SECTION 5

Design Criteria & Preliminary Analysis

This section of the report describes the hydraulic design criteria used during the system hydraulic modeling evaluation described in Section 6. This section also presents a preliminary analysis of the Town's residential service line sizes and the required storage volumes to satisfy future demand conditions.

Table 5-1 displays the design criteria adopted for this study that were used to size the water system network components including: pump stations, storage tanks, control valves, and pipeline diameters. A discussion of the following design requirements is provided in this section.

- Water Supply
- System Pressure
- Fire Flow Demand
- System Storage
- Piping Hydraulics
- Emergency Conditions

5.1 Water Supply

Industry accepted standards[1] associated with municipal water supply facilities suggest that a pumping station should provide the MDD with the largest pump out of service. This condition is defined as the "firm capacity" of the pumping station. The firm pumping capacity plus the available storage is required to satisfy peak hour demand (PHD) or fire flow demand.

5.1.1 Town of Cary Supply

For master planning purposes, Town of Cary pumping facilities were sized based on projected MDD, which is based on the project ADD. The Town of Cary staff rigorously monitors daily water demands so that demand projections are based on data that are as realistic as possible. Some operational requirements such as filling and drafting of elevated tanks may require higher pumping rates in excess of the MDD, but these conditions are usually encountered when existing storage is excessive or due to system specific operational preferences. Excessive storage is not considered a problem in the Town of Cary's distribution system.

[1] AWWA M32 – Computer Modeling of Water Distribution Systems, p.69

TABLE 5-1
Water Distribution System Hydraulic Evaluation Criteria

System Parameter	Evaluation Criterion	Value	Design Standard/Guideline
Water Supply	Firm Pumping Capacity[a]	MDD[b]	Industry Standard Practice
	Firm Pumping Capacity + Elevated Storage Tank Supply	PHD[c]	Industry Standard Practice
	Firm Pumping Capacity + Elevated Storage Tank Supply	MDD + FF	Industry Standard Practice
	System Emergency Capacity[d]	ADD[e]	Developed for this Master Plan
System Pressure	Minimum, during ADD or MDD	40 psi	Town of Cary Policy Statement 129
	Minimum, during PHD	30 psi	Town of Cary Policy Statement 129 and NCAC T15A:18C.0405(b)
	Minimum, during MDD + Fire Flow	20 psi	Town of Cary Policy Statement 129 and NCAC T15A:18C.0405(b)
	Recommended Maximum Pressure	125 psi	Developed for this Master Plan
Water Storage	Minimum Combined Elevated and Ground Storage Capacity	½ ADD	NCAC T15A:18C.0805
	Equalization Volume	12-24% of ADD[f]	Developed for this Master Plan
	Fire Flow Volume	3,500 gpm x 3 hrs	Town of Cary Master Plan (2000)
	Emergency Volume	25% of ADD	Town of Cary Master Plan (2000)
Fire Flow Demand	Maximum Fire Flow[g]	3,500 gpm	Town of Cary Master Plan (2000)
	Minimum Residential Fire Flow	1,000 gpm	Town of Cary Standard Spec. Sect. 6
	Minimum Non-Residential Fire Flow[h]	1,500 gpm	Town of Cary Standard Spec. Sect. 6
Piping Hydraulics	Maximum Velocity during MDD	5 ft/sec	AWWA M32 (p. 68)
	Maximum Velocity during PHD or MDD+FF	10 ft/sec	AWWA M32 (p. 69)
	Maximum Head Loss (D<16-inch)	6 ft per 1000 ft[i]	AWWA M32 (p. 68)
	Maximum Head Loss (D>16-inch)	2 ft per 1000 ft[i]	AWWA M32 (p. 68)

[a] Firm Pumping Capacity: Capacity of pumping facility with largest pump out of service.

[b] MDD: Peaking factor of 1.64 was selected for use in this Master Plan to calculate the maximum day demand as a function of average day demand.

[c] PHD: Peak hour demand was simulated based on diurnal demand curve; defined as the maximum volume (or flow rate) of water delivered to the system during any single hour of the MDD.

[d] System Emergency Capacity: Total capacity of all pumping facilities minus largest facility (i.e. Cary/Apex WTP High Service Pump Station CPZ pumps or 42-inch transmission main out of service) plus total emergency storage volume of storage tanks.

[e] ADD: Average day demand, defined as the average volume (or flow rate) of water delivered to the system or pressure zone during a single day.

[f] Equalization factors by pressure zone: 12% (CPZ), 16% (WPZ), and 24% (SPZ). Tanks not allowed to drop below 20-ft during modeling analysis.

[g] Maximum Fire Flow: Fire flow requirement at commercial, industrial, and institutional customers when ISO "needed fire flow" information is not available.

[h] Minimum Non-Residential Fire Flow: Minimum fire flow when ISO "needed fire flow" is less than 1,500 gpm.

[i] Value shown is recommended for the design of new facilities. Existing facilities may have a higher value.

5.1.2 Town of Apex Supply

The demand projections developed by CH2M HILL for the Town of Apex 2007 Local Water Supply Plan were used in this Master Plan. Determining the Town of Apex's available and required storage was not included in the scope of this project, and the extent to which the Town of Cary may or may not be conveying flow to the Town of Apex in excess of the MDD is unknown. Evaluation of SCADA data for the Town of Apex's Jenks and Green Level flow meters from August 12-15, 2008 revealed that the total hourly flow varied from 500-4,500 gpm due to the on/off operation of the Green Level control valve which conveyed a majority of the flow. For this reason, the modeling analysis described in Section 6 was conducted using the assumptions listed below for the Town of Apex's system. Recommendations for further investigation of the Apex system are included in Appendix G.

- Existing MDD modeling runs were performed using a varying hourly supply rate to the Town of Apex typical of summer conditions
- Future MDD modeling runs (year 2010 through build-out) were performed assuming a constant hourly supply rate to the Town of Apex

5.2 System Pressure

The North Carolina Administrative Code (NCAC T15A:18c.0405b) states that elevated storage tanks should be designed to provide at least 20 psi during fire flow conditions and 30 psi during peak flow conditions.

The Town of Cary applies its Policy Statement 129 (included in Appendix D) which is similar to the NCAC criteria described above. Policy Statement 129 states that minimum pressure for water distribution systems, including pumping facilities and storage tanks or reservoirs, should be designed so that water pressures of at least 40 psi at ground level will be maintained at all points in the system, including the highest ground elevations in the service area. A minimum pressure of 30 psi is allowed given that peak flow requirements can be satisfied. However, during fire flow events the water pressure should not fall below 20 psi at any hydrants in the systems. Maximum pressure goal in the system is not to exceed 125 psi, but despite that requirement, static pressures above 125 psi are tolerable. High pressure areas are primarily located in the Morrisville and RDU Airport areas, and reducing high pressures in this area would require a modification of pressure zone boundaries as described in Section 6.2.

Pressure requirements in a water distribution system are typically defined spatially as the pressure required "at the curb" or at the customer meter demarcation point. However, planning departments typically evaluate the entire land area or parcel to ensure that high elevation areas are identified and addressed with appropriate pipe configuration and sizing. This section addresses both requirements and includes an evaluation of residential service lines (Section 5.2.1) and areas of low pressure in the system (Section 5.2.2).

5.2.1 Evaluation of Residential Service Line Sizing

In recent years, the Town has received pressure complaints primarily at high elevation areas where pressures "at the curb" were approaching the limits of Policy Statement 129. It was

suggested by Town staff that the pressure complaints had arisen due to a number of factors but most importantly at those residential customers with multi-story dwellings and irrigation systems that connected to the customer's domestic water service line.

In order to verify that the above policies were appropriate for the Town of Cary water system, considering the "typical" pressure losses from the street, through the customer meter, and to the point of use (POU), the Town of Cary requested an analysis of appropriate procedures and policies for the selection of residential water service line and meter sizes. Additional information about this analysis is included in Appendix D and Appendix G.

Typically, the size of a service line for residential service is ¾-inch. However, the Town of Cary requires 1-inch service lines for new residential customers. There are predictable pressure losses that occur in a residential water service line related to the water meter, check valve, and length of the line. Depending on the flow rate in the line, these losses can be substantial. The flow rate in the service line is related to the number of fixtures in use concurrently. For most homes, these losses are not substantial enough in a standard ¾-inch service line and meter to cause noticeable low pressures inside a residence. However, extensive irrigation system use, and/or a larger home with many bathrooms or stories can exacerbate this problem. In this case, a larger service line and water meter may be needed to alleviate these pressure losses and maintain adequate pressures for indoor water fixtures.

5.2.1.1 Baseline Assumptions

For this evaluation, a number of assumptions were made including:

- The house must have been constructed after the Town began requiring separate irrigation meters which occurred in August 2000
- The house criteria are: 2 or more stories; 3 or more bathrooms; and 4,000 square feet or greater
- Separately metered irrigation connected to domestic water service line
- The fixtures in this house will all meet the maximum flow rates listed in the current 2002 North Carolina Plumbing Code, Section 604.4, shown in Appendix D. However, the code does not specify maximum flow rates for water-using appliances. For those water-using appliances such as dishwashers and clothes washers the flow rates are assumed to be similar to a kitchen faucet for the purpose of the analysis

The length of the service line is also a factor in the pressure losses that occur in the service line. If the service line is longer than average, the pressure loss will be greater, and should be considered when sizing the service line.

5.2.1.2 Prior Investigations

The Town of Cary performed an "Individual Plumbing and Irrigation Study" in 2006, which investigated ten homes for low pressures related to indoor and irrigation water use. Of those ten existing homes, seven were investigated for indoor plumbing pressures. The study included fairly new, existing homes only, and no assumptions could be made about deterioration of plumbing components. The results are documented in a summary dated November, 2006. The results related to indoor pressures include the following:

- Only one home had a problem between the water main and meter
- Pressure losses following the meter could usually be reduced by removing or adjusting the pressure reducing valve
- Beyond the removal of the pressure reducing valve, more expensive options were to replace the service line with a larger size or to install an individual tank and pump system, but none of the customers were interested in either of these options

The study also documented the issues related to irrigation systems, and the common theme was lack of maintenance. Problems identified in the study included the following:

- Zone valve stuck in the open position, thus running more than one zone at the same time, resulting in lower overall pressure and poor performance of the sprinkler heads
- Pipe or valve leaking resulting in lower overall pressure and poor performance of the sprinkler heads

5.2.1.3 Billing Data Review

The Town's billing data was queried to find some customers that meet the criteria described above, and their data is presented below. These data are recorded on a monthly basis, so the flow is a monthly average, and does not represent the peak instantaneous flow rate that may occur when multiple fixtures and water-using appliances are in use. Also, when converted to gallons per minute from gallons per month, the result is much lower than the instantaneous flow rate. As shown in Table 5-2, this limited data set indicates that the larger residences with 3.5 bathrooms generally consume more water than the slightly smaller residences with 3 bathrooms. It can also be noted that those homes with the highest indoor use in the dataset also had the highest irrigation use.

TABLE 5-2
Town of Cary Residential Monthly Indoor Water Demands

House Type[a, b]	Maximum Monthly Indoor Demand in 2005 (gpm)	Average Monthly Indoor Demand in 2005 (gpm)
2 story; 4,400 square feet 3.5 or more bathrooms	2.85	0.54
2.5 story; 3,823 square feet 3.5 or more bathrooms	1.93	0.46
2 story; 3,332 square feet 3.5 or more bathrooms	1.92	0.59
2 story; 3,174 square feet 3 bathrooms	0.45	0.15
2 story; 3,212 square feet 3 bathrooms	0.29	0.11

[a] Houses were built in 2004.

[b] Parcel database contains a maximum of 2.5 stories and 3.5 or more bathrooms.

Because instantaneous flow readings were not available, it was recommended that the Town install several digital flow recorders made by Meter Master on select residential meters to obtain hourly consumption data. The Town currently owns several Meter Masters and routinely uses them to help identify service line leaks. Collecting this data would provide information on the current customers' water use habits and peak instantaneous water demand at the larger residences. An example output screen of this information from the Town is shown in Appendix D. At the time this report was finalized, the Town had not conducted the flow monitoring.

5.2.1.4 American Water Works Association (AWWA) Manual M22 Review

The AWWA M22 Manual entitled "Sizing Water Service Lines and Meters" (2004) provides a methodology and protocol for calculating service line size that is accepted by the water industry. However, there are several disclaimers in document that declare much of the research behind the formulas and empirical calculations date back as far as 1940. Much has changed in the field of indoor water-using fixtures and appliances, especially since the early 1990's with the National Energy Policy Act that lowered the maximum flow rates for toilets, faucets, and showerheads. The success of the EPA Energy Star™ program in the late 1990's and 2000's has lowered the water use for clothes washers and dishwashers substantially. Many of these Energy Star™ appliances such as horizontal-axis, front-loading clothes washers are high-end and typically are installed in residences that meet the criteria above.

The methodology in M22 for sizing service lines is dependent on estimates of water use in a home, with the use rates provided by the Manual. Therefore, the flow rate calculations that are given for many of these fixtures and appliances are overestimated and are not representative of new homes that are being built in the Town of Cary. See Appendix D for an excerpt of the disclaimer by AWWA.

The overestimation of residential flows in M22 results in an overestimation of the pressure losses through the service line, as well as the meter and check valve. The length of the service line further exaggerates this overestimation, which could result in oversized meters and service lines. An example calculation is shown below demonstrating the values calculated based on the M22 methodology and those calculated based on the NC Plumbing Code. It is apparent that the M22 method would result in a larger service line due to the overestimation of instantaneous flow.

The Town of Cary also performed some sample calculations to demonstrate that an increase in service line size from ¾-inch to 1-inch provides the greatest opportunity to reduce pressure losses. While this conclusion is correct, it is based on flows that may be overestimated by the M22 Manual. Using a larger service line size decreases the pressure loss, but also costs more in capital costs of the service line, meter, check valve, and other appurtenances.

TABLE 5-3
Comparison of M22 and NC Plumbing Code Calculations for Flow and Head Loss

M22 Flows	NC Plumbing Code Flows
Bath = 8 gpm	Bath = 4 gpm
Toilet = 4 gpm	Toilet = 3 gpm
Clothes Washer = 6 gpm	Clothes Washer = 4 gpm
Flow rate assuming operating 3 toilets, 1 clothes washer, and 1 bath:	
(3x4)+6+8 = 26 gpm	(3x3)+4+4 = 17 gpm
Head loss in a 50 foot service line of ¾-inch K-type copper:	
0.7 psi/ft at 26 gpm	0.35 psi/ft at 17 gpm
0.7x50 = 35 psi loss	0.35x50 = 17.5 psi loss

5.2.1.5 Other Utilities' Practices

The issue of water service line and meter sizing is not exclusive to the Town of Cary. Other water utilities face the same issue and have developed methodologies for addressing the issue. Two water utilities with growth trends similar to the Town's were interviewed to understand their practices with regard to service line and meter sizing. These two water utilities were the Town of Purcellville, Virginia and Forsyth County, Georgia. They are both ranked in the top five richest counties in the country, and are experiencing affluent, residential growth. Appendix G contains additional information about these and other utilities' practices.

The Town of Purcellville uses a methodology based on water supply fixture units that appears to have originated from the 2006 International Residential Code (IRC). The Town requires an application form (included in Appendix D to be completed prior to approval of water serves that specifies the values that the applicant must use to develop the water supply fixture units. This calculation is then used to determine the meter size the business or residence must use.

The Forsyth County Water and Sewer Department Plumbing Inspector recommends using the calculation methodology found in Section 29 of the 2006 IRC (included in Appendix D) for sizing water service lines and meters. The Department confirmed that the number of bathrooms provides a good indicator of the meter size needed and it require a home with 6 or more bathrooms to use a 1-inch meter and 1-inch service line instead of a standard residential ¾-inch service line and meter. Any residential customer may purchase a 1-inch meter if they are willing to pay the higher initial costs. Also, if the length of the service line is longer than an average of fifty to seventy feet, a 1-inch service line and meter is recommended.

5.2.1.6 International Code Council

The International Code Council is a membership association dedicated to building safety and fire prevention. The Council, headquartered in Washington, DC, develops the codes

used to construct residential and commercial buildings, including homes and schools. Their 2006 International Residential Code (IRC) is being used by many cities, counties and states in the United States that adopt codes. The 2006 IRC methodology results in residential flows and pressure losses that are significantly lower than those predicted using the AWWA M22 methodology. An example calculation is shown below demonstrating the values calculated based on the M22 methodology and those calculated based on the 2006 IRC for a 3-story house with two showers, two toilets and one sink operating.

TABLE 5-4
Comparison of M22 and International Code Council IRC Calculations for Flow and Pressure

M22 Flows[a]	2006 IRC Flows[a]
18 gpm	12.8 gpm
Head loss in a 70 foot service line, ¾-inch meter and check valve:	
51 psi loss	27 psi loss
For a ¾-inch meter and service line, and for a 1-inch meter and service line, the following pressure at the curb for a 3-story house would be required:	
¾-inch – 84 psi	¾-inch – 60 psi
1-inch – 62 psi	1-inch – 42 psi

[a] Based on 3-story house with two showers, two toilets and one sink operating.

5.2.1.7 Summary

Based on the findings of this evaluation, the number of bathrooms appears to be an important factor in determining the service line and meter size for a residential water customer. The breakpoint cannot be determined with the information collected as part of this study; additional indoor water consumption data, collected hourly over a 24-hour period, would be needed to determine the peak instantaneous flow rates for new, larger residences. It would also be critical to determine the length of the service line to the residence.

Based on the examples above, CH2M HILL recommends that the Town of Cary consider incorporating the 2006 International Residential Code calculation methodology as part of local policies and meter sizing practices.

5.2.2 Evaluation of Low Pressure Areas

A review of the high elevation areas in the Town and the existing pressure zone boundaries indicates that only small areas in each pressure zone are at high elevations that result in pressures that are only slightly above the design criteria shown in Table 5-1 for ADD and MDD and these may be considered marginal. Many of these areas have planned pipeline projects which will strengthen the piping network and reduce potential for peak hour pressure fluctuations. Appendix G contains additional information about some of the topics discussed in this section.

5.2.2.1 Western Pressure Zone (WPZ) High Elevation Areas

A review of elevation contours across the WPZ indicates that the Carpenter Elevated Tank overflow elevation of 540-feet is well established and increasing the overflow elevation in this zone is not necessary. Also, modifying the WPZ boundary due to high elevations is not recommended. As shown in Figure 5-1, there are some small areas of high elevation in the southeast area of the WPZ in the vicinity of High House Road, Carpenter Upchurch Road, Louis Stevens Drive, and Upchurch Meadow Road that are essentially in a "dead-end" portion of the zone. These high elevations can result in pressures that drop below the peak hour pressure criteria of 30 psi when the Davis Drive PRV is off-line as described in Section 6.1. Due to proximity, elevation, and the potential for irrigation systems to malfunction (Section 5.2.1.2), these areas are susceptible to low pressure problems. However, the modeling analysis described in Section 6.1 revealed that if the Davis Drive PRV were open during peak hour demands, pressures would be increased to levels above the 30 psi peak hour pressure criteria. In addition, the Town is planning to construct three pipeline projects in 2009 which will create loops and strengthen the southeast portion of the WPZ as shown in Figure 5-1: 12-inch High House Road Water Line (WT1165 from the 2000 Master Plan), 12-inch Carpenter Upchurch Road Water Line (WT1160 from the 2000 Master Plan), and 12-inch Louis Stevens Drive Water Line (WT1168 from the 2000 Master Plan).

5.2.2.2 Central Pressure Zone (CPZ) High Elevation Areas

A review of elevation contours across the CPZ indicates that the existing overflow elevation of 641-feet is adequate for the zone as a whole and increasing the overflow elevation in this zone is not practical or necessary. Also, modifying the CPZ boundary due to high elevations is not recommended. As shown in Figure 5-2, there are some small areas of high elevation inside the Maynard Road Loop primarily along the Kildaire Farm Road corridor. A smaller subdivision area in the vicinity of Holtz Lane is also at high elevation for the zone. These high elevations can result in marginal operating pressures. However, the Town is planning to construct two pipeline projects by the year 2010 which will strengthen the grid system inside the Maynard Road Loop: 12-inch Walnut Street Water Line Reinforcement (WT1154) and 16-inch Town Center Area Plan (TCAP) Water Line Upgrade (CIB). In addition, reinforcements were recommended in the 2000 Master Plan along the Maynard Road Loop south of these high elevation areas. While pressures at the high elevations will remain in the marginal range, the additional piping infrastructure will reduce potential for peak hour pressure fluctuations.

5.2.2.3 Southern Pressure Zone (SPZ) High Elevation Areas

A review of elevation contours across the SPZ indicates that the existing overflow elevation of 595-feet is adequate for the zone as a whole and increasing the overflow elevation in this zone is not necessary. Also, modifying the SPZ boundary due to high elevations is not recommended. As shown in Figure 5-3, there are some small areas of high elevation along the Ten Ten and Penny Road corridors west of the Plumtree Way Elevated Tank. As well, high elevations are found along Arthur Pierce Road just south of the Plumtree Way Elevated Tank. A 16-inch water line exists along Penny Road and Ten Ten Road at these high elevation areas. By connecting the two pipelines together as shown in Figure 5-3, a new trunk main will be completed from the Kildaire Farm Road and Cary Parkway OCVs to the Plumtree Way Elevated Tank. As well this pipeline will run along the high elevation areas.

While pressures at the high elevations will remain in the marginal range, the additional piping infrastructure will reduce potential for peak hour pressure fluctuations.

5.2.3 Conclusions and Recommendations

Based on the service line evaluation described in Section 5.2.1 and the evaluation of high elevation areas described in Section 5.2.2, Policy Statement 129 should not be modified at this time.

After collecting and reviewing a representative sample of hourly consumption data and after completing the current capital improvement pipeline projects identified above, the Town may then wish to re-evaluate Policy Statement 129 at that time.

While some of the high elevation areas described in this section can experience pressures that are slightly below the pressure criteria stated in Table 5-1, there are operational adjustments and current capital improvement projects that will eliminate these deficiencies "at the curb".

The Town may also wish to consider an additional strategy "beyond the curb" to minimize pressure complaints by adopting a policy that creates low pressure districts in which service lines would be required to be upsized to one size larger than the adopted meter sizing guidelines (AWWA M22 or 2006 IRC). These low pressure districts could be simply defined as a specific elevation above which any proposed development or permit application is required to adhere to the policy.

It is also recommended that the Town of Cary consider incorporating the 2006 International Residential Code calculation methodology as part of local policies and meter sizing practices.

FIGURE 5-1
High Elevations in Western Pressure Zone (High House Road Area)

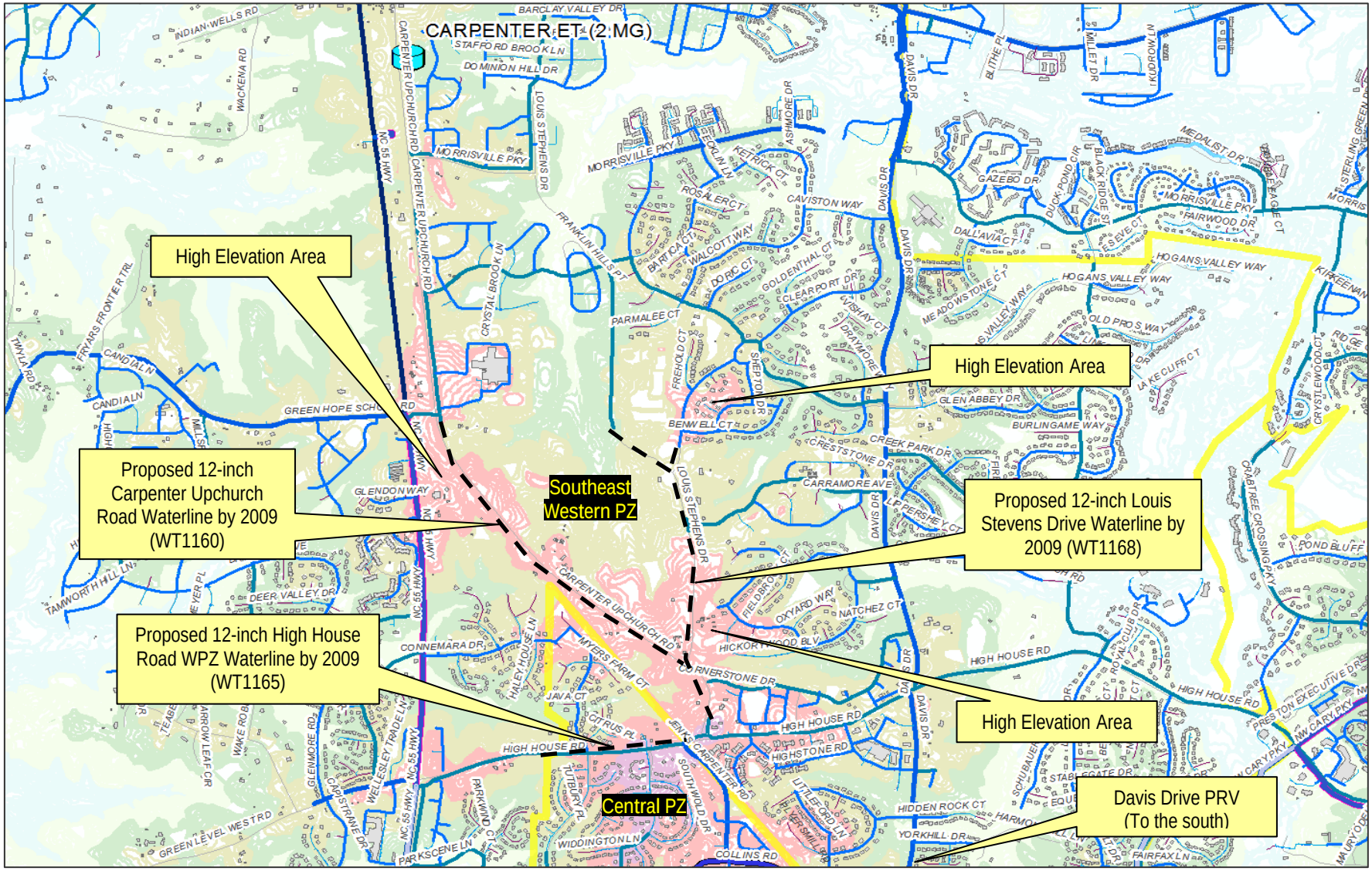


FIGURE 5-2
High Elevations in Central Pressure Zone (Maynard Road Loop Area)

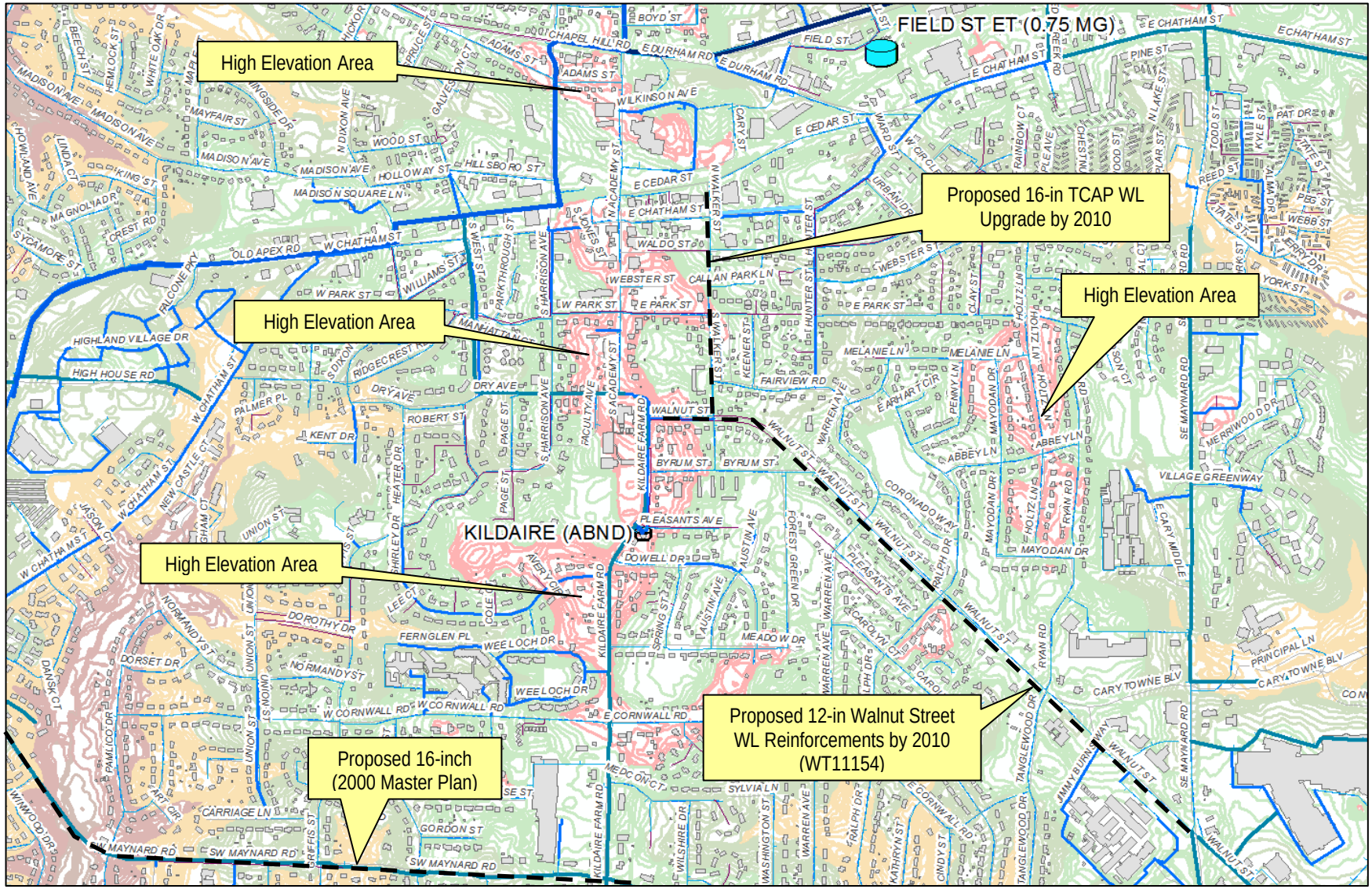
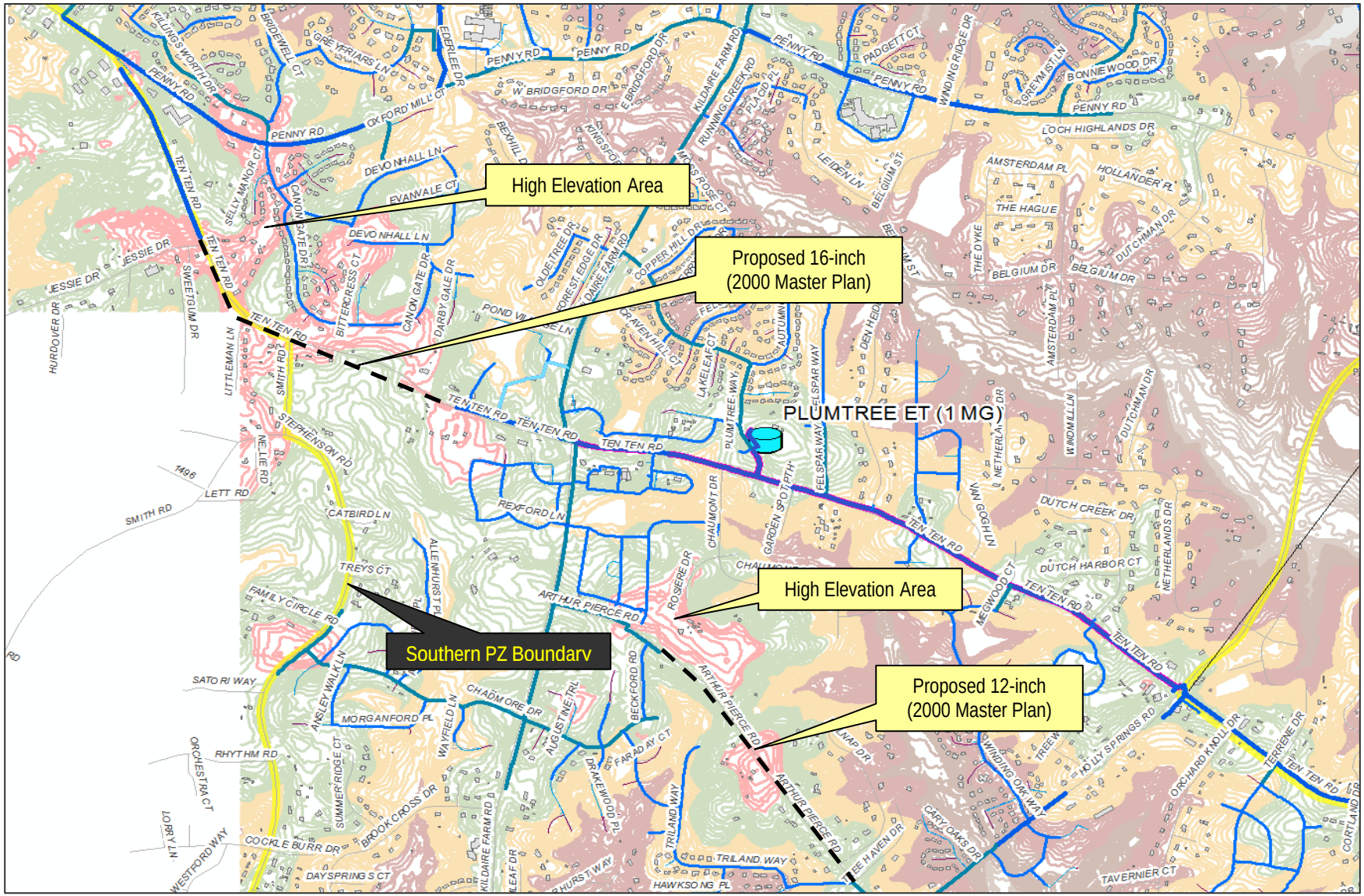


FIGURE 5-3
High Elevations in Southern Pressure Zone



5.3 Fire Flow Demand

The available fire flow (AFF) is typically defined as the flow rate from one or more hydrants that results in a residual pressure of 20 psi at an adjacent hydrant. The required or needed fire flow (NFF) at an unsprinklered building is typically determined based on local building or fire department code requirements and can vary from one jurisdiction to the next. The NFF is typically defined based on the land use, zoning, or a specific facility fire flow design using the Insurance Service Office (ISO) calculations[2].

As shown in Table 5-1, the Town has adopted the following fire flow requirements for unsprinklered buildings:

- Maximum NFF of 3,500 gpm for commercial, industrial, and institutional customers when ISO NFF calculations are not available
- Minimum NFF of 1,500 gpm for non-residential customers when calculations result in a NFF less than 1,500 gpm
- Minimum NFF of 1,000 gpm for residential customers per Town of Cary Standard Specification Section 6

The Town of Cary Fire Department requires that fire flow rates be determined utilizing the ISO methodology. During the 2000 Master Plan, the Fire Department provided ISO-calculated NFF rates for specific facilities to be used during the modeling analysis. For this Master Plan, individual facility NFF information was not available. For this reason, the following NFF rates were adopted for the fire flow modeling analysis: 3,500 gpm for commercial zoning and 1,000 for residential dwellings. As described in Section 6, an automated fire flow analysis was conducted in the model at every hydrant node in the system for existing and build-out demand conditions.

5.4 Water Storage

5.4.1 Storage Volume Criteria

Water system storage is theoretically comprised of three main components or volumes including: equalization, fire protection, and emergency storage[3]. The equalization component of storage supplies the hourly demand in excess of the average daily demand rate. Section 4.4.1 describes the diurnal demand pattern developed for this study. The integration of the peaks associated with the diurnal demand patterns was calculated for each pressure zone to determine the respective equalization factors as a function of the MDD: 16% (WPZ), 12% (CPZ), and 24% (SPZ). In the 2000 Master Plan an equalization factor of 30% was utilized across the board in sizing all future storage tanks, potentially overestimating storage requirements. For this Master Plan, it is recommended that the individually-calculated equalization factors be utilized instead. Further refinement of

[2] AWWA M31 - Distribution Requirements Fire Protection

[3] AWWA M32 - Computer Modeling of Water Distribution Systems, p. 74

diurnal demand patterns as part of the upcoming water quality modeling task will allow the Town to better forecast future storage requirements for the system.

As identified in Table 5-1, the fire flow component of storage must be sufficient to provide the maximum NFF for a minimum of 3 hours or 3,500 gpm x 3 hours. Additionally, this fire protection storage must be delivered to the Town's system within the minimum pressure requirement of 20 psi. For master planning purposes, a general assumption regarding fire protection storage was implemented that only one fire occurs in the system at a time.

The emergency component of storage is maintained for emergency circumstances, such as a water main break or major power outage. The Town of Cary adopted the criteria of 25 percent of the ADD for the 2000 Master Plan as the emergency storage requirement. This can be thought of as the volume of water that would supply the system for 6 hours (25% of 24 hours). This design criterion is again recommended for this study based on the fact that Cary has emergency supply capabilities from the Raleigh, Durham, and Apex connections. As well, the Cary/Apex WTP facility was designed and equipped with emergency back up power in case of power failures. For these reasons, a higher emergency factor was not utilized. For the WPZ and SPZ, an emergency component of storage was not included because it can be provided by the CPZ during an emergency and/or from the Durham and Apex connections.

In addition to the storage criteria stated above, NCAC Title 15A Subchapter 18C.0805 states that the minimum combined elevated and ground storage capacity should be equal to at least half of average day demand. The calculations required by the NC Department of Environment and Natural Resources (NCDENR) are provided in Section 5.4.3.

5.4.2 Storage Volume Analysis

Sufficient storage must be maintained in the distribution system under existing and future demand conditions. Table 5-5 provides the average and maximum day demand projections for existing conditions and the defined planning periods. In addition, demands are presented for an alternative in which the entire Morrisville and RDU Airport area is incorporated into the WPZ. Table 5-5 also provides detailed calculations for equalization, fire flow, and emergency components of storage for the existing and future demand conditions for both the existing and alternative pressure zone boundaries.

As shown in Table 3-3, the total and "usable" elevated and re-pumped storage for the Town's system is 9.3 MG and 8 MG, respectively. As defined in Section 3.4, "usable" volume addresses equalization, fire flow, and emergency volumes. It is based on the minimum water level in an elevated tank that is necessary to provide approximately 30 psi to all areas within the pressure zone. The "usable" volume is not the same as the daily "operational" volume that is utilized for equalization purposes.

A GIS analysis using the 2-foot elevation contour data was conducted and confirmed that 30 psi could theoretically be achieved at all points in the water system if the elevated tank water levels were at the bottom of bowl elevation. This analysis confirms that almost all areas in the system would have pressures greater than or equal to 30 psi at the end of an emergency when the elevated tanks were depleted. Based on this analysis, it was considered that the entire volume of the elevated tanks in the Cary System is "usable" storage. However, only 1.75 MG of 3 MG of the Old Apex GST is considered "usable" due to tank

level control set-points as described in Section 3. For this reason, the total "usable" elevated and re-pumped storage for the Town's system is considered to be 8 MG of the 9.3 MG total. In addition, the total Cary/Apex WTP clearwell storage is 8 MG. Based on chlorine contact time requirements in the clear-wells, the tank level is never dropped below 11-feet. For this reason, approximately 4 MG of the 8 MG is available for system storage.

Despite having this storage available, a goal of this storage analysis was to limit the HSPS pumping rate to MDD such that little or no clearwell storage was required. However, for the CPZ and SPZ storage analysis, 2 MG was allocated to the available storage calculation by 2010 and a total of 3 MG by 2015. As well, 1 MG of clearwell storage was allocated to the WPZ available storage calculation prior to the year 2015. It was also assumed that the Town of Apex has adequate storage and does not require additional storage from the Cary/Apex WTP clearwells. Recommendations for further investigation of the Apex system are included in Appendix G.

5.4.2.1 Western Pressure Zone Storage

Figure 5-4 displays a graph of the recommended vs. available storage volume for the WPZ. The desktop storage analysis and modeling analysis described in Section 6 revealed that the WPZ only requires one additional elevated tank. This proposed I-540 Elevated Tank is located north of the Carpenter Tank near the intersection of I-540 and NC 55. The tank is sized at 2 MG but the volume may need to be increased pending an expansion of the WPZ into Morrisville. Additional considerations about the size and location of the proposed tank are presented in Section 6.

5.4.2.2 Central and Southern Pressure Zone Storage

Figure 5-5 displays a graph of the recommended vs. available storage volume for the combined CPZ and SPZ. The storage analysis for these two zones was combined due to the nature of the connectivity between the two zones at the Kildaire Farm Road and Cary Parkway OCVs. For this analysis, the Old Apex GST was conservatively assumed to provide a total of 2 MG even though the total volume of the tank is 3 MG. As demands increase, it is recommended that the controls at the Old Apex GST be modified to increase the volume that can be utilized for re-pumping during projected maximum day demands.

For the combined CPZ and SPZ, only one additional elevated storage tank in the SPZ is required. The modeling analysis described in Section 6 revealed that a third supply main to the SPZ would delay the need to construct this proposed Holly Springs Elevated Tank in the SPZ until build-out. The proposed Holly Springs Elevated Tank is sized at 1 MG and is located near the intersection of Ten Ten Road and Holly Springs Road. This strategic approach minimizes water age and potentially disinfection by-product concerns in the SPZ. However, since a second tank in the SPZ does not currently exist and is not needed until build-out, the Kildaire Farm Road OCV, the Cary Parkway OCV, and a proposed third control valve will need to be operated in a manner that does not over-pressurize the SPZ when the Plumtree Way ET is taken out of service for maintenance.

Also, by build-out the Town will likely need to rehabilitate or replace the aging infrastructure of the Maynard Elevated Tank constructed in 1966 and the Harrison Elevated Tank constructed in 1977. Based on the desktop storage and modeling analyses, these tanks can be replaced with equivalent volume tanks at the same location.

5.4.3 Verification of NCAC Storage Requirements

As described above, under the NCAC, NCDENR requires that the total combined ground and elevated storage volume should be equal to half of the ADD. The projected average day demands for the years 2010 and build-out are 19.1 mgd and 31.5 mgd, respectively. Half of the projected 2010 ADD is 9.5 mgd; half of the ADD at build-out is projected to be 15.75 mgd.

As shown in Table 3-3, the total "usable" storage as of the date of this report is 12 MG based on only 4 MG of the 8 MG of clearwell storage being available and based on the current operational volume of the Old Apex GST (1.75 MG of the 3 MG). Based on the NCAC criteria, the existing available storage is greater than half of the projected 2010 ADD: (12 MG "usable" storage > 9.5 mgd [half of the 2010 ADD]).

At build-out the system will include an additional 4 MG of storage volume as follows: the proposed 2 MG I-540 Elevated Tank, the proposed 1 MG Holly Springs Elevated Tank, and the increase in "usable" volume of the Old Apex GST from 1.75 MG to 2.75 MG. The proposed total volume increase of 4 MG plus the existing available storage of 12 MG provides approximately 16 MG of total available storage at build-out. Based on the NCAC criteria, the build-out total available storage is greater than half of the projected build-out ADD: (16 MG "usable" storage > 15.75 mgd [half of the build-out ADD]).

Assuming that the infrastructure improvement recommendations provided in this Master Plan are followed, the Town of Cary should be in compliance with the NCAC storage requirements.

TABLE 5-5
Water Storage Analysis (Existing and Modified Pressure Zone Boundaries)

Existing PZ Boundaries

Town of Cary 2009 Master Plan Demands

Average Day Demand	Factor	2007	2010	2015	2025	Build-out
Apex		2.8	3.4	4.4	5.7	9.0
CPZ		9.5	11.1	12.3	13.1	16.0
SPZ		2.1	2.4	2.8	3.0	4.3
WPZ		3.1	5.6	8.0	9.0	11.2
Total (TOC + Apex)		17.5	22.5	27.5	30.8	40.5
Total (TOC Only)		14.7	19.1	23.1	25.1	31.5

Max Day Demand	(ADD x 1.64)	2007	2010	2015	2025	Build-out
Apex		4.8	5.8	7.5	9.7	15.3
CPZ		15.5	18.1	20.2	21.5	26.2
SPZ		3.4	4.0	4.6	5.0	7.1
WPZ		5.1	9.2	13.2	14.8	18.3
Total (TOC + Apex)		28.8	37.1	45.4	50.9	66.9
Total (TOC Only)		24.0	31.4	37.9	41.2	51.6

Storage Requirement (Existing Boundaries)

CPZ Storage Requirements	Factor	2007	2010	2015	2025	Build-out
Equalization	12%	1.9	2.2	2.4	2.6	3.1
Fire flow	3500	0.6	0.6	0.6	0.6	0.6
Emergency	25%	2.4	2.8	3.1	3.3	4.0
Total Required Storage		**4.9**	**5.6**	**6.1**	**6.5**	**7.8**

SPZ Storage Requirements	Factor	2007	2010	2015	2025	Build-out
Equalization	24%	0.8	1.0	1.1	1.2	1.7
Fire flow	3500	0.6	0.6	0.6	0.6	0.6
Emergency	25%	0.5	0.6	0.7	0.8	1.1
Total Required Storage		2.0	2.2	2.4	2.6	3.4
Total Required - Emergency		**1.4**	**1.6**	**1.7**	**1.8**	**2.3**
CPZ+SPZ Storage Require.		**6.3**	**7.2**	**7.9**	**8.3**	**10.1**

WPZ Storage Requirements	Factor	2007	2010	2015	2025	Build-out
Equalization	16%	0.8	1.5	2.1	2.4	2.9
Fire flow	3500	0.6	0.6	0.6	0.6	0.6
Emergency	25%	0.8	1.4	2.0	2.2	2.8
Total Required Storage		2.2	3.5	4.8	5.2	6.3
Total Required - Emergency		**1.4**	**2.1**	**2.7**	**3.0**	**3.6**

Modified PZ Boundaries (WPZ Expanded Into Morrisville/RDU Airport)

Town of Cary 2009 Master Plan Demands

Average Day Demand	Factor	2007	2010	2015	2025	Build-out
Apex		2.8	3.4	4.4	5.7	9.0
CPZ		9.5	11.1	12.3	13.1	16.0
SPZ		2.1	2.4	2.8	3.0	4.3
WPZ		3.1	5.6	8.0	9.0	11.2
Total (TOC + Apex)		17.5	22.5	27.5	30.8	40.5
Total (TOC Only)		14.7	19.1	23.1	25.1	31.5
Morrisville / Airport		1.9	2.9	3.3	3.6	4.5
CPZ without Morrisville / Airport		7.5	8.2	9.0	9.5	11.5
WPZ with Morrisville / Airport		5.1	8.5	11.4	12.6	15.6

Max Day Demand	(ADD x 1.64)	2007	2010	2015	2025	Build-out
Apex		4.8	5.8	7.5	9.7	15.3
CPZ		15.5	18.1	20.2	21.5	26.2
SPZ		3.4	4.0	4.6	5.0	7.1
WPZ		5.1	9.2	13.2	14.8	18.3
Total (TOC + Apex)		28.8	37.1	45.4	50.9	66.9
Total (TOC Only)		24.0	31.4	37.9	41.2	51.6
Morrisville / Airport		3.2	4.7	5.5	5.9	7.4
CPZ without Morrisville / Airport		12.4	13.4	14.7	15.6	18.9
WPZ with Morrisville / Airport		8.3	14.0	18.6	20.6	25.7

Storage Requirement (Modified Boundaries)

CPZ Storage Requirements	Factor	2007	2010	2015	2025	Build-out
Equalization	12%	1.9	2.2	1.8	1.9	2.3
Fire flow	3500	0.6	0.6	0.6	0.6	0.6
Emergency	25%	2.4	2.8	2.2	2.4	2.9
Total Required Storage		**4.9**	**5.6**	**4.6**	**4.9**	**5.8**

SPZ Storage Requirements	Factor	2007	2010	2015	2025	Build-out
Equalization	24%	0.8	1.0	1.1	1.2	1.7
Fire flow	3500	0.6	0.6	0.6	0.6	0.6
Emergency	25%	0.5	0.6	0.7	0.8	1.1
Total Required Storage		2.0	2.2	2.4	2.6	3.4
Total Required - Emergency		**1.4**	**1.6**	**1.7**	**1.8**	**2.3**
CPZ+SPZ Storage Require.		**6.3**	**7.2**	**6.4**	**6.7**	**8.1**

WPZ Storage Requirements	Factor	2007	2010	2015	2025	Build-out
Equalization	16%	0.8	1.5	3.0	3.3	4.1
Fire flow	3500	0.6	0.6	0.6	0.6	0.6
Emergency	25%	0.8	1.4	2.8	3.1	3.9
Total Required Storage		2.2	3.5	6.5	7.1	8.6
Total Required - Emergency		**1.4**	**2.1**	**3.6**	**3.9**	**4.7**

Note 1: Equalization % based on summer 2008 diurnal curve development from High Service Pump Station flows and elevated tank level variations

Note 2: Town of Apex demand projections from 2007 Local Water Supply Plan.

FIGURE 5-4
Water Storage Analysis (Western Pressure Zone)

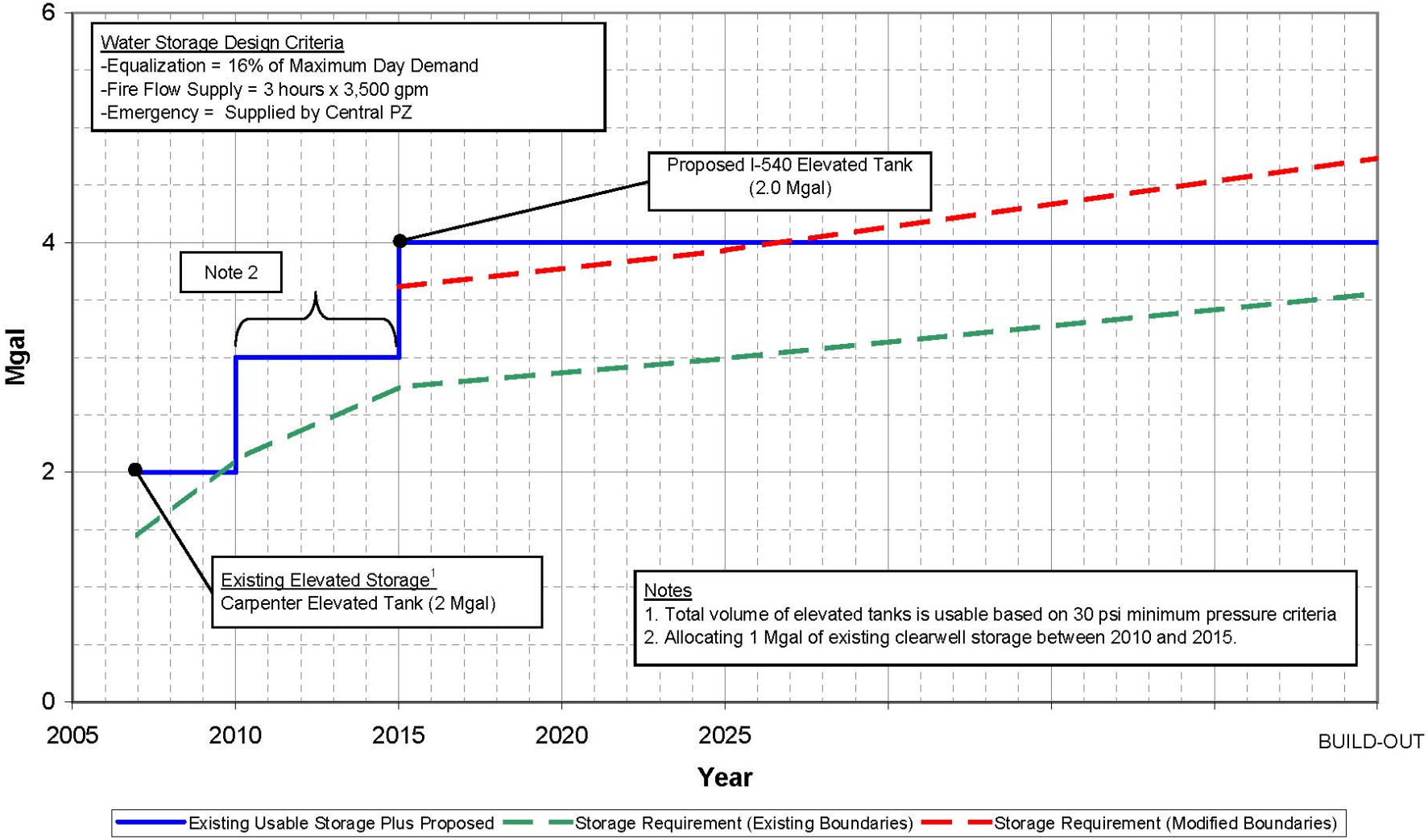
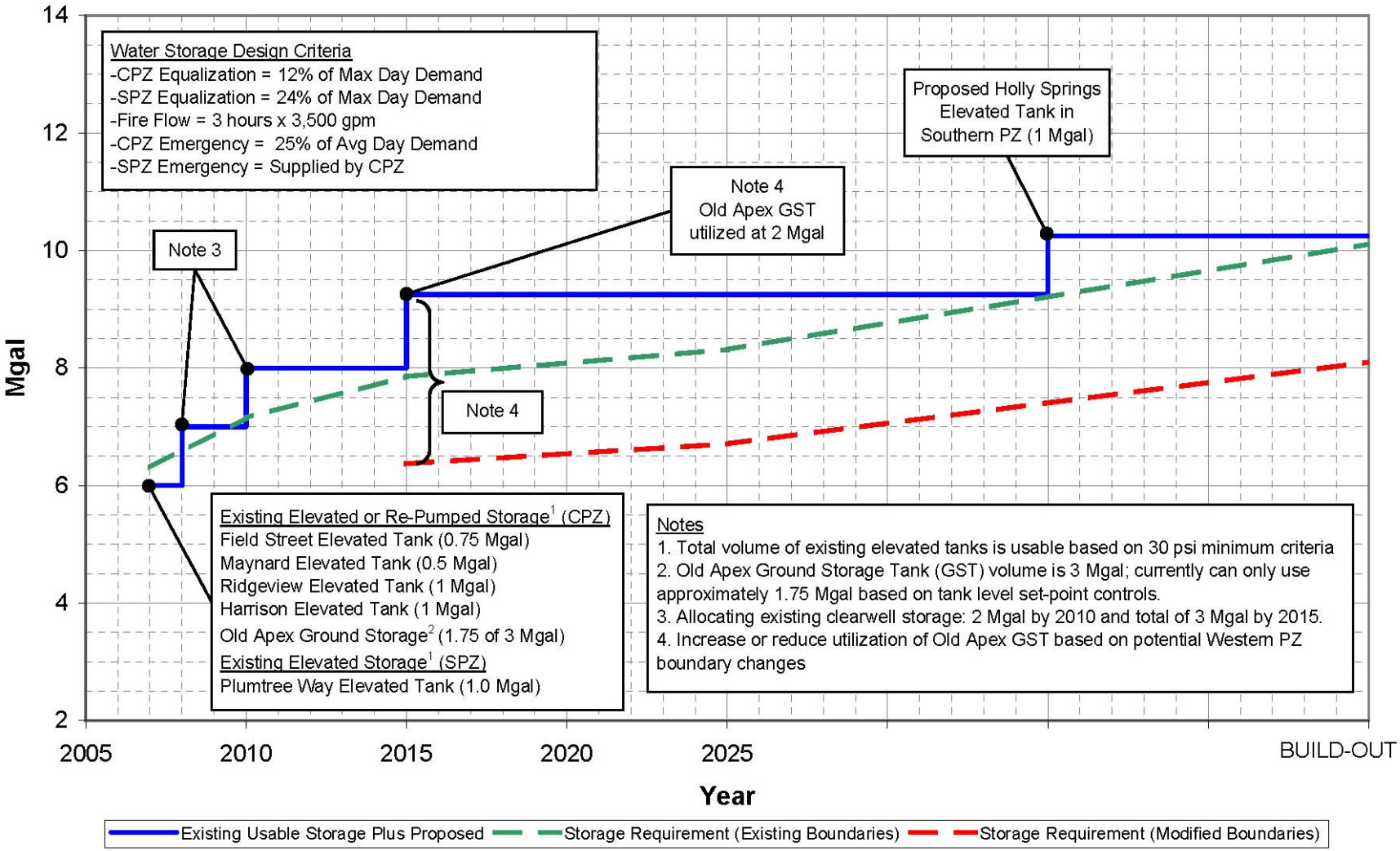


FIGURE 5-5
Water Storage Analysis (Central and Southern Pressure Zones)



5.5 Piping Hydraulics

Piping hydraulic design criteria consist of velocity and head loss criteria used during the computer modeling analysis. AWWA recommends a maximum design velocity of 10 feet per second (fps) with 5 fps as a more desirable range and head loss less than 2 ft/1000 ft for large transmission mains (>16-inch) and less than 10 ft/1000 ft for smaller piping (<16-inch)[4]. For this analysis, head loss guidelines were not strictly utilized, but transmission main velocities were limited to approximately 5 fps during maximum day and peak hour conditions which provided for a relatively flat system curve at the Cary/Apex WTP HSPS. For the remainder of the Town's system, 10 fps was used as a peak hour velocity criterion but it was found that almost all of the peak hour velocities were below 5 fps after the planned improvements were incorporated into the model.

5.6 Emergency Conditions

In addition to establishing design criteria for normal operating conditions, the water distribution system should also be evaluated during emergency conditions such as main breaks, power outages, natural disasters, or pump equipment malfunctions. Often the most critical emergency condition is the loss of a primary transmission main or high service station. This situation was evaluated for the Town of Cary by considering that the 42-inch transmission main from the Cary/Apex WTP to the CPZ was broken during both average day and maximum day demands for existing and future conditions.

The failure of the 42-inch main was selected for emergency condition analysis because it serves the largest portion of the system and represents the most critical emergency situation. A break of the 42-inch main would result in the temporary shut down of the CPZ high service pumps, isolation of the 42-inch main, reconfiguration of large valving between the WPZ 30-inch transmission main and the portion of the CPZ 42-inch main that would still be in service, and re-starting the CPZ pumps to supply flow to the entire system through the 30-inch transmission main. For this analysis, it was assumed a maximum flow rate of 24 mgd could be conveyed through the 30-inch transmission main; this is based on a peak velocity criterion of 7.5 fps and 107 feet of head loss.

In addition, the Davis Drive BPS (City of Durham connection) and the Trinity Road BPS (City of Raleigh connection) would be utilized at full capacity to provide flow to the Cary system. According to the recent Raleigh/Durham Interconnection Study (Hazen & Sawyer, 2008), the maximum flow rate that can be achieved at the Durham connection at the Davis Drive BPS is approximately 7 mgd. For this reason, a flow of 7 mgd was assumed at the Durham connection and the remaining demand deficit was made up by the Raleigh connection at the Trinity Road BPS.

A desktop flow balance analysis was conducted for normal operating conditions (Figure 1 in Appendix E). Under normal operating conditions the Cary/Apex WTP supplies the Town's system on a regular basis with no additional supply sources. The existing Davis Drive and

[4] AWWA M32 - Computer Modeling of Water Distribution Systems, p. 39

Trinity Road BPSs are not needed during normal ADD and MDD conditions for any of the defined planning periods.

A desktop flow balance was also conducted for the previously described emergency condition of the hypothetical loss of the 42-inch main (Figure 2 in Appendix E). The emergency flow balance indicated that during ADD conditions, the Raleigh and Durham connections were not necessary until year 2015 demands and that flows remained within the capacities of the Davis Drive and Trinity Road BPSs from 2015 until build-out as shown in Table 5-6. However, during MDD conditions the Durham connection was at full capacity (7 mgd) from 2007 until 2025 when flows were increased to 9 mgd in 2025 and 15 mgd at build-out. As well, during MDD conditions the Raleigh connection was within the range of the pump station capacity until year 2015. However, flows increased beyond the capacity of the station after 2015 to as high as 21 MGD by build-out.

TABLE 5-6
Estimated Flow from Raleigh and Durham Connections During Loss of 42-inch Transmission Main[a] (units in mgd)

Year	Durham ADD Flow	Durham MDD Flow	Raleigh ADD Flow	Raleigh MDD Flow
2007	0	7	0	0
2010	0	7	0	4
2015	3	7	4	10
2025	3	9	4	13
Build-out	7	15	8	21

[a] Assumes 24 mgd can be conveyed through 30-inch transmission main from the Cary/Apex WTP based on peak velocity criterion of 7.5 fps.

The Town considers that a breakage of this magnitude during a future MDD condition is quite conservative and the chance of this occurrence is low. To reduce the extremely large supply deficit that would occur in the future planning periods would require significant transmission main redundancy from the Cary/Apex WTP to the CPZ at great capital expense. Based on the conclusions of this analysis, the Town chose to only consider the loss of the 42-inch transmission main during average day conditions. For this reason, the supply rates required for the Durham and Raleigh systems were within known capacities.

It is recommended that further computer modeling analysis be conducted to simulate the loss of the 42-inch under average day demand and maximum month demand conditions to develop an emergency operations plan and to determine other weak points in the system. Within the Wallingford Software's modeling platform, criticality analyses can be conducted to evaluate a significant number of possible breakages and identify weak links in the system.