City of Greensboro

2010 Water Supply Master Plan

Water Resources
12/31/2009

GREENSBORO

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I. Purpose

Water supply has been a difficult issue for the City of Greensboro since the late 1990's. For decades, the Piedmont Triad Regional Water Authority's (PTRWA) Randleman Project was expected to fulfill the short and long range water supply needs of the City by this time. Unfortunately, the project was delayed repeatedly. This was primarily due to permitting issues, but reaching consensus among the six members on when to complete the water plant and what various members' obligations would be also proved difficult. Now that these issues have been settled, the lake, water plant, various transmission mains, and pumping station are all either complete or in progress. Finished water, another name for treated drinking water, is expected to flow into Greensboro from Randleman Lake by late summer of 2010.

As the long awaited Randleman Project has neared completion, the last 10 years have been predominated by drought conditions of near record severity. In response, demand management strategies including public education on water conservation and institution of conservation based rate structures have significantly reduced per capita water demand. Supply side augmentation projects, such as interconnections with water systems in neighboring cities and a raw water transfer station from the Haw River were also constructed to provide additional water during drought periods.

Upon the eve of receiving water from the PTRWA, it is time for the City of Greensboro to re-assess what the near and long term water needs are given the changes in consumption. The City should also address how best to meet those needs using its current lake supplies and Randleman, and how any or all of the supplemental water projects can be used to assure a safe supply for the City during drought or other water supply challenges. In this process, the City should also realistically address any safety factor that it wishes to adopt for given drought recurrences.

II. Historic Water Demands

Projections of future water demands for the City of Greensboro that were done over ten years ago overestimated demand. Greensboro has seen a reduction in manufacturing operations that are dependent upon large volumes of water. Additionally, all segments of the utility's customer base have significantly reduced water consumption per account as a result of public education and demand management through rate structure changes. These rate changes have encouraged less irrigation and efficient irrigation of lawns and landscapes. More efficient use of water in industrial applications has also been observed.

A. Industrial Use

As had been traditional in most water utilities, the City of Greensboro once employed a "declining block" rate structure that offered considerable discount to large volume customers. This discount was applied to monthly water use over 300 units (a unit being 100 cubic feet or 748 gallons), which is 224,000 gallons per month. In 1998 this discount was 47% on all units over 300 per month.

During the mid to late 1990's the City began a public education program to encourage water conservation that continues to this day. However, residential customers felt it was unfair that the City encouraged them to reduce water use while large customers were being offered lower priced water; large users not only were not penalized for using large volumes of water, but were encouraged to do so. During this time approximately 350 customers exceeded 300 units per month. While the declining block rate structures were used to encourage industrial development, many of those enjoying the discount were apartment complexes and other commercial enterprises. If the City was to maintain its credibility in the conservation message, the discount needed to be eliminated.

Recognizing the impact of eliminating the discount to large manufacturers, the City held meetings with the large customer community to explain why the changes were necessary. In these meetings, several mentioned ways they would be forced to reduce water consumption by employing different techniques and processes, yet not scaling back operations; changes that would benefit the City's need to manage demand. While not happy with the rate changes that would mean increased cost for these customers, there was widespread understanding of the issue and no push back. In 1999 the City began phasing out the large volume discount by increasing the threshold for the discount from 300 to 2,000 units per month on January 1, 1999. One year later the threshold was increased to 7,500 units; then in the following year the threshold was moved to 20,000 units. The discount was fully eliminated on January 1, 2002. To demonstrate the reduced consumption of large customers and a change in the mix of the top ten customers, Figure 1 shows the top ten customers as of the end of Fiscal Year 2000 and Figure 2 shows the top ten customers for Calendar Year 2008 based on revenue. Since the ranking is by revenue, customers outside the city limit who pay double inside rates may appear higher on the list with less consumption.

Greensboro Top Ten Water Customers, FY 2000				
		Usage, MG per Year	Water Revenue	Percent of Total Revenue
1.	Guilford Mills - Oakridge Textile	408	$439,506	2.1%
2.	Proctor and Gamble - Browns Summit (outside rate)	159	$420,780	2.0%
3.	Konica Manufacturing USA (outside rate)	76	$266,838	1.3%
4.	Guilford Mills - Fishman	189	$237,912	1.1%
5.	Stockhausen, Inc.	126	$180,126	0.8%
6.	Elastic Fabrics of America	110	$165,347	0.8%
7.	P. Lorillard, Division of Loews, Inc	87	$144,092	0.7%
8.	Moses H. Cone Hospital	85	$142,502	0.7%
9.	City/Bryan Park/Soccer	69	$128,839	0.6%
10.	Precision Fabrics Group	68	$126,000	0.5%
	Total Top Ten Annual Consumption	1,377	$2,251,942	10.6%

Figure 1

Greensboro Top Ten Water Customers, CY 2008				
		Usage, MG per Year	Water Revenue	Percent of Total Revenue
1.	Stockhausen, Inc.	172	$496,233	1.3%
2.	University of NC at Greensboro	171	$492,464	1.3%
3.	Proctor and Gamble – Browns Summit (inside rate, annexed)	147	$421,568	1.1%
4.	Moses H. Cone Hospital	103	$298,953	0.8%
5.	RF Micro Devices	79	$227,984	0.6%
6.	North Carolina A&T University	69	$198,589	0.5%
7.	Elastic Fabric of America	68	$196,972	0.5%
8.	P. Lorillard, Division of Loews, Inc.	66	$189,703	0.5%
9.	Shionogi Qualicaps	28	$162,384	0.4%
10.	Precision Fabrics Group	45	$129,548	0.3%
	Top Ten Annual Consumption	948	$2,814,398	7.3%

Figure 2

A specific analysis of each of the top ten customers will not be included here; however, several changes should be noted. Both Guilford Mills accounts, totaling 597 million gallons per year, are now completely gone, as well as Konica although it has been replaced by Zink, a smaller user. Stockhausen has moved into the number one spot, and RF Micro Devices has grown to the fifth largest customer. UNCG and A&T State University have crept into the top 10 for two reasons. Both campuses have expanded and built additional student housing, but the primary reason for the increase is that the utility has changed the way it calculates their total water consumption. In 2000, their usage was based solely upon their largest meter, whereas in 2008, their consumption is the sum of the water use of all of their meters. Detailed data from 2000 is not available to compare apples to apples in this case.

Taken in total, the top ten customers have shrunk in total consumption 31%, or 429 million gallons per year, making large single account customers less significant in the overall mix of water customers. The Water Resources Department is aware through discussions with several of these customers that they have engaged in significant changes in practices and processes that have deliberately reduced their water consumption.

Greensboro has changed billing processes and computer programs used to capture consumption data, so it is difficult to combine with accuracy certain periods. However, Figure 3 captures the average monthly billed volume of the large volume accounts from 1992 through July 2007. A regression analysis derived trend line clearly shows the reduction in consumption per account over this period. Note that this represents *total* consumption of *all* large volume customers in the large customer billing cycle.

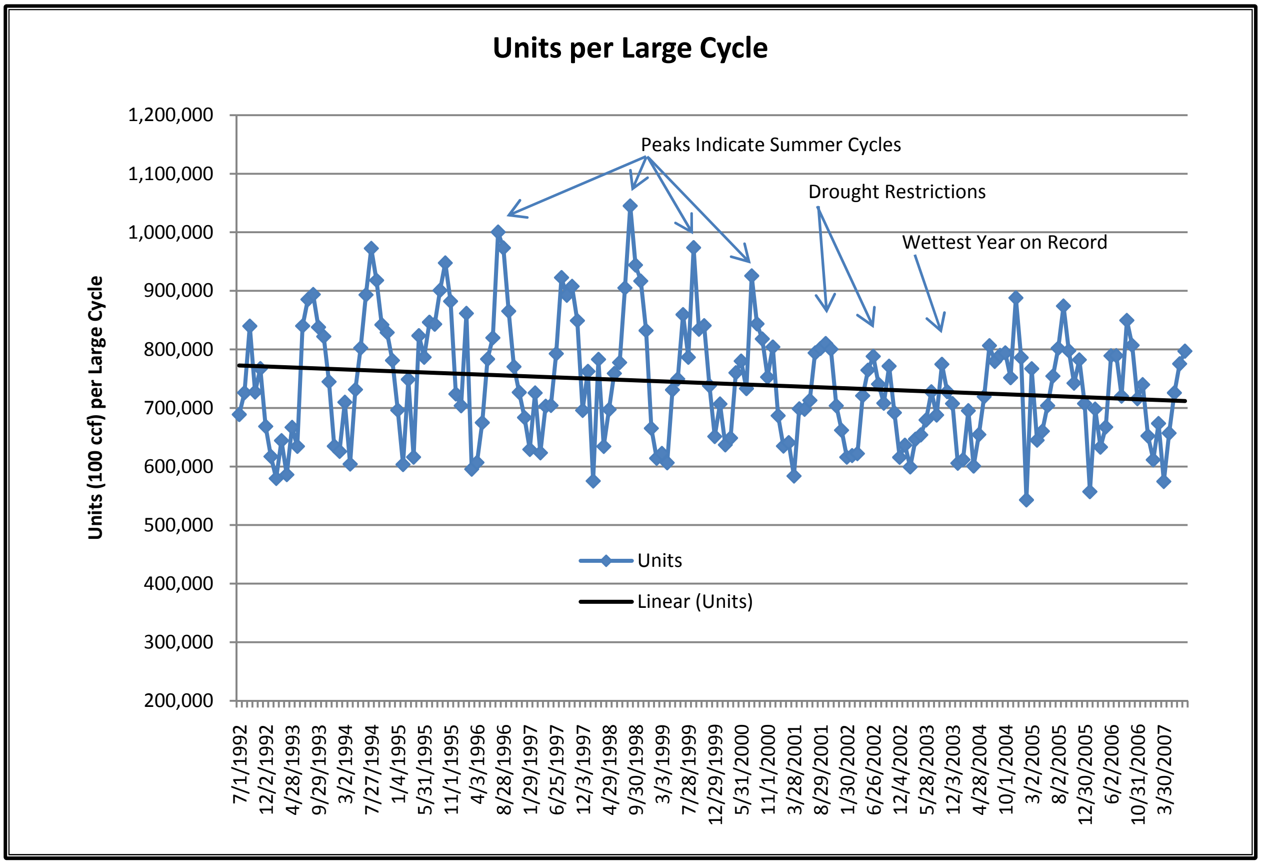


Figure 3

B. Residential Use

Greensboro residents have substantially changed their use of water. In the past decade the City has invested in public education to promote water conservation and instituted rate structures that discourage the use of large volumes of water for irrigation. In addition, since 1994 standard plumbing fixtures are required to be considerably more water efficient. So, newer homes use less water, and whenever owners replace plumbing fixtures, especially toilets, they are also saving water. It is not possible to conclusively determine how much each of these changes has contributed to the decline in per capita use. However, based on industry trends the Water Resources Department believes that the increasing block, or conservation residential rate structure, put in place on January 1, 2000 has played a predominant role in the change in customer consumption.

Figure 4 clearly demonstrates the reduction per residential account in Greensboro over the last ten years. This reduction, per account, is truly significant when considering that in 2009 there are approximately 84,000 residential accounts.

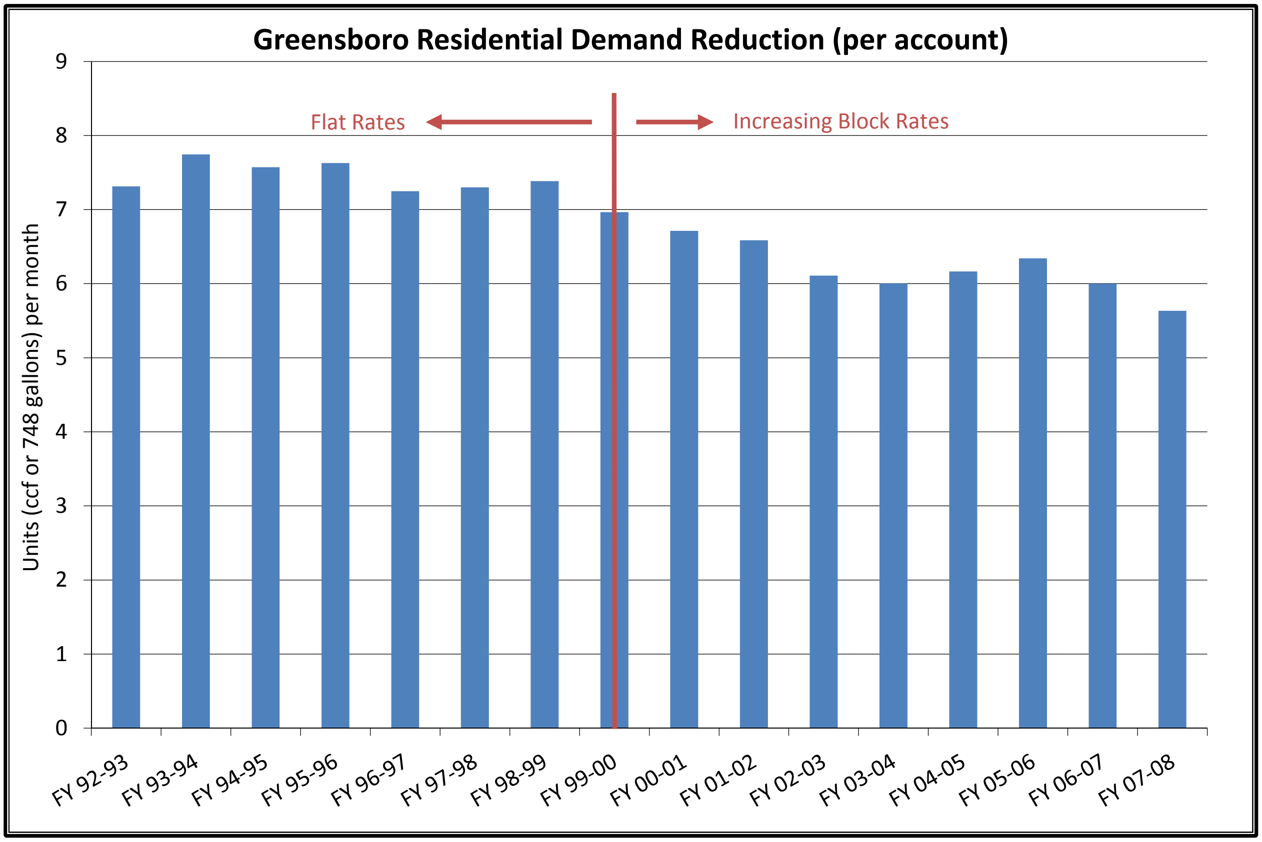


Figure 4

C. Historic Total Public Water Demand

The previous discussions illustrate how segments of the customer base of Greensboro have changed their consumption habits. Ultimately, the utility must satisfy the overall average and peak day demand as measured at the water plants and from supplemental sources. This includes losses from leakage and line breaks, firefighting, and flushing of the distribution system. It should be noted that with changes in regulatory standards which demand higher quality water at all points of the distribution system, flushing has increased by necessity and can be expected to increase further with the implementation of new requirements for disinfection by-products in 2011.

Greensboro has good public water demand data for both annual average and peak day demand beginning in the year 1960. Figure 5 illustrates the growth of demand and the major demand changes that have occurred in the last decade. As is typical for most growing cities, there was consistent growth in water demand from 1960 through the mid-1990's. However, as conservation strategies were implemented and drought vulnerability was revealed at the end of this period, major changes can be seen in the demands from that point forward. Most of the demand projections made up to the end of this period assumed a linear extension of the prior growth pattern, which clearly would overstate needs compared to the actual demands realized. It was very fortunate that demand growth was moderated substantially given the drought vulnerability Greensboro had with its limited supplies.

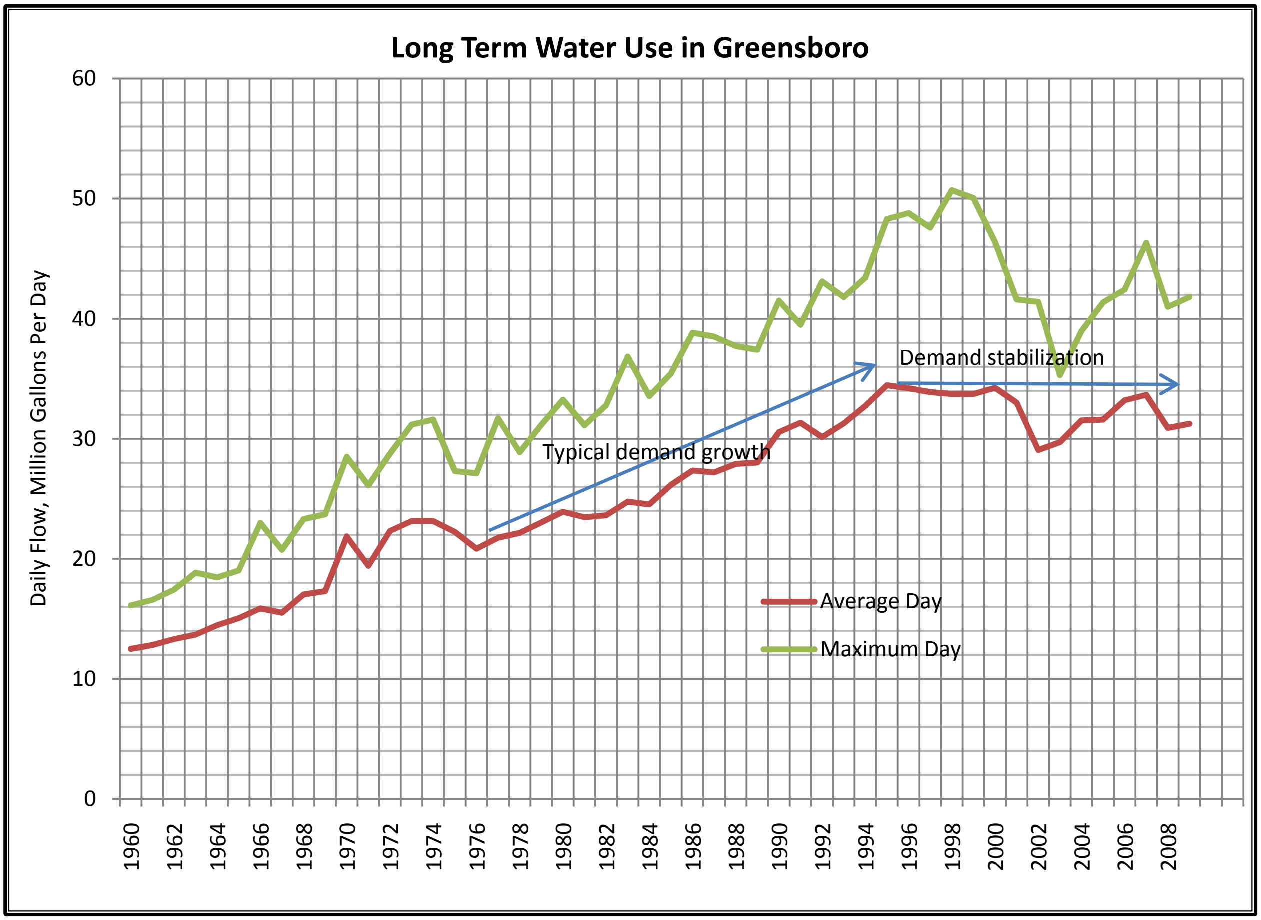


Figure 5

A closer examination of the recent total demand can be made with Figure 6, showing annual average demand and peak day demand for each year. Notes are included on Figure 6 to explain some of the variations in demand. Water consumption generally rises in the early stages of a drought, but restrictions imposed during later stages if water supply levels are endangered can significantly curtail water use, primarily irrigation. Restrictions were enacted in 1998, late 2001 through 2002, and in 2007 and early 2008. 2003 was a record rainfall year, so irrigation demand was not significant. Although January through September of 2009 was exceptionally dry, demand was only up 1.4% from the same period of 2008. The peak day for 2009 was almost 1.0 MGD higher than 2008, reflecting dry conditions. Staff of the Water Resources Department would have expected much greater water demand in both peak and annual average consumption but assume that deteriorated economic conditions caused both industrial and irrigation demand to be dampened. No water restrictions were needed during 2009 due to low water demand and water purchases from other cities. It is important to note that during the period covered by Figure 6, the number of customers served by the Greensboro water utility increased from 80,000 to 102,000.

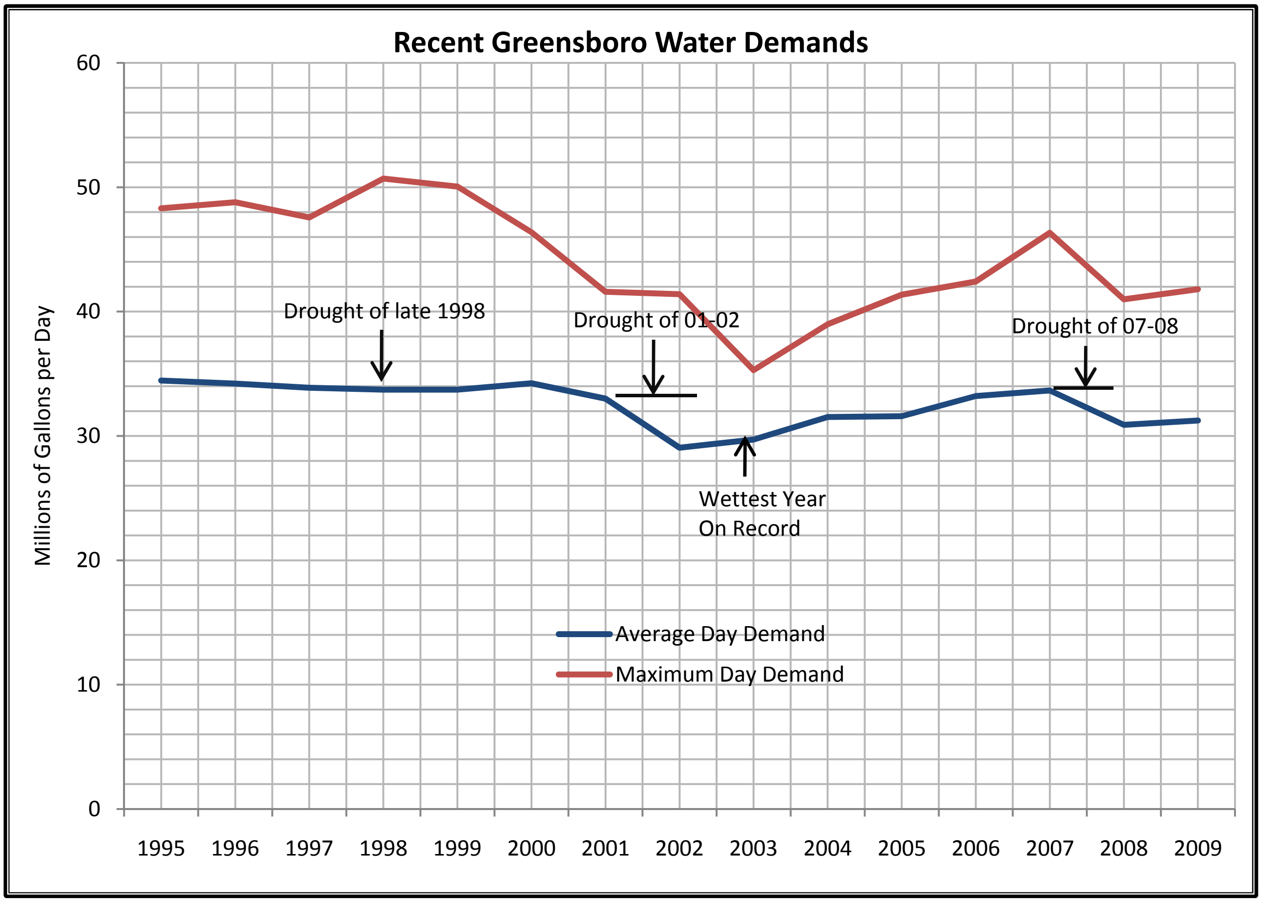


Figure 6

D. Summary

During the period of 1995 through 2009, the City of Greensboro saw a 27% increase in the number of customers, yet saw a relatively flat response in total water demand. In fact, if a regression analysis is done for total water demand, it is declining slightly over this period. This can be explained by changes in the customer base and changes in both industrial and residential per customer demand. It would be folly to expect this trend to continue as the City continues to grow. Sensible plans are needed to satisfy growth in demand. New source additions should be made on an incremental basis as demand grows. It is also important to recognize that much of the per customer demand reduction has come from reduced discretionary uses such as irrigation. For that reason future predictions of demand reduction during drought through restrictions should be cautious. This is referred to as “demand hardening” in the utility industry.

III. Projected Future Water Demands

The City of Greensboro operates a moderately complicated water transmission and distribution system with two water plants and five pressure zones. In anticipation of the startup and longer term future increases of water from the Randleman Water Plant, the City commissioned Hazen & Sawyer Environmental Engineers and Scientists to produce a Distribution System Master Planning and Modeling Study. The purpose was not to project water supply management of supply and demand, but to address the distribution system capacity and ability to transport water to customers as the City grows. To make sound decisions for this report's purposes, total water supply demand needed to be projected (and more importantly where the demand was likely to be), and with Water Resources direction, assumptions were made that would allow source flexibility.

The Distribution System Master Planning and Modeling Project is on file in the Water Resources Department. This is the underlying data and analysis that provides the demand assumptions used within the body of this Water Supply Master Plan, and references will be made to this work. Hazen and Sawyer used standard water supply planning techniques including past customer growth projected, population projections, and per customer use based on current data. Water Resources has reviewed the analyses and is in agreement with the projections. However, based on past experience and in keeping with sound engineering principals, the projections may be conservative (overestimating demand). Given the difficulties of predicting water demand growth as evidenced by the data of the last 10-15 years, it is prudent to assume the demands as projected by Hazen and Sawyer. Because of the planned incremental expansion of the Randleman project, Greensboro is fortunate that no major water supply initiative should be needed in the next 30 years. Timing those incremental expansions to occur when they are needed, which provides economic benefit, is a topic of this paper.

A. Hazen and Sawyer Demand Projections

Figure 7, Demand Projections by Zone and Service Area (H&S Table 12) and Figure 8, Future Water Requirements (H&S Figure 14) are directly taken from the Hazen and Sawyer Report. Data in this report details exactly where demand is expected to be realized in keeping with the needs to provide for a plan for the distribution system. That information is not relevant to the purpose of this paper, but may be of interest. This report is primarily to establish water supply sources for the average and peak daily demand of the overall Greensboro system, using current water plants, the Randleman plant, and supplemental sources as would be prudent.

Demand Projections by Service Area
Hazen and Sawyer Nov 2009 Distribution Report

		Average Day Demand (mgd)				Maximum Day Demand (mgd)			
Zone	WSSA	2007	2010	2020	2030	2007	2010	2020	2030
High	Existing		0.11	0.41	0.77		0.17	0.62	1.16
	A		0.23	0.35	0.49		0.35	0.53	0.74
	B		0.00	0.21	0.26		0.00	0.32	0.39
	C		0.00	0.00	0.08		0.00	0.00	0.12
	Subtotal	7.19	7.53	8.16	8.79	10.79	11.31	12.26	13.20
HP	Existing		0.06	0.12	0.19		0.09	0.18	0.29
	A		0.11	0.20	0.31		0.17	0.30	0.47
	Subtotal	1.72	1.89	2.04	2.22	2.58	2.84	3.06	3.34
Low	Existing		0.05	0.09	0.13		0.08	0.14	0.20
	A		0.41	0.67	0.95		0.62	1.01	1.43
	B		0.02	0.35	0.49		0.03	0.53	0.74
	C		0.00	0.01	0.24		0.00	0.02	0.36
	Subtotal	0.91	1.39	2.03	2.72	1.37	2.10	3.07	4.10
Main	Existing		0.30	1.26	2.41		0.45	1.89	3.62
	A		0.74	1.27	1.86		1.11	1.91	2.79
	B		0.05	1.58	2.23		0.08	2.37	3.35
	C		0.02	0.09	2.17		0.03	0.14	3.26
	Subtotal	23.41	24.52	27.61	32.08	35.12	36.79	41.43	48.14
West	Existing		0.01	0.01	0.01		0.02	0.02	0.02
	A		0.02	0.03	0.04		0.03	0.05	0.06
	B		0.00	0.08	0.13		0.00	0.12	0.20
	C		0.00	0.00	0.24		0.00	0.00	0.36
	Subtotal	0.44	0.47	0.56	0.86	0.66	0.71	0.85	1.30
Total		33.67	35.80	40.40	46.67	50.52	53.75	60.67	70.08
System	Existing	33.67	0.53	1.89	3.51	50.52	0.81	2.85	5.29
	A		1.51	2.52	3.65		2.28	3.80	5.49
	B		0.07	2.22	3.11		0.11	3.34	4.68
	C		0.02	0.10	2.73		0.03	0.16	4.10
	Total	33.67	35.80	40.40	46.67	50.52	53.75	60.67	70.08

Figure 7

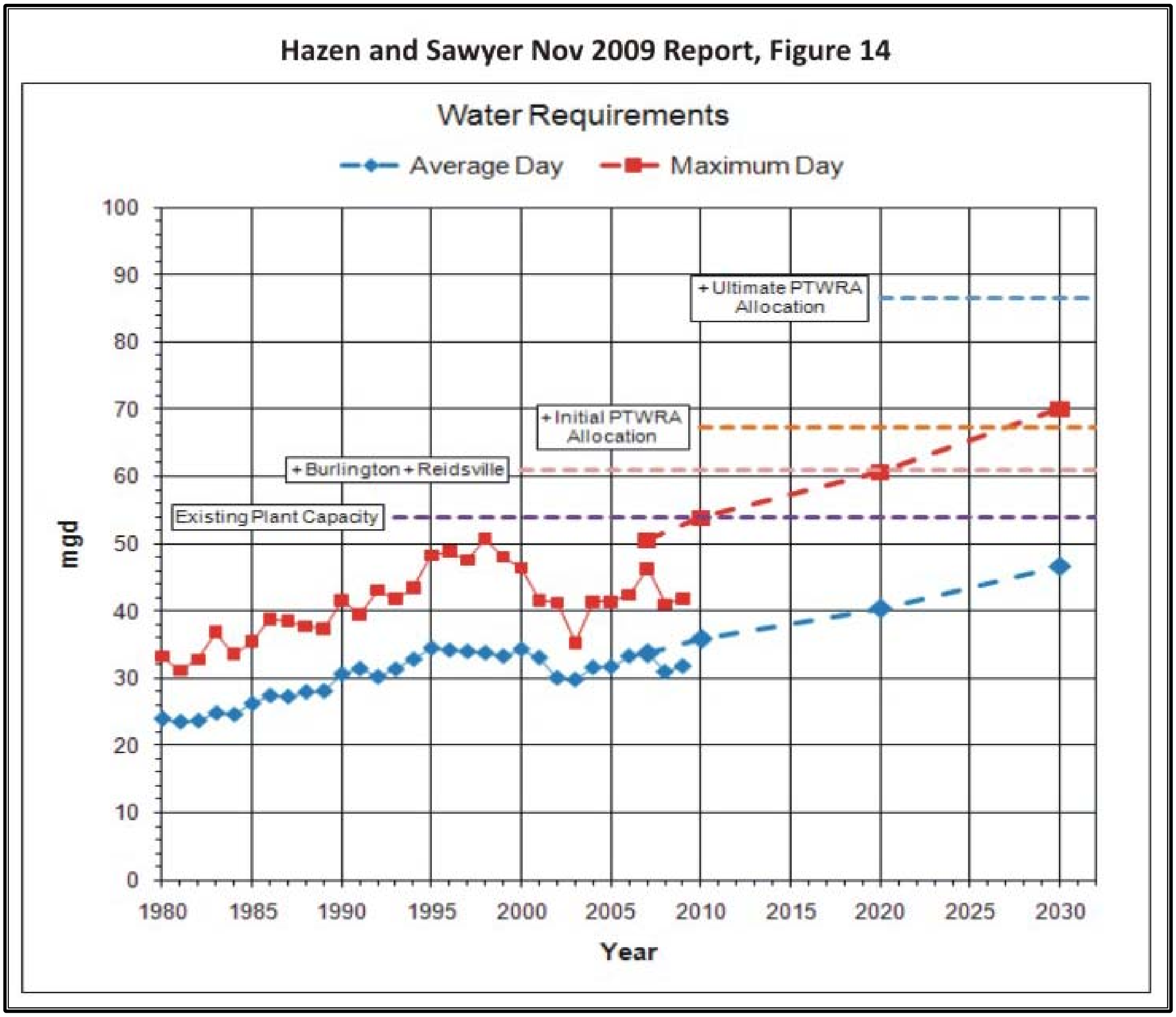
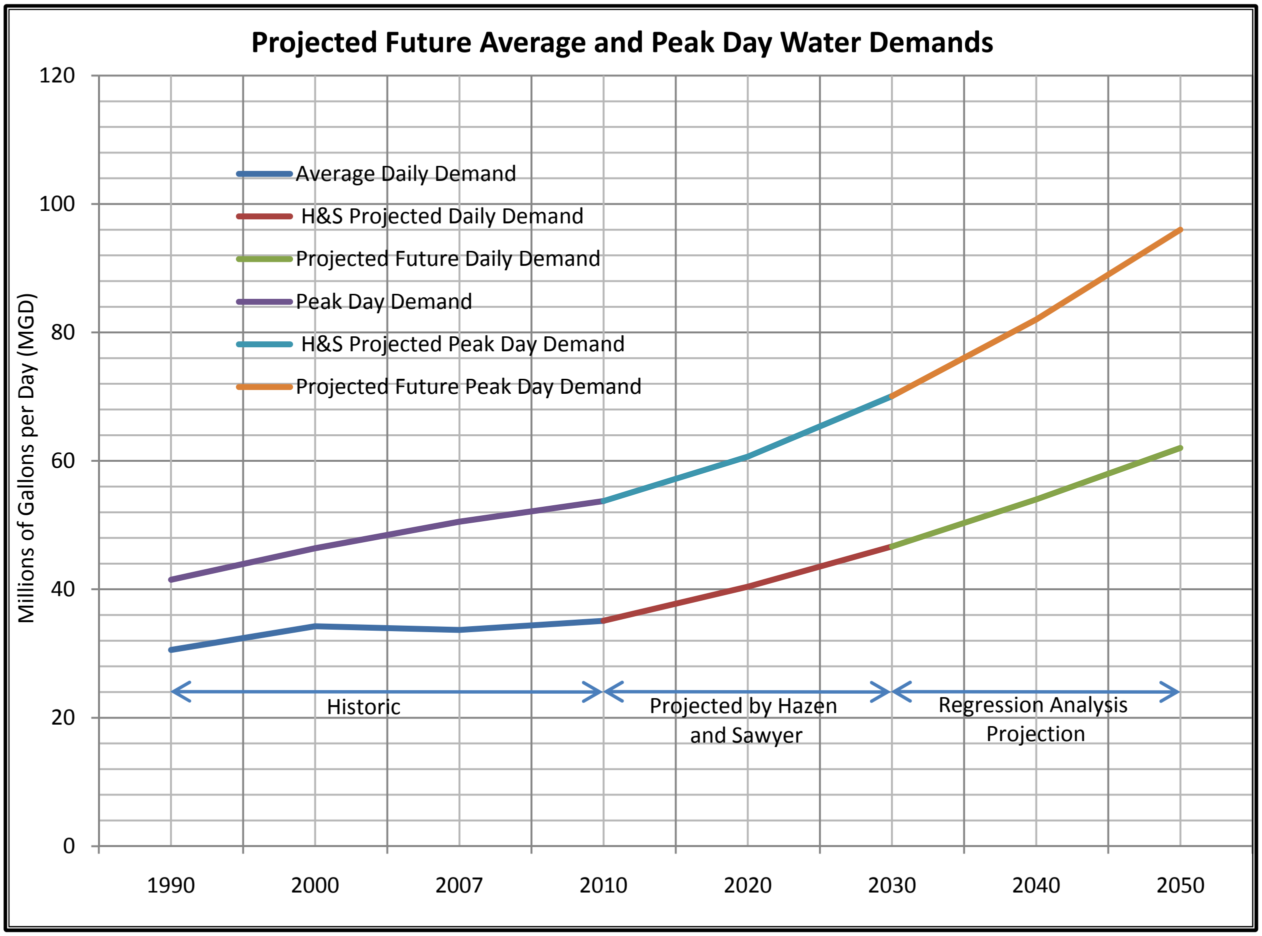


Figure 8

B. Demand Projections Beyond 2030

The timeframe of the Hazen and Sawyer report was through 2030, which is appropriate for modeling and planning distribution and system storage. However, given the difficulties of acquiring water supply in today's highly regulated and contested water environment, it is prudent that the City be planning for water supply through 2050. Given that the Hazen and Sawyer projections of average daily demand are linear or nearly so, Figure 9 takes the Hazen and Sawyer data and projects demand through the year 2050. The projection predicts a need by 2050 of 64 MGD as an annual average. Such a projection has a great chance of error since consumption habits and growth trends are subject to considerable change, but this projection is reasonable and as good as can be done for long range planning purposes given the many variables and unknowns.



Projected Future Average and Peak Day Water Demands
Millions of Gallons per Day (MGD)
120
100
80
60
40
20
0
Average Daily Demand
H&S Projected Daily Demand
Projected Future Daily Demand
Peak Day Demand
H&S Projected Peak Day Demand
Projected Future Peak Day Demand
Historic
Projected by Hazen and Sawyer
Regression Analysis Projection
1990
2000
2007
2010
2020
2030
2040
2050

Figure 9

IV. Current and Future Water Supply Sources

One of the most essential services provided by a city is water supply. It is imperative that when planning water supply one consider what vulnerabilities may exist in the sources of supply. In a city like Greensboro that is dependent upon surface water stored in reservoirs, the greatest vulnerability of supply is drought. Because of Greensboro's location at the top of the Cape Fear Watershed (this is why there are no major rivers in the area), full attention must be given to the dependability of expected reservoir yields during periods of drought. For this reason this report will expand upon the concept of reservoir yields and any assumed safety factor that is or is not assumed. This discussion will be framed around the statistics and performance of the three lakes that comprise Greensboro's water supply reservoirs (Higgins, Brandt, and Townsend), but it is applicable to most reservoir systems, especially of the Piedmont.

A. Safe Yield

The safe yield of a reservoir system is the amount of water, in millions of gallons per day (MGD), that is assumed can be withdrawn at a uniform rate from the system over a long period of time, including droughts, without emptying the system. Safe yield is usually designated based on return frequencies of droughts of various severities. In most cases the 50-year safe yield is used, as has been the case in models and conclusions derived by Hazen & Sawyer who generated safe yield reports for the City in 1987 and then again in 2000. It is important to recognize that designation of droughts, or for that matter floods, in terms of "50-year" or "10-year" can be misleading. When faced with a 10-year or 50-year drought or flood, people tend to falsely assume that another similar event won't occur for another 10 or 50 years. Statistically it is more correct to call these events a drought with an expected occurrence of 2% in any given year (50-year) or expected occurrence of 10% in any given year (10-year).

The concept of safe yield modeling is relatively simple, but collecting the appropriate data for the model can be challenging. Interpreting results requires care and understanding. Safe yield modeling is essentially a mass balance model that runs over time using stream flow data as the input and an assumed withdrawal rate for a fixed volume of lake storage. In the case of Greensboro's water supply reservoirs, they are all treated together as one common storage vessel draining one watershed of 105 square miles.

Until 1999 the usable storage volumes of Greensboro's lakes were not known with a great deal of certainty. In early 1999 an extensive bathymetric survey was conducted to determine the profile of the lake bottoms to establish definite storage volume to lake level correlations. Tests were also conducted on the raw water pumping stations at the two withdrawal points in Lakes Brandt and Townsend to determine the lowest point that water could be withdrawn. With this information, it was determined that the practical storage volume of the three lakes is 7.9 billion gallons (BG). To put this in perspective, starting with full lakes a raw water withdrawal rate of 35 MGD would empty the lakes in 225 days if there was *no* stream flow coming into the lake system. Having no streamflow is rare because streams are fed by groundwater even in dry periods and continue to flow; however, groundwater supplies are also stressed during a drought, which causes very low streamflows.

While rainfall generates stream flow, it is not used to determine reservoir performance. Rainfall can be deceptive because stream flow generated from a given number of inches of rain can vary wildly depending on ground conditions, temperature, time of year, and the intensity of precipitation. Fortunately, there are a number of long term USGS stream gauging stations in the local area of the Piedmont that have collected reliable stream flow data as early as 1928. The current Reedy Fork Gauge is located within the watershed of Greensboro's lake system and has data for over 53 years. Other gauges that predate this one have been used to establish a stream flow history back to 1928.

The safe yield model assumes all the lakes were in existence and full, with 7.9 BG of water. With no withdrawal, the model shows that the lakes remain full over the entire history with the exception of very dry periods when evaporation, which is accounted for in the model, exceeds stream flow. The model is then run with assumed withdrawal rates to test how lake levels would be drawn down at various rates. The Hazen & Sawyer Safe Yield Evaluation of 2000 demonstrated that with 7.9 BG of usable storage and the entire watershed that drains to Lakes Higgins, Brandt, and Townsend, a safe yield of 35 MGD was appropriate. Figure 10 is included as produced in the 2000 Hazen and Sawyer report showing the entire historic record of data; Figure 11 shows the limiting drought of the sixties.

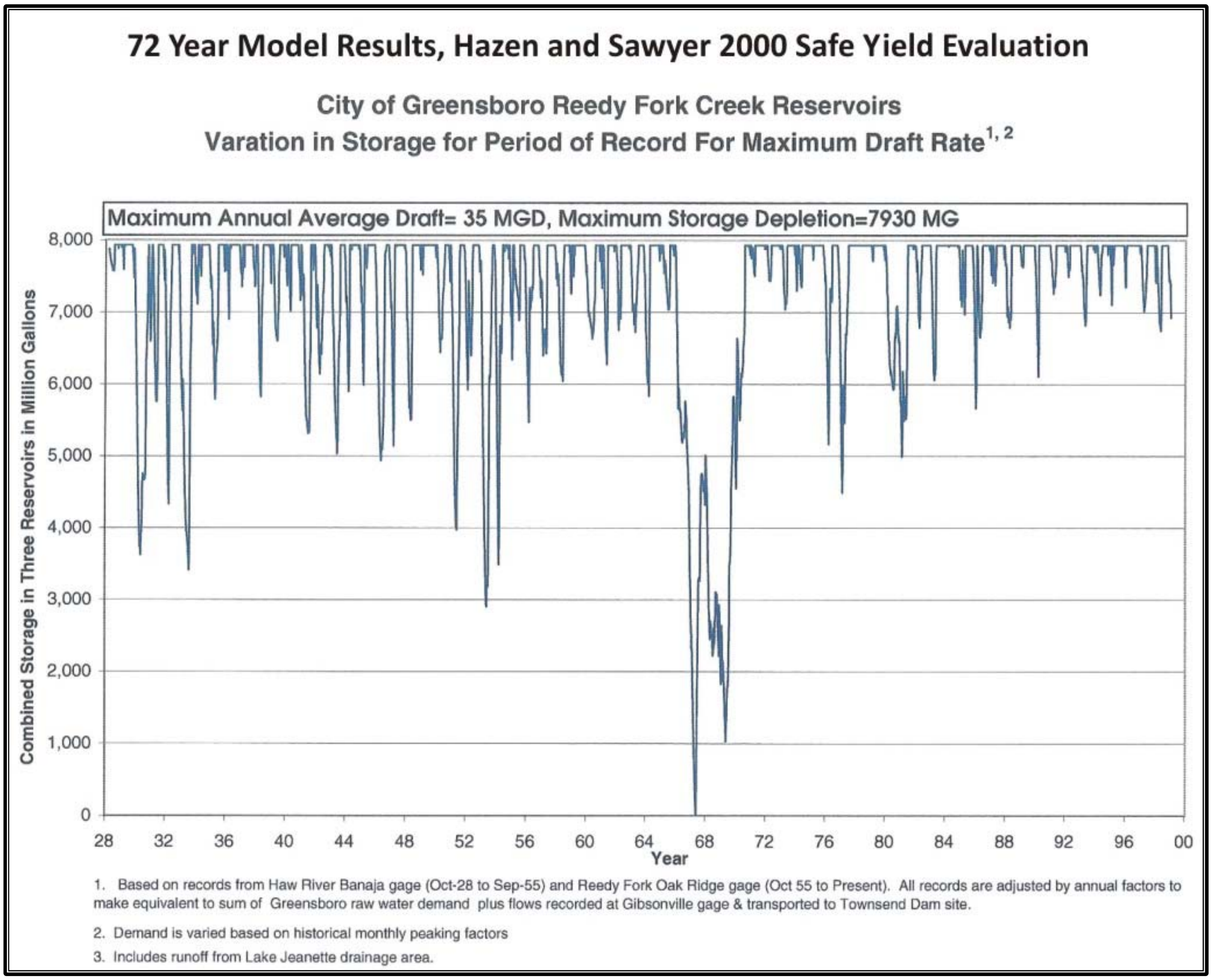


Figure 10

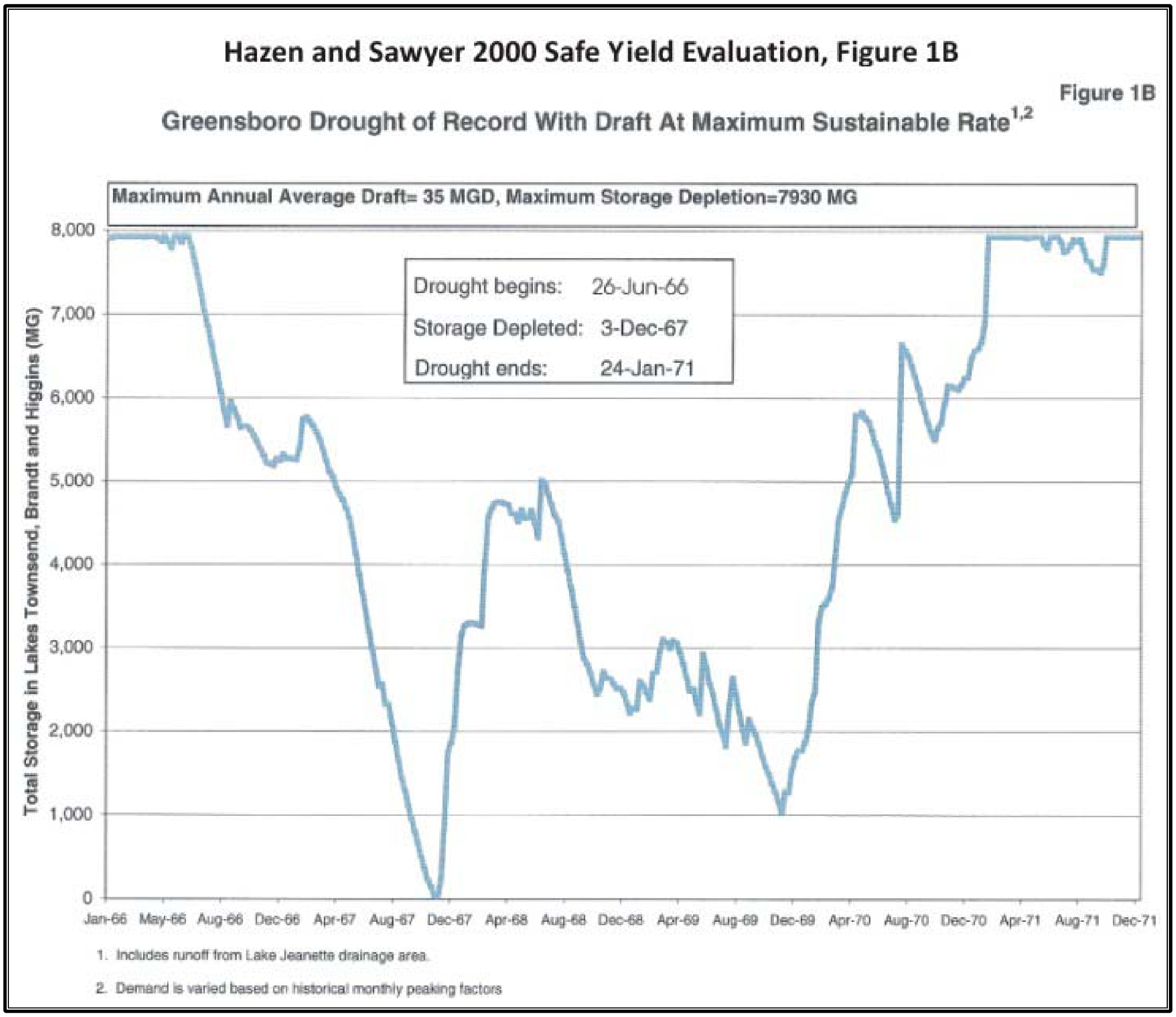


Figure 11

B. Interpretation of Safe Yield

It is easy to assume that once a reservoir model has been done for Greensboro, it can be concluded that the reservoirs will always be able to produce the given yield for the purposes of producing potable water. There are fallacies to this assumption as indicated below:

Reservoir Performance

Figure 11 demonstrates how far reservoir levels would drop in the drought of record. It is particularly disturbing that not only would the lakes not fill up for over *five* years, they would be at alarming levels (below 50% full) for over half that period, dropping down to the "last drop" once and nearly returning to empty two years later. In the last 10 years, lake levels have dropped to less than 50% twice; in 1998 with no significant supplemental sources, public alarm was considerable. In the drought of 2001-2002 with the addition of Reidsville to bolster reservoir sustainability, lake levels dropped to 70% as early as June and restrictions (no broadcast irrigation) were enforced. Public concern (and concern from water supply management in the Water Resources Department) was substantial in all of these droughts. It is almost inconceivable what the levels of concern, or hysteria, would have been if the lakes had been allowed to drop to less than 5%.

The Water Resources Department has in depth records of daily consumption during these droughts. Performance data has also been established for past usage patterns that determine what reduction in summertime use occurs when Water Restrictions Stage IIA (one day a week broadcast irrigation allowed) and Water Restrictions Stage IIB (no broadcast irrigation allowed) are enforced. During the drought of 01-02 actual reservoir performance was compared to what would have happened if a) no restrictions had been imposed, b) no water was purchased from Reidsville or Winston-Salem, and c) neither had occurred. Figure 12 is a graphic presentation of these projections to demonstrate why restrictions and purchases were necessary. As a further check upon the recent history of Greensboro's reservoir performance to past modeling projections, Hazen & Sawyer was requested to update the safe yield model in October of 2009, which is included as Figure 13. When presented with this, it was immediate confirmation to the Water Resources Department that the very difficult water supply droughts the City had been experiencing were exactly what stream flow based modeling would predict based on USGS data.

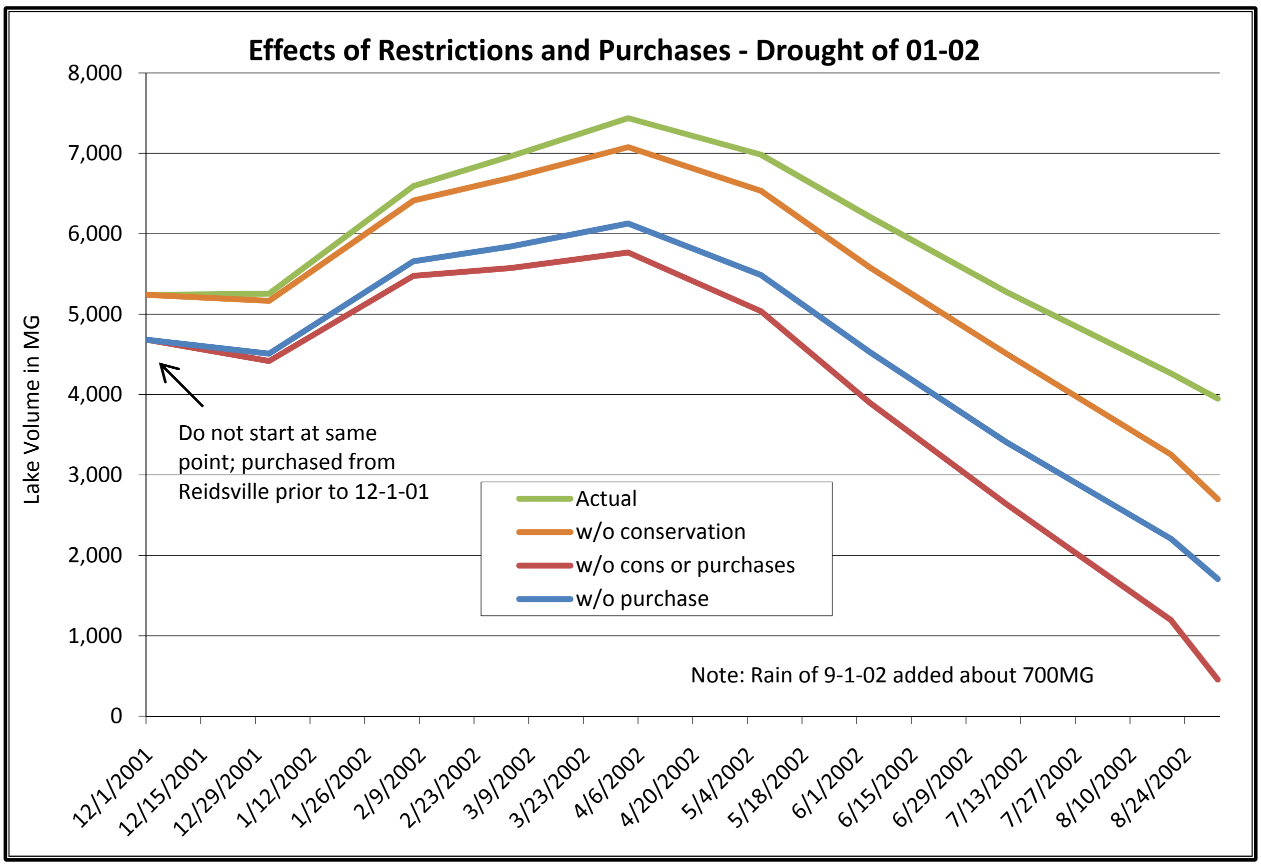


Figure 12

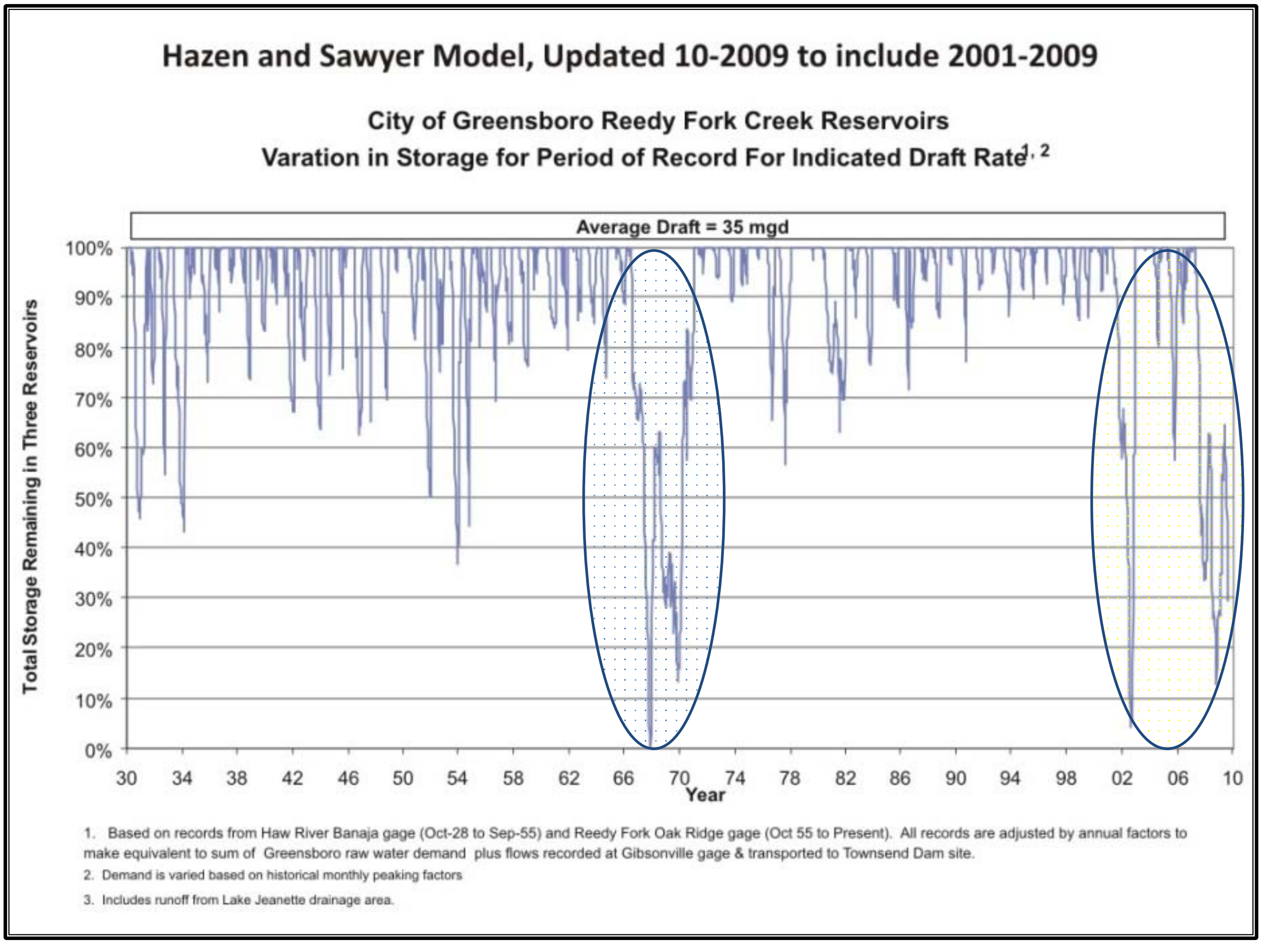


Figure 13

The data of the last ten years presents results from the model that are nearly as ominous as the drought of record in the 1960's. The only reason Greensboro's reservoirs did not drop to the predicted levels was that the City enacted restrictions and purchased considerable volumes of water from neighboring communities, thereby dropping the draw of raw water substantially below the model's assumption of 35 MGD.

Water Quality

Safe yield modeling assumes that the water drawn from the reservoirs can be effectively used as levels approach zero. It has been Greensboro's experience that significant water treatability issues arise when the lakes approach 60%. Chemical dosages increase, and taste and odor problems arise. Water Resources has now secured equipment to allow addition of activated carbon for the latter. Furthermore, as the water becomes more difficult to treat, the loss of water in production increases because the run times between filter backwashing decreases. It becomes somewhat of a downward spiral as reservoir levels drop; water quality deteriorates and even more water needs to be withdrawn to produce a given volume of finished water.

Greensboro has no experience with lake levels below about 40%. There has been one occurrence when lakes did not refill over the winter (the winter of 01-02) and provide some degree of flushing or "freshening" of the stagnant water. It is believed that algal mass and treatability would become extreme in a drought like is modeled in the sixties or the last 10 years (with full 35 MGD withdrawals) as levels drop to 20, 10, or 5%.

Data Confidence

Water Resources is confident in the quality of the safe yield modeling done to date by Hazen & Sawyer. However, it is based upon data that begins in 1928 with the assumption that this span of time is representative of the past. It has been noted by North Carolina climatologists that tree ring analyses have shown substantially worse dry periods in the last several centuries. Furthermore, there is evidence of climate change (it is irrelevant whether it's man induced or not) and there should be concern about what effect this may have on rainfall.

Townsend Low Flow Requirements

The deteriorated Townsend Dam required replacement, which opened up the reservoir system to new permitting constraints. Permitting a dam requires sustaining a minimum flow to be released for downstream water quality purposes. What minimum flow requirements may be established for the Townsend Dam remain contested. Under NC rules the amount can be up to 10% of the safe yield (3.5 MGD), but it is the position of the City and its consultants that Reedy Fork Creek downstream of the dam consists of some of the most unique and high quality stream, wetlands, and ecosystem as established by 40 years with no minimum release. In fact, freshwater mussel species below the dam were collected that demonstrated having survived well through the drought of 01-02. However, it is possible that the State may require releases in spite of this evidence. In that case, the safe yield would need to be adjusted to as low as 31.5 MGD.

Addition of a Safety Factor

Most of what is included above pertaining to the safe yield of Greensboro's reservoirs is directed at the danger in placing total confidence in the ability to sustain a city the size of Greensboro on a reservoir system assumed to produce the maximum yield as established by the typical "50-year safe yield." There is no safety factor, and it could be argued that such an assumption assumes a 1 in 50, or 2% risk, every year, that the City is entering a period during which it will see its reservoirs drop to nearly empty and deal with substantial water quality issues and public hysteria. It does not represent sound public policy or responsible engineering.

During the drought of 01-02 the City became aware of a defunct dam and pumping station, previously built by the City of Burlington, on the Haw River in northeast Guilford County. The station was built by Burlington to transfer water to its Lake Cammack in the event of drought following its experience with a substantial drought in 1953. The City worked with regulatory agencies to determine how it could benefit Greensboro in the event of a drought of long duration. The value of this source is that raw water flowing in the Haw River is outside the watershed that feeds the City's lakes, and in a long drought could be used during the winter to assist filling Lake Townsend (the City's largest storage lake with 5.3 BG). Models showed that primarily in the winter time when stream flows would be enough to meet a minimum release of 23 cubic feet per second, the City could "skim" up to 12-13 MGD and significantly affect the performance of its reservoirs. The City purchased the pumping station and dam, designed and constructed a 13 mile 30" transmission main, and designed and refurbished the pump station in six months. The impact of the Haw River Pump Station upon the model performance in the drought of the 1960's is demonstrated in Figure 14. While it does not assure filling of the reservoirs (Figure 14 demonstrates that it nearly would in 1966-1967, but not quite) it almost eliminates the occurrence of times when the City would not get a "fresh start" in the spring. It was used during the winter of 07-08 to transfer approximately one BG of water to Lake Townsend. It hastened the filling of the lake, but late winter precipitation likely would have filled the lake by spring. Regardless, its value and performance were established.

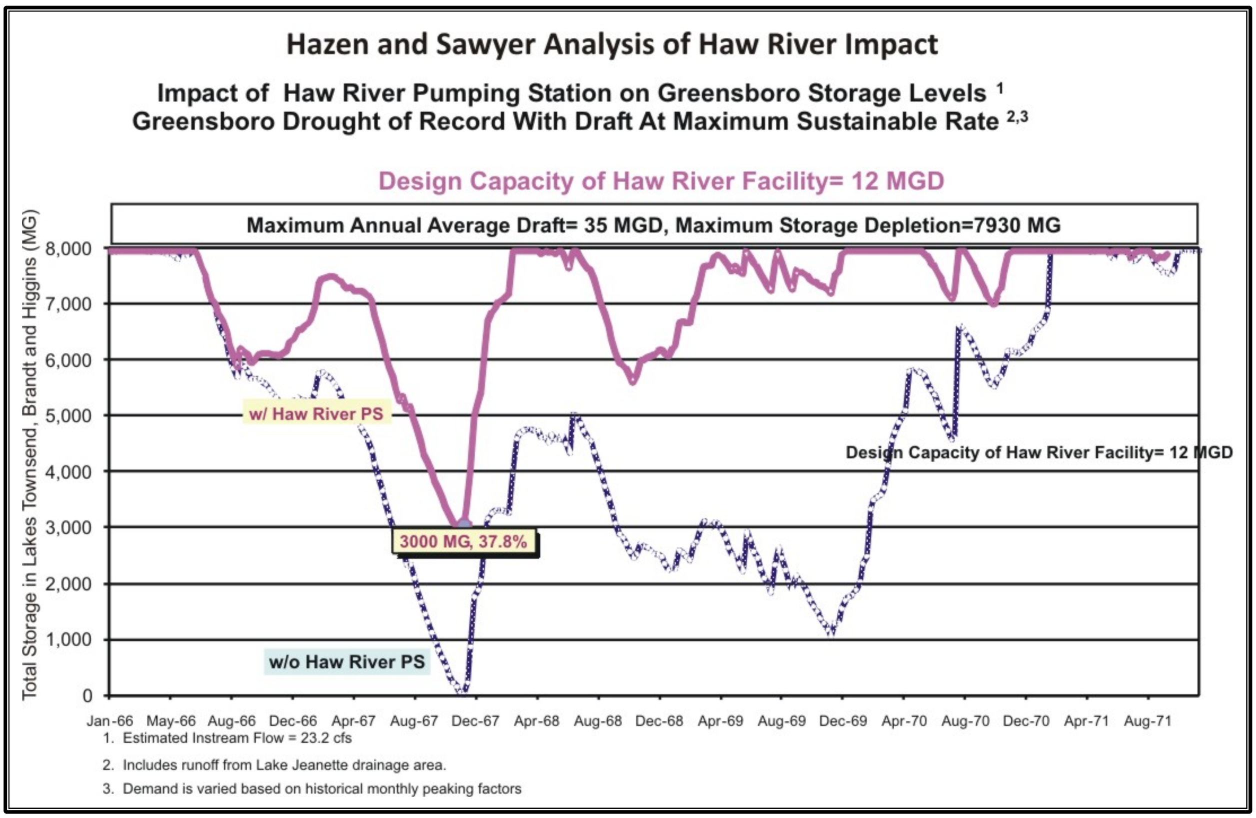


Figure 14

The above modeling assumed a 35 MGD demand upon the reservoirs. No modeling attempt has been made to establish what the reservoir system could be pushed to assuming the Haw River Pump Station's contribution. Instead, a decision was made to use the Haw River Pump Station as a safety factor to avoid the devastating scenarios when the lakes would drop to zero or be below 50% for long periods of time. This is in keeping with the current permit status of the Haw

Project as only an emergency supply. Assuming a yield of 35 MGD, the Haw River Pump Station in place and operating, and the data since 1928 as representative of what future conditions will occur, 44% of lake storage would remain in the event of a repeat of the drought of record.

C. Greensboro Finished Water Capacity

All of the safe yield discussions above have dealt with raw water yield as delivered to the Mitchell and Townsend Water Treatment Plants. Water treatment involves production losses. Filters need to be backwashed and then flushed before contributing finished drinking water to the system. Sedimentation basins that accumulate settled solids need to be emptied. All losses generally total approximately 10% at most times. For this reason, the amount of finished water that can be dependably expected from the Greensboro Reservoirs and Water Plants is 31.5 MGD assuming a safe yield of 35 MGD raw water. This provides a safety factor from the Haw River Pumping Station as explained above, but assumes no substantial minimum release is imposed by the State of North Carolina in the final permitting of the Townsend Dam Replacement.

If the City were to desire a safety factor equivalent to what the Haw Station provides (lakes not drawn down below about 40% full with the historic record of the last 80 years) *without the Haw Station,* then the finished water capacity of the system would be lowered to about 28 MGD finished water. This explains why the City was exposed to such risk from as early as 1989, when finished water consumption was 28 MGD. By 1993 finished water consumption was over 31 MGD, and any safety factor was lost from this point forward without the ability to access supplemental water sources in substantial volumes. Any criticism that the City did not desperately need Randleman as early as 1993 is without merit.

For the purposes of prudent water supply planning and adopting a policy that a safety factor should be employed to endeavor to prevent lakes from dropping below 40% full during droughts as severe as have been experienced in the last 80 years, the Greensboro lakes and water plants can be assumed to produce 31.5 MGD on an annual average basis.

D. Supplemental Finished Water Sources

The City has contracted with two cities for substantial capacity of water augmentation; Reidsville and Burlington. There are other interconnects to Winston-Salem and High Point, but given inter-basin transfer rule restrictions and the susceptibility of High Point to drought vulnerability of its own, these sources are not considered nor contracted for supplemental use during droughts. They may offer water in emergencies, but the Water Resources Department does not feel they are dependable sources for long term water supply planning and drought response.

Reidsville

Recognizing the vulnerability of the Greensboro water supply system to droughts, the City contracted with the City of Reidsville in 1999 for an interconnect that can supply up to 5.0 MGD to Greensboro when needed. As part of the contract Greensboro agreed to a minimum “take or pay” volume of 2.5 MGD for the first 5 years, decreasing to 1.0 MGD for the second 5 years of the contract. The contract was renewed in 2009 with a minimum purchase of 0.5 MGD, which is the minimum amount that Greensboro determined could be drawn to keep the water fresh and meet standards. This was important as several customers, including the Brown Summit Elementary School, have been connected to this main and the line must remain in service. Otherwise, approximately $1.5 million would need to be invested to loop a smaller line to provide service to these customers. The cost of the minimum purchase is approximately $250,000 per year and assures readiness to serve Greensboro in the event of a drought. For reasons of hydraulic interference, the City is only able to bring about 4.5 MGD of water into Greensboro during periods of high demand, but the source has proven to be highly dependable. This includes the drought of 2001-2002 when Reidsville continued to supply water to Greensboro even though their lake dropped below the level at which they could have stopped supply per the contract.

Burlington

In 2002, recognizing the value that the Reidsville interconnect was playing in sustaining Greensboro's water reserves during one of the worst two year droughts of record, discussions were opened up with the City of Burlington to explore an additional interconnect. An agreement was reached and a contract approved by the City Council and Burlington that was signed in May of 2002. The agreement required substantial capital improvements on the part of Burlington as well as Greensboro, and in exchange the City of Greensboro agreed to a minimum purchase of 2.0 MGD. The improvements allowed Greensboro to access up to 5.0 MGD whenever needed. The contract continues through July 1, 2013 and provides that the two parties may renegotiate the terms at that time. The Greensboro Water Resources Department hopes to decrease the minimum purchase to between 0.5 and 1.0 MGD depending upon other term adjustments to the contract. At current water rates, the minimum purchase is approximately $1.6 million per year.

Supplemental Finished Water Sources Summary

The two major interconnects that Greensboro relies on for drought protection, Burlington and Reidsville, provide a dependable source of up to 9.5 MGD whenever needed. The cost to maintain these relationships, not including the sunk capital investments, is about $1.9 million annually, which is about 2% of the budget of the water and sewer enterprise. The protection this provides is akin to an insurance policy; in some years the premium is paid and no call is made on the protection. However, there have been years when the ability to access these sources has avoided the need to issue mandatory water restrictions or experience lake levels that cause appropriate concern for the City to sustain supply through a drought. While the minimum purchase and larger drought event purchases are not insignificant, the ability to continue to meet demands during dry periods with this water is offset by the revenues during these periods when restrictions are avoided. This is not insignificant; water that is purchased from these providers costs about 40% of what it is sold in Greensboro under the irrigation price.

E. Piedmont Triad Regional Water Authority (PTRWA) (Randleman)

The long awaited Randleman source is nearing completion. The dam was complete in 2002 and the lake is full (other than when minimum release during dry periods drops levels somewhat). Financing agreements have been executed and the water plant, transmission main to the Greensboro/High Point transfer pump station, and the pump station are under construction by the PTRWA. The transmission main from the pump station to Greensboro is under construction by the City of Greensboro. While there are no guarantees with so many related projects under way, there is every reason to expect that Greensboro will be able to receive its allocation from the Randleman Project by the end of the summer of 2010.

The Randleman Water Treatment Plant is being completed for a total of 12 MGD of the full 48 MGD capacity. Greensboro's share of the 12 MGD is 6.39 MGD. Unlike the cautions regarding safe yield assessment included in this report pertaining to Greensboro's reservoir system, there would be no vulnerability to the 12 MGD during the most severe droughts. As the reservoir is more fully developed to its 48 MGD capacity of finished water, the safe yield relationships and historic performance may need to be reviewed, but there is no reason to anticipate any problems until the project is fully developed. That is many decades in the future and far more will be known at that time. In any case, the Water Resources Department considers the 6.39 MGD allocation to be fully dependable for water supply purposes. Since it will be received under a "take or pay" arrangement, it is anticipated that the full 6.39 MGD will be received each and every day as a base load supply. Greensboro's other sources will be used to address the variation in demand on a daily and seasonal basis.

The full allocation of Greensboro from PTRWA is four times the first phase. The plant was designed to be expanded from 12 to 24 to 36 and then 48 MGD. It is likely that the expansion needs will be driven by Greensboro's needs, but that is not knowable at this time. At such time that Greensboro needs more than the 6.39 MGD, negotiation will be required with the PTRWA, and will require agreement of its member governments.

V. Meeting Future Water Supply Demands

The primary water source for Greensboro will continue to be its three lakes (augmented by the Haw Transfer Project). This provides a finished water capacity of 31.5 MGD (during a drought year), somewhat below what current demand is (31-34 MGD). The Piedmont Triad Regional Water Treatment Plant (Randleman) is nearing completion with an additional base supply of 6.4 MGD, placing the City very capable of meeting near term demands, assuming no highly irregular weather patterns.

The two supplemental sources, Reidsville and Burlington, remain viable sources of large volumes of finished water in the event of plant disruptions or extraordinary drought. It should be noted that in 2009 Greensboro purchased maximum amounts from Reidsville and Burlington, totaling 9 to 10 MGD for several months to avoid restrictions. In spite of these large added volumes, the lakes were lower in early September than ever recorded, yet the confidence of the large supplement avoided restrictions or public concern. Reidsville has been re-negotiated to a low minimum purchase of 0.5 MGD and it is anticipated that Burlington can also be renegotiated in the near future. Abandonment of Reidsville would entail $1-2 million to loop the distribution system to current customers if the transmission main from Reidsville goes stagnant. This alone would support continuation of the Reidsville relationship. Assuming a reduction in minimum purchase from Burlington, at that time a decision could be made as to the benefit of continuing the ability to access 5 MGD from that source at any time. Based on Greensboro Water Resources staff experience and the trend in the water industry to have as much interconnection and redundancy as possible, it is highly recommended to continue both interconnection agreements, with or without considering Randleman.

The Greensboro water supply equation has two basic variables. The first, demand, is predictable but subject to swings in the economy and usage patterns as price rises (which it clearly will as system deterioration and regulatory changes demand greater capital). The second is supply. Current lake finished water yields are known (31.5 MGD) and so is the amount that will be supplied by the upcoming Randleman Phase I (6.4 MGD). Fortunately for the City of Greensboro, unlike many other communities looking into their water futures, the needs beyond Randleman Phase I are dependent only upon negotiating for the realization of its full allocation up to 25.56 MGD from Randleman. The additional 19.2 MGD comes in three phases of 6.4 MGD each. With a few years of negotiations and construction, each phase can be brought on line as the City experiences its actual needs. It may be possible and certainly could offer capital savings to stall these phases if supplemental water from Burlington and/or Reidsville can be used in the future to provide drought safety until Randleman can contribute more water, just as these cities did during the last decade.

Given the water supply needs as projected from the Hazen & Sawyer report (Figure 9), the safe finished water supply capacity of Greensboro's lakes and plants, the currently known capacities of Burlington and Reidsville, and the four phases of Randleman, Figure 15 was constructed to project the *approximate* timing of Randleman expansions. These can easily be expected to slide forward or back depending on actual growth, customer demand, or use of interconnections. As has been discussed earlier, the projected demands are likely conservative (on the high side) and this analysis needs to be revisited every few years to gauge true growth of demand.

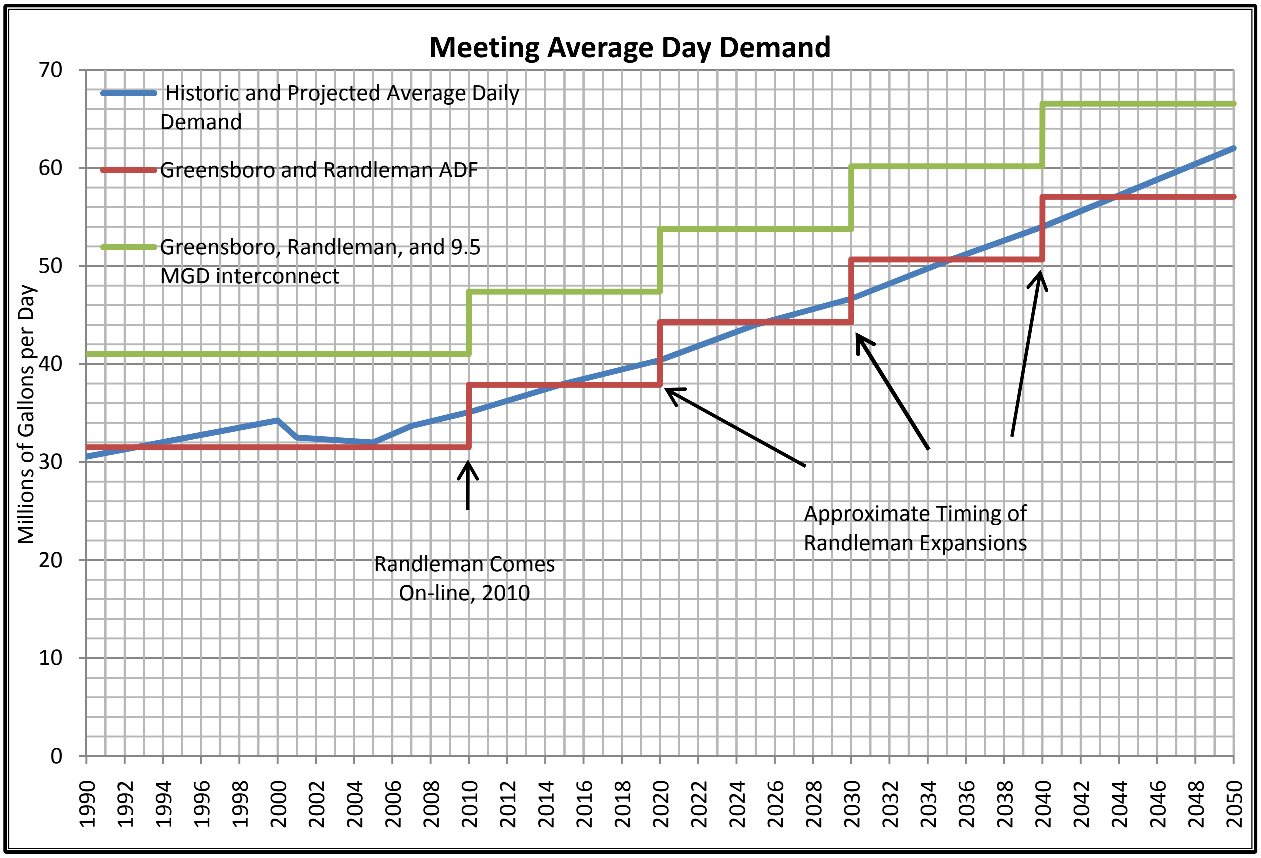


Figure 15

Nearly all of the discussions of this report reflect the ability to supply *average daily demand,* especially as it relates to drought vulnerability and plant capacity. There is another significant requirement, and that is that the system must be capable of supplying *peak demand.* While Greensboro's water plants have been established in this report as capable of supplying a dependable 31.5 MGD average daily flow, they are capable of producing 54 MGD for many days at a time provided the lakes can provide the raw water. At this time, it is understood that Randleman capacities as used herein represent average *and* peak day capacity for Greensboro.

Historically, the ratio of peak to average annual has been much higher due to inexpensive irrigation water, but Greensboro has also seen a transition from large industrial customer base to more residential, which historically tends to have higher peak ratios. The Hazen & Sawyer report and the projections of this report use an industry standard peaking factor of 1.5 times annual average. This is very likely to be overly conservative given expected changes in customer behaviors. However, for the purposes of this report it is a reasonable assumption. As is the case with average daily demand, this report should be re-evaluated every few years to gauge peak needs.

Both Figures 15 (Average Day) and 16 (Peak Day) include a representation of what the two interconnects can add to the supply mix from Reidsville and Burlington. They represent an excellent buffer, not only for adjusting the timing of Randleman expansions, but also for exceptional weather changes or plant/transmission main failures. However, beyond contract periods the City should be cautious in relying on these sources. It is most likely they would be available for the next decade or even two. However, as growth demands change for these cities, they may not be willing to extend peaking or drought capacity to Greensboro. For these reasons, one should be cautious in assuming that if demands (both average day and peak) grow as fast as this report has assumed, that the interconnections will be available to meet shortfalls.

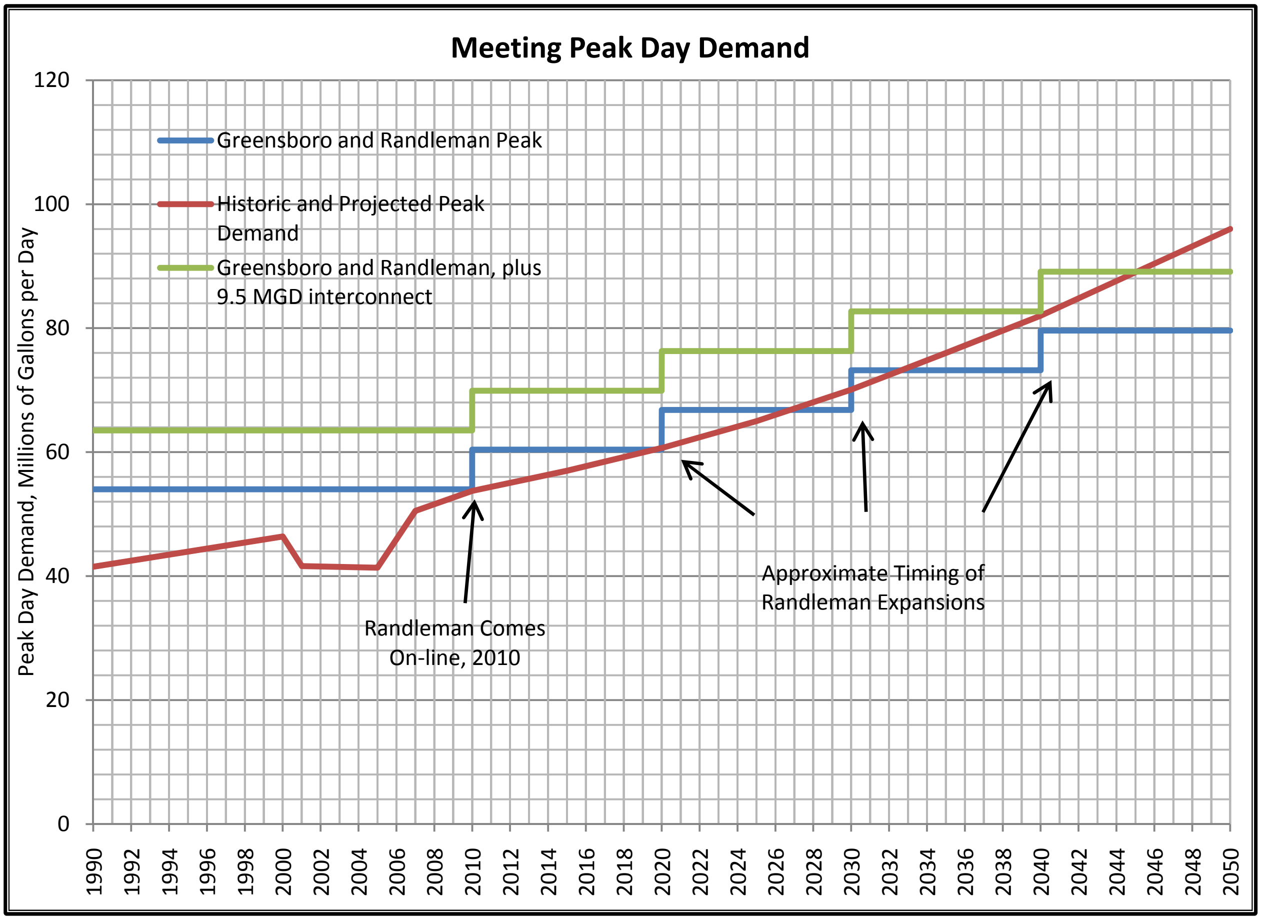


Figure 16

VI. Summary and Conclusion

Greensboro's water situation has changed dramatically in the past 15 years:

- In the mid-nineties the City was dangerously vulnerable to drought
- Public education and rate incentives have markedly reduced per capita consumption of water
- Interconnections to Burlington and Reidsville provided desperately needed drought safety
- The long delayed Randleman Project phases can meet Greensboro's water needs over the next 30-40 years, or longer with supplemental purchases. This is based upon relatively conservative projections of demand growth.
- The phased nature of Randleman production will allow Greensboro to match its production needs to demands as they materialize.

As of the late summer of 2010 the City will have realized the ability to access the first phase of the Randleman Project. In addition to the City's existing water plants and lake supplies that have been established with firm safety factors, for a modest cost of operation, the City can continue to use interconnections in the time of drought or to pursue a strategy to delay subsequent expansions of Randleman to save capital investment. The combination of lakes with safety factors applied to yields for climate variability, supplemental sources, and the ability to expand Randleman capacity as needed for growth means Greensboro has one of the most robust Piedmont water supplies in North Carolina. The use of demand management such as rate design and public education has dramatically changed the demand characteristics such that these supply side improvements will add longevity to the overall water supply and demand balance for the City.