photographs. A scoring system was developed using this detailed flood and building information to assess flood risk as described below.

Flood Scoring System

A flood scoring system was developed to quantitatively assess and compare flood risk for the 178 identified floodprone buildings in the TCAP study area. The scoring system considers a variety of physical building data, floodplain modeling and mapping, building/property use, and previous documented flooding history, to assign a relative score for each building. Each category has a weight and an associated number of base points (i.e. maximum value) that is used to develop a probability-based score based on which storm event the condition first occurs. The annual probability of a given storm event can be calculated as the reciprocal of the storm event (e.g. a 25-yr storm has a 4% (= 1 / 25) chance of occurring in a given year period). More severe flood situations (e.g. flooding of the finished floor) are assigned a greater weight than lesser flooding situations (e.g. flood waters touching the building). Probability based scores are calculated for each category and totaled to obtain a raw score. Adjustment factors are then calculated based on the building meeting additional criteria and then added to the raw score to compute the total flood risk score. The raw scoring matrix and adjustment factors are provided in the following tables.

Table 3.14 – Flood Risk Raw Score Matrix

Label	Condition	Metric	Weight	Base Points	Points Based on Storm Event			
					10-yr *(10%)*	***25-yr*** *(4%)*	***50-yr*** *(2%)*	***100-yr*** *(1%)*
A	Finished Floor (FF) Flooding - Moderate	Flood elevation above FF	35%	3500	350	140	70	35
B	Finished Floor (FF) Flooding - Major	Additional weight for FF flooding > 2'	25%	2500	250	100	50	25
C	Flooding Surrounds Building	Building is surrounded by flood waters	25%	200	250	100	50	25
D	Flooding at Building - Moderate	Flood elevation above lowest adjacent grade (LAG)	5%	500	50	20	10	5
E	Flooding at Building - Major	Additional weight of LAG flooding => 3'	10%	1000	100	40	20	10
Totals / Maximum Scores			100%	10,000	1,000	400	200	100

Table 3.15 – Flood Risk Adjustment Factors

Label	Condition	Description	Adjustment to Raw Score
F1	Critical Facility or High-Occupancy Facility	Flooding of hospitals, treatment plants, multi-family residences that would increase importance or impact more people	20%
F2	Located in Floodway	Building located in floodway	10%
F3	Has Previous Documented Flooding	Building/Property is Repetitive Loss structure or have made previous flooding complaint	3%
F4	Significant Property Improvements Flooding	Property with significant exterior property improvements that would be damaged by floodwaters	2%

As shown in the tables, there are a maximum of 10,000 base points. However, when applied to probabilistic storm events shown above, the maximum raw score is 1,000 (i.e. all conditions met in 10-yr storm event: = 350 + 250 + 250 + 50 + 100). For the adjustment factors, the maximum adjustment to a given raw score is 35% (= 20% + 10% + 3% + 2%) if all criteria is met. Thus the maximum possible total adjusted score is 1,350 (=1,000 + 1,000*35%).

If a building experiences significant flooding in only the 100-yr event, it would typically receive a score of 100 or above, thus a score of 100 or above can generally be used to identify properties at risk. Conversely, a score of 10 or less would likely reflect limited flooding in only the larger storm events. It is important to note that a risk score of 0 is not intended to imply no risk. These structures may experience flooding in events larger than the 100-yr event or in intense localized events.

An example flood risk score calculation is provided below.

<u>Example Flood Risk Score Calculation</u>

A single-family residential house with typical property improvements meets the following characteristics:

- experiences moderate finished floor flooding starting in the 25-yr storm event, but never more than 2 feet in any of the larger defined storm events (i.e. 50- and 100-yr events)
- is completely surrounded by the mapped 100-yr floodplain
- experiences moderate flooding at the lowest portion of the building starting at the 10-yr storm event, and starts to experience major (i.e. => 3') flooding at the building in the 100-yr event
- is not a critical facility

- is not located in a mapped floodway
- has drainage requests associated with flooding

The calculated raw flood risk score for the building is 450. The building has documented flood history which adds a 3% adjustment equal to 14 (=450 * 3%, rounded to nearest integer). Thus the total flood risk score for the building is 464, as shown below.

Label	*Condition*	*Base Points*	*Min Qualifying Storm Event*	*Score*
A	Finished Floor (FF) Flooding - Moderate	3500	4% (25-yr)	140
B	Finished Floor (FF) Flooding - Major	2500	N/A	0
C	Flooding Surrounds Building	200	10% (10-yr)	250
D	Flooding at Building - Moderate	500	10% (10-yr)	50
E	Flooding at Building - Major	1000	1% (100-yr)	10
			Raw Score	*450*

Label	*Condition*	*Min Qualifying Storm Event*	*Score*
F1	Critical Facility or High-Occupancy Facility	N	0%
F2	Located in Floodway	N	0%
F3	Has Previous Documented Flooding	Y	3%
F4	Significant Property Improvements Flooding	N	0%
		Adjustment%	*3%*
		Adjusted Score	464

TCAP Flood Risk Scoring Results

Risk scores for the 178 floodprone buildings within the TCAP study area were calculated. Results of the scoring analysis showed that most buildings are at relative low risk to flooding. Sixty-four (64) (36%) of the 178 total buildings had a score of 0, and 83 (47%) had a score of less than 10. Only 11 (6%) buildings had a score greater than 100, with the maximum score being 500. Nearly half (84 of 178) of the buildings had a score between 10 and 100, indicating moderate risk. The table below summarizes the results of the scoring. Maps showing building flood risks are provided in Figures 3-14 – 3-16 at the end of this subsection. A table with more detailed information for each individual building is included in Appendix A.

Table 3.16 – TCAP Study Area Flood Risk Score Summary

Risk Score	No. of Primary Buildings	Percent of Total (by No. of Buildings)
> 500	0	0%
201 - 500	5	3%
101 - 200	6	3%
81 - 100	9	5%
51 - 80	33	19%
11 - 50	42	24%
1 - 10	19	11%
0	64	36%

Of the 11 buildings that scored above 100, five (5) are along Walnut Creek, four (4) are along Swift Creek Tributary, and two (2) are along Coles Branch. All are single-family homes with the exception of two apartment buildings. The structures along Walnut Creek are all clustered in the downstream portion of the TCAP study near the stream crossing at Urban Drive, which was assessed to experience significant roadway overtopping as well. The high scoring buildings along Swift Creek Tributary and Coles Branch are not in close proximity to each other; however, there are similarities in the nature of the flooding. For example, both high scoring buildings along Coles Branch are immediately upstream of undersized road or railroad crossings. One of the buildings near the top of the study area is just upstream of a railroad

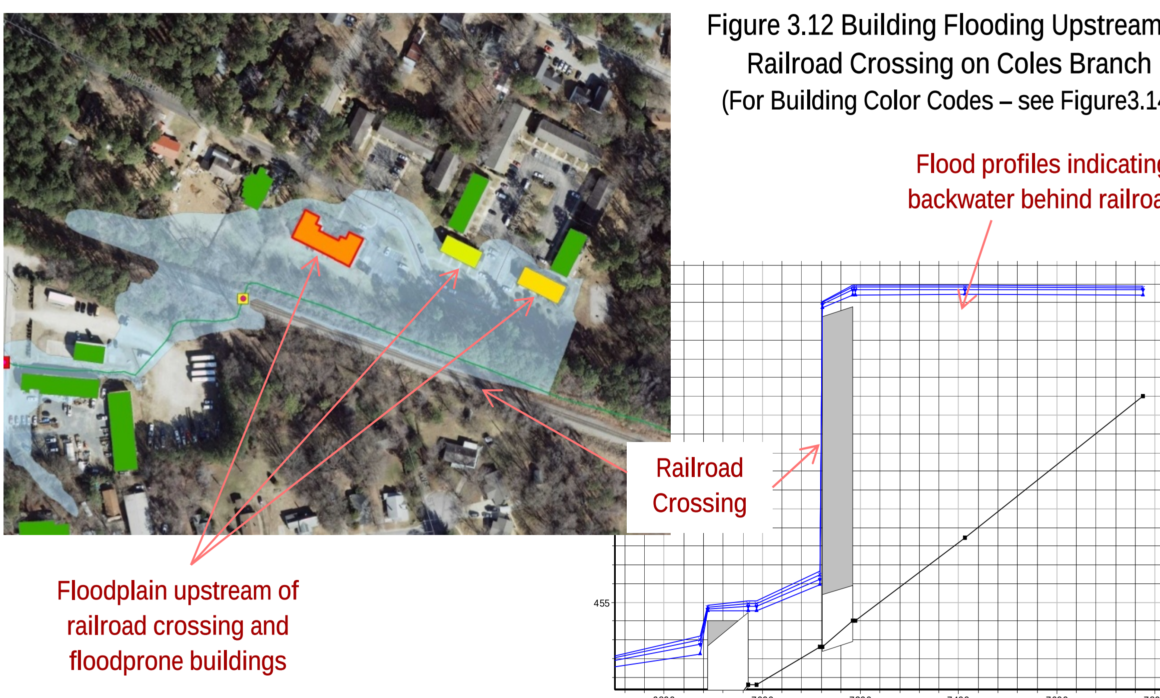


Figure 3.12 Building Flooding Upstream of Railroad Crossing on Coles Branch
(For Building Color Codes – see Figure3.14)

crossing, which appears to be "backing up" flood waters significantly during large storm events.

Figure 3.13 Buildings in Low-Lying Areas Adjacent to Stream

This is illustrated in the graphic above which shows a view of the floodplain and flood profiles. In addition to the apartment building that has a score above 100, there are several other buildings affected by the backwater flooding with moderate risk scores (> 50) as shown in the graphic. In these cases where the potential for building flooding appears to be the result of downstream culverts or bridges backing up flood waters, infrastructure improvements (e.g. upsizing culverts and bridges) are often a cost-effective mitigation technique.

Although it appears that backwater from undersized culverts and bridges is a significant cause of building flooding in the TCAP study area, there are areas where other factors contribute, such as proximity to streams, low elevations, and increased flood flows from development. In many cases, the primary cause of flooding appears to be from the fact that a given building is located in a low-lying area adjacent to the stream. An example of this situation along the tributary to Swift Creek is shown in the graphic on the left. In these situations, a number of techniques such as upstream detention, structure elevation, flood barriers, or acquisition may be available as mitigation options. Discussion of mitigation improvement options and recommendations are discussed later in this chapter and also in Chapter 6.

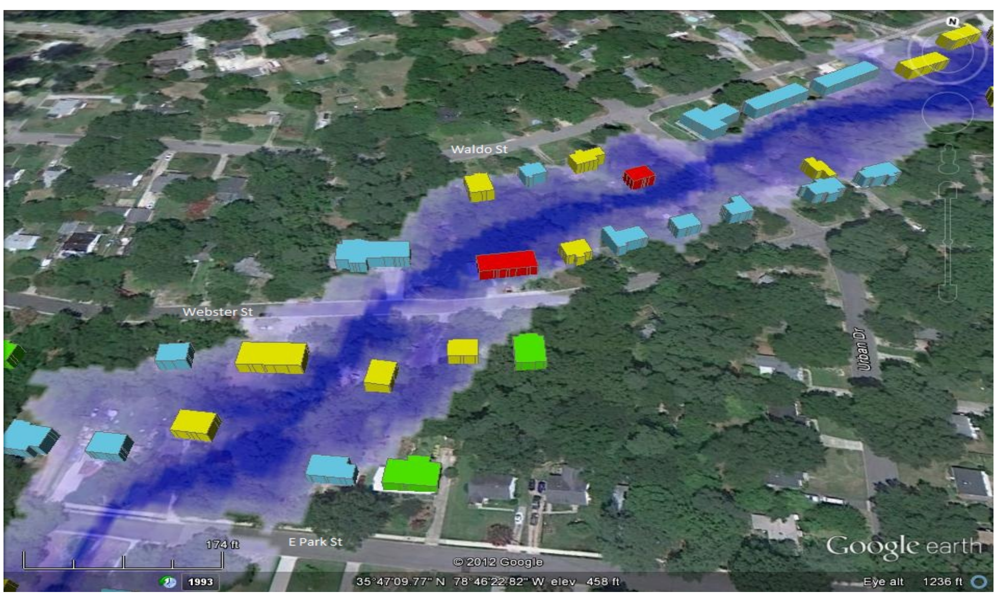


Figure 3.13A - 3D Representation of Flood Risk Areas

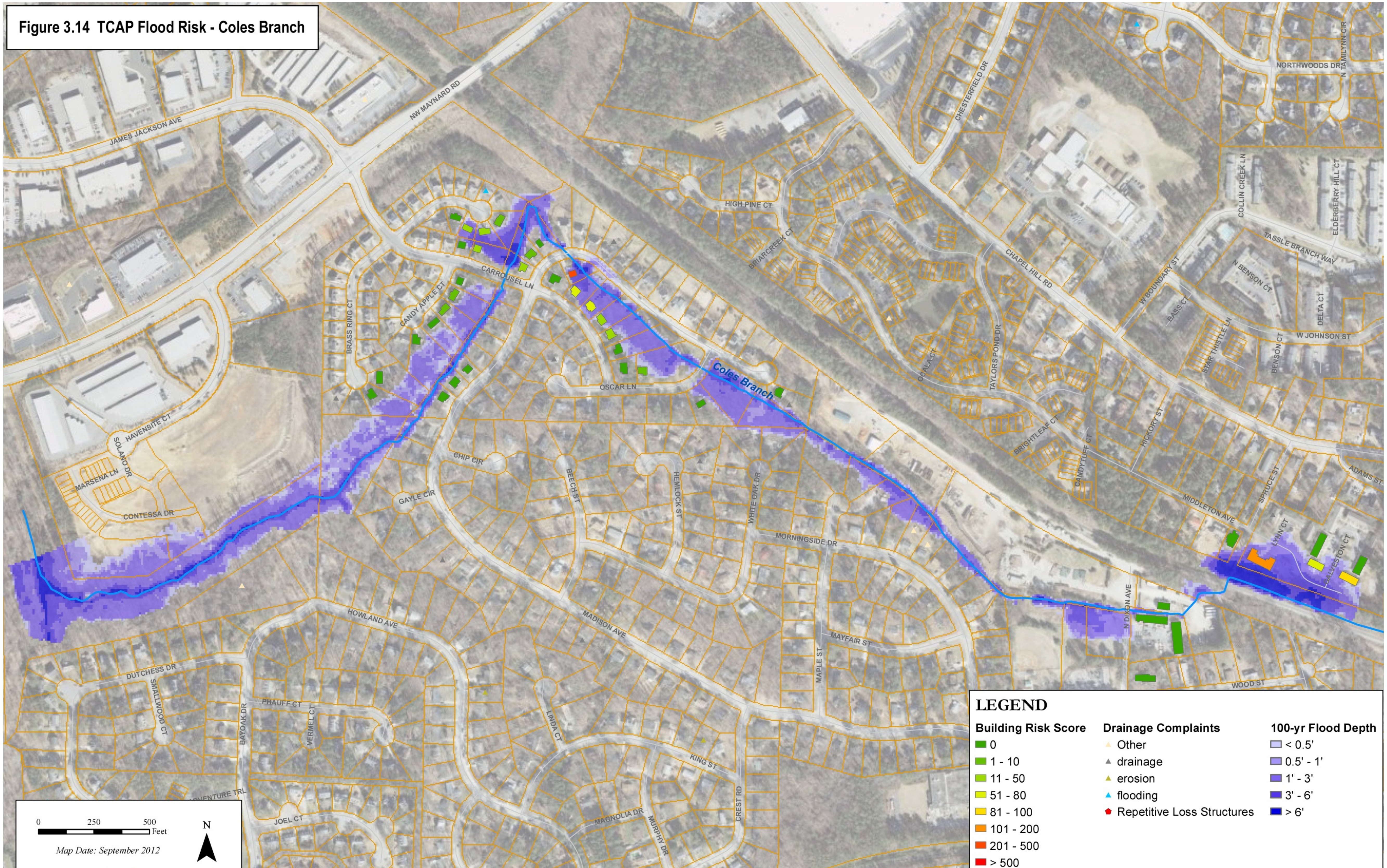


Figure 3.14 TCAP Flood Risk - Coles Branch
NW MAYNARD RD
JAMES JACKSON AVE
HIGH PINE CT
BRIARCREEK CT
CHESTERFIELD DR
CHAPEL HILL RD
NORTHWOODS DR
N TAMILYNN CIR
COLLIN CREEK LN
ELDERBERRY HILL CT
TASSLE BRANCH WAY
N BENSON CT
W BOUNDARY ST
BASS CT
DELTA CT
W JOHNSON ST
STAR THISTLE LN
BENSON CT
CARROUSEL LN
CANDY APPLE CT
BRASS RING CT
OSCAR LN
Coles Branch
TAYLORS POND DR
OCALA CT
BRIGHTLEAF CT
CANDYTUFF CT
HICKORY ST
MIDDLETON AVE
SPRUCE ST
ADAMS ST
LOGIN CT
KILLINGSTON CT
HAVENSITE CT
SOLAND DR
MARSENA LN
CONTESSA DR
CHIP CIR
GAYLE CIR
BEECH ST
HEMLOCK ST
WHITE OAK DR
MORNINGSIDE DR
N DIXON AVE
HOWLAND AVE
MADISON AVE
MAYFAIR ST
MAPLE ST
WOOD ST
DUTCHESS DR
SMALLWOOD CT
BAYOAK DR
PHAUFF CT
VERMEL CT
LINDA CT
KING ST
CREST RD
ADVENTURE TRL
JOEL CT
MAGNOLIA DR
MURPHY DR
0 250 500 Feet
N
Map Date: September 2012
LEGEND
Building Risk Score
0
1 - 10
11 - 50
51 - 80
81 - 100
101 - 200
201 - 500
> 500
Drainage Complaints
Other
drainage
erosion
flooding
Repetitive Loss Structures
100-yr Flood Depth
< 0.5'
0.5' - 1'
1' - 3'
3' - 6'
> 6'

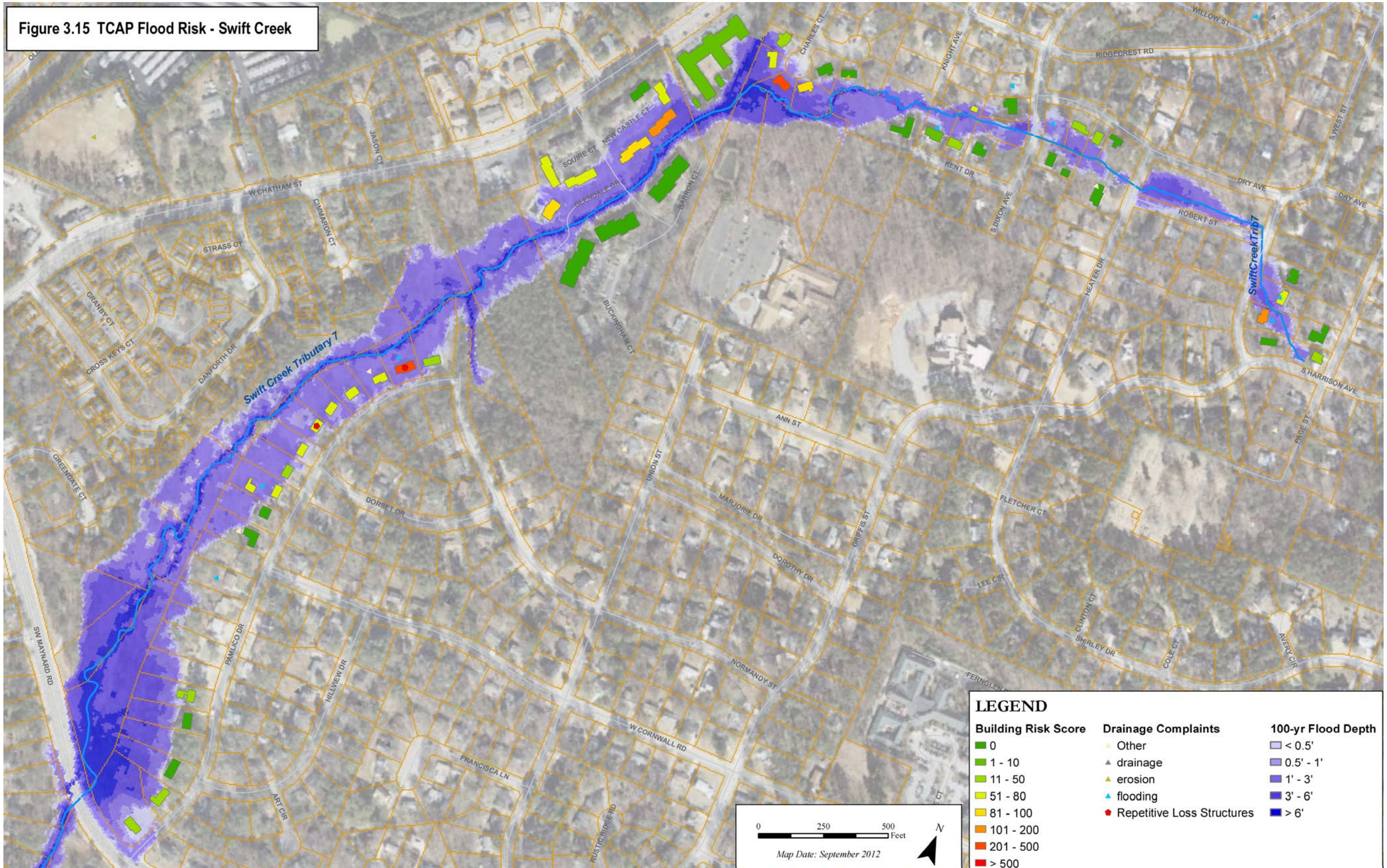


Figure 3.15 TCAP Flood Risk - Swift Creek

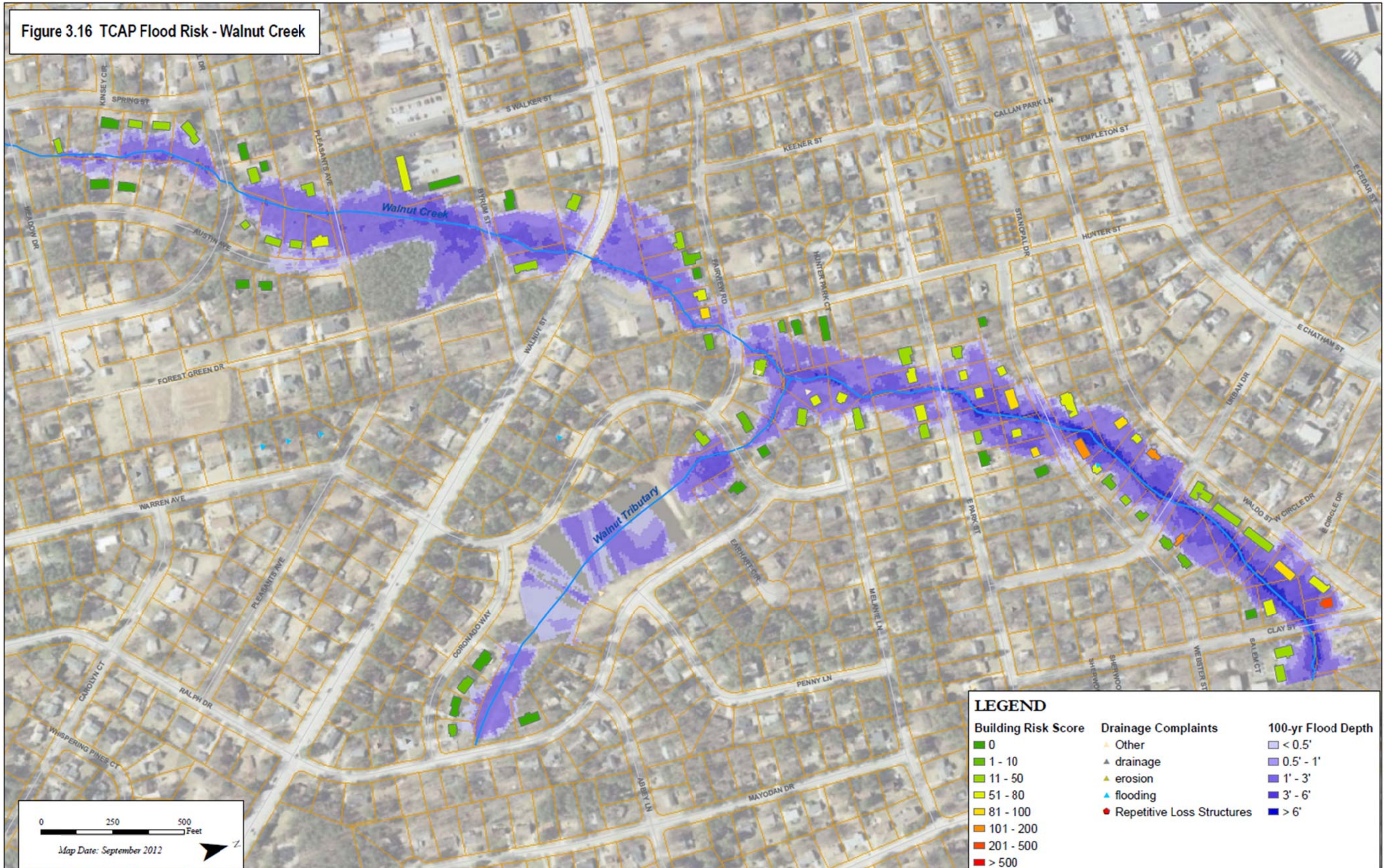


Figure 3.16 TCAP Flood Risk - Walnut Creek

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F. Building and Property Flooding Hot Spots

Building and property flooding hot spots within the Town were identified from available floodplain mapping data, building footprints, drainage requests, and available flood insurance claim information. This information was compiled and spatially analyzed to identify locations. Areas that were identified in the risk assessment, or had a concentrated number of buildings in the floodplains and/or previous flood history from drainage requests or insurance claims were flagged.

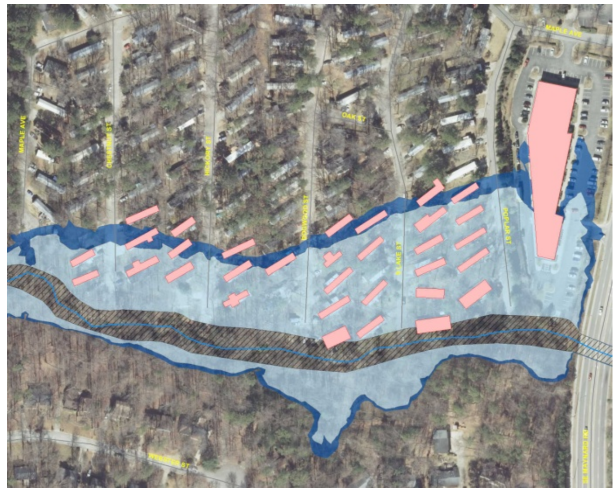

Figure 3.17 Example Building Hotspot along Walnut Creek near SE Maynard Rd

Based on the evaluation, nine (9) building and property hot spots were identified throughout the Town planning limits. Seven (7) of the hot spots were located within mapped floodplains (i.e. in larger scale drainage areas), while the remaining two (2) hot spots were in more localized drainages (i.e. upstream of mapped floodplains). The flooding hot spots are shown in Figure 3-18 and summarized in the table below.

Table 3.17 – Building/Property Flooding Hot Spots

ID	Location Description	Problem Description	Flood Scale	Named Flooding Source
1	Swift Creek U/S of Holly Springs Rd.	Significant buildings in floodplain; Numerous complaints of street, yard, garage, and crawl space flooding during large events	Larger Scale	Swift Creek
2	Swift Creek at Kildaire Farm Rd.	Significant buildings in floodplain and several in floodway; Complaints of flooding during large events	Larger Scale	Swift Creek
3	Brittany Pl. and Versailles Dr.	Numerous complaints of yard flooding	Localized	N/A
4	Jodhpur Dr. in Parkway Homeowners Neighborhood	Numerous complaints of yard and accessory building flooding	Localized	N/A

ID	Location Description	Problem Description	Flood Scale	Named Flooding Source
5	Swift Creek Tributary #7 near Lake Pine Dr.	Several complaints of erosion and complaint of flooding due to blocked culvert	Larger Scale	Swift Creek Tributary #7
6	Walnut Creek near SE Maynard Rd.	Significant buildings in floodplain and several in floodway	Larger Scale	Walnut Creek
7	Swift Creek Tributary #7 near South Dixon Av.	Several buildings in floodplain; Numerous complaints of structure and yard flooding	Larger Scale	Swift Creek Tributary #7
8	Pamlico Dr. and Dorset Dr.	Several buildings in floodplain	Larger Scale	Swift Creek Tributary #7
9	Urban Dr. and Webster St.	Several buildings in floodplain	Larger Scale	Walnut Creek

As shown in the figure, the building and property hotspots are concentrated in the central and southern portions of the Town, several of which are in the vicinity of the TCAP area. In addition, the majority of the hotspots are larger scale drainage issues located in the Swift Creek and Walnut Creek watersheds. The most prevalent factor contributing to potential structure flooding appears to be buildings located within the FEMA floodplain and / or floodway. Potential improvement options for these hot spots are discussed in Chapter 5.

Figure 3.18 Building / Property Flooding Problem Area Hot Spots