WATER SUPPLIES, DEMANDS, AND ALTERNATIVES IN SOUTHEAST VIRGINIA

Prepared by

BOYLE ENGINEERING CORPORATION

Newport Beach, CA

local representation in

Charlotte, N.C.

and

DIVISION OF WATER RESOURCES

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH AND NATURAL RESOURCES

Raleigh, North Carolina

REVISED MAY, 1995

Tom Fraser

PREFACE

This report was prepared jointly by Boyle Engineering Corporation and the North Carolina Department of Environment, Health and Natural Resources, Division of Water Resources. The analysis of supplies was a joint effort of engineers from both groups. The analysis of demands was prepared by the Division of Water Resources.

For many years, there has been great controversy about water needs in the southeastern Virginia area. No reasonable choices can be made on this subject without a full understanding of the nature of the need for additional water. Specifically, any evaluation of additional supplies must take into account the range of supplies that may be available under current and anticipated circumstances, the frequency with which additional supplies may be necessary, the circumstances in which water conservation and demand reduction during dry periods can reasonably be used, the circumstances in which drought emergency wells should be tapped, and a number of other factors. This report is designed to address these questions.

Part I of the report analyzes the current regional supply and demand situation. Part II evaluates supply and demand alternatives currently under development in the region. Part III analyzes the supply, demand, and drought specific alternatives which can be used to offset any remaining deficit.

TABLE OF CONTENTS

Preface i

Table of Contents ii

Executive Summary iv

Part I. Existing Water Supplies and Demands 1

A. Supply 1

1. The Area Will Have A Water Supply Deficit Only During Severe Drought 1

2. The Amount of Water Available During Drought Is Likely to Be Much Greater Than Predicted 3

3. Supply Summary 11

B. Demand 11

1. Population Projections 11

2. Per Capita Water Use 13

3. Demand Summary 15

C. Projected Need (Supply Minus Demand) 15

Part II. Alternatives Under Development 17

A. Supply 17

B. Demand Reduction By Use Of Required Water Efficient Fixtures 18

C. Projected Need Including Alternatives Under Development (Supply Minus Demand) . . 20

Part III. Alternatives 21

A. Supply and Demand Alternatives Available for Use During Drought Periods 22

1. Voluntary and Mandatory Conservation 22

2. Modified Reservoir Operating Procedures 24

3. Additional Pumpage from Conjunctive Use Wells 25

4. Emergency Wells 26

B. Alternatives for Reducing Demand in both Normal and Dry Conditions 27

1. Plumbing Retrofit 27

2. Leak Detection 29

3. Rate Structures 29

4. City Planning Relative to Changing Customer Cross Section 30

5. Education 31

C. Alternatives for Increasing Supply in both Normal and Dry Conditions 31

1. Conjunctive Use of Groundwater 31

2. Water Banking (ASR) 32

3. Water Re-use 33

4. Sea Water Desalting 33

5. Exchanges of Water Rights 34

6. Interconnection of Various Utility Systems 34

7. Other Sources 35

D. Cost of Various Alternatives 35

1. Lake Gaston Pipeline 35

2. Realistic Alternative Scenarios 37

3. Summary 40

References 41

EXECUTIVE SUMMARY

The results of studies by the U.S. Army Corps of Engineers (Corps) and the Virginia Department of Environmental Quality—Water Division (DEQ, formerly the State Water Control Board) indicate that by the year 2030, the Five-City Area (Chesapeake, Norfolk, Portsmouth, Suffolk, and Virginia Beach) will have a water demand greater than the available water supply during drought. Federal Energy Regulatory Commission (FERC) Scoping Document 2 has suggested that the amount of this shortage is 60 mgd. The analysis in this report demonstrates that this 60 mgd figure only applies in the most serious drought of record (the worst drought in the last 150 years), and even then, only by assuming that several available supplies will not be used or will be lost, and that reservoirs will never be reduced below 75% full. It also assumes that population will continue to grow at the rapid rate of the mid-1980s (even though current growth rates are substantially below that measure), and that per capita water use will increase (even though it is actually decreasing). It assumes no voluntary conservation or other demand management measures will be implemented during drought. These assumptions are discussed in more detail in Part I, Existing Water Supplies and Demands.

Even if the 60 mgd figure were accurate based on the circumstances known today, it clearly will be substantially reduced based on supplemental supply and demand reduction alternatives already under development. Chesapeake is in the process of adding 10 mgd safe yield to its water supply system. Suffolk is building a 4 mgd expansion, and Portsmouth is increasing its yield by 2 mgd. In addition, the adoption of new building codes and, in particular, the Federal Energy Policy Act of 1992 (P.L. 102-486) will have a profound effect on water consumption. This law requires that as of January 1, 1994, all toilets manufactured in the United States be of the ultra low-flow variety, and all showers and faucets use state-of-the-art flow restrictors. As a result, per capita use in Southeast Virginia and throughout the nation will begin to be markedly reduced. These reductions in demand are estimated to be 24 mgd in the Five-City Area. In brief, supply and demand alternatives already under development will meet 40 mgd of Southeast Virginia's 2030 drought need. These factors are described in more detail in Part II, Alternatives Under Development.

There are many available supply enhancing and demand reducing alternatives available in southeastern Virginia. Because all analyses agree that there is no need for additional water in the region except during drought conditions, many of these sources can be specifically tailored to drought use, including voluntary conservation (15 mgd), restrictions on outdoor water use during severe drought (an additional 7 mgd), modified reservoir operating procedures (20 mgd), additional pumpage from conjunctive use wells (more than 5 mgd), and emergency wells (50 mgd). Alternatives for reducing demand in both normal and dry conditions include plumbing retrofit (19 mgd), and leak detection, conservation rate structures, city planning and education, which together can provide large additional demand reductions. Alternatives for increasing supply in both normal and dry conditions include conjunctive use of ground water (a minimum of 10 mgd), water banking (which can begin at as little as 3 mgd and expand if needed to well in excess of the region's total needs), non-potable water reuse (9 to 12 mgd already identified, large additional quantities likely available), seawater desalting (available in any amount, most economically at the end of the planning period), interconnection of local water systems (5 mgd), and other mechanisms.

The cost of each of these alternatives is far lower than a highly capital intensive project like the Lake Gaston pipeline. Indeed, some of the sources, like plumbing retrofit and use of conservation during drought, are cost free. Use of a combination of alternatives also allows supplies to be added as needed, rather than decades before need arises. In contrast, costs for the Lake Gaston pipeline are far greater than earlier suggested. Because fixed costs for the pipeline are very high and additional water is needed only in drought conditions, the cost of water through the pipeline is substantially in excess of $100 per thousand gallons. This is over 20 times the cost estimated in the FERC DEIS, and substantially greater still than the cost of the readily available local alternatives. These matters are described in detail in Part III.

PART I. Existing Water Supplies and Demands

A. Supply

1. The Area Will Have a Water Supply Deficit Only During Severe Drought.

The results of studies by the Corps and DEQ have been based on the amount of water available during the worst drought of record. Indeed, the terms, "safe yield" and "reliable treated delivery" are by definition based upon the amount of water available during severe drought. In this area, the period of record is 1929-1990, which includes the 1980-81 drought, which caused the greatest water supply problems, and the 1930-33 drought, which available information indicates was the worst drought in the past 150 years (1 at 14, Appendix C at 8-22).

All investigators agree that in normal years, adequate supplies will be available, and no further supplies are necessary. FERC's Final Environmental Assessment found:

> "Findings of the James Water Supply Plan concerning Virginia Beach were that water resources within the planning area were adequate to meet the area's average and peak water demands during normal and average flow conditions. During periods of low flow, such as those that occur once in 30 years, some areas will have difficulty meeting demand, especially if the water users are solely dependent on naturally available streamflow (James Water Supply Plan, p. III-13)."

(FEA at 11) This remains true "throughout the 50-year planning period." (3 at III-13 and xxxv).

For this report, the availability of water in years other than the worst drought in 150 years was determined by comparing the current supply components for the Five-City Area with the 2030 demand level of 152 mgd projected by the DEQ (4) using stream flow records over the 62-year period of record. The water supplies for these communities were separated into three categories based on source: surface water, conjunctive use wells, and emergency wells. The yields of the conjunctive use and emergency wells were kept constant each year, but the surface supply varies from year to year due to the natural variability of stream flow during the period of record. The demand figure was "without conservation" as defined by the DEQ (assumes no use of water saving fixtures and devices required since 1987), and also assumes there will be neither mandatory nor voluntary water use reduction during drought.

To account for the variability of stream flow, yields from surface water sources were indexed to annual flows. To determine the yield for each year, the ratio of the local inflow to the system for that year to the minimum annual local inflow over the available period of record was multiplied by the lowest reported safe yield of that system. Surface water yields in any year were limited to no more than twice the safe yield value to provide a reasonable upper limit on system yields. All these assumptions understate actual supply. The local inflows used for the various systems were taken from the input used for the STELLA model developed by the Corps. (1) The supply for Chesapeake also took into account actual Northwest River withdrawal records since 1985. This process permits examination of the performance of the system under a wide

range of water supply conditions over a period which includes both wet and dry years. It shows how often and how severely the system is tested over time.

The values used for surface water safe yields, conjunctive use well capacity, and emergency well capacity for each supply system are presented in Table 1. The values used for safe yield are the lowest in a wide range of published estimates including the FERC DEIS. (2, 3, 4, 36) As the subsequent sections of this report note, much higher values may be appropriate.

TABLE 1

FIVE-CITY SAFE YIELDS

SYSTEM	SURFACE WATER SAFE YIELD (MGD)	CONJUNCTIVE USE WELLS (MGD)	EMERGENCY WELLS (MGD)
Chesapeake	0.0	3.0*	9.0*
Norfolk	56.4	13.2	8.0
Portsmouth	18.8	5.4	10.0
Suffolk	0.45	4.25	2.93
Virginia Beach	0.0	0.0	20.0
TOTALS	75.65	25.85	49.93

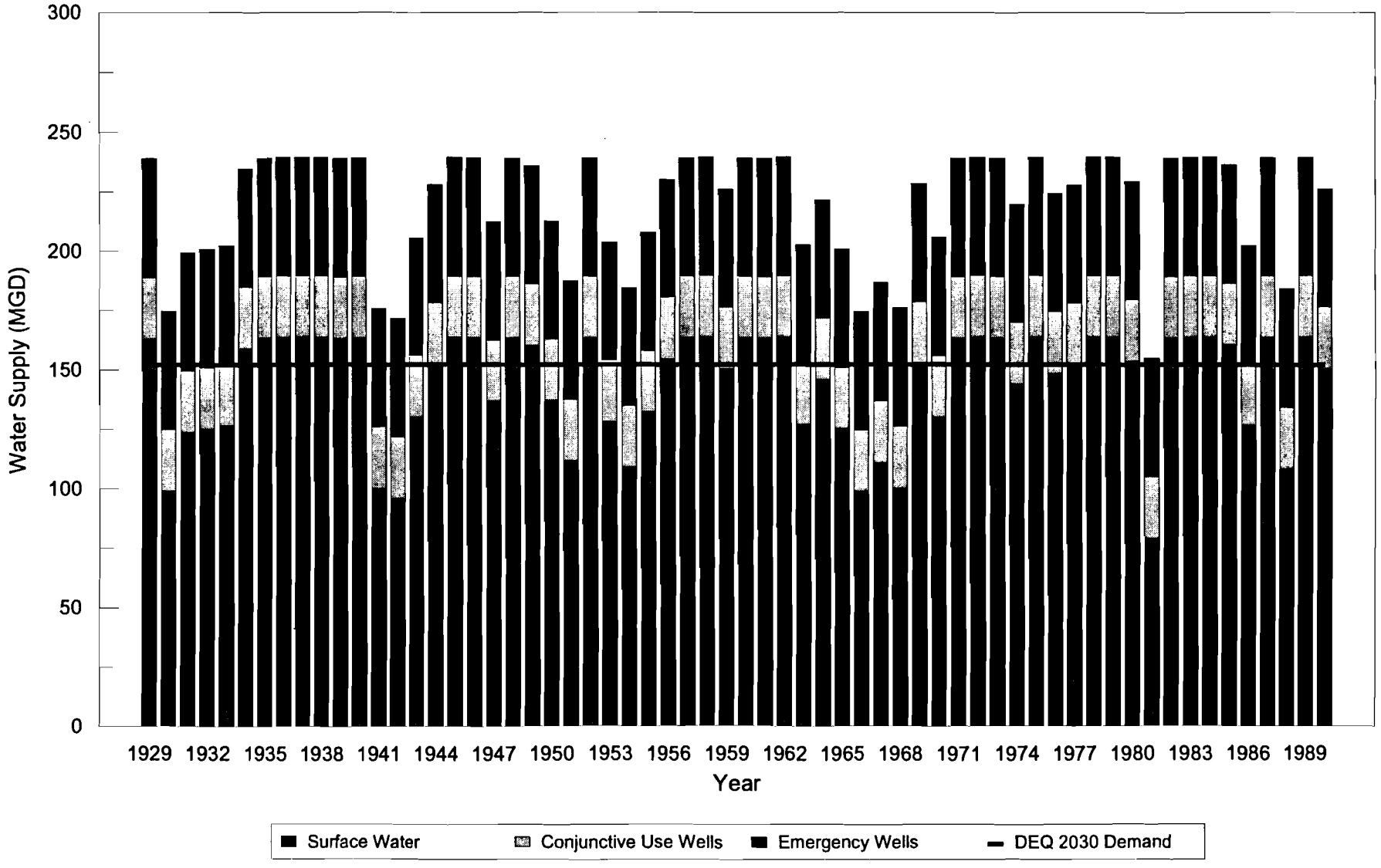
*As noted below, some sources (including the DEIS) treat all 12 mgd of Chesapeake's wells as for emergency use. However, Chesapeake can use one 3 mgd well for conjunctive use purposes, and has operated the well for those purposes in 1994 (58).

Estimated supplies from surface water, conjunctive use wells, and emergency wells are shown as stacked bars on Figure 1 for each year from 1929 through 1990. Also shown on Figure 1 is the DEQ projected 2030 demand of 152 mgd "without conservation," (i.e., without accounting for use of more modern fixtures) and with no voluntary or mandatory water use reductions during drought. If the top of the supply bar is above the demand line, no shortage is predicted. Examination of Figure 1 reveals that in 35 of the 62 years, or 57 % of the time, existing surface water supplies alone are estimated to be adequate to meet the 152 mgd demand. In 14 out of 62 years, use of the conjunctive use wells to some degree would be required. In 13 out of 62 years, some use of the emergency wells likely would be required. In none of the years is there less potential supply than demand, although the top of the supply bar is only slightly higher than the demand line for a year with the same hydrologic conditions as 1981.

The comparison of supply and demand for the Five City Area is admittedly an approximation and a simplification of a complex system. However, as described below, it was derived from information developed by or for the municipalities and incorporates assumptions which substantially underestimate supplies. Even with the inherent conservatism of the approach, Figure 1 demonstrates the ability of existing supply sources to meet 2030 demands in all but very dry conditions. This is particularly noteworthy because the calculations were made without

Figure 1. Existing Five-City Water Supply Components (Lowest Estimates)

DEQ 2030 Projected Demand - 152 MGD (w/o Water-Efficient Fixtures or Conservation during Drought)



accounting for either the use of more modern plumbing fixtures or the water use reductions which are standard during times of reduced supply.

2. The Amount of Water Available During Drought is Likely to be Much Greater Than Predicted.

a. The Corps and DEQ relied on extremely conservative assumptions.

The value of safe yield will vary depending on the assumptions used. While it is possible to measure the number of gallons that can be stored in a reservoir, safe yield is a prediction of the amount of water that will be available to an area under certain defined circumstances. It is the choice of those circumstances, and the assumptions made in the calculations, that determine the resulting safe yield value. For example, investigators preparing models of the water system must assume the severity of drought upon which safe yield is to be calculated. In some circumstances, that safe yield is based on a 30-year drought—in others it may be the drought of record. Modelers then must make certain assumptions about how the water systems will operate during that drought, what minimum reservoir levels will be maintained, how the availability and use of ground water will be calculated, what degree of losses will occur during transmission, and so on. Based on all these varying assumptions, the safe yield can be modeled. Changes in any one of the assumptions can cause significant changes in the final number chosen as a system's "safe yield."

In calculating the safe yield for the Southeastern Virginia systems, a number of perhaps overly conservative assumptions were made. First, unrealistic assumptions regarding reservoir levels were modeled, reducing safe yield by 20 mgd. Second, the period of record included the most severe drought in 150 years. Third, several available supplies were discounted without supporting technical rationale. These factors are explained below:

Safe yield was reduced by 20 mgd by assuming that reservoir levels would never fall below 75% full.

The Norfolk water supply system obtains raw water from two major reservoir systems that collect local runoff, diversions from the Blackwater and Nottoway Rivers, and wells. Norfolk's Intown Reservoirs consist of Lake Lawson, Lake Smith, Little Creek Reservoir, Lake Wright, Stumpy Lake, Lake Taylor, and Lake Whitehurst. The Western Lakes System consists of three major interconnected reservoirs -- Lake Prince, Western Branch Reservoir, and Lake Burnt Mills. The total capacity of these reservoirs is approximately 15,700 million gallons (MG) [48,200 acre-feet], of which approximately 15,300 MG [47,000 acre-feet] is considered active or useable. (1) These reservoirs are operated to maintain a minimum storage level of 75% of their useable capacity. The Corps (2) and DEQ (4) estimate the safe yield values by assuming the reservoirs must continue to maintain a 75% minimum storage level even during the most severe drought. The FERC DEIS (36) incorporates DEQ estimates, but does not evaluate the validity of this assumption.

The establishment of the 75% of storage constraint appears arbitrary. The only explanation appears to be that when storage levels reach 75% full, the localities begin water conservation efforts. (7) Virginia Beach wishes to avoid such efforts. This criteria is maintained during droughts, for which no explanation is tendered. During times of shortage, reservoir levels would certainly be reduced below this level.

The firm yield of a reservoir has been defined as "the draft or withdrawal that lowers the water content in a reservoir from a full condition to a minimum level just once during the critical historical drought." (5) The Virginia State Water Control Board (now DEQ) (6) defines safe yield for complex intakes (i.e., impoundments in conjunction with streams) according to Maidment's (5) definition of firm yield: "the minimum withdrawal rate available to withstand the worst drought of record in Virginia since 1930." The State further defines the critical drought period as "the period of time from the beginning of drawdown until the time when the minimum pool level is reached, i.e., water supply storage = 0, and the reservoir begins to recover." Failing all other forms of estimating available storage, the State defines supply storage to be "75% of normal storage. Normal storage is the amount of water held in storage when the water level is at the same elevation as the crest of the principal spillway." None of the previously referenced Corps and DEQ safe yield estimates were calculated on this basis.

The consequences of using more realistic storage level assumptions has been examined in some detail by David Moreau of the North Carolina Water Resources Research Institute. (7) The results of his analyses show that, "... the existing Norfolk reservoirs would be used hardly at all during the next 50 years if the area is provided with a constant 60 mgd supply." The constant 60 mgd supply referred to is the proposed yield from the Lake Gaston project. Additional analysis and explanation of the 75% storage level assumption is found in Little, McCrodden, and Moreau, A Yield Analysis of the Surface Water Supply System Serving Southside Hampton Roads, Virginia. (35) Interpretation of Moreau's results indicate that on the order of an additional 20 mgd yield could be obtained if the minimum storage criteria were set at 50 % of useable capacity. Fifty percent of useable capacity would not raise quality concerns, would not violate DEQ guidelines, and would still maintain a significant reserve.

<u>The period of record included the worst drought in 150 years.</u>

Safe yield may reasonably be calculated based on the worst drought on record, as it was done by the Corps and DEQ, and adopted in the DEIS. However, since the period of record included the worst drought in 150 years, there is a high level of conservativeness in the estimate.

<u>Safe yield results were repeatedly reduced for a number of questionable reasons.</u>

In 1984, the Corps calculated the safe yield of the systems at 132 mgd (2 at 130). It then reduced that number to 110.0 mgd for the reasons cited in Table 2.

TABLE 2

1984 CORPS SAFE YIELDS-EXISTING AND AS REDUCED FOR "PLANNING PURPOSES"

SUPPLY	EXISTING SUPPLY	PLANNING SUPPLY	BASIS FOR CHANGE
Norfolk			
Western reservoirs	68.0 mgd	63.0 mgd	Allowed only 50% of increased pumping capacity, because pumps had not yet been tested in drought.
Wells	16.0 mgd	13.0 mgd	Reduced by 20% even though they produced 15.3 during most recent drought.
In-town lakes	8.0 mgd	4.0 mgd	Reduced by 50% due to uncertainty in the operation of the lakes.
Sub-Total	92.0 mgd	80.0 mgd	
Portsmouth			
Reservoirs	19.0 mgd	19.0 mgd	
Wells	5.5 mgd	4.0 mgd	Reduced past drought yields by 20%, although wells can pump full amount.
Sub-Total	24.5 mgd	23.0 mgd	
Suffolk			
Wells and surface	5.5 mgd	0.0 mgd	Suffolk supply dropped from region total without explanation.
TOTALS	132.3 mgd	110.0 mgd	

In 1988, DEQ reduced the Corps planning projection to 100 mgd, again assuming that further supplies might not be available. (3) Table 3 quantifies these reductions.

TABLE 3

DEQ REDUCTIONS FROM CORPS PLANNING SUPPLY

SUPPLY	CORPS PLANNING SUPPLY	1988 DEQ AVAILABLE YIELD	BASIS FOR CHANGE
Norfolk			
Western reservoirs	63.0 mgd	57.0 mgd	Allowed 0 increase for new pumps.
Wells	13.0 mgd	12.0 mgd	Reduced by 25% even though they produced 15.3 mgd during most recent drought.
In-town lakes	4.0 mgd	8.0 mgd	
System losses		-7.7 mgd	Losses due to leaks, evaporation, and system condition.
Sub-Total	80.0 mgd	69.3 mgd	
Portsmouth			
Reservoirs	19.0 mgd	19.9 mgd	
Wells	4.0 mgd	5.5 mgd	
Sub-Total	23.0 mgd	25.4 mgd	
Chesapeake			
Northwest River	7.0 mgd	0.0 mgd	
Wells	0.0 mgd	0.3 mgd	0 due to chloride intrusion problems.
Sub-Total	7.0 mgd	0.3 mgd	
Suffolk			
Wells and surface	0.0 mgd	5.0 mgd	
TOTALS	110.0 mgd	100.0 mgd	

DEQ's 1993 Water Supply Update increased the estimated safe yield to 104 mgd, then estimated that water losses would reduce the total to 99 mgd of "reliable treated delivery." (4) This presumably increases the allowance for water leaks.

During normal hydraulic conditions, Chesapeake can produce at least 7 mgd from the Northwest River; during drought conditions the Norfolk wells can produce 15.3 mgd, if maintained; some credit should be given for the new pumps in the Norfolk pumpover system; unaccounted for losses should not be subtracted twice in the Norfolk system (these losses appear to be already factored into the 57 mgd safe yield determination); the Portsmouth wells should be capable of

delivering their permitted 5.4 mgd capacity, and Suffolk's supply should be included if its demand is included. These reasonable alternative conclusions could add 17 to 22 mgd to the above estimates of safe yield during years of normal runoff, and 10 to 15 mgd during droughts.

In sum, values of safe yield can range significantly, depending upon which assumptions are employed. It may be as low as 99 mgd (DEQ 1993, "reliable treated delivery"), 110 mgd if Corps reduced safe yields are used (115 mgd including Suffolk), and 132 mgd if full credit is given to available sources. The current yields described in the DEIS appear to be about 1 mgd higher than DEQ values, although precise comparison is difficult because the DEIS does not consider raw water losses (i.e., reliable treated delivery) source by source, but instead subtracts an assumed 6% loss from all sources. Each of the yield results would be increased by 20 mgd if yields were calculated assuming reservoir levels were allowed to drop to 50% of capacity during severe droughts (as they actually do).

b. The conservative assumptions result in a wide range of safe yield values.

Many of the reports on water resources in Southeastern Virginia over the past ten years have relied on the calculations and assumptions of one another, as described below. For example, all rely on the 75% reservoir level assumption, and all discount available sources. But even among these reports, there is a range of conclusions. Some supply components are rated approximately the same in the various references while others have been given yields that vary significantly. Table 4 summarizes these sources and rated yields as they have been presented in the noted references.

CHESAPEAKE

Northwest River: In its 1984 report (2) the Corps estimated the yield of this system to be to be 7 to 16 mgd. In the same report it is stated that the yield appropriate for establishing a planning deficit is 7 mgd.

The Virginia Water Control Board stated in its 1988 report (3) that the capacity of the system is 10 mgd, but due to salt water intrusion in the Northwest River a zero safe yield will be assigned to this system. In its 1993 update (4), the DEQ restates zero safe yield for the system.

Although 10 mgd is available most of the time, the safe yield for the Chesapeake surface water system is 0 mgd.

Chesapeake Civic Center Well: In its 1984 report (2), the Corps identified two 0.14 mgd wells which supply water to the Chesapeake Civic Center. The report notes that the wells are independent and are not integrated with the remaining distribution system. A 0.3 mgd capacity is credited to Chesapeake for these wells in the Corps summary of supplies. Zero mgd is credited to Chesapeake for the wells by the Corps in its establishment of a planning deficit.

The DEQ also credited Chesapeake with 0.3 mgd for these wells in its 1988 report (3), but does not show any credit for them in its 1993 update report.

TABLE 4
SUMMARY OF SOUTHEAST VIRGINIA FIVE CITY WATER SUPPLY ESTIMATED SAFE YIELDS

Jurisdiction	Raw Surface Water Source Safe Yield	Conjunctive Use Well Safe Yield	Total Raw Water Source Safe Yield	Current Reliable Treated Water Safe Yield	2030 Reliable Treated Water Safe Yield	Emergency Well Permitted Capacity	Reference
Chesapeake	10 mgd	0.3 mgd	10.3 mgd	10.3 mgd	7 mgd	12 mgd	(2) at 130, 138
	0 mgd	0.3 mgd	0.3 mgd	0.3 mgd	0.3 mgd		(3) at II-409, 410, 424
	0 mgd	0 mgd	0 mgd	0 mgd			(4), II-12
	0 mgd	3 mgd	0 mgd	0 mgd		9 mgd	(1) at 72, 87
Norfolk	76 mgd (8 mgd, E; 68 mgd, W)	16 mgd	92 mgd	92 mgd	80 mgd	8 mgd	(2) at 126, 128, 130, 137, 138, 139 Reduced E by 50% due to deteriorating water quality, pg. 138; reduced W by 5 mgd for uncertainty of new pumps at 137; reduced wells by 20% below 1980-81 pumpage rates at 137.
	65 mgd (8 mgd, E; 57 mgd, W)	15.5 mgd	80.5 mgd	69.3 mgd	69.3 mgd	8 mgd	(3) at II-405, 406, 424 W considers old pumps on Blackwater & Nottoway and >50 & >155 cfs flow-by respectively. Considers 10% unaccounted for losses from W.
	60 mgd est.(8 mgd, E; 52 mgd, W)	14 mgd	74 mgd	69.6 mgd	69.6 mgd	8 mgd	(4), pg. II-12 Discounts 74 to 69.6 mgd due to system losses
Portsmouth	19 mgd	5.5 mgd	24.5 mgd	24.5 mgd	23 mgd		(2) at 127, 130, 136, 138 Reduced well output to 80% of 1980-81 production.
	19 mgd	5.5 mgd	25.4 mgd	25.4 mgd	25.4 mgd	10 mgd	(3) at II-408, II-424 5.5 mgd goes to clearwell from wells 1 & 2. 10 mgd goes to Lakes Meade & Kilby
	19 mgd	5.5 mgd	25.4 mgd	25.4 mgd	24.3 mgd	10 mgd	(4), pg. II-12; (5), pg. 76 Reduced conjunctive use wells to 80% of their 1980-81 production.
Suffolk		5.5 mgd	5.5 mgd	5.5 mgd			(2) at 130
		5 mgd	5 mgd	5 mgd	5 mgd		(3) at II-411, II-424
		4.9 mgd	4.9 mgd	4.7 mgd	4.7 mgd		(4), pg. II-12
		3.97 mgd	3.97 mgd	3.97 mgd	3.97 mgd		(1) at 77, 78
Virginia Beach						20 mgd	(2) at 128, 129, 130; (3) at II-406
Isle of Wight Co		2 mgd	2 mgd	2 mgd	2 mgd		(2) at 130, 131
		0.18 to 0.11 mgd	0.18 to 0.11 mgd	0.18 to 0.11 mgd	0.18 to 0.11 mgd		(4), pg. II-12
SUMMARY							
Chesapeake	0 to 10 mgd	0 to 3 mgd	0 to 10.3 mgd	0 to 10.3 mgd	0 to 7 mgd	9 mgd	
Norfolk	60 to 76 mgd	14 to 16 mgd	74 to 92 mgd	69.3 to 92 mgd	69.3 to 80 mgd	8 mgd	
Portsmouth	19 to 21 mgd	5.5 mgd	24.5 to 25.4 mgd	24.5 to 25.4 mgd	23 mgd to 25.4 mgd	10 mgd	
Suffolk		4.7 to 5.5 mgd	4.7 to 5.5 mgd	4.7 to 5.5 mgd	4.7 to 5 mgd	2.93 mgd	
Virginia Beach					0 mgd	20 mgd	
Isle of Wight Co		0.11 to 2 mgd	0.11 to 2 mgd	0.11 to 2 mgd	0.11 to 2 mgd		
TOTALS	79 to 107 mgd	24.31 to 32 mgd	103.31 to135.2	98.61 to 135.2 mgd	97.11 to 119.4 mgd	49.3 mgd	

Since the wells are not connected to the system and only serve the Civic Center, they should not be considered a supply component as long as the Civic Center demand is not added into the total demand.

Other Wells: The Corps in its 1984 report (2) noted that the City drilled an emergency well in the Bowers Hill area during the 1980-81 drought that was tested at 1 mgd, but was not put into service.

In the DEQ 1988 report (3), it is stated that the City has commenced construction of four deep wells in the Branch-Bowers Hill section for an auxiliary water supply of 10-12 mgd. In the 1993 DEQ update (4), it is noted that the City has four emergency wells and that one of the wells is being used with the pilot aquifer storage and recovery project. No capacities are noted.

The Corps stated in its 1994 Drought Preparedness Study (1) that the city has four deep wells in the Western Branch-Bowers Hill section of the city. It is noted that each well has a capacity of about 3 mgd. Well number 1 was grandfathered under the 1973 Ground Water Act and the City considers it a non-emergency well. Withdrawals of 3 mgd could be made from each of the other three wells when chlorides are greater than 250 mgd in the Northwest River intake or mandatory water conservation measures were invoked.

Chesapeake has completed conversion of one of these wells for aquifer storage and retrieval (ASR). That process proved to work effectively (55), and the well is now used for conjunctive use purposes (58). The DEIS incorrectly states that this ASR well has been abandoned. (36 at 1-14, n. 6)

Chesapeake has 4 wells rated at 3 mgd each for a total supply of 12 mgd. Two of these wells (6 mgd) are for drought purposes only. One (3 mgd) is the ASR well, and designed for supplemental use. One (3 mgd) is considered and used by Chesapeake as a conjunctive use well and by the DEQ to be an emergency well. The wells yield 3 mgd for production and 9 mgd for drought use.

NORFOLK

Western Reservoirs: The 1984 Corps report (2) defined the then safe yield of the Western Reservoir System as 57 mgd. Planned new pumps at the Blackwater and Nottoway Rivers would increase this yield during recurrence of the most severe drought of record by 11 mgd, from 57 mgd to 68 mgd, according to the report. To establish the planning period deficit, the Corps reduced the 68 mgd to 63 mgd, stating that the new pumps had not been tested under actual drought conditions and only 50% of the increased capacity would currently be considered safe yield.

The Corps also noted that four Norfolk wells with a total capacity of 16 mgd are available to supplement the natural flow into the reservoirs. The Corps discounted the 16 mgd by 20% to 13 mgd in establishing the planning period deficit because of the performance of the Portsmouth wells during the 1980-81 drought. This was clearly a low estimate because the average yield of the Norfolk wells during the 1980-81 drought was 15.3 mgd over a 12 month period.

The DEQ stated in its 1988 report (3) that the safe yield of the Western Reservoir system, including pumpover from the Blackwater and Nottoway Rivers, is approximately 57 mgd. It projected no increase in capacity for the already installed new pumps (which should increase safe yield by 11 mgd), but simply noted that if the pumps prove to be more efficient, the safe yield of the Western Reservoir system could be higher. (3 at II-406)

DEQ also states that the 16 mgd ground water wells were only pumped approximately 75% of the time during the 1980-81 drought. Therefore, it estimated the actual yield from the Norfolk wells would be 12 mgd, or 75% of their total rated capacity. It did not suggest the wells were not able to supply all 16 mgd. Indeed, the wells supplied 15.3 mgd over a 12-month period. DEQ merely noted that the wells only needed to be pumped 75% of the time, and the yield was therefore reduced. DEQ then further reduced the total safe yield and well capacities by 7.7 mgd for unaccounted-for losses to arrive at its estimated available yield. In its 1993 update report (4), DEQ defines Norfolk's total raw water source safe yield, including the Intown Reservoir System, to be 74 mgd, and the reliable treated system delivery to be 69.6 mgd (a reduction for unspecified raw water loses).

Estimates of the Western Reservoir System safe yield range from a high of 76 mgd (81 mgd if the newer pumps work as predicted, 83 mgd if the Norfolk wells work as they did in the last drought) to a low of 61.6 mgd, the DEQ estimate of "reliable treated delivery." The rated capacity should be arrived at giving some credit to the new Blackwater and Nottoway pumps and counting wells based on how much they are able to provide.

Intown Reservoirs: All of the previous investigators rated the Intown Reservoir System safe yield at 8 mgd. For the purpose of establishing a planning deficit, the Corps (2) uses 4 mgd citing quality, operation, and limited data as the reasons for discounting the yield. All more recent studies use the larger figure.

Eight mgd should be used for the safe yield of the Intown Reservoirs.

Other Wells: All of the references identified two 4 mgd wells that Norfolk drilled on U.S. Navy property in Suffolk. Norfolk currently maintains and operates the wells as drought emergency wells.

Norfolk has 8 mgd drought emergency well capacity.

PORTSMOUTH

Reservoirs: The most recent estimates by the DEQ (4) rated the reliable treated system delivery capabilities of the reservoirs at 19.9 mgd.

The Portsmouth reservoir system safe yield is 19.9 mgd.

Wells to Water Treatment Plant Clearwell: All reports identified two wells with a total capacity of 5.5 mgd that pump directly into the Portsmouth treatment plant clearwell. In estimating a planning deficit, the Corps (2) reduces this number to 3.5 mgd. The Corps states that the yield of the wells during the 1980-81 drought was only 80% of the rated capacity and that it is

reasonable to assume that in future droughts the wells would only yield 80% of what they yielded during the 1980-81 drought. More recent reports return to the higher figure. The Corps (1) noted that the wells are permitted at 5.4 mgd.

The wells should be developed to their permitted capacity and contribute a safe yield of 5.4 mgd.

Other Wells: In its 1988 report (3) the DEQ identified three wells that pump directly into the reservoir system. One has the capacity to pump 4 mgd into Lake Meade. Two others have a total capacity to pump 6 mgd into Lake Kilby. The Corps (1) defines these wells as drought emergency wells.

Portsmouth has an additional 10 mgd well capacity available for emergency use.

SUFFOLK

Reservoirs/Wells: In 1984, the Corps (1) rated the safe yield of the Suffolk system at 5.5 mgd. In 1988, the DEQ (3) rated the safe yield of the Suffolk system at 4.96 mgd. This consists of: Lone Star Lakes wells - 0.45 mgd; two wells near the filtration plant - 0.36 mgd; the fluoride well - 0.63 mgd; City Farm Well - 3.09 mgd; and Wilfor Industrial Park Well - 0.43 mgd. In 1993, the DEQ defined the reliable treated system delivery for Suffolk to be 4.7 mgd with no breakdown of where the supply comes from.

The reliable treated system delivery for Suffolk will be considered 4.7 mgd.

Other wells: The Corps Drought Preparedness Study (1) concludes that Suffolk has a 2.93 mgd well for drought purposes.

Suffolk has a 2.93 mgd emergency well.

VIRGINIA BEACH

All Sources: All references concurred that Virginia Beach currently has a zero safe yield. All references also concurred that Virginia Beach has five 4 mgd emergency wells - two in Suffolk, two in Isle of Wight County, and one in Southampton County. Virginia Beach has contracts with each of these entities for use of these wells, but limited to times of drought emergency.

Virginia Beach's current safe yield is zero and drought emergency supply yield is 20 mgd.

ISLE OF WIGHT COUNTY

Wells: If the Isle of Wight County demand is included in the regional demand to be satisfied, then the Isle of Wight County safe yield should be included in the supply total.

In 1984 the Corps (2) credited the County with nine separate systems having 15 wells with a total capacity of 2.0 mgd.

In 1993 DEQ (4) stated the Isle of Wight County raw water sources safe yield was 0.18 mgd and the reliable treated system delivery was 0.11 mgd.

If Isle of Wight County demand is included in the regional demand total, available supplies from Isle of Wight should also be included in the available regional supply.

After consideration of the previous discussion and the range of supply estimates by previous investigators, the safe yield values presented in Table 5 have been adopted. While larger in most cases than previous estimates, they are still highly conservative. It is assumed that historic yields can be maintained with appropriate well and pump maintenance. Total supplies during the drought of record range from 98 mgd to 135 mgd. The appropriate estimate of safe yield is 122 mgd. All estimates are based on the highly conservative assumptions regarding reservoir storage. More realistic assumptions would increase the safe yield estimate by 20 mgd.

3. Supply Summary

All studies agree that in normal flow periods, there is more supply than needed to meet 2030 demand. During the worst drought of record, supply estimates in various studies range from 99 mgd to 132 mgd. If safe yield were calculated by allowing reservoir levels to be reduced to 50% (as they actually are during severe drought), all these safe yield figures would be increased by 20 mgd. For drought years less than the worst drought of record, available supply increases substantially.

B. Demand

All estimates of water demand in Southeast Virginia have been computed by first projecting expected populations, then estimating the portion of the population that will be served by the various municipal water systems, and then finally multiplying that estimate by a per capita water use estimate. Some studies use a combined residential and commercial/industrial water use average, some use separate residential estimates and commercial/industrial estimates, and some evaluate in a more detailed manner.

1. Population Projections

Several previous studies have forecast population for Southeast Virginia. The Corps' *Water Supply Study - Hampton Roads, Virginia* (1984) and DEQ's *James Water Supply Plan* (1988) based future population estimates on employment projections prepared by U.S. Department of Commerce Bureau of Economic Analysis (BEA). (2, 3) More recent (1992) estimates are now available from BEA (56). The Virginia Employment Commission (VEC) provides population projections for Virginia's local jurisdictions corresponding with the decennial U.S. census. VEC uses the cohort-component method, and forecasts to 2010 based on the rate of growth between 1980 and 1990. (13) This method is appropriate only for short term projections and considers birth rates, mortality rates, and net migration. Additional and more current information is necessary to project longer term population trends, including local land use regulations, land carrying capacity, and economic growth indicators. Because land carrying capacity is a clear

TABLE 5
ESTIMATE OF REASONABLE SAFE YIELDS FOR SUPPLIES IN SOUTHEASTERN VIRGINIA

Jurisdiction	Raw Surface Water Source Safe Yield	Conjunctive Use Well Safe Yield	Total Raw Water Source Safe Yield	Current Reliable Treated Water Safe Yield	Emergency Well Permitted Capacity	COMMENTS
Chesapeake	0 mgd	3 mgd	3 mgd	0 mgd	9 mgd	
Norfolk	8 mgd E, 63 mgd W	15.3 mgd	86.3 mgd	86.3 mgd	8 mgd	Some credit should be given for the new pumps at the Blackwater and Nottoway Rivers. Per ref. (1) 63 mgd includes 50% of the potential increased capacity. This number could be as high as 68 mgd. Ref. (2) discounted the yield by 7.7 mgd due to unaccounted for losses. The 57 mgd safe yield with the old pumps already includes consideration of unaccounted for losses. Eight mgd should be allowed for the Intown Reservoirs. 63+8=71mgd Per ref. (2) the yield of the Norfolk wells was 15.3 mgd maximum 12-month pumpage average during the 1980-81 drought. They should be maintained at this capacity and not discounted.
Portsmouth	19.9 mgd	5.4 mgd	25.3 mgd	25.3 mgd	10 mgd	The clearwell wells are permitted at 5.4 mgd. They should be maintained at 5.4 mgd.
Suffolk		5.5 mgd	5.5 mgd	4.7 mgd		Per the Va. DEQ-WD (4), the reliable treated system delivery is currently 4.7 mgd.
Virginia Beach		0 mgd	0 mgd	0 mgd	20 mgd	
Isle of Wight Co		2 mgd	2 mgd	2 mgd		If the demand that can be served by this supply is included in the 2030 demand total, then this supply should also be included.
TOTALS	90.9 mgd	28.5 mgd	122.1 mgd	118.3 mgd	47 mgd	
TOTALS from Table 2+A10	79 to 107 mgd	23.58 to 32 mgd	102.58 to 135.2 mgd	97.88 to 135.2 mgd	47 to 50 mgd	

limit on growth, cohort-component projections lose utility as carrying capacity is approached. VEC can only provide projections beyond 2010 by straight line extrapolation.

The Hampton Roads Planning District Commission (HRPDC) is a group made up of local governments in the region. Its membership consists of city officials from the area, including Virginia Beach and its neighbors. The members of the Virginia Beach City Council Water Committee are represented on the Commission. The HRPDC makes population forecasts by its own method.

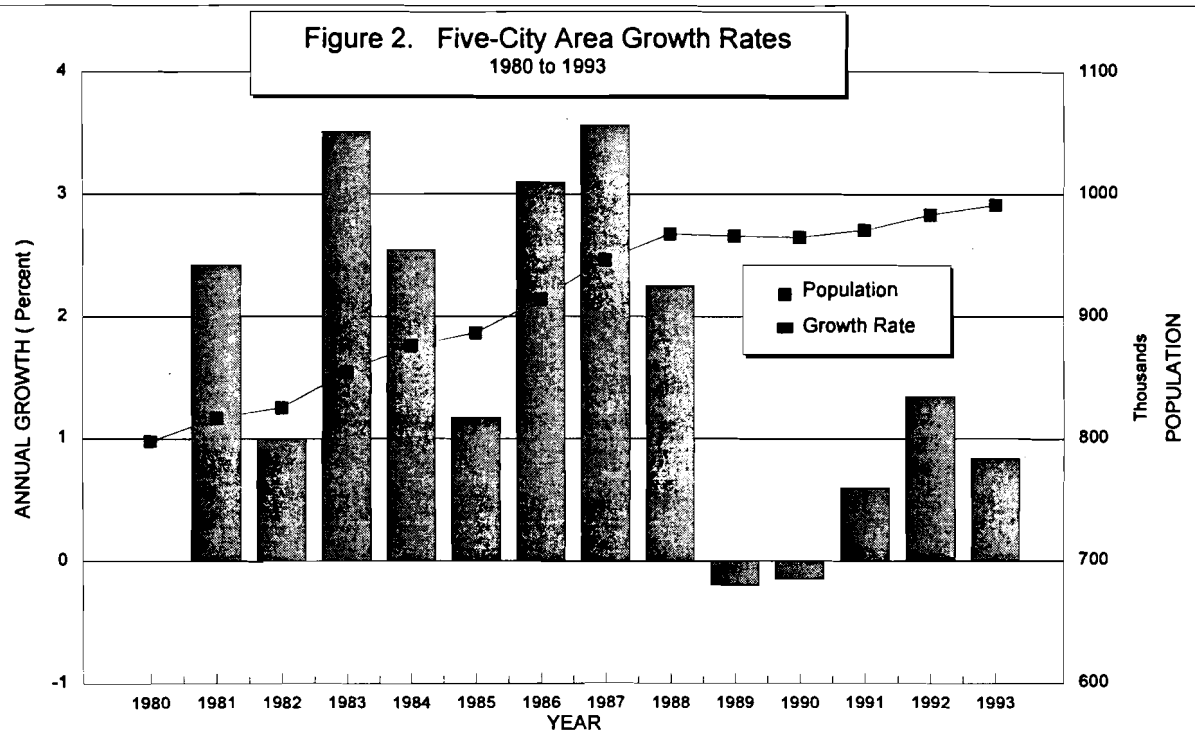
Recent economic events in Southeast Virginia have cast doubt on all forecasts performed during the economic expansive period of the 1980's or that relied on growth trends at that time. Growth rates of close to 4% in the early and mid-1980s are below 1 % since 1988. Populations in Norfolk and Portsmouth have already been seen to decline rather than increase as predicted. (13) Military cutbacks and the almost 50% reduction in the size of the naval fleet have been the most serious concern in an economy heavily dependent on ship building and other military support activities. For this and other reasons, growth in the area has now slowed markedly. For example, home building is the most important measure of population growth. While home building increased in the United States in 1994, it declined in Southeast Virginia (57). Figure 2 shows the increasing growth rate in the early 1980's and the declining growth rate since 1988. A Commission formed by local business leaders fears that growth may stop entirely. (14)

U.S. census data shows that actual population for the Five-City Area in 1990 was below all projections made since 1984. Intercensus estimates for 1993, released by the Center for Public Service (CPS), University of Virginia, show that in 1993 area population fell short of DEQ, VEC, HRPDC, and BEA projections for that year. (15) The various projections and actual population figures for 1980, 1990, and 1993 are set out in Table 6.

In the DEIS, FERC staff relied on the highest projections, those reported by the HRPDC, the regional body which represents the interests of the applicants. (36) HRPDC's annual growth estimate of 1.3% has proved the least accurate of all projections. The 1992 BEA/Department of Commerce projections are the most accurate, although they also overstate actual growth. See Figure 2.1.

NC-DWR took into account actual population numbers and the various population projections, and contacted planning staff in Virginia Beach and Chesapeake for information on current land use policies and development trends. (16, 17) From this data, NC-DWR developed estimates of the maximum population growth that could be expected through 2030. The material below does not attempt to project actual population -- merely to define the upper limit of population growth. Actual population will almost certainly be lower, and may be distributed among the cities in a different fashion.

Virginia Beach currently limits development south of the "green line," a boundary which separates the developed northern areas of the city from the rural southern areas. Virginia Beach staff noted that the area south of the green line cannot support the same level of development as areas in the north due to existing soil conditions. Sewer extensions into the southern area are presently considered undesirable. (16) Virginia Beach's 1994 Comprehensive Plan estimates



Source: Virginia Employment Commission. 2010 Projections. 1993.
Center for Public Service, Univ. of Virginia, 1994.

Table 6. Comparison of Previous Population Estimates with Actual Population

				Intercensus	Projected			
	Study	1980	1990	1993	2000	2010	2020	2030
5-City Area	Corps 1,2		882,125	904,018	955,100	1,029,450	1,089,200	1,140,000
	DEQ 1,3		987,150	1,009,005	1,060,000	1,134,150	1,193,750	1,244,450
	HRPDC (FERC) 4,7			1,002,246	1,095,280	1,197,975		1,306,000
	VEC 4,5			1,000,990	1,091,095	1,210,957		
	BEA 1,6,10			991,182	1,058,400	1,137,200	1,193,600	1,216,150
	Actual 8,9	795,862	962,374	989,300				
Va. Beach	Corps		311,350	325,735	359,300	409,450	446,200	479,150
	DEQ		383,200	397,585	431,150	481,300	518,050	551,000
	VEC			420,230	483,559	579,590		
	Actual	262,199	393,089	416,200				
Norfolk	Corps		271,450	271,675	272,200	272,850	273,300	273,650
	DEQ		283,000	283,240	283,800	284,500	285,000	285,400
	VEC			259,703	256,094	253,809		
	Actual	266,979	261,250	245,300				
Portsmouth	Corps		107,700	108,600	110,700	113,200	115,700	118,000
	DEQ		109,100	110,000	112,100	114,600	117,100	119,400
	VEC			103,625	102,961	101,965		
	Actual	104,577	103,910	103,600				
Chesapeak	Corps		137,100	141,240	150,900	164,500	177,600	188,300
	DEQ		158,850	162,990	172,650	186,250	199,350	210,050
	VEC			163,087	188,999	211,100		
	Actual	114,486	151,982	170,400				
Suffolk	Corps		54,525	56,768	62,000	69,450	76,400	80,900
	DEQ		53,000	55,190	60,300	67,500	74,250	78,600
	VEC			54,345	59,482	64,493		
	Actual	47,621	52,143	53,800				

Notes:
1. Straight-line Interpolation between 1990 and 2000 projections.
2. Corps of Engineers. Water Supply Study, Hampton Roads, Virginia, 1984.
3. Virginia Department of Environmental Quality-Water Division. James Water Supply Plan, 1988.
4. Straight-line Interpolation between 1990 actual and 2000 projection.
5. Virginia Employment Commission. Virginia Population Projections 2010, June 1993.
6. Bureau of Economic Analysis. BEA Regional Projections to 2040, North Carolina and Virginia Counties, 1992.
7. Hampton Roads Planning District Commission. Hampton Roads 2015 Economic Forecast, 1993.
8. U.S. Census, 1980 and 1990.
9. 1993 estimate reported by Center for Public Service, Univ. of Virginia.
10. Straight-line interpolation between 2020 and 2040 BEA reported values.

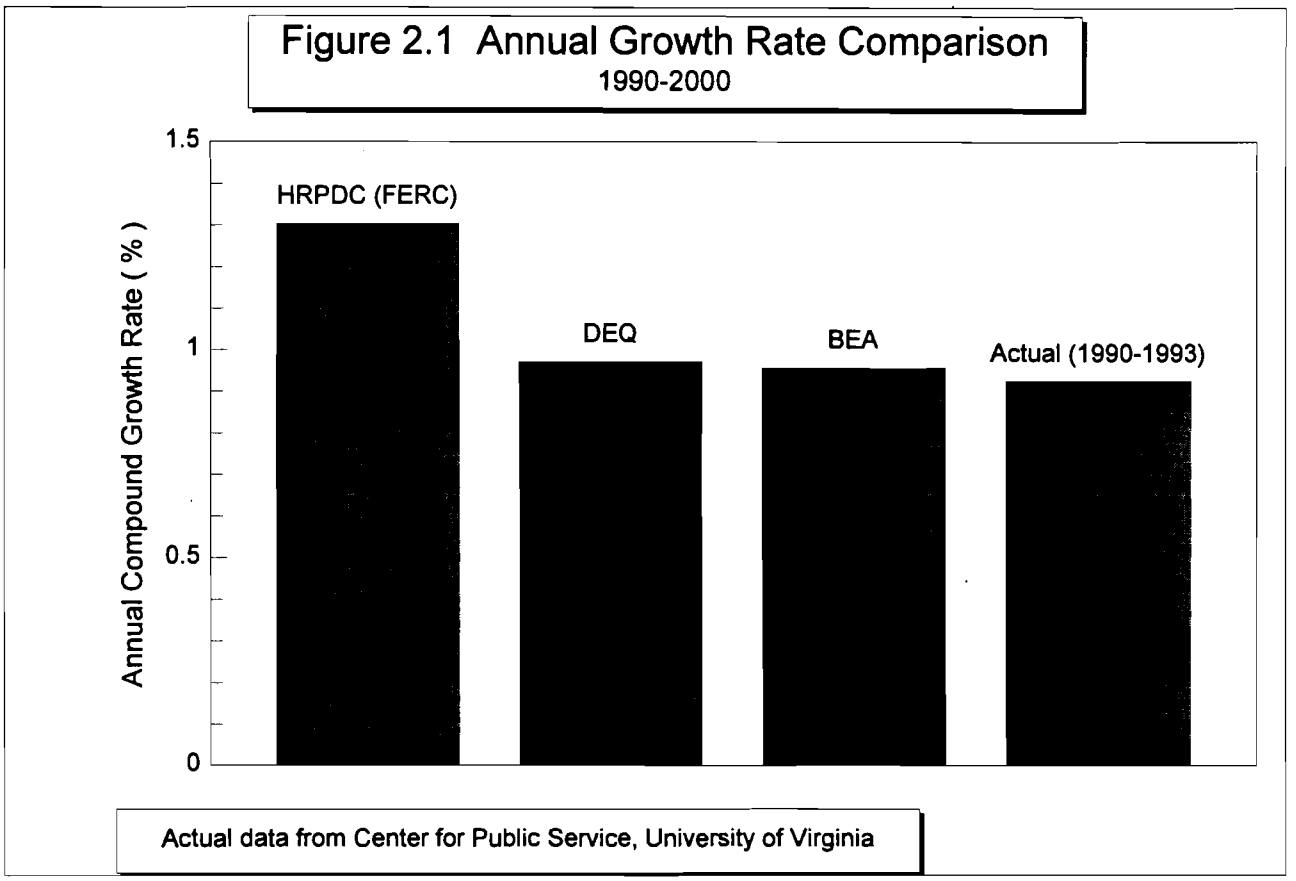


Figure 2.1 Annual Growth Rate Comparison
1990-2000
Annual Compound Growth Rate (%)
1.5
1
0.5
0
HRPDC (FERC)
DEQ
BEA
Actual (1990-1993)
Actual data from Center for Public Service, University of Virginia

citywide buildout at 598,800 (including a population of 105,800 south of the green line, a 1553% increase from 1990 population of 6400 south of the green line). (18) This buildout figure is similar to Malcolm Pirnie's (1991) estimated buildout of 578,000, DEQ's 2030 projection of 551,000, and VEC's projection of 579,950 for 2010 (which does not take into account limitations of buildout). (3, 13, 19) NC-DWR assumes that Virginia Beach's higher buildout figure of 598,800 is correct. Because construction on every buildable lot is not likely to occur, NC-DWR assumes that Virginia Beach's maximum population will be 95 % of buildout, or 568,860.

Norfolk and Portsmouth are both declining in population as is typical in older established cities where few development opportunities exist. Population in each city declined from 1980 to 1990, and then again from 1990 to 1993. VEC projections show both cities in continuing decline. (13) To establish maximum possible population, however, NC-DWR has adopted 1993 intercensus figures, and assumed no further decline. (15) On this basis, maximum 2030 population for Norfolk is 245,300, and maximum 2030 population for Portsmouth is 101,965.

Chesapeake has, and continues to grow rapidly. Suffolk is also growing, albeit less rapidly. To estimate maximum possible growth potential, NC-DWR chose the highest of the population projections for those cities by the Corps, DEQ, and a straight-line extrapolation of VEC figures to 2030. (2,3,13) The highest 2030 estimate for Chesapeake is the extrapolation of the VEC estimates to 2030--255,302. (13) The highest estimate for Suffolk is the 1984 Corps projection--80,900. (2)

For the year 2030, NC-DWR's maximum population estimate for the Five-City Area is 1,252,327--a figure within 1% of the 1988 DEQ forecast (1,244,450). (3) The maximum estimates for the individual cities are higher than DEQ projections for Virginia Beach, Chesapeake and Suffolk, but lower than DEQ estimates for Norfolk and Portsmouth, (reflecting the actual, but then unanticipated decline in those cities). DEQ's previous population estimates and the maximum growth estimated by NC-DWR are compared in Table 7. Because these totals are so close, we have incorporated the DEQ projections as the maximum possible population growth in the area. However, it is important to note that actual population is running below DEQ estimates. Furthermore, growth rates are now appreciably lower than projected by DEQ, and therefore population should be expected to remain below projected levels. Figure 3 compares DEQ's population estimates with actual values. Accurate population projections must be adjusted for growth trends over the last five years. This would suggest a population somewhat less than the BEA's 1992 projections, or about 1,200,000.

2. Per Capita Water Use

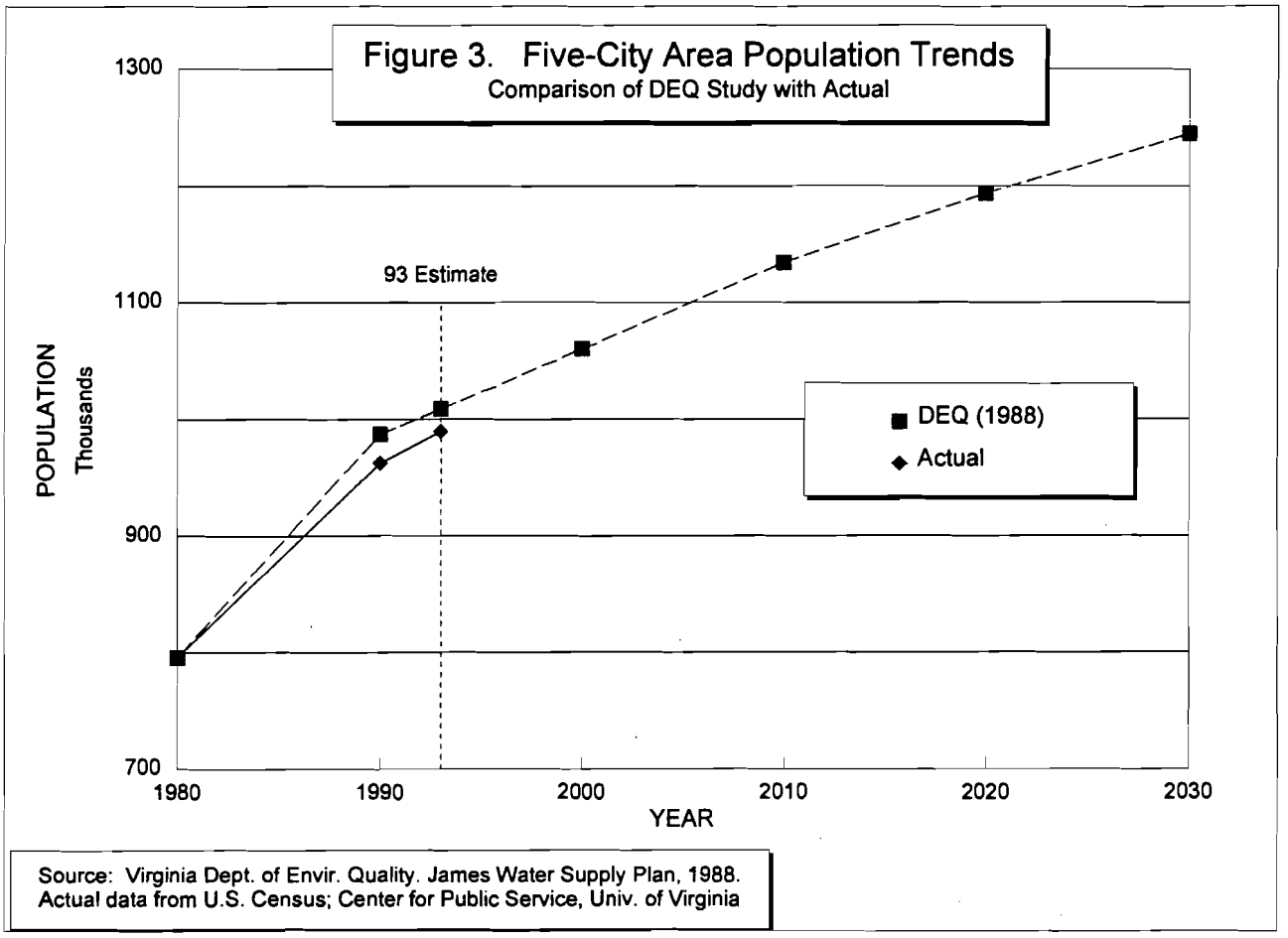
The Corps' 1984 *Water Supply Study* projected per capita water use using both pre-1987 BOCA (Building Officials and Codes Administration) and the 1987 revised BOCA plumbing codes. (20) The Corps' methodology relied heavily on estimates of per capita use for residential, commercial, industrial, and military categories. (2) When multiplied by projected population, those estimates yielded future water demands with and without the use of the more water efficient fixtures ("with conservation" and "without conservation").

Table 7. Comparison of DEQ and NC-DWR Maximum Population Projections

	Study	1990	2000	2010	2020	2030
Va. Beach	DEQ 1	383,200	431,150	481,300	518,050	551,000
	NC-DWR Maximum	393,089	483,559	531,193	555,689	568,860
Norfolk	DEQ	283,000	283,800	284,500	285,000	285,400
	NC-DWR Maximum	261,250	245,300	245,300	245,300	245,300
Portsmouth	DEQ	109,100	112,100	114,600	117,100	119,400
	NC-DWR Maximum	103,910	102,961	101,965	101,965	101,965
Chesapeake	DEQ	158,850	172,650	186,250	199,350	210,050
	NC-DWR Maximum	151,982	188,999	211,100	233,201	255,302
Suffolk	DEQ	53,000	60,300	67,500	74,250	78,600
	NC-DWR Maximum	52,143	59,482	64,493	76,400	80,900
5-City Area	DEQ	987,150	1,060,000	1,134,150	1,193,750	1,244,450
	NC-DWR Maximum	962,374	1,080,301	1,154,051	1,212,555	1,252,327

Notes:

1. Virginia Department of Environmental Quality. James Water Supply Plan, 1988.
2. NC Division of Water Resources, 1994.



Source: Virginia Dept. of Envir. Quality. James Water Supply Plan, 1988.
Actual data from U.S. Census; Center for Public Service, Univ. of Virginia

DEQ revised the Corps' estimates in 1988 by using updated population figures from 1980s intercensus estimates. Per capita use was again projected using both pre-1987 BOCA codes and revised BOCA conservation and leak repair strategies. DEQ also described these projections as "with conservation" and "without conservation." The 1993 *Hampton Roads Water Supply Update* incorporates the basic figures from the 1988 DEQ study. (4)

The Corps and DEQ derived their pre-1987 BOCA per capita estimates by assuming that future per capita use would not be affected by more water efficient fixtures. The post-1987 BOCA ("with conservation") estimates, assumed that these fixtures would be installed and would reduce per capita water use. Prior to 1987, plumbing codes in Virginia were based on earlier revisions of BOCA which did not contain any conservation guidelines. (21) Other than in Virginia Beach, which established its own set of minimum plumbing standards in 1977, the other cities all fell under this earlier code. In 1987, the State of Virginia amended the statewide uniform building code to reflect new water conserving fixture standards. (20) The plumbing provisions of the 1987 BOCA provided low-flow specifications for toilets (3.5 gallons/flush) and other bathroom fixtures (maximum 3 gpm flow rate for showers and faucets). The BOCA code preempted Virginia Beach's water conservation standards until 1991 when localities were enabled to enforce local codes more stringent than the state building code.

The 1984 Corps and 1988 DEQ post-1987 BOCA ("with conservation") projections assumed that the more modern fixtures embodied in the 1987 BOCA code standards would be installed in new and renovated construction. The Corps assumed toilet flush standards would be reduced from 6 gallons per flush under pre-1987 BOCA standards to 4 gallons per flush under the 1987 code. Actual code reductions were greater, to 3.5 gallons per flush. Lower flow rates were also calculated for showers and faucets. The Corps found that toilet use amounted to 45% of domestic water use, and showers and faucets together amounted to 35%. (2) Savings for more efficient fixtures is therefore substantial. Because Virginia Beach had more efficient plumbing standards in place since 1977, per capita use would decrease less there than in the other municipalities. DEQ also took into account leak repair plans in its "with conservation" totals.

Both the 1984 Corps and DEQ 1988 studies assumed that per capita water use (both pre-1987 and post-1987 BOCA) would grow over the years based in part on the assumed relative growth of commercial over residential water use and in part on increases in unaccounted water losses as systems age. (2, 3) Neither has proved to be the case. Residential use has remained at high relative levels, and leak repair and maintenance has been successful. Per capita use is in fact declining. (22, 23) Therefore, per capita use figures in the DEQ report clearly represent the maximum possible per capita use. Actual per capita use will certainly be lower, both with and without accounting for the 1987 BOCA code.

The FERC based its per capita demand assumption on water usage in 1990, after the adoption of the 1987 BOCA code. It projects an average per capita use of 121 gallons per person per day, slightly less than the 123 gallons projected by DEQ "with conservation." (36, 3)

3. Demand Summary

As noted, demand is projected by multiplying the number of people served by the system by the per capita water use. The 1984 Corps study predicted that, without taking into account the 1987 BOCA code, the Five-City Area would require 144 mgd to meet its needs in 2030. (2) The 1988 DEQ report projected that figure would rise to 152 mgd. (3) In the 1993 *Hampton Roads Water Supply Update*, DEQ repeated that forecast. (4) The individual cities reported to DEQ higher forecasts still (164.8 mgd), but there is no documentation in the reports to support those claims. (3, 4) DEQ reported them, but did not adopt them. (3, 4)

As noted earlier, we believe that DEQ's population and per capita use forecasts are the maximum reasonable estimates for the region. Table 8 lists the Corps and DEQ forecasts for demand, both with and without conservation, and includes actual water use values for comparison. The 1984 Corps study forecast a demand with the 1987 BOCA in place of 135 mgd for the five cities in 2030. (2) The 1988 DEQ report projected a higher figure of 142 mgd. (3) The FERC DEIS adopted higher population estimates than DEQ, but slightly lower per capita use projections to estimate water use of 148.2 mgd. Actual 1990 water use was 110.19 mgd, below DEQ projections for 1990 both with and without conservation, but above both Corps 1990 estimates. Water use in Virginia Beach actually declined in the most recent fiscal year. (65) The range of figures shows a 2030 demand ranging from 135 mgd (Corps with revised BOCA code) to 152 mgd (DEQ without revised BOCA code or leak repairs). Figure 4 illustrates the range of estimates available and the actual 1990 water demand.

C. Projected Need (Supply Minus Demand)

All analysts agree that there is no need for additional regional water supply during normal conditions. In conditions similar to the worst drought in 150 years, supply estimates range from 99 mgd to 132 mgd. All these estimates would be 20 mgd higher if modelers had assumed that reservoirs would reach 50% of capacity during the most severe drought, a clearly realistic assumption. Projected 2030 demand ranges from 139 to 152 mgd. The range of supplies and demands is set out at Figure 5.

The 60 mgd regional "deficit" (52 mgd as calculated by DEQ) is based on a number of assumptions stacked upon one another.

- None of the supplies originally included in safe yield, but later discounted the basis of "uncertainty," will work as planned (e.g., the improved pumps installed on the Blackwater and Nottoway Rivers will provide none of their designed 11 mgd safe yield; conjunctive use wells will never be pumped longer than they were in the 1980 - 81 drought, even if water from those wells is needed and readily available).

- Reservoirs will never fall below 75% full.

- Population growth will return to the levels of the mid-1980's, and military reductions will have no effect on growth.

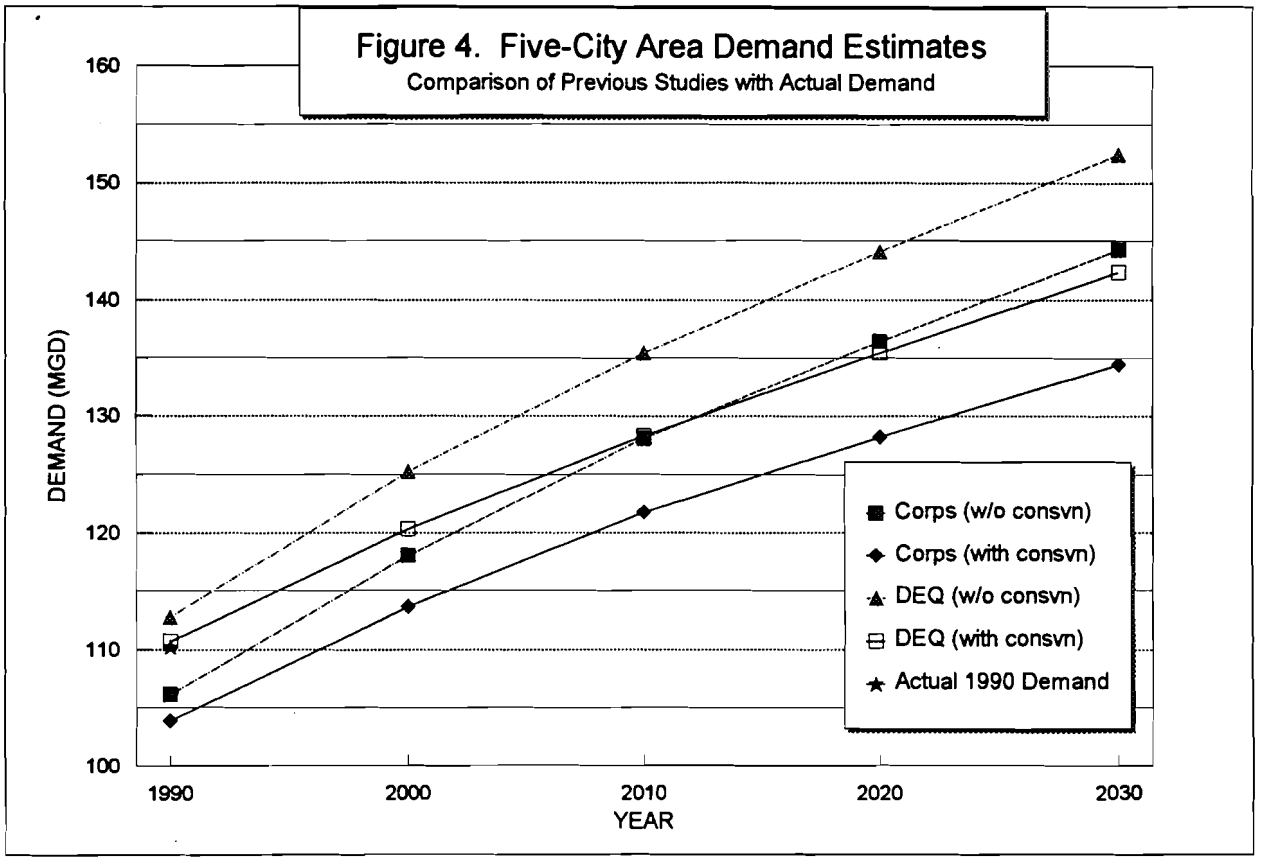
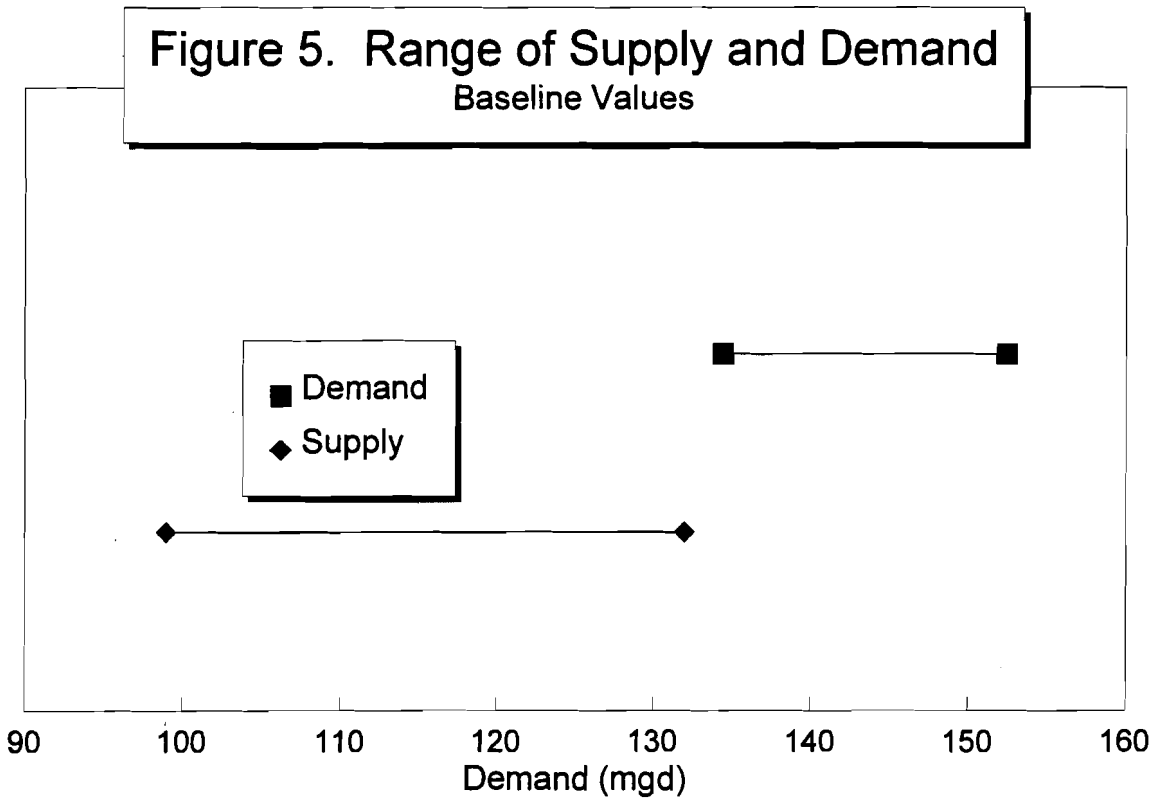


Table 8. Comparison of Previous Five-City Demand Estimates with Actual Demand

		Demand (mgd)				
	Study	1990	2000	2010	2020	2030
5-City Area	Corps (w/o consvn)	106.2	118.0	128.1	136.5	144.3
	Corps (with consvn)	103.9	113.7	121.7	128.2	134.5
	DEQ (w/o consvn)	112.8	125.3	135.5	144.1	152.5
	DEQ (with consvn)	110.7	120.3	128.3	135.4	142.4
	Actual	110.2				

Notes

1. Corps of Engineers, Water Supply Study - Hampton Roads, Virginia, 1984.
2. Virginia Department of Environmental Quality, James Water Supply Plan, 1988.
3. Localities reported 1990 water use in DEQ, Hampton Roads Water Supply Update, 1993.



All supply estimates assume reservoir levels will never drop below 75%. If modelers assume reservoir levels may fall to 50% full during severe drought, supply estimates increase by 20 mgd.

- Low flow fixtures required by building codes in Virginia since 1987 will not result in any water savings.
- Citizens will not be asked to reduce water use during severe drought, either voluntarily or with mandatory restrictions.
- Drought emergency wells will never be used.

If all of these events were to happen, Southeastern Virginia would have a supply deficit approaching 60 mgd in 2030 during the worst drought of record. However, the nature of this supply deficit makes a number of alternative approaches available. These are discussed in Parts II and III.

It is important to note that the figures discussed above are regional supply figures. Virginia Beach currently imposes water use restrictions year round in normal periods. However, adjacent Portsmouth has a sufficient surplus to meet all of Virginia Beach's current shortfall and is willing to provide the water.

PART II. Alternatives Under Development

A. Supply

Several new water supplies are currently being developed in Southeast Virginia.

CHESAPEAKE

Over the past several years the City of Chesapeake has worked closely with the Virginia DEQ to develop a treatment system that will result in a safe yield of 10 mgd from a combination of Northwest River water and local groundwater. According to DEQ Inter-Office Correspondence (10), a future safe yield of 10 mgd from these sources is now under development.

The Malcolm Pirnie Conjunctive Use report (11) stated that the City recently received a draft groundwater withdrawal permit for a 5 mgd brackish groundwater well field to be located near its Northwest River plant. When the Northwest River becomes too salty to provide the full 10 mgd of fresh water, brackish water will be withdrawn and desalted, providing 7 mgd of treated fresh water. Water from the new well field will also be desalted, providing 3 mgd of treated fresh water. Together, these sources will provide a net safe yield of 10 mgd. Although all other sources agree that 10 mgd will be available, (11,34,55) the DEIS only credits 8.5 mgd (9 mgd less 6% water loss). (36)

Chesapeake is in the process of increasing its safe yield by 10 mgd.

SUFFOLK

In 1994 Malcolm Pirnie (11) stated that Suffolk has received a draft groundwater withdrawal permit for an average annual yield of 4 mgd from the Reids Ferry well. This well is currently one of the two 4 mgd emergency wells contracted out to Virginia Beach. The contract expires in 1997 at which time Suffolk plans to increase its raw water source safe yield by 4 mgd. The reliable treated water delivery capacity is stated to be increased by 3.58 mgd when the well is added. Adding this well to Suffolk will reduce Virginia Beach's emergency supply wells from five to four. Suffolk is also adding 2 mgd in emergency supplies. The DEIS notes these additions.

Suffolk is in the process of increasing its safe yield by 3.58 mgd. It is also adding emergency well yield of 2 mgd.

Virginia Beach emergency well capacity will be reduced from 20 mgd to 16 mgd.

PORTSMOUTH

Chesapeake is joining resources with Portsmouth to relocate Portsmouth's raw water intake on Lake Meade. By relocating the intake, 2 mgd safe yield will be added to the Portsmouth system and delivered to Chesapeake. (10, 4, 34) The DEIS does not include this addition. (36)

The Portsmouth reservoir safe yield will be increased by 2 mgd.

Table 9 adds these additional supplies to the yields shown in Table 1.

Table 9

FIVE CITY SAFE YIELD - INCLUDING SOURCES UNDER DEVELOPMENT

SYSTEM	SURFACE WATER SAFE YIELD (MGD)	CONJUNCTIVE USE WELLS (MGD)	EMERGENCY WELLS (MGD)
Chesapeake	[0 + 7] 7.0	[3 + 3] 6.0	9.0
Norfolk	56.4	13.2	8.0
Portsmouth	[18.8 + 2] 20.8	5.4	10.0
Suffolk	0.45	[4.25 + 3.58] 7.83	2.93
Virginia Beach	0.0	0.0	[20 - 4] 16.0
TOTALS	84.65	32.43	45.93

B. Demand Reduction by Use of Required Water Efficient Fixtures

In 1991, state enabling legislation allowed Virginia Beach to adopt a more stringent local code, which required new ultra low-flush toilets. In 1993, BOCA was revised to comply with new ultra low-flow fixture requirements of the Federal Energy Policy Act of 1992 (FEPA). It requires a 1.6 gallon standard for all toilets and flow limitations on showers and faucets. Because toilets, showers and faucets together represent 80 % of residential water use (2), these new standards offer the single most important opportunity for reductions in per capita demand. These new requirements are now mandatory nationwide--no less efficient fixtures may be built after January 1, 1994. (24) These changes are not yet reflected in per capita water use reduction. However, all new construction and renovation must use these fixtures, and the savings will unquestionably be reflected in the coming years.

The importance of requiring water saving fixtures throughout America should not be underestimated. EPA, Congress, and all those involved in the Energy Policy Act of 1992 understood the way in which this legislation would preserve the nation's water resources.

The first step in quantifying the new ultra low-flow fixture savings was to develop savings factors to represent the percent change in per capita demand from pre-conservation to post-conservation conditions. This was accomplished by calculating the percent reduction in water use accomplished by the use of each type of fixture (that is, reducing toilet use from 6.0 gal/flush to 1.6 gal/flush reduces toilet water use by 73.3 %) This figure was then multiplied by the percentage of residential or commercial water use represented by that fixture (that is, toilet use represents 45 % of residential use). These fixture use rates were taken directly from the 1984 Corps study. (2) Savings factors were estimated for two categories: residential and commercial sanitary use. Table 10 shows NC-DWR's method of calculating savings factors.

Baseline figures were presumed to be at pre-1987 BOCA standards, except in Virginia Beach which established water savings measures in 1977. Use of pre-1987 BOCA figures allowed

Table 10. Demand Savings Factors for Ultra Low-flow Plumbing Fixtures

Fixture Type	Consumption Rates 1 Pre-BOCA 87	Post-BOCA 93	Percent Reduction	x Portion of Daily Use 3	= Savings Factor
Virginia Beach					
Domestic					
Toilets (gal)	5.0	1.6	68.0%	45%	0.31
Showers (gpm)	4.0	2.5	37.5%	30%	0.11
Faucets (gpm)	4.0	2.2	45.0%	5%	0.02
Domestic Savings Factor					0.44
Commercial Sanitary 2					
Toilets (gal)	4.0	1.6	60.0%	80%	0.48
Faucets (gpm)	4.0	2.2	45.0%	5%	0.02
Commercial Savings Factor					0.50
Other Cities					
Domestic					
Toilets (gal)	6.0	1.6	73.3%	45%	0.33
Showers (gpm)	6.0	2.5	58.3%	30%	0.18
Faucets (gpm)	6.0	2.2	63.3%	5%	0.03
Domestic Savings Factor					0.54
Commercial Sanitary 2					
Toilets (gal)	5.0	1.6	68.0%	80%	0.54
Faucets (gpm)	6.0	2.2	63.3%	5%	0.03
Commercial Savings Factor					0.58

Notes:

1. Pre-BOCA fixture rates are based on average consumption of fixtures in use prior to 1987. Future fixture consumption rates are based on 1993 BOCA Plumbing code revisions.
2. Commercial category includes all workplaces.
3. Portion of daily fixture use from 1984 Corps study.

more accurate use of published DEQ data for per capita use. Of course, all savings must therefore be deducted from DEQ's pre-1987 BOCA (without conservation) scenario. Demand savings were determined for each jurisdiction by the following formulas:

Residential Savings = (Resid. Per Capita Demand) x (Resid. savings factors)

x (New Resid. Population + Population in Retrofit)

Commercial Savings = (Comm. Per Capita Demand) x (Comm. savings factors)

x (New Employees + Employees in Comm. Retrofit)

Summing residential and commercial savings for each jurisdiction resulted in conservation demand savings. The actual calculations are set out in Tables 11a through 11e. In 2030, ultra-low flow fixtures are expected to save almost 24 mgd from the Five-City Area demand, reducing the DEQ "without conservation" total from 152 mgd to 129 mgd. These savings are summarized in Table 12.

The accuracy of this analysis was confirmed by assuming that the 1987 BOCA (with conservation) scenario was in place. Similar calculations were made, but compared to the lower water use provided by the 1987 standards. Reducing toilet consumption from 3.5 gallons to 1.6 gallons, showers from 3.0 gallons to 2.5 gallons/minute and faucets from 3.0 to 2.25 gallons/minute yielded demand savings of 15.7 mgd for the five city area. See Table 13 for demand factors, Tables 14a-e for city by city calculations of savings, and Table 15 for a Savings Summary. This reduced the DEQ "with conservation" demand from 142 mgd to 127 mgd. This compares closely to the 129 mgd total calculated from the "without conservation" scenario.

The above savings represent an overall demand reduction of 16%, a figure consistent with many studies. Use of state of the art fixtures typically results in demand reductions of approximately 20% (26, 27, 28, 29, 30, 31, 32). Greater reductions are possible than reported when, as in this case, plumbing upgrades are applied to commercial as well as residential buildings.

The Federal Energy Policy Act of 1992 also requires each Federal agency to install in its facilities by January 1, 2005, all water conservation measures with payback periods of less than ten years. In addition, on March 8, 1994, the President issued Executive Order 12902 ("Energy Efficiency and Water Conservation at Federal Facilities"), which requires all federal agencies to accelerate water conservation audits and the implementation of all cost-effective water conservation installations at their facilities. These programs would apply to the military installations in the Five-City Area. Earlier this year, the General Services Administration and the Department of Energy specifically identified Defense Department facilities as having among the highest potential for substantial water conservation. (33)

The military is a large user of water in the Southeast Virginia area. This new requirement can be expected to result in substantial additional reductions in regional water use over the next decade. While military water use reductions are difficult to quantify, their implementation should ensure that the 24 mgd estimated reduction described above is the minimum reduction--larger savings should actually occur.

Table 11-a. Demand Savings with Ultra Low-Flow Plumbing Fixtures

	1990	2000	2010	2020	2030
Virginia Beach					
Residential					
New Construction					
Estimated Service Population 1	370,250	422,700	472,850	509,600	542,500
Accum. Popln. Change		52,450	102,600	139,350	172,250
x SWCB GPCD (gpd) 2		72.6	72.6	72.6	72.6
x Domestic Savings Factor		0.44	0.44	0.44	0.44
= Accum. Savings (mgd)		1.68	3.28	4.46	5.51
Replacement					
Estimated Service Population 1	370,250	422,700	472,850	509,600	542,500
Accum. 1% Ann. Replacement 3		37,025	74,050	111,075	148,100
x SWCB GPCD (gpd) 2		72.6	72.6	72.6	72.6
x Domestic Savings Factor		0.44	0.44	0.44	0.44
= Accum. Savings (mgd)		1.19	2.37	3.56	4.74
Commercial					
New Employment					
Estimated Population 4	383,200	431,150	481,300	518,050	551,000
Estimated Employment 5	184,975	208,121	232,329	250,069	265,974
Accum. New Employment		23,146	47,354	65,094	80,999
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.50	0.50	0.50	0.50
= Accum. Savings (mgd)		0.17	0.36	0.49	0.61
Replacement					
Estimated Employment 4	184,975				
Accum. 1% Ann. Replacement 3		18,498	36,995	55,493	73,990
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.50	0.50	0.50	0.50
= Accum. Savings (mgd)		0.14	0.28	0.42	0.56
Total Accum. Savings - Virginia Beach		3.18	6.29	8.93	11.42

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.
4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 11-b. Demand Savings from Ultra Low-Flow Plumbing Fixtures

	1993	2000	2010	2020	2030
Norfolk					
Residential					
New Construction					
Estimated Service Population 1	283,000	283,800	284,500	285,000	285,400
Accum. Popln. Change		800	1,500	2,000	2,400
x SWCB GPCD (gpd) 2		68.4	68.4	68.4	68.4
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.03	0.06	0.07	0.09
Replacement					
Estimated Service Population 1	283,000	283,800	284,500	285,000	285,400
Accum. 1% Ann. Replacement 3		28,300	56,600	84,900	113,200
x SWCB GPCD (gpd) 2		68.4	68.4	68.4	68.4
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		1.04	2.08	3.12	4.16
Commercial					
New Employment					
Estimated Population 4	283,000	283,800	284,500	285,000	285,400
Estimated Employment 5	256,042	256,766	257,399	257,851	258,213
Accum. New Employment		724	1,357	1,809	2,171
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.01	0.01	0.02	0.02
Replacement					
Estimated Employment 4	256,042				
Accum. 1% Ann. Replacement 3		25,604	51,208	76,813	102,417
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.22	0.44	0.66	0.88
Total Accum. Savings - Norfolk		1.30	2.59	3.87	5.15

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 11-c. Demand Savings from Ultra Low-Flow Plumbing Fixtures

	1990	2000	2010	2020	2030
Portsmouth					
Residential					
New Construction					
Estimated Service Population 1	109,100	112,100	114,600	117,100	119,400
Accum. Popln. Change		3,000	5,500	8,000	10,300
x SWCB GPCD (gpd) 2		55.6	55.6	55.6	55.6
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.09	0.16	0.24	0.31
Replacement					
Estimated Service Population 1	109,100	112,100	114,600	117,100	119,400
Accum. 1% Ann. Replacement 3		10,910	21,820	32,730	43,640
x SWCB GPCD (gpd) 2		55.6	55.6	55.6	55.6
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.33	0.65	0.98	1.30
Commercial					
New Employment					
Estimated Population 4	109,100	112,100	114,600	117,100	119,400
Estimated Employment 5	61,554	63,247	64,657	66,068	67,365
Accum. New Employment		1,693	3,103	4,514	5,811
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.01	0.03	0.04	0.05
Replacement					
Estimated Employment 4	61,554				
Accum. 1% Ann. Replacement 3		6,155	12,311	18,466	24,622
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.05	0.11	0.16	0.21
Total Accum. Savings - Portsmouth		0.48	0.95	1.41	1.87

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.
4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 11-d. Demand Savings from Ultra Low-Flow Plumbing Fixtures

	1993	2000	2010	2020	2030
Chesapeake					
Residential					
New Construction					
Estimated Service Population 1	118,343	141,228	152,725	163,866	173,291
Accum. Popln. Change		22,885	34,382	45,523	54,948
x SWCB GPCD (gpd) 2		75	75	75	75
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.92	1.38	1.83	2.21
Replacement					
Estimated Service Population 1	118,343				
Accum. 1% Ann. Replacement 3		11,834	23,669	35,503	47,337
x SWCB GPCD (gpd) 2		75	75	75	75
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.48	0.95	1.43	1.91
Commercial					
New Employment					
Estimated Population 4	158,850	172,650	186,250	199,350	210,050
Estimated Employment 5	59,615	64,794	69,898	74,814	78,830
Accum. New Employment		5,179	10,283	15,199	19,215
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.04	0.09	0.13	0.17
Replacement					
Estimated Employment 4	59,615				
Accum. 1% Ann. Replacement 3		5,962	11,923	17,885	23,846
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.05	0.10	0.15	0.21
Total Accum. Savings - Chesapeake		1.49	2.53	3.55	4.49

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 11-e. Demand Savings from Ultra Low-Flow Plumbing Fixtures

	1993	2000	2010	2020	2030
Suffolk					
Residential					
New Construction					
Estimated Service Population 1	28,700	32,600	37,100	41,600	44,500
Accum. Popln. Change		3,900	8,400	12,900	15,800
x SWCB GPCD (gpd) 2		55	55	55	55
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.12	0.25	0.38	0.47
Replacement					
Estimated Service Population 1	28,700				
Accum. 1% Ann. Replacement 3		2,870	5,740	8,610	11,480
x SWCB GPCD (gpd) 2		55	55	55	55
x Domestic Savings Factor		0.54	0.54	0.54	0.54
= Accum. Savings (mgd)		0.08	0.17	0.25	0.34
Commercial					
New Employment					
Estimated Population 4	53,000	60,300	67,500	74,250	78,600
Estimated Employment 5	19,862	22,598	25,296	27,826	29,456
Accum. New Employment		2,736	5,434	7,964	9,594
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.02	0.05	0.07	0.08
Replacement					
Estimated Employment 4	19,862				
Accum. 1% Ann. Replacement 3		1,986	3,972	5,959	7,945
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.58	0.58	0.58	0.58
= Accum. Savings (mgd)		0.02	0.03	0.05	0.07
Total Accum. Savings - Suffolk		0.24	0.50	0.76	0.96

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 12. Demand Savings Summary for Ultra Low-Flow Fixtures

	Savings (MGD)				
	1990	2000	2010	2020	2030
Va. Beach		3.18	6.29	8.93	11.42
Norfolk		1.30	2.59	3.87	5.15
Portsmouth		0.48	0.95	1.41	1.87
Chesapeake		1.49	2.53	3.55	4.49
Suffolk		0.24	0.50	0.76	0.96
5-City Area	0.00	6.69	12.85	18.51	23.89

Table 13. Demand Savings Factors - Reducing from BOCA 87 to BOCA 1993

Fixture Type	Consumption Rates 1 BOCA 87	Post-BOCA 93	Percent Reduction	x Portion of Daily Use 3	= Savings Factor
Virginia Beach					
Domestic					
Toilets (gal)	3.5	1.6	54.3%	45%	0.24
Showers (gpm)	3.0	2.5	16.7%	30%	0.05
Faucets (gpm)	3.0	2.2	26.7%	5%	0.01
Domestic Savings Factor					0.31
Commercial Sanitary 2					
Toilets (gal)	3.5	1.6	54.3%	80%	0.43
Faucets (gpm)	3.0	2.2	26.7%	5%	0.01
Commercial Savings Factor					0.45
Other Cities					
Domestic					
Toilets (gal)	3.5	1.6	54.3%	45%	0.24
Showers (gpm)	3.0	2.5	16.7%	30%	0.05
Faucets (gpm)	3.0	2.2	26.7%	5%	0.01
Domestic Savings Factor					0.31
Commercial Sanitary 2					
Toilets (gal)	3.5	1.6	54.3%	80%	0.43
Faucets (gpm)	3.0	2.2	26.7%	5%	0.01
Commercial Savings Factor					0.45

Notes:

1. Fixture consumption rates are based on 1987 and 1993 BOCA Plumbing code revisions.
2. Commercial category includes all workplaces.
3. Portion of daily fixture use from 1984 Corps study.

Table 14-a. Demand Savings - Reducing from BOCA 87 to BOCA 93

	1990	2000	2010	2020	2030
Virginia Beach					
Residential					
New Construction					
Estimated Service Population 1	370,250	422,700	472,850	509,600	542,500
Accum. Popln. Change		52,450	102,600	139,350	172,250
x SWCB GPCD (gpd) 2		72.6	72.6	72.6	72.6
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		1.17	2.29	3.11	3.85
Replacement					
Estimated Service Population 1	370,250	422,700	472,850	509,600	542,500
Accum. 1% Ann. Replacement 3		37,025	74,050	111,075	148,100
x SWCB GPCD (gpd) 2		72.6	72.6	72.6	72.6
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.83	1.65	2.48	3.31
Commercial					
New Employment					
Estimated Population 4	383,200	431,150	481,300	518,050	551,000
Estimated Employment 5	184,975	208,121	232,329	250,069	265,974
Accum. New Employment		23,146	47,354	65,094	80,999
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.16	0.32	0.44	0.54
Replacement					
Estimated Employment 4	184,975				
Accum. 1% Ann. Replacement 3		18,498	36,995	55,493	73,990
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.12	0.25	0.37	0.50
Total Accum. Savings - Virginia Beach		2.28	4.51	6.40	8.20

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.
4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 14-b. Demand Savings - Reducing from BOCA 87 to BOCA 93

	1993	2000	2010	2020	2030
Norfolk					
Residential					
New Construction					
Estimated Service Population 1	283,000	283,800	284,500	285,000	285,400
Accum. Popln. Change		800	1,500	2,000	2,400
x SWCB GPCD (gpd) 2		68.4	68.4	68.4	68.4
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.02	0.03	0.04	0.05
Replacement					
Estimated Service Population 1	283,000	283,800	284,500	285,000	285,400
Accum. 1% Ann. Replacement 3		28,300	56,600	84,900	113,200
x SWCB GPCD (gpd) 2		68.4	68.4	68.4	68.4
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.60	1.19	1.79	2.38
Commercial					
New Employment					
Estimated Population 4	283,000	283,800	284,500	285,000	285,400
Estimated Employment 5	256,042	256,766	257,399	257,851	258,213
Accum. New Employment		724	1,357	1,809	2,171
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.00	0.01	0.01	0.01
Replacement					
Estimated Employment 4	256,042				
Accum. 1% Ann. Replacement 3		25,604	51,208	76,813	102,417
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.17	0.34	0.52	0.69
Total Accum. Savings - Norfolk		0.79	1.58	2.36	3.13

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 14-c. Demand Savings - Reducing from BOCA 87 to BOCA 93

	1990	2000	2010	2020	2030
Portsmouth					
Residential					
New Construction					
Estimated Service Population 1	109,100	112,100	114,600	117,100	119,400
Accum. Popln. Change		3,000	5,500	8,000	10,300
x SWCB GPCD (gpd) 2		55.6	55.6	55.6	55.6
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.05	0.09	0.14	0.18
Replacement					
Estimated Service Population 1	109,100	112,100	114,600	117,100	119,400
Accum. 1% Ann. Replacement 3		10,910	21,820	32,730	43,640
x SWCB GPCD (gpd) 2		55.6	55.6	55.6	55.6
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.19	0.37	0.56	0.75
Commercial					
New Employment					
Estimated Population 4	109,100	112,100	114,600	117,100	119,400
Estimated Employment 5	61,554	63,247	64,657	66,068	67,365
Accum. New Employment		1,693	3,103	4,514	5,811
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.01	0.02	0.03	0.04
Replacement					
Estimated Employment 4	61,554				
Accum. 1% Ann. Replacement 3		6,155	12,311	18,466	24,622
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.04	0.08	0.12	0.17
Total Accum. Savings - Portsmouth		0.29	0.57	0.85	1.13

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 14-d. Demand Savings - Reducing from BOCA 87 to BOCA 93

	1993	2000	2010	2020	2030
Chesapeake					
Residential					
New Construction					
Estimated Service Population 1	118,343	141,228	152,725	163,866	173,291
Accum. Popln. Change		22,885	34,382	45,523	54,948
x SWCB GPCD (gpd) 2		75	75	75	75
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.53	0.79	1.05	1.27
Replacement					
Estimated Service Population 1	118,343				
Accum. 1% Ann. Replacement 3		11,834	23,669	35,503	47,337
x SWCB GPCD (gpd) 2		75	75	75	75
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.27	0.55	0.82	1.09
Commercial					
New Employment					
Estimated Population 4	158,850	172,650	186,250	199,350	210,050
Estimated Employment 5	59,615	64,794	69,898	74,814	78,830
Accum. New Employment		5,179	10,283	15,199	19,215
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.03	0.07	0.10	0.13
Replacement					
Estimated Employment 4	59,615				
Accum. 1% Ann. Replacement 3		5,962	11,923	17,885	23,846
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.04	0.08	0.12	0.16
Total Accum. Savings - Chesapeake		0.88	1.49	2.09	2.65

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 14-e. Demand Savings - Reducing from BOCA 87 to BOCA 93

	1993	2000	2010	2020	2030
Suffolk					
Residential					
New Construction					
Estimated Service Population 1	28,700	32,600	37,100	41,600	44,500
Accum. Popln. Change		3,900	8,400	12,900	15,800
x SWCB GPCD (gpd) 2		55	55	55	55
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.07	0.14	0.22	0.27
Replacement					
Estimated Service Population 1	28,700				
Accum. 1% Ann. Replacement 3		2,870	5,740	8,610	11,480
x SWCB GPCD (gpd) 2		55	55	55	55
x Domestic Savings Factor		0.31	0.31	0.31	0.31
= Accum. Savings (mgd)		0.05	0.10	0.15	0.19
Commercial					
New Employment					
Estimated Population 4	53,000	60,300	67,500	74,250	78,600
Estimated Employment 5	19,862	22,598	25,296	27,826	29,456
Accum. New Employment		2,736	5,434	7,964	9,594
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.02	0.04	0.05	0.06
Replacement					
Estimated Employment 4	19,862				
Accum. 1% Ann. Replacement 3		1,986	3,972	5,959	7,945
x SWCB GPED (gpd) 2		15	15	15	15
x Commercial Savings Factor		0.45	0.45	0.45	0.45
= Accum. Savings (mgd)		0.01	0.03	0.04	0.05
Total Accum. Savings - Suffolk		0.15	0.30	0.46	0.58

Notes:

1 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

2 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

3 Residential and commercial fixture replacement rate assumed 1 percent annually, or 10 percent every ten years.

4 Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.

5 Estimated 1990 employment from Hampton Roads Planning District Commission, Hampton Roads Data Book, 1992. Other years estimated by applying same employment/ population ratio.

Table 15. Demand Savings Summary - Reducing from BOCA 87 to BOCA 93

	Savings (MGD)			
	2000	2010	2020	2030
Va. Beach	2.28	4.51	6.40	8.20
Norfolk	0.79	1.58	2.36	3.13
Portsmouth	0.29	0.57	0.85	1.13
Chesapeake	0.88	1.49	2.09	2.65
Suffolk	0.15	0.30	0.46	0.58
5-City Area	4.38	8.45	12.16	15.68

The DEIS has suggested that water savings from FEPA fixtures are "speculative," and therefore FERC staff conducted no specific analysis of savings. Instead, it simply assumed that per capita demand will hold steady for the region, when it might otherwise have increased (36). Specific calculations simlar to those made in this report have been made around the nation (59.60), including earlier estimates by the Corps in Southeast Virginia (2). Other studies have confirmed large actual reductions in water use. (26,27,29) We believe savings of this magnitude are fully justified by engineering principles, are well proven by actual experience throughout the country, and will occur in Southeast Virginia as well.

C. Projected Need Including Alternatives Under Development (Supply Minus Demand)

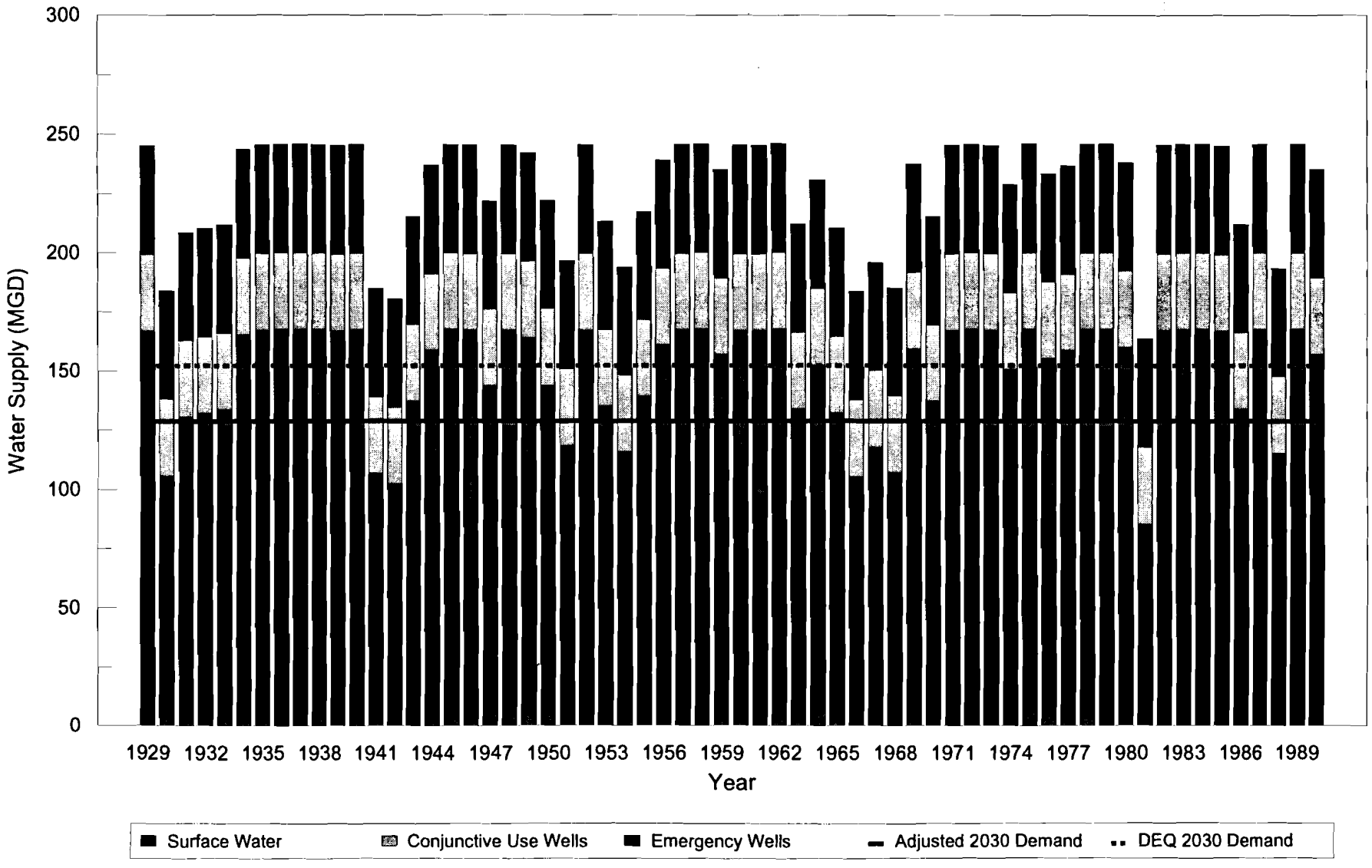
As noted above, 16 mgd in supply increases and 24 mgd in demand reductions are already under development. The supply components will be completed between 1995 and 1997, and the demand reductions will gradually take effect and will increase until the end of the planning period. Compared to earlier projections, the minimum available supply in the worst drought of record will increase from 99 mgd to 115 mgd. The maximum demand will be reduced from 152 mgd to 128 mgd. As noted in Part I C, even these numbers assume that reservoirs will never fall below 75 % full, that new pumps will not work as planned, that wells will not produce the yield to which they have been tested, that maximum population growth will be attained, that citizens will never be asked to reduce water use during severe drought, and that emergency wells will never be used. Notwithstanding all those assumptions, the supply available during the worst drought in 150 years will be 115 mgd and the demand for the five-city area will be 129 mgd. In other words, under the

worst of all conditions, with no use of even voluntary water use reductions during drought or emergency wells designed for use in drought, the water deficit will be between 13 and 14 mgd. If more realistic assumptions are used, there will be no deficit at all.

Estimated supplies from surface water, conjunctive use wells, and emergency wells, including supplies now under development, are shown as stacked bars on Figure 6 for each year from 1929 through 1990. Also shown on the figure is the projected 2030 demand of 128.6 mgd, based upon the use of water savings fixtures now required by law. If the top of the supply bar is above the demand line, no shortage is predicted. Examination of Figure 6 reveals that in 52 of the 62 years, or 84 % of the time, existing surface water supplies are estimated to be adequate to meet the 128.6 mgd demand. In 9 out of 62 years, use of the conjunctive use wells to some degree would be required. In only 1 out of 62 years, use of the emergency wells to some degree likely would also be required. In none of the years is there less regional supply than demand.

Figure 6. Five-City Water Supply Components - Existing (Lowest Estimates) & Under Development

Adjusted 2030 Projected Demand - 128.6 MGD (w/o Conservation during Drought)



Part III. Alternatives

As noted in Part I, earlier studies concluded that the region needs 60 mgd only in the worst drought of record, and only if assumptions are used which minimize supply and maximize demand. There has never been a study which found that the region needs additional water except during drought conditions. All studies agree that the region needs no additional water during normal periods. As noted in Part II, 16 mgd of additional regional supplies are already under development, and at least 24 mgd in regional demand reductions will be realized by the year 2030 as a result of water savings devices. The amount of additional water that may be needed beyond the alternatives already under development, and the frequency in which it will be needed, are critical questions for determining the availability and cost of alternatives. Because alternatives are not needed at all times, but only periodically during dry conditions, many additional choices are available. In addition, while water use restrictions are not appropriate for year-round planning, they are an important part of drought planning. DEQ has clearly set out mechanisms for meeting needs in dry conditions:

> "There are ways, however, of increasing available supply during low flow periods. One is to provide more surface storage. Another way is by temporarily drawing down ground water storage. Still another way is by reducing demands during period of low flow."

(3 at xxxv) For purpose of analyzing which additional supplies are appropriate, we have assumed the 35 mgd deficit in the worst drought of record suggested in the FERC DEIS (36). While this deficit is overstated by more than 20 mgd, it nevertheless provides a baseline for analysis. Notwithstanding the DEIS finding of a 35 mgd deficit, FERC suggests that 60 mgd should be provided, thereby creating a 25 mgd surplus in 2030. Such a surplus is not consistent with standard water supply planning, and in any event would not be a consideration except in the worst drought of record. It is nevertheless included in our costing calculations.

As the following analysis demonstrates, substantial additional alternatives are available in three categories - supply and demand alternatives available during drought, alternatives to reduce demand in both normal and dry conditions, and alternatives to increase supply in both normal and dry conditions. We also evaluate the cost of various alternatives in light of the fact that no additional water is needed under normal circumstances, and the maximum drought deficit will not be reached until 2030. As might be expected, a highly capital intensive project like the Lake Gaston pipeline has a far higher unit cost when the water is needed infrequently than when water is needed at all times. When no water is needed much of the time, fixed capital costs must be recovered from a far smaller volume of water.

A fair evaluation of alternatives must also consider a no action alternative. The no action alternative is especially important here because during drought conditions, the region already has sufficient reservoir and emergency supplies to carry it throughout the planning period without taking any further action. The region also has the ability to reduce demand substantially if necessary under drought conditions.

A. Supply and Demand Alternatives Available for Use During Drought Periods

1. Voluntary and Mandatory Conservation

A program of demand management and water conservation during drought is a key component of drought contingency plans. It is both industry standard and common sense to reduce water use during drought conditions. The Corps has noted that even if new water sources are available, many believe that

> "curtailing water demand is a partial substitute for aggressively pursuing other water supply alternatives which are likely to require a significant expenditure of money for what is hoped will be a temporary water shortage. The inconvenience of restricted water use for a short period is thought to be more palatable to the public than increased water rates to cover the costs of additional water supplies that are only needed once a decade based on drought frequencies of the past." (1 at 97)

Typically a tiered program of voluntary and mandatory conservation measures is recommended with voluntary restrictions if the supply shortfall is not large, and increasingly stringent water use restrictions if the shortfall becomes large. (US Water Resources Council, October 1980, State Water Conservation Planning Guide, pg. 4-18).

As reported by the Corps of Engineers (1 at 52-62), each of the communities in the Five City Area has a program in place for demand reduction during drought. While the specifics of each program vary, each consists of a phased program of water use measures. The first levels are typically instituted during moderate supply reductions and consist of a call for voluntary curtailment of water use. These levels provide a reduction in water use of from 10% (Norfolk) to 15% (Portsmouth). The next levels are typically instituted during periods of greater shortage and require curtailment of uses for such purposes as landscape watering, car and street washing, and other non-essential uses. These levels provide a reduction in water use of 15% (Norfolk). Subsequent levels are instituted when water supplies are critically limited, and provide savings of up to 25% by use of allocations, punitive charges for violations, and other measures. These ordinances generally empower the mayor, city manager, or a designated emergency manager to enforce the conservation program and make decisions regarding specific exemptions or enforcement procedures.

To illustrate the tiered structure of the conservation program, the algorithmic representation of the conservation program used in the STELLA II model prepared as part of the Corps' Drought Preparedness Study (1) for the Norfolk and Portsmouth reservoirs is summarized below. The representation of the conservation program in the model is an interpretation of the program and serves as an approximation of its probable implementation. In the model, demands are reduced as a function of total useable reservoir capacity. As the level of supply in the reservoir system drops to a specified amount of the total capacity, a specific reduced demand is enforced. If the reservoir storage drops further, increasingly larger demand reductions are imposed. The Corps is assuming a simple, but very realistic approach to triggering varying degrees of demand

reductions commonly employed by water supply agencies. For the local reservoir systems, the Corps' STELLA II model uses the following conservation policy:

NORFOLK

Reservoir Capacity as Percent of Total	Demand Reduction as Percent	Water Conservation Program Level
60	5	Tier 1-Voluntary
55	10	Tier 2-Voluntary
50	15	Tier 3-Mandatory
45	25	Tier 4-Mandatory

PORTSMOUTH

Reservoir Capacity as Percent of Total	Demand Reduction as Percent	Water Conservation Program Level
80	10	Tier 1-Voluntary
70	15	Tier 2-Voluntary
60	25	Tier 3-Mandatory

Using the Norfolk Reservoir system as an example that can be applied region wide, these assumptions mean that when the Norfolk reservoir storage drops to 60 percent of total capacity, a regional application of the first tier of the conservation program would result in a voluntary reduction in demand of 5 percent. When the storage level drops to 55 percent, an additional 5 percent demand reduction would be achieved by asking citizens to voluntarily save water. At a storage level of 50 percent, the third tier of the conservation program would require citizens to curtail outdoor uses, and would result in a reduction in demand of 15 percent. At a storage level of 45 percent, the final tier of the conservation program would require allocations and penalties, and would result in a reduction in demand of 25 percent.

Depending on the level of demand prior to the beginning of conservation, the amount of water represented by a specific reduction level will vary. The following table shows the savings at specific reduction levels for the 148 mgd demand level forecast by FERC and the more realistic 129 mgd level discussed in Parts I and II of this report.

Percent Reduction in Demand	Demand Level of 148 mgd (mgd)	Demand Level of 129 mgd (mgd)
5	7.4	6.4
10	14.8	12.9
15	22.2	19.3
20	29.6	25.8
25	37	32.2

The amount of water saved by demand reduction during drought can be quite significant, as shown in the table above. Voluntary conservation, generally considered to produce 10% savings, would reduce demand from FERC suggested levels by 15 mgd. Restricting outdoor uses would produce an additional 5% savings, for a total savings of 22 mgd. These programs are already in place. With good management, they will be implemented very infrequently, perhaps three times in 63 years, if the driest period of record is repeated. See Figure 7. There are no direct water supply costs associated with these savings.

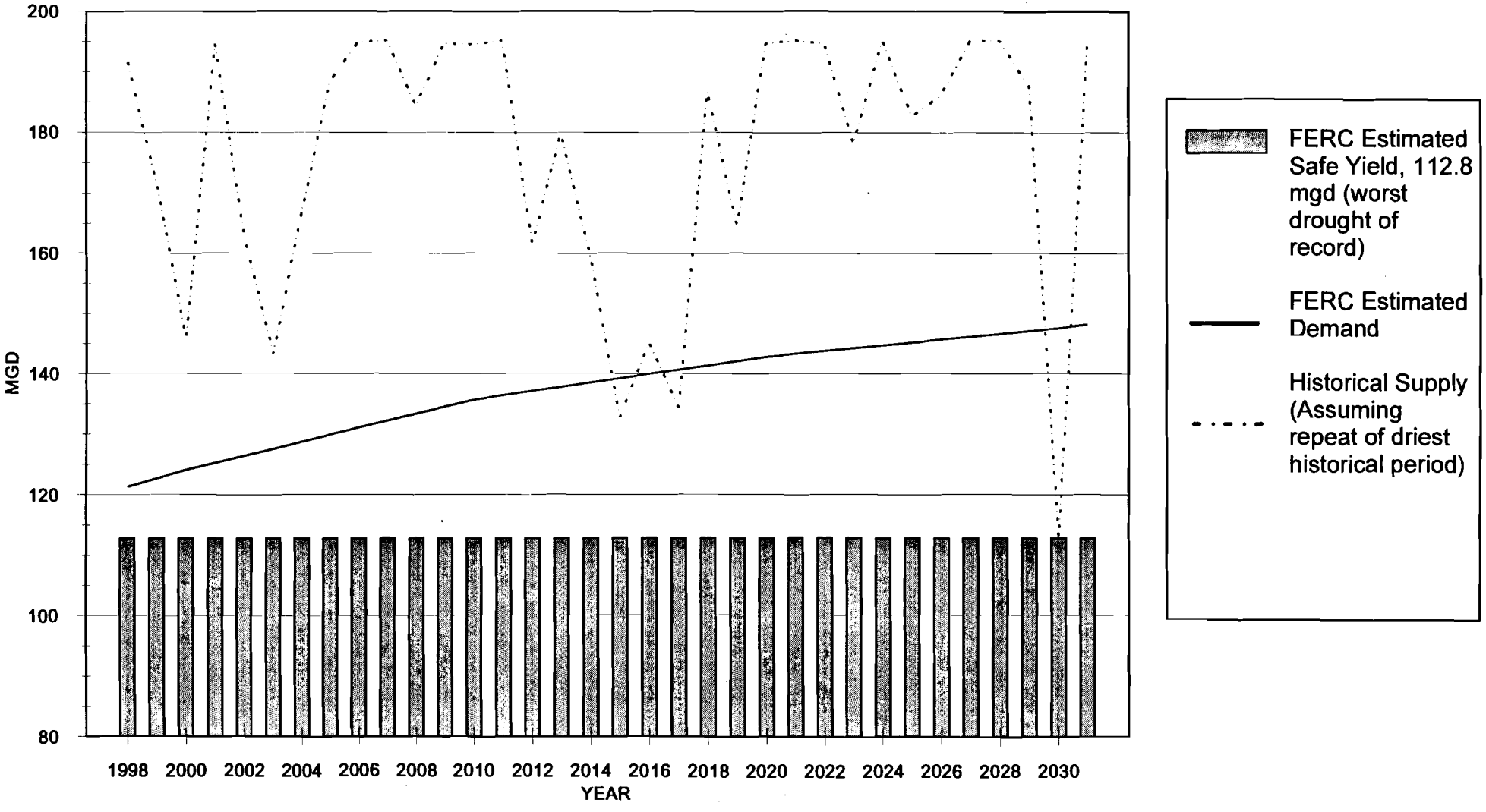
2. Modified Reservoir Operating Procedures

Reservoir storage is available in the water supply systems of Norfolk and Portsmouth. Reservoir operators naturally prefer to keep storage levels high. The safe yields of the Norfolk reservoir system were calculated on the presumption that storage levels would be kept at or above 75 percent of total storage capacity. This does not mean that the reservoirs cannot be drawn lower. Reservoir levels were about 50 percent during the 1980-81 drought (3 at II-422), and again in the winter of 1994. Indeed, reservoir records indicate that reservoir levels average 74-75% full during the low level months of October and November. (61) It is not surprising that reservoir levels fluctuate. That is, after all, the purpose of a reservoir system.

Safe yield estimates have been calculated for these reservoirs based on maintaining the arbitrary 75 percent storage levels, even during severe drought. Safe yield estimates based on maintaining a lower storage criterion (or stated another way, allowing the use of more of the storage capacity the reservoirs were built to provide) would produce higher estimates of safe yield. Moreau investigated this concept and determined frequency distributions of minimum annual storage levels in Norfolk's reservoirs at different levels of constant supply from Lake Gaston. Interpretation of Moreau's work (7, Figure A1, following page 16) indicates that on the order of 20 mgd additional safe yield would be available if a storage level of 50 percent of total capacity rather than 75 percent were used. (2 at 145) This finding was subsequently reported and used by the DEQ (3 at 423).

The only reasonable justification for assuming that reservoirs would always be maintained at this level was to avoid conservation during the worst drought of record. In 1984, the Corps theorized

Figure 7
FERC Estimates and Existing Supply



(incorrectly) that if reservoirs were drawn below 75 percent, mandatory conservation would begin. To avoid this, the Corps sought an additional 19 mgd in supplies, to be sure that the 75 percent level was never threatened. While it is reasonable to design a system to avoid severe water rationing, it is not reasonable to require that citizens never be asked to stop washing cars, even in the worst drought in 150 years.

Modification of reservoir operations during droughts is a common practice. Case studies of reservoir operations during droughts (K.F. Kelly, 1986, Reservoir Operation During Drought: Case Studies, US Army Corps of Engineers, Research Document No. 25) identified four basic methods for increasing water supply in the midst of a drought. These methods are 1) Water Supply Loans, 2) Consolidation of Storage, 3) Minimum Pool Release, and 4) Project Purpose Change. Minimum pool releases allow water to be released for use when it would otherwise be reserved for maintaining minimum pool levels. Minimum pool releases are the method for increasing safe yield described in the preceding paragraph.

The work by Kelly was expanded by the Corps under a broader examination of reservoir operations during droughts (US Army Corps of Engineers, August 1990, Modifying Reservoir Operations to Improve Capabilities for Meeting Water Supply Needs During Drought, Research Document 31). This report concludes, "... the basic general authority and policy framework is well established for the USACE to modify operations of existing reservoirs to increase water supply capabilities. Past studies and experiences in implementing modifications indicate a broad range of potential approaches to increasing water supply capabilities of existing reservoirs."

The Corps of Engineers operates over 500 reservoirs throughout the United States. The Corps has in the past modified the operations of its reservoirs to increase water supply during drought, compiled case studies of other reservoir owners who have modified operations to increase water supply during droughts for comparison to their own policies, and has stated a policy of modifying reservoir operations to increase water supply during drought. Ample precedent is thereby established for modifying target storage levels in reservoirs as a matter of policy for meeting the specific water supply needs which arise under the extreme conditions of drought. As noted above, this is the reason reservoirs are built. Otherwise, 75 percent of available water would never be used.

An additional supply of approximately 20 mgd safe yield would be available from the Norfolk reservoir system if the reservoir operating criteria were changed to allow drawdown of reservoirs from 75 percent of total usable capacity to 50 percent of total usable capacity during severe drought. No additional costs are associated with this supply. Costs would be the same as existing costs for current supplies from the reservoir system.

3. **Additional Pumpage from Conjunctive Use Wells**

The 1980-81 drought, which began in the spring of 1980 and continued for 18 months, is considered the most severe drought in southeastern Virginia in this century (1 at 58). During this period Norfolk used its conjunctive use wells approximately 75 percent of the time (3 at II-423,424). The 1980-81 experience indicates that significant production from wells is possible over prolonged periods, and that even during periods of severe drought, production from wells

may not be required continuously. The Corps and DEQ have based their assignment of safe yield on historic pumpage, not actual hydrologic capacity. The historic use of wells 75 percent of the time during the 1980-81 drought confirms that these wells can be used at least to 75 percent of their capacity, but there is no reason to believe that these wells cannot be used at full capacity. There is no evidence that all these wells could not supply their entire rated capacity. In 1980-81 additional pumping was possible, but was not required. Increased pumpage of conjunctive use wells during drought can increase the safe yield of the Five-City region. The cost would be the same as existing conjunctive use well water.

4. **Emergency Wells**

Emergency well capacity represents a significant source of supply which can be used during a drought period. This is precisely the purpose for which these wells were built. As stated by DEQ in a letter from Peter W. Schmidt to the Secretary of FERC dated August 18, 1994 (62 at 3). "Ground water is a viable source of emergency water during drought conditions when mandatory water use restrictions are in place."

Emergency well capacity is currently maintained by Chesapeake, Norfolk, Portsmouth, Suffolk, and Virginia Beach as shown in Table 1 of this document. The total capacity represented by these wells is now approximately 50 mgd. (1 at 87) As part of the extension of its water supply system, Suffolk plans to convert the 4 mgd Reids Ferry well from emergency capacity (contracted to Virginia Beach) to a conjunctive use well, and to increase its own emergency well capacity by 2 mgd. The current contract with Virginia Beach expires in 1997, at which time the emergency well capacity available in the Five City Area will be reduced by a net of 2 mgd, to approximately 48 mgd. See 1 at 71-79; 3 at II-403-411, III-13, 18; 4 at II-1,5,16.

There has been some suggestion that water from some of the drought emergency wells may require additional treatment. (1 at 78-89) However, improvements to Norfolk's treatment facilities beginning in 1995 should eliminate any such problems. Even if additional treatment were necessary, Suffolk has shown that additional treatment is available at very low cost. All or part of the existing emergency well supply capacity should be considered as a supply alternative during drought periods.

In addition, the Corps has noted that additional emergency well capacity could be added if needed.

> "Preliminary studies by the U.S. Geological Survey suggest that some of the aquifers which underlie southeast Virginia could sustain significant additional pumpage for a short period of time -- 6 to 12 months -- and be naturally recharged over several years once normal rain patterns resumed."

(1 at 93) Emergency well supplies alone could offset all of the projected supply shortfalls in drought. The cost of this alternative will vary from less than the cost of existing conjunctive use well supplies to the cost required to treat some supplies to DEQ standards.

B. Alternatives for Reducing Demand in both Normal and Dry Conditions

The lowest cost means of providing additional water resources is by reducing demand through conservation. For example, the Metropolitan Water District of Southern California, which supplies 1.8 billion gallons of water per day to nearly 16 million people in southern California, budgets approximately $20 million per year for its conservation program. It reports that:

> "conservation--one of the most efficient uses of available resources--is one of the tools available to maintain reliable water supplies for an increasing population. Up to 40 percent of the supply shortfall projected for southern California in the year 2010 can be offset by conservation programs." (63 at 44)

Activities that have been proven effective include plumbing retrofit, leak detection, conservation rate structures, city planning, and education. In the discussion below, we examine the potential for existing and new conservation programs to reduce demand in the Five City area. Plumbing retrofit, in particular, can result in rapid demand reduction. Water use from affected fixtures is 80 percent of domestic consumption. The other measures should keep general usage and waste from increasing, so that per capita use can continue to decline.

1. Plumbing Retrofit

Household retrofit programs should involve flow restricting devises such as aerators, low flow shower heads, toilet dams or bags, and replacement of existing toilets with current ULF (ultra low flush) toilets using 1.6 gallons per flush (gpf). As a result of the Federal Energy Policy Act of 1992, all toilets sold are new ULF models. Currently, Virginia Beach distributes water conservation kits and has a rebate program for retrofitting older toilets with ULF models. No mention of similar programs for the other four cities has been found. Although Virginia Beach has reduced its per capita demand by this program and by its 1977 adoption of intermediate plumbing standards, the potential exists for substantial additional savings in the replacement of older 3.5 to 6.0 gallon per flush toilets and the low-flow fixtures. Even larger potential for savings exists in the other four cities where plumbing codes were not changed prior to 1990 and no retrofit programs have been used.

Water utilities around the country have had great success reducing residential water demands with retrofit programs. San Simeon, California is reportedly the first community in the nation to require all toilets be replaced with ULF models. This resulted in a 39 percent reduction in total water demand with no negative impacts on the wastewater system (26). In Santa Monica, California, over 30,000 toilet and low flow showerheads have been retrofitted (representing over 39 percent of residential households), resulting in a permanent reduction of 1.9 mgd, or a 15 percent reduction in the average system demand and a 19 percent reduction in the wastewater flows (29). Approximately 70 percent of the plumbing in Wrightsville Beach, North Carolina has been retrofitted since 1983. The City has determined that plumbing retrofit resulted in an average reduction in household water use of 35 percent (48). Tampa, Florida saw a reduction of 6.1 gallons per day per capita (gpdc) due to toilet retrofits, and an overall 15.6 percent reduction of indoor use due to a combination toilet/low flow showerhead retrofit test program (27,28). Reductions in monthly household water consumption of 18.8 percent due to the

installation of ULF toilets have been seen in El Paso, Texas (30). Retrofit programs are not limited to single family residences. Toilet retrofits are being studied by Army bases (51), apartments (38,28), and public schools (28) as well. It is clear that retrofit programs are an expanding concept with great potential to reduce water use.

Retrofit programs vary in their approach. Ideally, programs should target the oldest and most consumptive toilets for replacement first, but reasonable payback occurs regardless of the age of the original unit. Some programs offer rebates for only one toilet per household; other programs have no limit. A typical retrofit program in Southeastern Virginia would replace 3.5-6.0 gallons per flush toilets with 1.6 gallon units, and install low flow shower heads and faucet restrictors. In Table 16, savings factors for each locality were estimated based on prevailing plumbing codes and preexisting conservation programs. These calculations underestimate savings because many of the older fixtures to be replaced have developed leaks and use substantially more water than their ratings suggest.

For this study, we assumed that a program would retrofit 1.5 bathrooms per household at an average cost of $150 per retrofit (retrofits in Southern California have ranged from $100 to $138 per retrofit (Metropolitan Water District of Southern California)). This cost would include $110 for purchase of the fixtures and $40 for installation. The target population was the 1990 service population - the population preceding the 1.6 gallon flush requirement. Water savings for participation rates of 10, 20, 40, and 60 percent were calculated. In Part II, we assumed that one percent of older plumbing fixtures would be replaced annually thorough normal market forces. If these savings are not factored into the computation of base per capita demand (they were not factored into DEIS computations), then even greater savings in aggressive retrofit are available. Savings for the five-city area range from a low of 3.11 mgd with 10 percent participation up to 18.67 mgd with 60 percent participation. 10 mgd would be saved if 32% participation were achieved. Program payback periods range from 1.3 to 2.6 years depending on local water and sewer rates. If the utility provides a 50 percent rebate, customers would actually experience paybacks of 0.7 to 1.3 years on their share of the cost. Tables 17 a-e show water savings calculations and payback periods. Table 18 sums the water savings for the five-city area.

Because payback periods are so short, retrofit is a money saving enterprise for both citizens and water utilities. Therefore, use of innovative marketing can result in extremely high participation rates. For example, cities can adopt an approach in which all initial costs are advanced by the city. The city's costs (including any interest expenses) are repaid by keeping the participant's monthly water bill constant (rather than the decline that would otherwise occur) until the participant's share is paid off. The participant therefore incurs no out of pocket expenses and simply continues to pay a normal water bill. Once the payback period is completed, the participant would realize substantial dollar savings. Some municipalities have contracted with private or public-private organizations to sell this program door-to-door, in the process generating profit to the contractor, savings to the city and the citizen, and providing jobs and economic growth to the community.

Plumbing retrofit programs have proven successful throughout the country in reducing overall demand. If implemented in the five-city area, demand savings would range from 3.1 MGD with

Table 16. Demand Savings Factors for Ultra Low-flow Plumbing Retrofit

Fixture Type	Average Fixture Rate Pre-retrofit	Post-Retrofit	Percent Reduction	x Portion of Daily Use 2	= Savings Factor
Virginia Beach					
Domestic					
Toilets (gal)	5.0	1.6	68.0%	45%	0.31
Showers (gpm)	4.0	2.5	37.5%	30%	0.11
Faucets (gpm)	4.0	2.2	45.0%	5%	0.02
Domestic Savings Factor					0.44
Other Cities					
Domestic					
Toilets (gal)	6.0	1.6	73.3%	45%	0.33
Showers (gpm)	6.0	2.5	58.3%	30%	0.18
Faucets (gpm)	6.0	2.2	63.3%	5%	0.03
Domestic Savings Factor					0.54

Notes:

1. Pre-retrofit fixture rates are based on estimated average consumption of fixtures in use prior to 1987. Post-retrofit fixture rates are based on 1993 BOCA Plumbing code revisions.
2. Portion of daily fixture use from Corps of Engineers, Water Supply - Hampton Roads, Virginia, 1984.

Table 17-a. Demand Savings with Ultra Low-Flow Plumbing Retrofit

Virginia Beach

	Percent of Households Retrofitted 2			
1990 Service Pop. = 370,250 1	10%	20%	40%	60%
Water Savings				
Retrofit Population	37,025	74,050	148,100	222,150
x GPCD (gpd) 1	72.6	72.6	72.6	72.6
x Domestic Savings Factor	0.44	0.44	0.44	0.44
= Accum. Savings (mgd)	1.19	2.37	4.74	7.11
Overall cost				
Persons/household 3	2.82	2.82	2.82	2.82
Households retrofitted	13,129	26,259	52,518	78,777
x Toilets/household	1.5	1.5	1.5	1.5
= No. retrofits (bathroom)	19,694	39,388	78,777	118,165
Cost at $160 per retrofit	2,954,122	5,908,245	11,816,489	17,724,734
Payback 4				
Simple Payback period (years)	1.33	1.33	1.33	1.33

Notes:

1. Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2. Percent households retrofitted is based on 1990 service population (population existing prior to new BOCA plumbing requirements)
3. Hampton Roads Planning District Commission, Hampton Roads 2015 Economic Forecast, Vol II, August 1994.
4. Based on combined water-sewer charge of $5.12 per thousand gallons

Table 17-b. Demand Savings with Ultra Low-Flow Plumbing Retrofit

Norfolk

	Percent of Households Retrofitted 2			
1990 Service Pop. = 283,000 1	10%	20%	40%	60%
Water Savings				
Retrofit Population	28,300	56,600	113,200	169,800
x GPCD (gpd) 1	68.4	68.4	68.4	68.4
x Domestic Savings Factor	0.54	0.54	0.54	0.54
= Accum. Savings (mgd)	1.04	2.08	4.16	6.23
Overall cost				
Persons/household 3	2.55	2.55	2.55	2.55
Households retrofitted	11,098	22,196	44,392	66,588
x Toilets/household	1.5	1.5	1.5	1.5
= No. retrofits (bathroom)	16,647	33,294	66,588	99,882
Cost at $160 per retrofit	2,497,059	4,994,118	9,988,235	14,982,353
Payback 4				
Simple Payback period (years)	1.56	1.56	1.56	1.56

Notes:

1. Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2. Percent households retrofitted is based on 1990 service population (population existing prior to new BOCA plumbing requirements)
3. Hampton Roads Planning District Commission, Hampton Roads 2015 Economic Forecast, Vol II, August 1994.
4. Based on combined water-sewer charge of $5.12 per thousand gallons

Table 17-c. Demand Savings with Ultra Low-Flow Plumbing Retrofit

Portsmouth

	Percent of Households Retrofitted 2			
1990 Service Pop. = 109,100 1	10%	20%	40%	60%
Water Savings				
Retrofit Population	10,910	21,820	43,640	65,460
x GPCD (gpd) 1	55.6	55.6	55.6	55.6
x Domestic Savings Factor	0.54	0.54	0.54	0.54
= Accum. Savings (mgd)	0.33	0.65	1.30	1.95
Overall cost				
Persons/household 3	2.62	2.62	2.62	2.62
Households retrofitted	4,164	8,328	16,656	24,985
x Toilets/household	1.5	1.5	1.5	1.5
= No. retrofits (bathroom)	6,246	12,492	24,985	37,477
Cost at $160 per retrofit	936,927	1,873,855	3,747,710	5,621,565
Payback 4				
Simple Payback period (years)	2.61	2.61	2.61	2.61

Notes:

1. Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2. Percent households retrofitted is based on 1990 service population (population existing prior to new BOCA plumbing requirements)
3. Hampton Roads Planning District Commission, Hampton Roads 2015 Economic Forecast, Vol II, August 1994.
4. Based on combined water-sewer charge of $5.12 per thousand gallons

Table 17-d. Demand Savings with Ultra Low-Flow Plumbing Retrofit

Chesapeake

	Percent of Households Retrofitted 2			
1990 Service Pop. = 118,343 1	10%	20%	40%	60%
Water Savings				
Retrofit Population	11,834	23,669	47,337	71,006
x GPCD (gpd) 1	75	75	75	75
x Domestic Savings Factor	0.54	0.54	0.54	0.54
= Accum. Savings (mgd)	0.48	0.95	1.91	2.86
Overall cost				
Persons/household 3	2.87	2.87	2.87	2.87
Households retrofitted	4,123	8,247	16,494	24,741
x Toilets/household	1.5	1.5	1.5	1.5
= No. retrofits (bathroom)	6,185	12,370	24,741	37,111
Cost at $160 per retrofit	927,776	1,855,552	3,711,105	5,566,657
Payback 4				
Simple Payback period (years)	1.54	1.54	1.54	1.54

Notes:

1. Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2. Percent households retrofitted is based on 1990 service population (population existing prior to new BOCA plumbing requirements)
3. Hampton Roads Planning District Commission, Hampton Roads 2015 Economic Forecast, Vol II, August 1994.
4. Based on combined water-sewer charge of $5.12 per thousand gallons

Table 17-e. Demand Savings with Ultra Low-Flow Plumbing Retrofit

Suffolk

	Percent of Households Retrofitted 2			
1990 Service Pop. = 28,700 1	10%	20%	40%	60%
Water Savings				
Retrofit Population	2,870	5,740	11,480	17,220
x GPCD (gpd) 1	55	55	55	55
x Domestic Savings Factor	0.54	0.54	0.54	0.54
= Accum. Savings (mgd)	0.08	0.17	0.34	0.51
Overall cost				
Persons/household 3	2.78	2.78	2.78	2.78
Households retrofitted	1,032	2,065	4,129	6,194
x Toilets/household	1.5	1.5	1.5	1.5
= No. retrofits (bathroom)	1,549	3,097	6,194	9,291
Cost at $160 per retrofit	232,284	464,568	929,137	1,393,705
Payback 4				
Simple Payback period (years)	1.64	1.64	1.64	1.64

Notes:

1. Virginia Dept. of Environmental Quality, James Water Supply Plan, 1988.
2. Percent households retrofitted is based on 1990 service population (population existing prior to new BOCA plumbing requirements)
3. Hampton Roads Planning District Commission, Hampton Roads 2015 Economic Forecast, Vol II, August 1994.
4. Based on combined water-sewer charge of $5.12 per thousand gallons

Table 18. Demand Savings Summary for Retrofit Program

	Savings (MGD)			
	Percent Households Retrofitted 1			
	10%	20%	40%	60%
Va. Beach	1.19	2.37	4.74	7.11
Norfolk	1.04	2.08	4.16	6.23
Portsmouth	0.33	0.65	1.30	1.95
Chesapeake	0.48	0.95	1.91	2.86
Suffolk	0.08	0.17	0.34	0.51
5-City Area	3.11	6.22	12.44	18.67

Notes:

1. Percent households retrofitted is based on 1990 service population (population existing prior to new BOCA plumbing requirements)

moderate participation up to 18.7 MGD under a more aggressive long-term program. Payback periods average around 1.7 years, making retrofits a no cost alternative.

2. Leak Detection

Both DEQ and the DEIS calculated water use in the Five City Area by assuming 10 percent "unaccounted for" water losses for both old and new facilities. In fact, actual losses are much lower. Virginia Beach reports 5-6 percent unaccounted-for water (Pirnie, 1991), Chesapeake reports 6-7 percent water loss (groundwater permit), and Suffolk reports 10 percent unaccounted-for water. Suffolk proposes beginning a water audit and loss reduction program (groundwater permit). Aggressive leak detection programs should maintain these rates of water losses for the systems in the region. Figures for Norfolk and Portsmouth were not available for this report. With the exception of Norfolk (no information was available at this time), the other four cities report active meter replacement programs, large meter testing, and metering on the entire system.

With on-going and active leak detection programs, there is no reason to assume that water losses in the system will increase from 5 percent to 13 percent, as suggested in Virginia Beach's FERC application. Likewise, there is no reason to assume increases in leaks will offset savings provided by modern fixtures in new construction, as suggested in the DEIS (36 at 1-12). On the contrary, as pipes age and begin to leak more heavily, the ongoing program can identify these pipes and repair or replace them as necessary. In this way, water loss for the system should remain the same. The continued use of these programs should allow per capita use to continue to decrease as new homes are added in the region. The capital expenditure needed to replace old and leaky lines is substantially lower than building new water sources. It may also be beneficial to decrease the number of years small meters are in service, to test large meters more frequently, and to determine if meters are sized properly to further reduce the percentage of unaccounted-for water.

3. Rate Structures

Traditionally, water suppliers have relied on a cost-of-service flat rate structure. Within the past decade this method of covering water service costs has moved toward more conservation oriented water pricing. The 1990 National Water Rate Survey estimated that communities using an increased, or inverted, block rate structure doubled from 8 percent in 1985 to 16 percent in 1989 (41). The 1992 National Water Rate Survey indicated this trend is continuing (39). The rising costs of providing water will necessitate evaluations of present water rate structures and induce more conservation pricing policies.

Virginia Beach, Norfolk, and Portsmouth presently use a flat rate structure, while Chesapeake and Suffolk use a declining rate structure. Neither type of rate structure provides the greatest incentive for water conservation among all classes of users. Chesapeake and Suffolk charge a fixed amount for the first 600 and 400 cubic feet, respectively. The next block of consumption is charged at a lower rate per cubic foot. This practice encourages water usage and penalizes conservation -- within the first block the same amount is charged regardless of use. Flat rate structures in the other three cities provide only marginal incentive to conserve.

On the other hand, inverted block rate prices provide a strong incentive to conserve. This method prices water at increasingly higher rates as consumption increases. Other approaches to conservation pricing include the use of seasonal rates or a surcharge for consumption above a certain volume during the on-season (50), and time-of-day rates where a higher rate is charged during peak demand periods (43). One method of determining block size is to estimate essential water usage for the average size household. An increased block rate will be applied to all water bills greater than this average consumption. It may be advantageous to determine a separate rate for commercial and residential users.

The inverted block rate has been successfully used by many municipalities to control water demands. The Spalding County Water Authority in Spalding County, Georgia has converted from a declining rate structure to an inverted rate structure as their water conservation program. Water demands per customer decreased 5 percent. Water use per connection decreased from 243 gpd to 231 gpd; monthly water use decreased from 7381 gallons to 7028 gallons per connection (44). Another study in Georgia found that after implementing an increasing rate structure water use declined from 503 gpd to 352 gpd (45). The City of Tucson, Arizona implemented inverted block rates and seasonal rate surcharges for high summer usage (49). The rate structure changes resulted in a decrease of approximately 25 percent in the average daily water use per capita (47). The City of Newport News has employed a Summer Consumption Rate surcharge applied to consumption "which is greater than the average system-wide difference between the 6-month summer season and the winter control season." The City of Santa Barbara, California implemented an inverted block rate structure during 1989 while in a water shortage due to drought. The City also implemented a retrofit program with rebate incentives. Single family usage declined 36 percent; multi-family use declined 41 percent; wastewater flow decreased from 9 mgd to 6 mgd. The City determined that the inverted block rate structure was a "useful and flexible tool for shaping demand under a variety of water supply conditions" (40). The City of Boca Raton, Florida has implemented an inverted block rate structure as of 1990 to encourage water consumption reductions of 7 percent (37).

Virginia Beach implies that the use of an inverted block rate structure will penalize large families and force them to subsidize small water users (19). This is incorrect. Block rates can be designed to fit any criteria. A basic block could consider family size or any other appropriate criteria. In this manner, only wasteful users would pay a higher rate.

Adoption of inverted block rate structures would reduce year-round water demand. Likewise, seasonal or time-of-day rate structures will also reduce peak and total demands at no net cost. At a minimum, a conservation rate structure should be employed during periods of water shortage due to drought.

4. <u>City Planning Relative to Changing Customer Cross Section</u>

Virginia Beach has suggested that water consumption will increase due to a changing residential/commercial customer mix. The DEIS has adopted this suggestion to justify failure to reduce per capita demands from FEPA fixtures. (36 at 1-11). The city has indeed adopted a stance of trying to attract more commercial and industrial operations. However, Virginia Beach comprehensive plans continue to describe a residential/commercial mix of 80% . Even if this

goal is ultimately achieved, economic recruitment activities should be aimed at businesses and facilities with lower water consumption rates. These businesses often offer higher quality jobs than water intensive operations. Planning in this way could forestall much of the anticipated need for additional water supplies.

5. Education

Education plays an important role in reducing per capita water use. For local conservation efforts to be effective, customer education must be included as a key component. The "Water Conservation Plan for the Hampton Roads Region" (42) describes the "Hampton Roads Water Efficiency Team" actions being taken in the region. This team, established in 1994, has plans for multi-media activities to increase public awareness and change personal habits. Continued sponsorship of education activities should help ensure high levels of participation in conservation programs, and allow per capita usage to decrease as more efficient fixtures are added in new construction.

C. Alternatives for Increasing Supply in both Normal and Dry Conditions

1. Conjunctive Use of Groundwater

Under the 1992 Ground Water Management Act, DEQ has reviewed all previously issued ground water withdrawal permits and has substantially reduced the total permitted withdrawals. As a result, DEQ has been willing to issue a number of new permits, including major permits to private concerns, a proposed racetrack, and the cities of Chesapeake and Suffolk (52). DEQ has indicated that additional permits will be issued based upon applicant's demonstrated need, past use, and the impacts on the aquifer being pumped. Virginia groundwater regulations make supply for human consumption the first priority. DEQ has said that only limited additional withdrawals will be permitted, but without a comprehensive model of the aquifer system, it does not know the upper limit. Even though Virginia Beach cites water supply shortages during drought, the City has not taken advantage of opportunities to build either full production or conjunctive use wells (for use in relatively dry times). It did apply for, and was granted a permit for a test well long before Chesapeake and Suffolk sought their permits, but never initiated the tests. As indicated in a memo from Frank Sanders to Amar Dwarkanath, both public utilities officials in Chesapeake, Virginia Beach prefers to pursue water outside of the region instead of available water within the region.

The DEIS considered, as part of its "conjunctive use" alternative, a 10 mgd groundwater system based on Virginia Beach's existing 16 mgd emergency well supply. It concluded that the system was feasible and very inexpensive, but indicated that aquifer drawdowns could result. However, the DEIS assumed that the wells would be operated at full production at all times. If the wells were operated only when other available supplies were sufficiently limited (no more than once each decade on average), this concern would be eliminated. Permits to other cities were issued without delay. There has never been any evidence that other cities in the region would object to such withdrawals.

DEQ has not determined what portion of any projected supply shortfall could be provided by conjunctive use of groundwater. However, a minimum of 10 mgd appears clearly available. The cost of this supply would be comparable to the cost of water from the existing conjunctive use wells, although modest payments to other municipalities may be required.

2. Water Banking (ASR)

Water banking is a proven technology. Many public water supplies throughout the United States and the world utilize water banking, otherwise known as aquifer storage and recovery (ASR), as a tool to manage both the volume of their water supply and its quality. In 1994, the Las Vegas Valley Water District was injecting over 80 mgd during the storage cycle. The Environmental Protection Agency notes the benefits of ASR. (53) There is no longer any serious question about the value and dependability of this technology.

Water banking has also proven to be successful in Southeast Virginia (12). The City of Chesapeake has built, and is operating, a 3 mgd system. The Chesapeake Director of Public Utilities states "ASR has demonstrated that treated water could be stored below ground without mixing with native water and be recovered for later use." (12). In 1994, Chesapeake advised DEQ that "the technology of the ASR well has been successful." (55 at F-2). Chesapeake did not expand its system to the originally planned 10 mgd because the treatment costs of the planned source water--the Dismal Swamp Canal--was more expensive than desalting local supplies. If better quality water had been available, the program would have been expanded (55).

The water banking program proposed by Boyle (9 at 25-34) can make use of a number of high quality alternative water sources, including the water currently used by the City of Norfolk in its conventional water treatment plant. Because higher quality water will be banked, the twenty percent loss cited by FERC will not occur. The losses FERC references occur only when the aquifer's native water is not cost effectively treatable.

Boyle's alternative called for capturing 11 mgd average spillage from Norfolk's western reservoirs, 10 mgd average from Portsmouth Reservoir spillage, additional water if needed from the Blackwater and Nottoway Rivers during high flow periods or water from Lake Chesdin or from Lake Gaston. This water would then be treated and injected into the Middle and Lower Potomac aquifers for use during low flows periods. The water being injected into the aquifer will be of the same quality as that currently being produced by the City of Norfolk at its water treatment plants.

Boyle's proposed alternative was discussed in detail in 1992 (9), and that material will not be repeated here. However, subsequent events in Southeast Virginia and around the country have confirmed its accuracy. Aquifer banking has the added benefit of being added incrementally as needed. For example, one 8 mgd water bank can be developed from Norfolk reservoir spillage immediately, and another can be developed years later (when needed) from Portsmouth spillage, or from the variety of other available sources.

3. Water Re-use

Use of wastewater reclamation is growing rapidly in both water-poor and water-rich areas. Water-poor areas reclaim wastewater for obvious reasons. Supplies are limited and reclaimed water is a resource that can be used for a multitude of domestic, commercial and industrial purposes other than potable use. Water-rich areas can nevertheless effect great savings by use of this technology--in lower water supply costs and lower wastewater costs. This is a preferred alternative of the Environmental Protection Agency. (54) The FERC DEIS (36) fails to consider the greatest potential for this fully accepted alterative by considering reclaiming wastewater only for potable use.

The literature is replete with examples of reuse for irrigation, industry, non-potable household uses in new developments, and a number of other innovative uses. Even water-rich Charlotte, North Carolina, is in the process of evaluating reclaimed water use to reduce peak demands on its water treatment systems by using reclaimed wastewater for irrigation/industrial purposes that are currently supplied with potable water. In most cases, wastewater is treated to a purity considerably better than the river water it is discharged into.

Southeast Virginia has a regional wastewater utility, the Hampton Roads Sanitation District (HRSD). The regional approach to dealing with wastewater in Southeast Virginia has proven very successful. By regionalizing the wastewater utility, redundancy has been eliminated and the most efficient approach to meeting the area's wastewater handling needs has been implemented. The HRSD has offered its reclaimed water resource (over 100 mgd) to the water utilities in Southeast Virginia for use in augmenting their water supply needs. (64) To date this water resource has not been considered or utilized to a fraction of its potential in Southeast Virginia.

Boyle (9) identified 9 to 12 mgd of potential water reuse in the region. Seven mgd of wastewater can be provided by the Cities of Suffolk and Franklin for use as process water in the Union Camp Paper Mill and 2 to 5 mgd from HRSD for immediate use for landscape irrigation in Virginia Beach. Additional quantities can be used for irrigation in the remainder of the Five-City Area. The highly industrialized portions of Norfolk and Portsmouth are likely candidates for large industrial reuse. A comprehensive water reuse study conducted in the region would undoubtedly identify considerably more potential for water reuse to free potable supplies for future water supply needs.

4. Sea Water Desalting

Sea water desalting is a proven and effective method of providing water. While it would be an expensive alternative for supplying 54 or 60 mgd immediately, it is nevertheless an efficient and cost effective component of a comprehensive water supply program. The FERC DEIS suggests extremely high costs by assuming that desalting plants would be built in large increments immediately, and used at all times. (36) The costs of sea water desalting have been declining consistently for many years. If, as expected, these costs continue to decline, use of seawater desalting as a component toward the end of the planning period, or as a drought reserve, would be far more cost effective than a highly capital intensive pipeline.

Furthermore, costs vary among the various desalting methods. FERC proposes to utilize multi-stage flash distillation to desalt sea water. This process is one of the most energy intensive and costly methods of desalting sea water. If co-generation is desired along with desalting, multi-effect distillation would be less energy intensive and costly. However, the most cost effective approach to desalting sea water in Southeast Virginia would be reverse osmosis.

5. **Exchanges of Water Rights**

Boyle (9) identified the possible exchange of surplus Blackwater and Nottoway River water for groundwater that the Union Camp Paper Mill has traditionally pumped. Under this alternative, Virginia Beach would build a treatment plant near the Union Camp facilities and provide treated river water to Union Camp during periods of high flow in the Blackwater and Nottoway Rivers in exchange for groundwater that Union Camp would otherwise be pumping. During this mode of operation Union Camp would not pump groundwater and the aquifer storage would increase by the amount of water not pumped. During periods of low flow in the rivers, groundwater would be used by both Union Camp and Virginia Beach. Water exchanges could also be negotiated with cities closer to Union Camp to avoid transport costs. The net amount of water taken from the aquifers would not increase.

6. **Interconnection of Various Utility Systems**

All of the safe yield analyses for the Norfolk and Portsmouth reservoirs considered the yield during the worst drought of record as the reservoirs safe yield. These lowest yields of record were then totalled to determine the combined safe yield of the two reservoirs. The lowest yield for Portsmouth's reservoirs was 19 mgd in 1981. The lowest yield for Norfolk's reservoirs was 57 mgd in 1955. The total safe yield of the two systems was therefore calculated as 76 mgd.

However, the lowest yields of record for each system did not fall in the same year. It is not surprising that the systems had their lowest yields in different years. It is a natural phenomenon that rain often falls in one watershed but not in another, or visa versa. If the two systems were connected, the lowest total supply available in any year would be 5 mgd higher than if the systems remain separate. For 1955 the combined yield was 81 mgd (Norfolk-57 mgd plus Portsmouth-24 mgd). For 1981 the combined yield was 82 mgd (Norfolk-63 mgd plus Portsmouth-19 mgd). The increase in safe yield is 5 mgd at very little cost. Increasing safe yield by interconnection is a common and well-understood approach. It increases usable supply without development of new sources. The most common example is the highly successful system in the Potomac River and Washington, D.C. metropolitan area. (66)

Interconnection also serves the important benefit of preventing the waste of water in one area while insufficient water is available in another. This has been the situation in Virginia Beach for some time. While Portsmouth's surplus can be fully utilized to meet 2030 regional needs without interconnection (i.e., Portsmouth is already connected to Chesapeake and Suffolk), interconnection would provide immediate benefit to Virginia Beach.

7. Other Sources

The DEQ identifies Somerton Creek as a possible 8 mgd source of potable water. This alternative was eliminated solely due to hydrologic limitations. "Due to the low hydrologic capability of the proposed impoundment, the Somerton Creek alternative will not be considered as a potential source of water to meet the long-range needs of the Five Cities Demand Center. However, when combined with other small sources, this alternative could have potential for further consideration." (3, II-441) Depending upon how demand develops over the next thirty-five years, the 8 mgd Somerton Creek supply could provide a very large portion of the projected additional supply needs of the Five Cities Demand Center.

In its 1994 Conjunctive Use Alternative Report (11, Table 3-3), prepared for Virginia Beach, Malcolm Pirnie identifies a 2.5 mgd treated water safe yield fresh groundwater supply in Virginia Beach. The report estimates that after development the wells should produce water for $1.70/1000 gal.

The City of Chesapeake has recently discussed "plans to add additional lakes in Boers Hill and Deep Creek to reserve water." (67) The availability of various local sources should be further examined.

D. Cost of Various Alternatives

1. Lake Gaston Pipeline

The DEIS provided detailed costing estimates for the Lake Gaston Pipeline, and concluded that levelized project cost per 1000 gallons would be $5.34 over the project life. The DEIS made two fundamental errors. First, it incorrectly calculated the actual costs involved in building and operating the pipeline. Second, and far more importantly, it made fundamental errors in assumptions about the amount of water that will be needed through the pipeline.

With respect to cost estimates, FERC underestimates the cost of Norfolk treatment of water from the pipeline. The DEIS assumed that Norfolk's total treatment charge was $1.06/1000 gallons in 1991 dollars, half of which it assumed would pay off existing debt incurred by Norfolk in constructing improvements. In 1993, Norfolk and Virginia Beach contracted for a charge of $1.51/1000 gallons for these purposes. In addition, the DEIS does not take into account associated costs which have been or must be paid by Virginia Beach, including substantial payments to municipalities along the pipeline route in exchange for local consents, payments to the Corps of Engineers, potential payments to riparian owners in connection with a pending riparian lawsuit, potential payments to Virginia municipalities (Virginia communities near Lake Gaston have already declined a $10 million offer proffered by Virginia Beach), substantial legal costs, and so on. In contrast, a portion of the pipeline originally intended has now been abandoned, and lower costs will result. The additional costs associated with building and operating the pipeline exceed the savings.

Virginia Beach has suggested that many of these capital costs should not be included in FERC's calculation, because some costs have already been expended and some will be paid by its

partners. All such costs must be included in the calculation. FERC regulations require that decisions not be influenced by money already spent, and Virginia Beach's presumed need for the project is premised upon the participation of its partners.

Far more important than the discussions about capital and operating costs, however, is the issue of levelized cost per 1000 gallons. Costs per 1000 gallons are determined based on the amount of water needed through the pipeline. The DEIS used a cost model to make these calculations. However, the DEIS assumed that the worst drought of record (1981) would be repeated each and every year of the planning period. In other words, the analysis assumes that normal rainfall will never occur, and that the pipeline must pump all of the region's drought deficit each year, and a large additional surplus as well, even when local reservoirs are full. By exaggerating the amount of water needed, the analysis vastly underestimates the actual unit cost.

To determine the unit cost of the Lake Gaston Pipeline project, an estimate of the water actually needed through the pipeline needs must be made. As discussed earlier, the estimates of demand deficits in the year 2030 range from 0 (if conservation or increased storage capacity is used during droughts) to 13 mgd (incorporating the 16 mgd additional supplies currently being developed and the 24 mgd demand reduction due to water saving devices) to 35 mgd (the DEIS calculation which discounts available supplies and maximizes demand), to 60 mgd (if an additional surplus is provided to avoid conservation during drought).

In the following discussions, the supplies and demands are assumed to be as presented in the DEIS. The demands are estimated at 121.3 mgd in the year 1998 growing to 148.2 mgd in the year 2031. Unit costs are presented utilizing the cost estimating procedure established as part of the DEIS. Values are stated as levelized present value per 1000 gallons of water supplied over the life of the project. Four scenarios are presented in order to demonstrate how the unit cost of the water varies with the amount of water that is needed through the pipeline.

The first scenario represents the project as described in the DEIS. The supply for each year is assumed to be 112.8 mgd. This assumes that the worst drought of record is repeated every year. In other words, the DEIS assumes that the pipeline will operate under extreme drought conditions continuously throughout the life of the project. In addition, Scenario 1 adds an additional surplus at all times, amounting to 24.6 mgd in the year 2030. This surplus is derived by calculating the difference between supplying FERC's estimated shortfall of 35 mgd and its overall conclusion of 60 mgd need - apparently to allow the region to avoid water use restrictions during the worst drought of record. Scenario 1 is described in Table 19.

The second scenario also assumes that the worst drought of record is repeated each year, and that no more that 112.8 mgd can ever be supplied. However, it does not include the 24.6 mgd surplus requirement. Scenario 2 is also described in Table 19.

The third and fourth operating scenarios are similar to the first two scenarios, except that they no longer assume that each year is the worst drought of record. Instead, in an attempt to demonstrate the amount of water needed through the pipeline under the worst realistic circumstances, we have examined the hydrological record, and repeated the driest 34 year period. This includes both the severe droughts of 1966 to 1969, and 1981. The driest recorded period

Table 19. Pipeline Delivery Rates for Lake Gaston Project
Scenario 1 & 2: Assuming the worst drought on record is repeated every year

Scenario 1: Utilizing FERC's supply and demand estimates, assuming the worst drought on record is repeated every year and adding surplus to match FERC's pipeline pumpage rate.

Scenario 2: Utilizing FERC's supply and demand estimates, assuming the worst drought on record is repeated every year, without adding surplus.

		Scenario 1				Scenario 2			
Year	Demand, mgd	Supply, mgd	Surplus Req'd, mgd	Pipeline Pumpage Rate, mgd	Pipeline Delivery Rate, mgd	Supply, mgd	Surplus Req'd, mgd	Pipeline Pumpage Rate, mgd	Pipeline Delivery Rate, mgd
1998	121.30	112.80	26.47	34.97	31.47	112.80	0.00	8.50	7.65
1999	122.70	112.80	25.33	35.23	31.71	112.80	0.00	9.90	8.91
2000	124.10	112.80	24.21	35.51	31.96	112.80	0.00	11.30	10.17
2001	125.26	112.80	23.32	35.78	32.20	112.80	0.00	12.46	11.21
2002	126.42	112.80	22.42	36.04	32.44	112.80	0.00	13.62	12.26
2003	127.58	112.80	21.54	36.32	32.69	112.80	0.00	14.78	13.30
2004	128.74	112.80	20.65	36.59	32.93	112.80	0.00	15.94	14.35
2005	129.90	112.80	19.76	36.86	33.17	112.80	0.00	17.10	15.39
2006	131.06	112.80	18.87	37.13	33.42	112.80	0.00	18.26	16.43
2007	132.22	112.80	17.98	37.40	33.66	112.80	0.00	19.42	17.48
2008	133.38	112.80	17.09	37.67	33.90	112.80	0.00	20.58	18.52
2009	134.54	112.80	16.19	37.93	34.14	112.80	0.00	21.74	19.57
2010	135.70	112.80	15.31	38.21	34.39	112.80	0.00	22.90	20.61
2011	136.41	112.80	15.53	39.14	35.23	112.80	0.00	23.61	21.25
2012	137.12	112.80	15.88	40.20	36.18	112.80	0.00	24.32	21.89
2013	137.83	112.80	16.21	41.24	37.12	112.80	0.00	25.03	22.53
2014	138.54	112.80	16.56	42.30	38.07	112.80	0.00	25.74	23.17
2015	139.25	112.80	16.89	43.34	39.01	112.80	0.00	26.45	23.81
2016	139.96	112.80	17.24	44.40	39.96	112.80	0.00	27.16	24.44
2017	140.67	112.80	17.57	45.44	40.90	112.80	0.00	27.87	25.08
2018	141.38	112.80	17.91	46.49	41.84	112.80	0.00	28.58	25.72
2019	142.09	112.80	18.25	47.54	42.79	112.80	0.00	29.29	26.36
2020	142.80	112.80	18.59	48.59	43.73	112.80	0.00	30.00	27.00
2021	143.28	112.80	19.16	49.64	44.68	112.80	0.00	30.48	27.43
2022	143.76	112.80	19.73	50.69	45.62	112.80	0.00	30.96	27.86
2023	144.24	112.80	20.30	51.74	46.57	112.80	0.00	31.44	28.30
2024	144.72	112.80	20.87	52.79	47.51	112.80	0.00	31.92	28.73
2025	145.20	112.80	21.44	53.84	48.46	112.80	0.00	32.40	29.16
2026	145.68	112.80	22.01	54.89	49.40	112.80	0.00	32.88	29.59
2027	146.16	112.80	22.58	55.94	50.35	112.80	0.00	33.36	30.02
2028	146.64	112.80	23.15	56.99	51.29	112.80	0.00	33.84	30.46
2029	147.12	112.80	23.72	58.04	52.24	112.80	0.00	34.32	30.89
2030	147.60	112.80	24.29	59.09	53.18	112.80	0.00	34.80	31.32
2031	148.20	112.80	24.60	60.00	54.00	112.80	0.00	35.40	31.86
Average Delivery, mgd					39.76				21.84
Levelized PV/1000 gal					$5.34				$9.57

began in 1949 and ended in 1981. Utilizing specific inflow records provided by the Corps of Engineers in its STELLA II model in the manner described earlier and adjusted to FERC's determination of safe yield, we have calculated the amount of water that would be available if this driest historical period were repeated. Scenario 3 assumes that a surplus is necessary to avoid water use restrictions in the worst drought of record. Scenario 4 assumes that no such surplus is needed. Both scenarios 3 and 4 are described in Table 20.

The difference in levelized cost per 1000 gallons under these various scenarios is dramatic. While FERC concluded that the levelized cost of the project was $5.34/1000 gallons (Scenario 1), that cost increases to $9.57/1000 gallons simply by not requiring the surplus (Scenario 2). More fundamentally, however, when the highly conservative projections of water availability are included (assuming the driest historical period is repeated), levelized cost per 1000 gallons are $99.29 if a surplus is provided (Scenario 3), and $113.31 if no surplus is provided (Scenario 4). Table 20 also demonstrates that if surpluses are required, additional water is necessary in only six of the thirty-four years. If no surplus is required, additional water is necessary in only two of thirty-four years. A significant amount of water is needed only in the worst drought of record.

The cost figures provided for Scenarios 3 and 4 are in fact substantially underestimated. Because of limitations of the cost model provided by FERC, it is impossible to factor in a pipeline delivery rate of 0, even when reservoirs in the region are overflowing. Therefore, to make the model operate properly, we assumed that 1 mgd must be delivered at all times whether additional water was necessary or not.

The comparison of these scenarios is dramatic indeed. However, it is unreasonable to assume that it will never rain. Because the Gaston pipeline is so capital intensive, when operated to meet actual regional needs, it is exorbitantly expensive.

Figure 7 is a graphic demonstration of the difference between needs in the area assuming that the worst drought of record is repeated every year and assuming that the driest period of historical record is repeated. We note again that all of the analyses described above, as well as the representation in Figure 7, assumes that FERC's conclusions regarding supply and demand are correct. We believe that FERC has overestimated demand and underestimated supply.

2. Realistic Alternative Scenarios

This report has presented numerous components of supply, demand reduction, and modified water supply operation that, in various combinations, can meet the water supply needs of Southeastern Virginia through the year 2030 without utilizing water from Lake Gaston. Any number of such combinations may be used. The following scenarios are presented as examples to demonstrate how these components can be combined to yield 35 mgd and more in additional water. The most cost effective approaches phase in low cost components during the near term and more expensive components during later years. Phasing also allows supply to be added as demand grows. The Lake Gaston option, as proposed by Virginia Beach, provides all of the Virginia Beach projected 2030 demand now and ceases to use local water resources, wasting money, energy, and water resources.

Table 20. Pipeline Delivery Rates for Lake Gaston Project
Scenario 3 & 4: Assuming the driest historical period (1949-1981) is repeated

Scenario 3: Utilizing FERC's demand estimate and historic supply quantities. Historic supplies based on Corps 1994 STELLA Model adjusted to match FERC supply conclusions, and assuming Lake Gaston will supply the deficit between demand and supply. Assuming the driest historical period (1949 to 1981) is repeated. Include surplus as noted in Scenario 1. Include a minimum 1.0 mgd Lake Gaston Supply to allow for cost model limitations.

Scenario 4: Utilizing FERC's demand estimate and historic supply quantities as in Scenario 3. Does not include surplus requirement. Include a minimum of 1.0 mgd Gaston supply to allow for cost model limitations.

		Scenario 3				Scenario 4			
Year	Demand, mgd	Supply, mgd	Surplus Req'd, mgd	Pipeline Pumpage Rate, mgd	Pipeline Delivery Rate, mgd	Supply, mgd	Surplus Req'd, mgd	Pipeline Pumpage Rate, mgd	Pipeline Delivery Rate, mgd
1998	121.30	191.66	26.47	0.00	0.00	191.66	0.00	0.00	0.00
1999	122.70	171.43	25.33	0.00	0.00	171.43	0.00	0.00	0.00
2000	124.10	145.92	24.21	2.39	2.15	145.92	0.00	0.00	0.00
2001	125.26	194.77	23.32	0.00	0.00	194.77	0.00	0.00	0.00
2002	126.42	162.60	22.42	0.00	0.00	162.60	0.00	0.00	0.00
2003	127.58	143.31	21.54	5.81	5.23	143.31	0.00	0.00	0.00
2004	128.74	166.77	20.65	0.00	0.00	166.77	0.00	0.00	0.00
2005	129.90	188.49	19.76	0.00	0.00	188.49	0.00	0.00	0.00
2006	131.06	194.96	18.87	0.00	0.00	194.96	0.00	0.00	0.00
2007	132.22	195.16	17.98	0.00	0.00	195.16	0.00	0.00	0.00
2008	133.38	184.42	17.09	0.00	0.00	184.42	0.00	0.00	0.00
2009	134.54	194.76	16.19	0.00	0.00	194.76	0.00	0.00	0.00
2010	135.70	194.63	15.31	0.00	0.00	194.63	0.00	0.00	0.00
2011	136.41	195.16	15.53	0.00	0.00	195.16	0.00	0.00	0.00
2012	137.12	161.45	15.88	0.00	0.00	161.45	0.00	0.00	0.00
2013	137.83	179.99	16.21	0.00	0.00	179.99	0.00	0.00	0.00
2014	138.54	159.60	16.56	0.00	0.00	159.60	0.00	0.00	0.00
2015	139.25	132.77	16.89	23.37	21.03	132.77	0.00	6.48	5.83
2016	139.96	145.19	17.24	12.01	10.81	145.19	0.00	0.00	0.00
2017	140.67	134.36	17.57	23.89	21.50	134.36	0.00	6.31	5.68
2018	141.38	186.79	17.91	0.00	0.00	186.79	0.00	0.00	0.00
2019	142.09	164.58	18.25	0.00	0.00	164.58	0.00	0.00	0.00
2020	142.80	194.66	18.59	0.00	0.00	194.66	0.00	0.00	0.00
2021	143.28	195.16	19.16	0.00	0.00	195.16	0.00	0.00	0.00
2022	143.76	194.70	19.73	0.00	0.00	194.70	0.00	0.00	0.00
2023	144.24	178.24	20.30	0.00	0.00	178.24	0.00	0.00	0.00
2024	144.72	195.16	20.87	0.00	0.00	195.16	0.00	0.00	0.00
2025	145.20	182.68	21.44	0.00	0.00	182.68	0.00	0.00	0.00
2026	145.68	186.11	22.01	0.00	0.00	186.11	0.00	0.00	0.00
2027	146.16	195.16	22.58	0.00	0.00	195.16	0.00	0.00	0.00
2028	146.64	195.16	23.15	0.00	0.00	195.16	0.00	0.00	0.00
2029	147.12	187.55	23.72	0.00	0.00	187.55	0.00	0.00	0.00
2030	147.60	112.80	24.29	59.09	53.18	112.80	0.00	34.80	31.32
2031	148.20	194.69	24.60	0.00	0.00	194.69	0.00	0.00	0.00
Average Delivery, mgd					3.45				1.30
Levelized PV/1000 gal (1 mgd min. delivery)					$99.29				$113.31

Each example has been depicted graphically in Figures 8 through 12. These scenarios all assume the supply and demand assumptions used by FERC. Note that when these assumptions are combined with historic flows, only three years out of the driest 34 years of record requires any additional water supply measures. See Figure 7.

Scenario #1A - No Action (Figure 8)

- Voluntary conservation at 10% of demand, 12 to 14.8 mgd; $0/1000 gal.
- Modified reservoir operation; 20 mgd; $1.51/1000 gal.

All actions during drought only.

Implementation of Scenario #1A results in a cost of $0.68/1000 gal.

Scenario #1B - No Action (Figure 9)

- Voluntary conservation at 10% of demand, 12 to 14.8 mgd; $0/1000 gal.
- Modified reservoir operation; 20 mgd; $1.51/1000 gal.
- Mandatory conservation at 5% of demand, 6 to 7 mgd; $0/1000 gal.
- Emergency wells; up to 50 mgd; $1.75/1000 gal. (cost/1000 gal. extrapolated from DEIS for similar sources)

All actions during drought only.

Implementation of Scenario #1B results in a cost of $0.68/1000 gal., since emergency wells should never be needed.

Scenario #2 - Reduce Demand and Increase Conjunctive Use Well Capacity (Figure 10)

Immediate:

- Voluntary conservation at 10% of demand (during drought only), 12 to 14.8 mgd; $0/1000 gal.

By 2005 - FERC Estimated Deficit is 12 mgd, add

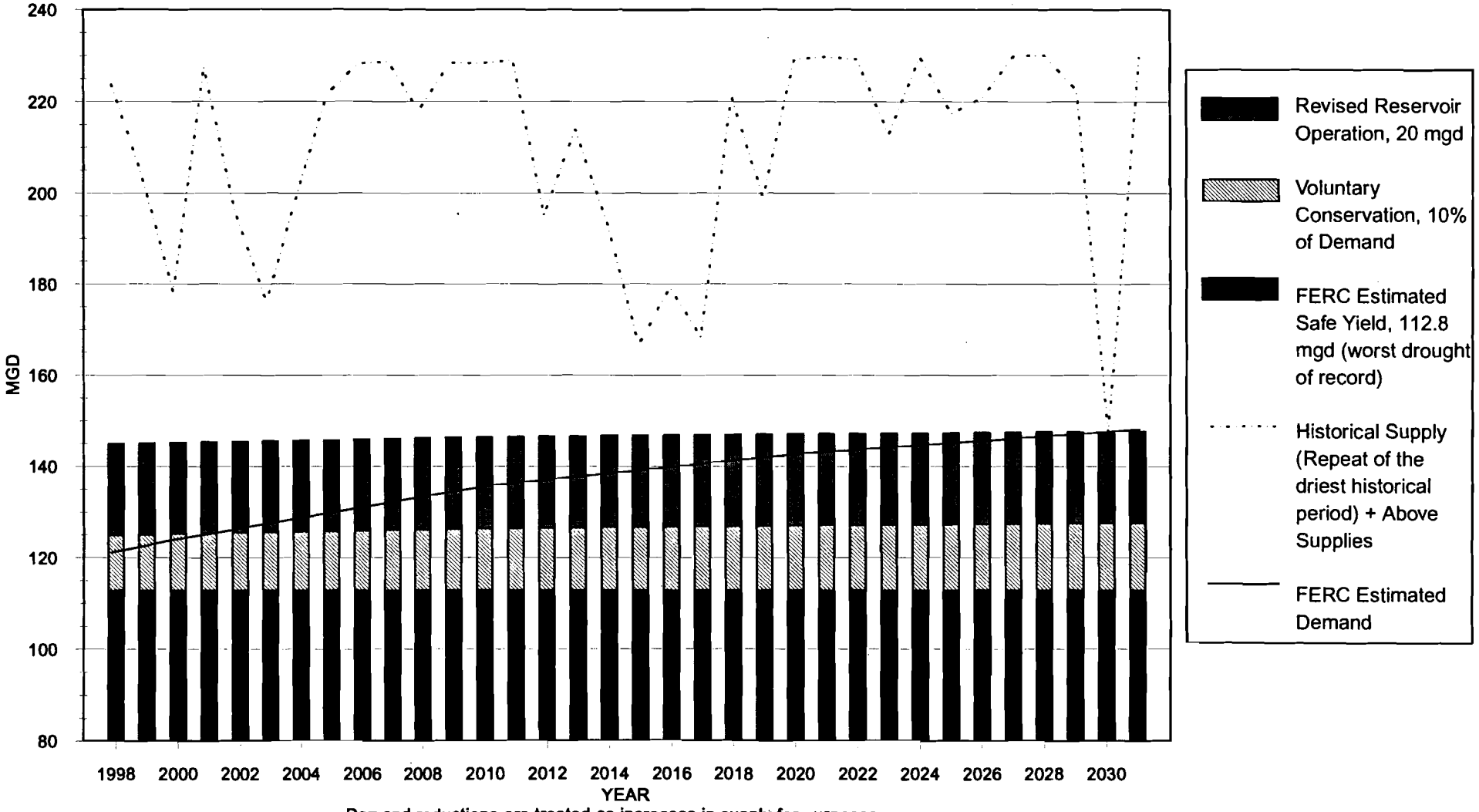
- 10 mgd of conjunctive use wells (as described in the DEIS) but used during drought only; 10 mgd; $1.75/1000 gal. (cost per 1000 gal. extrapolated from DEIS for similar sources)

By 2017 - FERC Estimated Deficit is 23 mgd, add

- Retrofit fixtures; 10 mgd; $0/1000 gal.

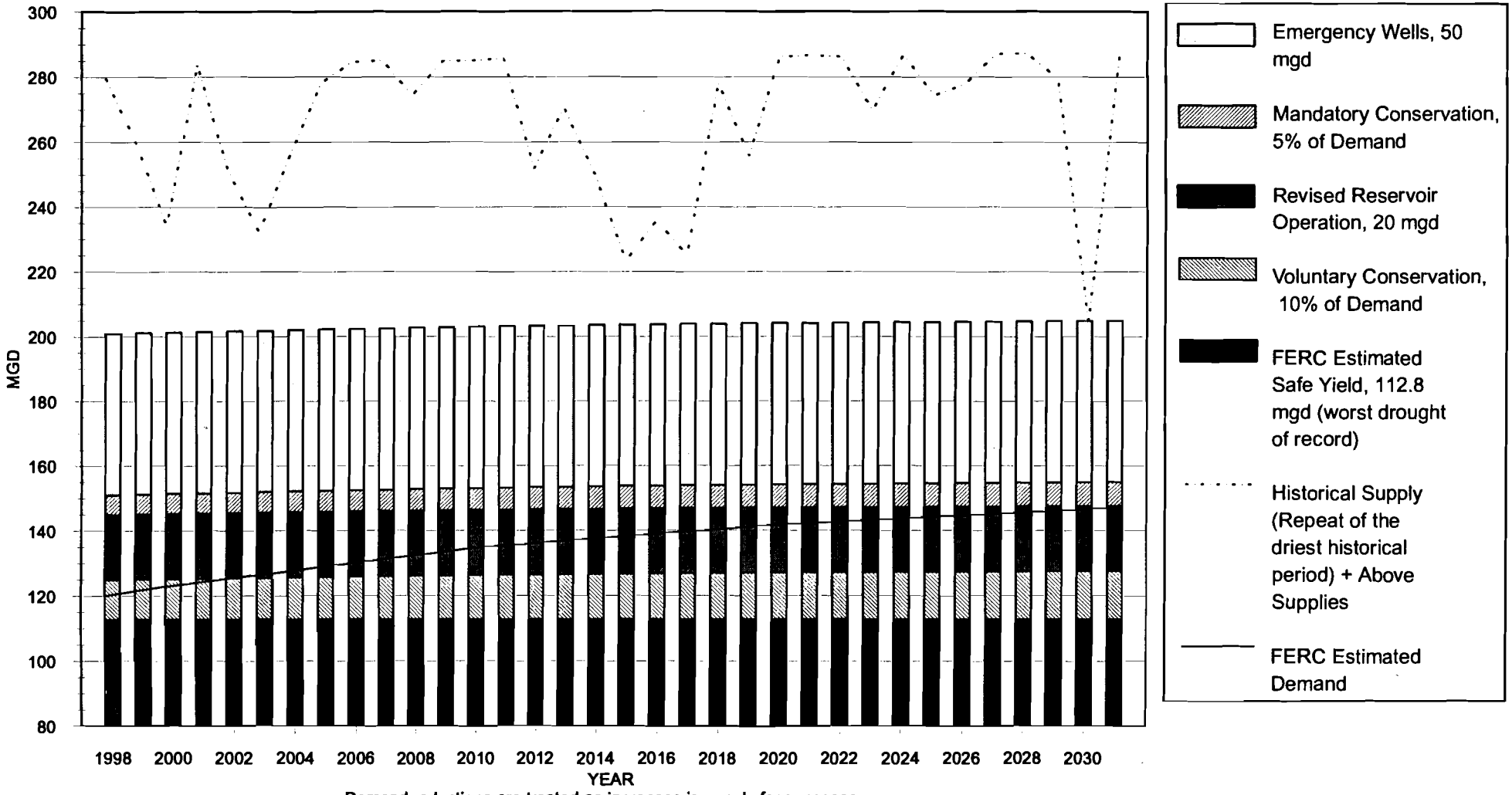
Implementation of Scenario #2 results in a consolidated cost of $0.54/1000 gal.

Figure 8
Scenario #1A-No Action
Voluntary Conservation During Drought Only and Revised Reservoir Operation



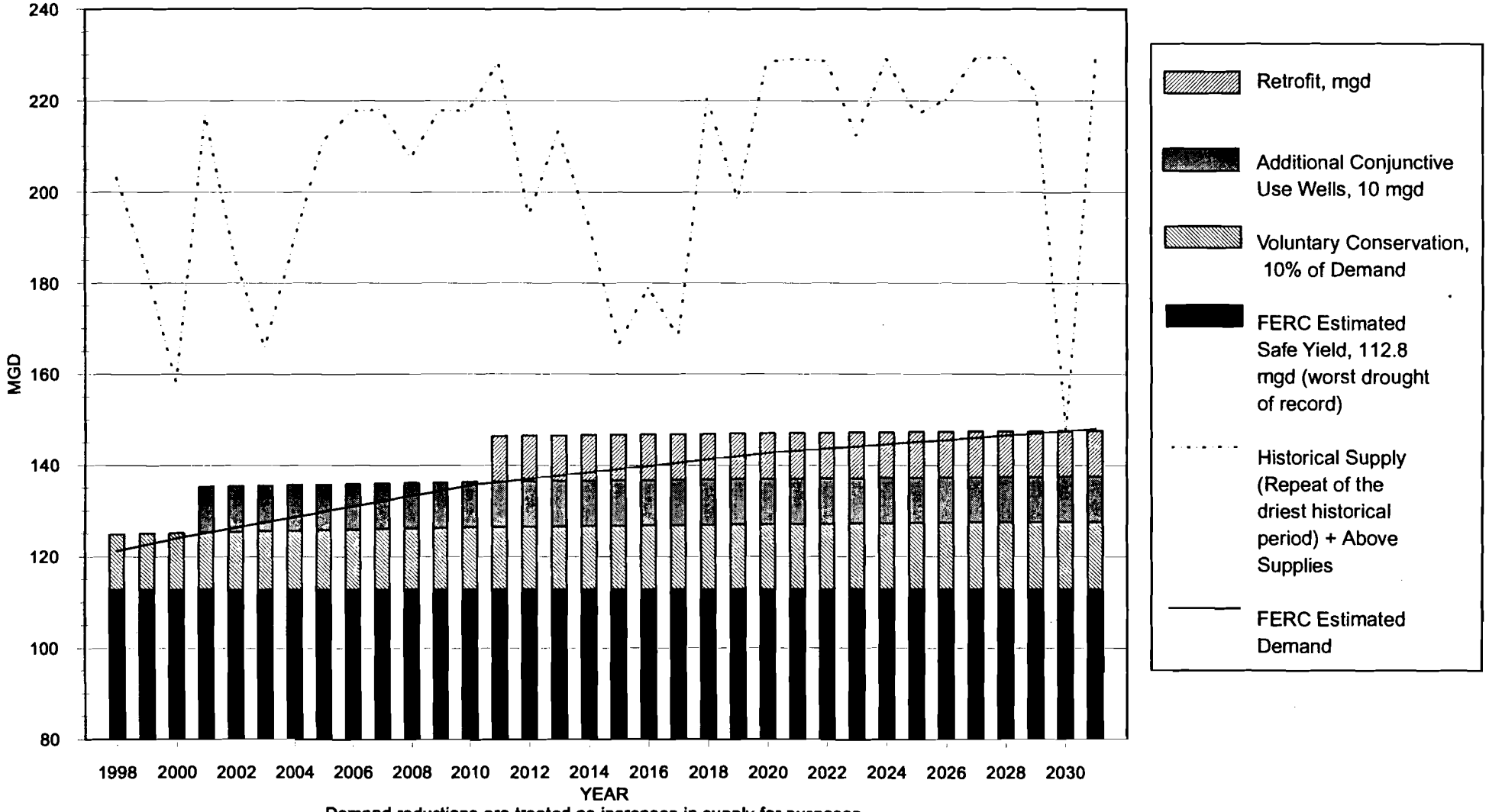
Demand reductions are treated as increases in supply for purposes of graphic representation.

Figure 9
Scenario #1B - No Action
Voluntary Conservation, Revised Reservoir Operation, Mandatory Conservation and Emergency Wells During Drought Only



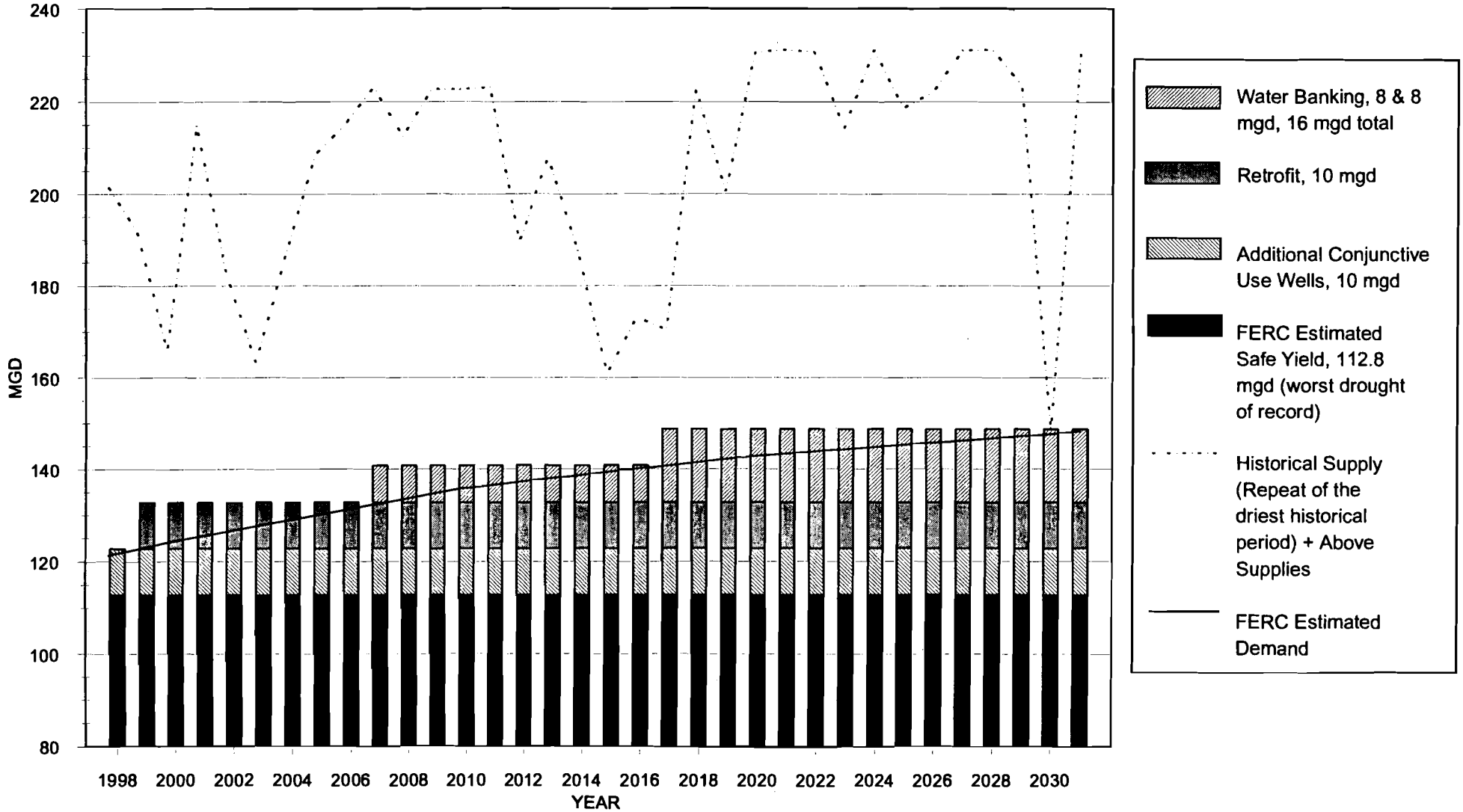
Demand reductions are treated as increases in supply for purposes of graphic representation.

Figure 10
Scenario #2 - Voluntary Conservation, Additional Conjunctive Use Wells During Drought Only and Retrofit



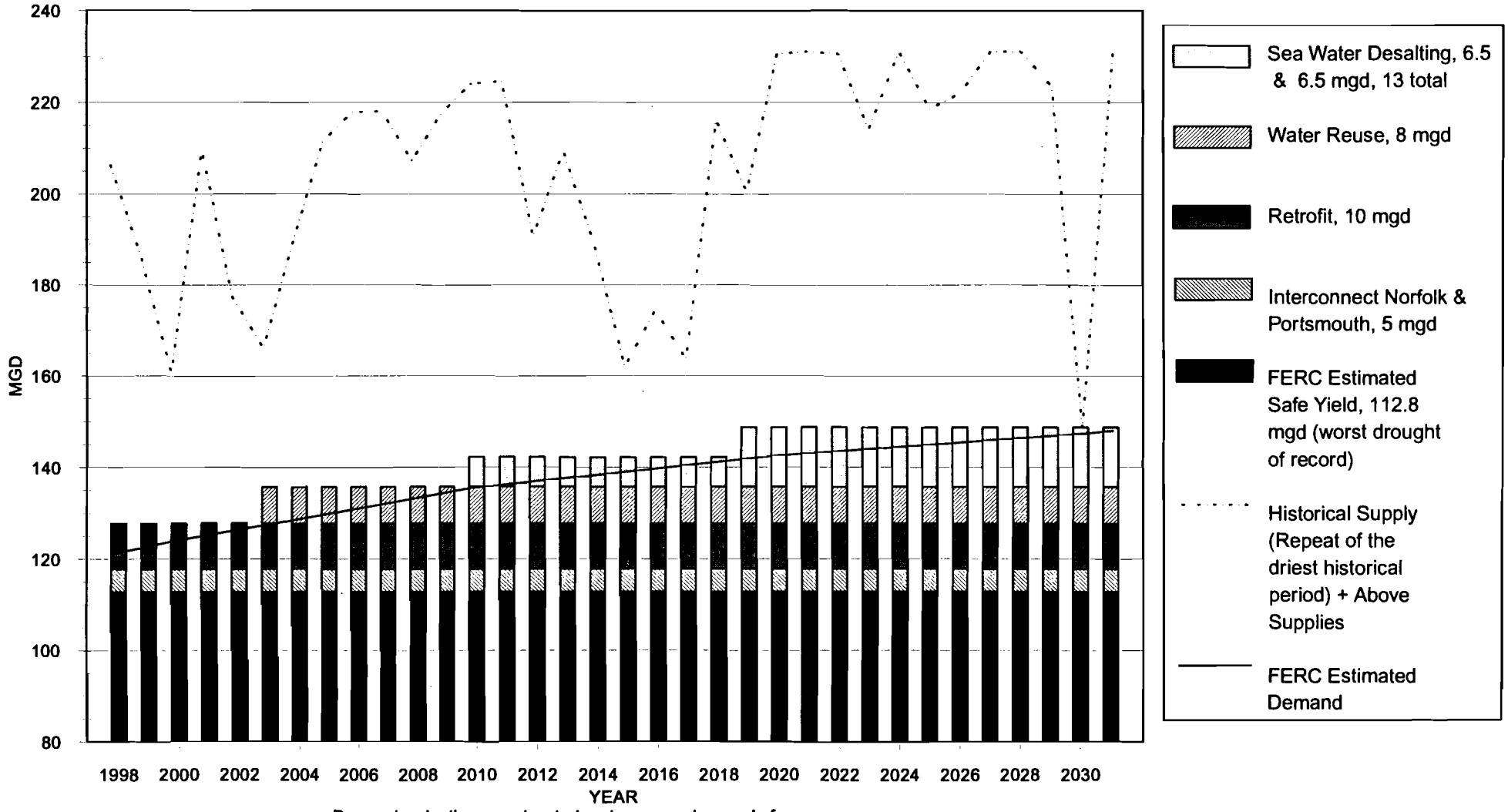
Demand reductions are treated as increases in supply for purposes of graphic representation.

Figure 11
Scenario #3 - Additional Conjunctive Use Wells During Drought Only, Retrofit, and Water Banking



Demand reductions are treated as increases in supply for purposes of graphic representation.

Figure 12
Scenario #4 - Interconnect Norfolk and Portsmouth, Retrofit, Water Reuse, and Sea Water Desalting



Demand reductions are treated as increases in supply for purposes of graphic representation.

Scenario #3 - Increase Conjunctive Use Well Capacity, Water Banking and Reduced Demand (Figure 11)

Immediate:

- 10 mgd of conjunctive use wells (as described in the DEIS) but used during drought only; 10 mgd; $1.75/1000 gal. (cost per 1000 gal. extrapolated from DEIS for similar sources)

By 2003 - FERC Estimated Deficit is 10 mgd, add

- Retrofit fixtures; 10 mgd; $0/1000 gal.

By 2014 - FERC Estimated Deficit is 20 mgd, add

- Water banking; 8 mgd; $4.00/1000 gal. (cost/1000 gal. derived from Boyle (9) increased for inflation and additional 20% for reduced project scale factor)

By 2022 - FERC Estimated Deficit is 27 mgd, add

- Water banking; 8 mgd; $4.00/1000 gal.

Implementation of Scenario #3 results in a consolidated cost of $1.74/1000 gal.

Scenario #4 - Reduce Demand, Interconnect Norfolk and Portsmouth Systems, Water Reuse, and Sea Water Desalting (Figure 12)

Immediate:

- Interconnect the Norfolk and Portsmouth systems; 5 mgd; $1.00/1000 gal. (A preliminary design is required to establish an accurate cost for this component. However, $1.00/1000 gal. is a very conservative estimate based upon the available information.)

By 2009 - FERC Estimated Deficit is 14 mgd, add

- Water Reuse; 8 mgd; $2.00/1000 gal. (Most areas report that reclaimed water costs $0 to $3.00/1000 gal. A relatively high figure, $2.00/1000 gal., is used as a conservative estimate.)

By 2017 - FERC Estimated Deficit is 23 mgd, add

- Sea Water Desalting; 6.5 mgd; $5.50/1000 gal. (The DEIS utilizes the most costly and energy demanding process for desalting. Reverse osmosis is much more cost effective where electricity is readily available.)

- Sea Water Desalting; 6.5 mgd; $5.50/1000 gal.

Implementation of Scenario #4 results in a consolidated cost of $1.64/1000 gal.

3. Summary

As the scenarios described above clearly show, and as Figures 8 through 12 graphically represent, there are far more efficient and realistic ways of meeting Southeastern Virginia's water needs than a highly capital intensive project like the Lake Gaston Pipeline. Indeed, we find it difficult to understand why a project of that scale has even been proposed for this region. Perhaps fifteen years ago, when building new large supplies was often considered the plan of choice, such a project would have made sense. However, in today's environment of conservation and more realistic growth, a project of this scale is simply not reasonable.

Given the conservation that will occur (for example by use of water saving fixtures) without any additional action, and the additional conservation measures such as retrofit which are no cost alternatives, combined with the easy ability of a community to conserve water once in a several decade period, the other alternatives described in this report are far more reasonable, cost effective, and efficient measures than the proposed pipeline project.

REFERENCES

(1) Corps of Engineers, July 1994. *James River Basin Drought Preparedness Study*, Final Report.

(2) Corps of Engineers, December 1984. *Water Supply Study, Hampton Roads, Virginia.*

(3) Virginia State Water Control Board, March 1988. *James Water Supply Plan.*

(4) Department of Environmental Quality-Water Division, Tidewater Regional Office, July 1993. *Hampton Roads Water Supply Update. Part II: Southeastern Division.*

(5) Maidment, David R., ed, 1993. *Handbook of Hydrology.* McGraw-Hill, New York, pp. 27.7 to 27.8.

(6) Virginia State Water Control Board, 1985. *Safe Yield of Municipal Surface Water Supply Systems in Virginia (Planning Bulletin No. 335).* Commonwealth of Virginia, Richmond, pp. iii and v.

(7) Moreau, David H., November 5, 1987. Comments on Extent of Need for an Additional Water Supply for Virginia Beach.

(8) Maguire Associates, Inc., June 26, 1992. Comments on Boyle Report. Correspondence with Thomas Leahy.

(9) Boyle Engineering Corporation, June 1992. *Analysis of Alternative Water Supplies for Virginia Beach. Prepared for the State of North Carolina.*

(10) Daniel B. Horne, P.E., September 28, 1993. Inter-Office Correspondence with Allen R. Hammer, P.E. Virginia State Department of Health.

(11) Malcolm Pirnie, Inc., August, 1994. Conjunctive Use Alternative Report, Virginia Beach.

(12) Amar Dwarkanath, August 26, 1993. Memorandum to Claude Wright, City of Chesapeake.

(13) Virginia Employment Commission. *Virginia Population Projections 2010.* June, 1993.

(14) Hampton Roads Chamber of Commerce, December 1993. *Plan 2007, Work in Progress.*

(15) Tolson, Donna J., 12/8/94. Weldon Cooper Center for Public Service, University of Virginia. Telephone conversation with Mark Broadwell, NC Division of Water Resources.

(16) White, Stephen, December 7, 1994. Planning Dept., City of Virginia Beach. Telephone conversation with Mark Broadwell, NC Division of Water Resources.

(17) Pett, Jeleah, December 7, 1994. Planning Dept., City of Chesapeake. Telephone conversation with Mark Broadwell, NC Division of Water Resources.

(18) Virginia Beach, 1994. *The Comprehensive Plan.* Virginia Beach, Virginia, pp II-A-3.

(19) Malcolm Pirnie, Inc., February 1991. *FERC Application for Project No. 2009, Exhibit 8, Description of Public Need and Benefit*; prepared for the City of Virginia Beach, Dept. of Public Utilities.

(20) BOCA (Building Officials and Code Administration), 1987. BOCA National Plumbing Code, 1987 Edition.

(21) Britt, Emory,12/20/94. Chief Plumbing Inspector, Department of Code and Compliance, City of NewPort News. Telephone conversation

(22) Frank, Joe, July 20, 1994. Hampton Roads Planning District Commisssion. Testimony before FERC public hearing, Virginia Beach.

(23) Leahy, Tom, July 20, 1994. Virginia Beach Dept. of Public Utilities. Testimony before FERC public hearing, Virginia Beach.

(24) BOCA (Building Officials and Code Administration), 1993. BOCA National Plumbing Code, 1993 Edition.

(25) Hampton Roads Planning District Commission, February 1993. *Hampton Roads 2015 Economic Forecast.*

(26) Konen , Thomas P., Srinivasan Pongavanam, and R. Bruce Martin, 1993. "Low Flush Plumbing Fixtures and Wastewater Systems" in Hon, Katherine (32).

(27) Mulville-Friel, Diane, Damann L. Anderson, and Wendy L. Nero, 1993. "The Impact of Water Conserving Fixtures on Residential Water Use Characteristics in Tampa, Florida" in ASCE (31).

(28) Nero, Wendy L., Diane Mulville-Friel, and Damann L. Anderson, 1993. "The Impact of Water Conserving Plumbing Fixtures on Institutional and Multi-Family Water Use: Case Studies of Two Sites in Tampa, Florida" in ASCE (31).

(29) Perkins, Craig and Susan Munves, 1993. "The Water and Waste Water Savings Achieved by Ultra Low Flush Toilets in Santa Monica, California" in Hon, Katherine (32).

(30) Tarquin, Anthony J., John T. Sutton, Peter Chan, and Srinivasa Vagwala, 1993. "Effectiveness of an Ultra-Low-Flush Toilet Program" in ASCE (31).

(31) ASCE (American Society of Civil Engineers), December 12-16, 1993. *Proceedings of Conserv 93 - The New Water Agenda.* Las Vegas, Nevada.

(32) Hon, Katherine, ed., 1993. *Water Management in the '90s.* Conference proceedings, Seattle, Washington, May 1-5, 1993.

(33) Spence, Betty, August 15, 1994. National Wildlife Federation. Letter to Lois D. Cashell, Secretary, Federal Energy Regulatory Commission.

(34) Leahy, Tom, October 27, 1994. Virginia Department of Public Utilities Testimony before Virginia Corporation Commission.

(35) Little, Keith, et al., July 1986. Research Triangle Institute. *A Yield Analysis of the Surface Water Supply System Serving Southside Hampton Roads, Virginia.*

(36) Federal Energy Regulatory Commission. January 1995. *Draft Environmental Impact Statement, Nonproject Use of Project Lands and Water for the City of Virginia Beach Water Supply Project, Brunswick County, Virginia.*

(37) Chansler, James M. and V.J. Pujals, 1993. "Water Conservation- One City's Approach." In: ASCE (31) *Proceedings of Conserv93: The New Water Agenda*, December 12-16, 1993. pp 1373-1387.

(38) Durand, Roger, R.C. Allison, and J. Durand, 1994. "Effectiveness of Retrofit in Multi-Family Apartments." In: ASCE, *Water Policy and Management: Solving the Problems.* Proceedings of the 21st Annual Conference, ASCE.

(39) Ernst and Young, 1992. *1992 Water and Wastewater Rate Survey.* 45 pp.

(40) Ferguson, Bill and A. Whitney, 1993. "Demand Reduction in Response to Drought: The City of Santa Barbara Experience. In: ASCE (31),*Proceedings of Conserv93: The New Water Agenda*, December 12-16, 1993. pp 429-439.

(41) Giardina, R.D., 1992. "State of the Cost in Rate Setting: Results of the 1990 National Water Rate Survey. In: ASCE (31),*Proceedings of Conserv90.* American Water Works Association, Denver, Colorado. pp 1035-1036.

(42) Hampton Roads Planning District Commission, October 1994. *Water Conservation Plan for the Hampton Roads Region.*

(43) Hasson, David A., 1993. "Selecting a Conservation Rate Structure." In: ASCE (31),*Proceedings of Conserv93: The New Water Agenda*, December 12-16, 1993. pp 629-655.

(44) Jordan, Jeffrey L., 1994. " The Effectiveness of Pricing as a Stand-Alone Water Conservation Program." *Water Resources Bulletin*, American Water Resources Association. Vol 30, No. 5. October 1994. pp 871-877.

(45) Jordan, Jeffrey L., 1993. "Water Pricing in Georgia." In: Proceedings of the 1993 Georgia Water Resources Conference. University of Georgia, Athens, Ga. pp 153-156.

(46) Metropolitan Water District of Orange County, 1994. Memo from Intergovernmental Relations Committee, December 21, 1994.

(47) McKinley, J. Rowe, 1983. "Financing Water Utility Improvements." American Water Works Association Journal, September 1983. p 455.

(48) Nesbit, John, January 9-10, 1995. Director of Public Works, Wrightsville Beach. Personal communication with Woody Yonts, NC Division of Water Resources.

(49) Peart, Larry A. and K.D. Warner, 1993. "Tucson's Rate Structure Changes Designed to Strengthen Pricing Incentives." In: ASCE (31), *Proceedings of Conserv 93: The New Water Agenda*, December 12-16, 1993. pp 655-673.

(50) Raftelis, George A. 1993. "Comprehensive Guide to Water and Wastewater Finance and Pricing." Lewis Publishers. pp 73-230.

(51) Scholze, Richard J. Jr. 1993. "Investigation of Water Conserving Toilet Retrofit Devices." In: ASCE (31), *Proceedings of Conserv93: The New Water Agenda*, December 12-16, 1993.

(52) Meeker, Thomas H. July 2, 1994. President and CEO, Churchill Downs. Letter to the Editor, *Virginian Pilot*, July 12, 1994.

(53) Hankinson, John H., Jr. and Peter H. Kostmayer. August 12, 1994. Letter to Lois D. Cashell, Secretary, FERC.

(54) McClory, Sue. 1995. "Water Recycling." *Western Water*, January/February, 1995.

(55) City of Chesapeake. March 1994. "Attachment F., Evaluation of Other Water Sources, Revision 1." Submittal to Virginia Department of Environmental Quality.

(56) U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System. 1992. *BEA Regional Projections to 2040, North Carolina and Virginia Counties*. Washington, D.C.

(57) *Virginian-Pilot*. 1995. "U.S. Housing Trend Bypasses Region." January 21, 1995.

(58) *Virginian-Pilot*. 1994. "Chesapeake Uses Well Water Reserves to Cut Chloride Levels." November 9, 1994.

(59) Behling, Patrick J. and Nicholas J. Bartilucci. 1992. "Potential Iimpact of Water-Efficient Plumbing Fixtures on Office Water Consumption." *Journal of American Water Works Association*, October 1992.

(60) Vickers, Amy. 1989. "New Massachusetts Toilet Standard Sets Water Conservation Precedent." *Journal of American Water Works Association*, March, 1989.

(61) Virginia Beach. March 19, 1992. Submittal to U.S. Department of Commerce, Volume 1, Tab 6.

(62) Schmidt, Peter W. August 18, 1994. Virginia Department of Environmental Quality. Letter to Secretary, FERC.

(63) Metropolitan Water District of Southern California. "Our Committment to Water Conservation."

(64) *Virginian Pilot*. 1995. "Irrigation Plan Would Recycle Wastewater." August 9, 1994.

(65) *Virginian Pilot*. 1994. "$291,000 Flows From Norfolk to Virginia Beach". December 31, 1994.

(66) Sheer, Daniel P. 1985. "Managing Water Supplies to Increase Water Availability." *National Water Summary 1985*.

(67) *Virginian-Pilot*. 1995. "Chesapeake Experience Has Prepared Butt for National Role." February 3, 1995.