DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER AND SEWER
HARFORD COUNTY MARYLAND

DRAFT REPORT

FIRST ZONE WATER SYSTEM EVALUATION AND RECOMMENDATIONS

OPEN-END CONTRACT 04-139

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IN ASSOCIATION WITH
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SECTION I

EXECUTIVE SUMMARY

Project Purpose

The purpose of this study is to verify Harford County's Capital Improvement Plan for the First Zone Water Distribution System, and identify and recommend for implementation those First Zone Water system improvements which are required to supply the incremental demands resulting from the proposed Base Relocation and Closure (BRAC) Program. In addition, this study and evaluation is to provide an estimate of incremental capital cost expenditures required to implement the recommended Capital Improvement Program identified as needed to meet the BRAC water supply requirements.

Projected Water Demands

Based on its Master Plan the County has projected population growth within the County through 2025, and water demands expected to be generated by this growth over the same period. The County's central water system is divided into four pressure zones which form water service area boundaries. The total maximum day demands for Zones 1, 2, 3 and 4 for combined residential/commercial and industrial users are projected to be 25.7 mgd in 2010, 28.0 million gallons per day (mgd) in 2015, and 38.3 mgd in 2025.

The First Zone water distribution system average day demands are projected to increase from 11.3 mgd in 2010 to 16.8 in 2025. Maximum day demands are expected to increase from 15.5 mgd in 2010 to 23.4 mgd in 2025. Projected demands related to the BRAC Program for the Aberdeen and Edgewood areas of the Aberdeen Proving Grounds (APG) will be supplied through the First Zone distribution system. The demands from the APG are

expected to be either 8.5 mgd or 4.0 mgd phased in over the period of 2010 through 2020. With a BRAC Program demand of 8.5 mgd the total First Zone average day and maximum day demands will increase from 19.8 mgd and 25.3 mgd, respectively in 2010 to 24.0 mgd average day and 31.9 mgd maximum day demands. At the lower BRAC demand of 4.0 mgd, the total average and maximum day demands within the First Zone will be 15.3 mgd and 20.8 mgd respectively in 2010, and increase to 19.5 mgd average day and 27.4 mgd maximum day demands in 2025.

Harford County Capital Improvement Plan

The County's computer hydraulic model of the First Zone water distribution system was used to evaluate the proposed Capital Improvement Plan (CIP) and phased staging. Water distribution system design parameters developed by the County were used with the projected non-BRAC average and maximum demands to evaluate the hydraulic performance of the system. Based on this evaluation the County's CIP and staging were verified. Additional capital improvements were recommended for implementation in 2010, 2015 and 2020 to improve the system's hydraulic performance. Cost estimates were developed for implementing the recommended water conveyance and storage improvements. The estimated project costs for the improvements recommended for 2010 are $23,474,600; for 2015 the estimated costs are $16,645,900; and for 2020 the estimated costs are $44,273,900. These costs do not include costs for expansion of the Abingdon Water Treatment Plant (WTP).

Additional Sources of Water Supply

The identification of additional facilities required to supply increased water demands includes consideration of sources of supply, treatment and finished water conveyance. An evaluation was made of two different alternatives to increase the County's water supply for the additional demands anticipated as a

result of the BRAC expansion of the Aberdeen and Edgewood APG facilities. The source and treatment alternatives that were evaluated included an additional allocation from the Susquehanna River through the City of Baltimore's Big Inch transmission main, with treatment provided by an expansion of the County's existing Abingdon WTP. The second alternative involved construction of a desalination WTP and withdrawal of brackish water from the Bush River through a surface water intake located near Church Creek. A conceptual design of the proposed desalination WTP was developed with conceptual project cost estimates and operation and maintenance costs were developed for a 20 mgd plant. For the alternative utilizing the Big Inch (Abingdon Supply) as a source, estimates were made of the project costs and operation and maintenance costs of an expansion of the Abingdon WTP from 20 mgd to 40 mgd. The two alternatives were evaluated using a range of criteria and recommendations were made to the County on the two alternatives. Present worth analyses taken together with an evaluation of other considerations such as environmental issues, land acquisition, constructability, and permitting issues suggest that Alternatives 1A and 1B, using the Abingdon Supply as the source, are the alternatives of choice.

Additional Conveyance Facilities Required for BRAC

An evaluation was made of the First Zone distribution system using the County's hydraulic model of the system to identify the incremental transmission or conveyance improvements to the system that would be required to meet the projected BRAC demands of 8.5 mgd and 4.0 mgd. The improvements that were identified included additional water transmission mains and upgrading of existing mains in order to convey the required BRAC demands to the Aberdeen and Edgewood APG areas. An analysis of incremental project costs of conveyance facilities to meet BRAC demands indicates that the cost of incremental conveyance improvements will be significantly higher for the desalination supply than those incremental costs associated with the Abingdon Supply.

Recommendations

In summary, two alternatives have been evaluated within the First Zone with regard to both development of water sources and conveying the finished water from these sources to the APG Aberdeen and APG Edgewood areas to meet demands from anticipated BRAC program activities program and at the same time satisfy the County's ultimate demands. Alternative 1 (Alternatives 1A or 1B) is the alternative of choice, especially from a cost consideration standpoint.

The total project cost for Alternatives 1A and !B ranges from $142 to $165 million depending upon the magnitude of the BRAC demands. A preliminary determination of project cost allocations for Alternatives 1A and 1B providing ultimate water demands of either 8.5 MGD or 4.0 MGD to the APG facilities as part of the BRAC Program suggests that $64 million be attributed to BRAC for Alternative 1A and $25 million for Alternative 1B. This tentative allocation does not consider the operation and maintenance costs, water source fees payable to Baltimore City, and potential consumptive use fees.

SECTION II

INTRODUCTION

A. Background and Understanding

Harford County is one of the most rapidly developing counties in the Baltimore Metropolitan region. As a result of its planned future development, Harford County estimates that its population will grow nearly 21% from its 2005 population of 235,000 to over 280,000 by 2025. These population estimates and projections, which have been developed by the County's Department of Planning and Zoning, are included in the County's *2004 Master Plan and Land Use Element Plan*, and its *Water and Sewer Master Plan (WSMP)* revised in October 2005. The guiding element of these plans is to focus new growth within an established "development envelope" so that it is consistent with the long-standing policies, goals and objectives of the County's planning efforts.

The orderly development of the County's public water supply system is controlled through the County's *Water and Sewer Master Plan* and the County's *Capital Budget and Five Year Capital Improvement Program (CIP).* The *WSMP* outlines phased improvements to its water supply system required to satisfy existing and future development and undergoes extensive review and public participation leading to formal adoption by the County Council, and approval by the State of Maryland. The *Capital Budget and Five Year Capital Improvement Program* lists specific improvements in water mains, pumping stations, storage tanks and water treatment plants that are required to meet future demands. These improvements are phased-in over time to ensure that adequate facilities for water supply and other services are maintained.

In anticipation of receiving a request from the Federal Government to provide additional water to support the proposed growth at the Aberdeen Proving Grounds (APG) resulting from the Military 2005 Base Realignment and Closure (BRAC) program, Harford County wishes to determine those improvements to the County's water system that may be required to accommodate the additional BRAC-associated water demands at the APG. For purposes of this study and evaluation, it is judged that that the additional demand precipitated by the BRAC program will occur in the First Zone of the County's system where the APG is located. It is anticipated that either 8.5 million gallons per day (mgd) will be required through County water system interconnections to supply Aberdeen APG and Edgewood APG with 4.5 mgd and 4.0 mgd, respectively or 4.0 mgd will be required to supply Edgewood APG alone.

B. Purpose

The purpose of this study, which is referred to as the "*First Zone Water System Evaluation and Recommendations"*, is to identify and recommend for implementation those First Zone Water system improvements which are required to supply the incremental demands resulting from the proposed BRAC program. In addition, this study and evaluation is to provide an estimate of incremental capital cost expenditures required to implement the recommended Capital Improvement Program identified to meet the BRAC water supply requirements.

C. Scope

To accomplish the ultimate purpose or objective of this study, the project scope has been subdivided into four major work elements or tasks. The four tasks taken together are intended to provide the County with an

evaluation of its current First Zone distribution system CIP to meet water demands for the design years 2010, 2015 and 2025, and to determine additional source, treatment, storage, pumping and distribution piping required to meet the projected on-base demands at both the APG Aberdeen and APG Edgewood areas resulting from the BRAC program.

The individual four tasks are identified as follows :

1. Evaluate Harford County's current hydraulic model and CIP, and recommend any additional modifications to the current CIP that may be required to meet projected demands from future planned development in the First Zone exclusive of the BRAC program.

2. Evaluate potential sources of water supply for meeting the projected demands from the BRAC Program and make recommendations. The two supply sources to be evaluated are the withdrawal of additional water from the City of Baltimore's Big-Inch transmission main, which draws water either from Loch Raven Reservoir or the Susquehanna River, and the development of a desalination water treatment facility that would be supplied by the Chesapeake Bay or its tributaries.

3. Employing the results from Tasks 1 and 2, identify and determine those additional capital improvements required to the First Zone water treatment, pumping and transmissions mains to enable it to supply water to meet the needs of the APG Aberdeen and APG Edgewood area BRAC program.

4. Provide a written report of Tasks 1, 2 and 3 that documents all aspects of the project including estimated costs of the alternatives and recommended capital improvements.

SECTION III
EXISTING WATER SYSTEM

A. General

The central water supply system serving Harford County is operated by the Department of Public Works, Division of Water and Sewer. The system serves an area encompassing approximately 30 square miles, generally outside of the limits of the three incorporated towns and cities. Because of varying topography, the County's system is divided into four pressure zones which form service area boundaries. Figure III-1 depicts the First Zone and the combined areas of the Second, Third and Fourth Zones. As indicated in the figure, the First Zone is divided into two primary sub-zones, 1A and 1B, and five smaller sub-zones described subsequently in Subsection B. A hydraulic diagram of the system is included in Figure III-2. This diagram shows the major facilities, both existing and proposed, and their orientation with respect to the various pressure zones. Overflow elevations of storage tanks range from 233 feet above msl in the First Zone and to 587 feet above msl in the Fourth Zone.

The water supply for the four pressure zones is obtained from three sources and treated at three water treatment plants --- Abingdon WTP, Havre de Grace WTP, and Perryman WTP. Currently, the primary source for the largest treatment plant, the Abingdon Water Treatment Plant (WTP), is the Loch Raven Reservoir through a major transmission main owned by Baltimore City. This supply flows by gravity from the Loch Raven Reservoir, however, during drought conditions water from the Susquehanna River is pumped by the Deer Creek Raw Water Pumping Station through the 108-inch Susquehanna Transmission Main (Big-Inch) to Baltimore City and the Abingdon WTP. The plant provides water to all

four pressure zones and in the future will be the sole source of supply for the Second, Third and Fourth Zones. This plant provides complete surface water treatment with coagulation, flocculation and filtration.

The Harford County Havre de Grace WTP also uses the Susquehanna River as a source, but withdraws water through an intake located at the plant near the River's confluence with the Chesapeake Bay. This plant provides complete surface water treatment. The County also purchases finished water from the City of Havre de Grace through an interconnection with the City's adjacent water treatment plant.

The Perryman WTP uses a well field comprised of seven deep wells drawing ground water from the Quaternary Deposits of the Atlantic Coastal Plain. In the future, both the Harford County Havre de Grace and Perryman Plants will supply water exclusively to the First Zone.

The County also maintains distribution system interconnections with the City of Aberdeen, the Town of Bel Air, the Aberdeen APG, and the Edgewood area of APG.

In addition to providing a water supply for domestic consumption and fire fighting to its expanding population, the County is responsible for maintaining the quality of water in the distribution system. As a result, while planning for improvements to the system to meet future demands, the County must also consider the effects of these improvements and their operation on distribution system water quality.

B. First Zone System

The First Zone system is the largest of the four pressure zones and serves the largest portion of the County's population. In addition to

pumping facilities at Abingdon, Havre de Grace, and Perryman Plants, the First Zone includes three elevated tanks, one ground water storage tank, and one standpipe, together with several booster stations. Two additional elevated tanks, the Trimble and Swan Creek tanks are planned to be constructed in the near future. Details of the characteristics of each storage facility including each tank's usable storage volume are provided in Table III-1.

As indicated previously, the First Zone is subdivided into Sub-zones 1A and 1B, and five smaller sub-zones. The smaller sub-zones are Sub-zone 1C (Magnolia Booster Station), Sub-zone 1D (Oak Grove subdivision Booster Station), Sub-zone 1E (Woodlawn subdivision Booster Station/MCI area), Sub-zone 1F (Carter Property Booster Station for the City of Aberdeen), and Sub-zone 1G (West Aberdeen area Booster Station for the Aberdeen APG). The zone separation between Zones 1A and 1B is accomplished by division valves at two locations, the 16-inch main near Pulaski Highway and Philadelphia Road, and the 12-inch valve at Old Philadelphia Road, approximately 2,000 feet NE of Perryman Road. Figure III-1 shows the First Zone and the areas served by the various sub-zones, with the exception for Sub-zones 1F and 1G. The geographical limits of these latter two sub-zones have not yet been defined.

SECTION IV
DESIGN PARAMETERS

As described earlier, Harford County's topography dictates that the water distribution system be divided into four pressure zones. While the scope of this water system evaluation is limited to the First Zone where the Aberdeen and Edgewood APG facilities are located, and where the majority of the increase in water demand is expected to occur through 2025, it is important to recognize that significant growth in water demands is also likely to occur in Zones 2, 3 and 4 during the 2005 to 2025 design period. These demands, which will be met solely by the Abingdon Water Treatment Plant, must of necessity be taken into account when addressing the planning requirements for the First Zone.

A. Projected First Zone Service Population

In its master plan for water distribution, Harford County projects that nearly 24,000 or 46% of the 51,000 new housing units to be built in the County between 2005 and 2025 with public water service will be served by the First Zone. Population projections for the First Zone indicate an increase from 47,565 in 2000 to approximately 92,000 in 2025.

B. Projected First Zone Water Requirements

Table IV-1 summarizes the projected First Zone average day and maximum day demands used in the County's hydraulic model for the period 2005 through 2025. The average and maximum day design demands for the Year 2005 are 10.3 mgd and 14.0 mgd, respectively. The demands projected to occur in 2025 are 16.8 mgd average day and 23.4 mgd for maximum day. These demands were developed in previous work by the County. It should be noted that these demands include the current design demands for the APG at the existing Chapel Hill and

Edgewood interconnections with the County's system, but exclude the increased demands required to support the proposed growth at the APG resulting from the BRAC program.

C. Projected Combined Second, Third and Fourth Zone Water Requirements

The Year 2005 average and maximum day demands for the combined Second, Third and Fourth Zones are 6.0 mgd and 9.4 mgd, respectively. By the Year 2025, these demands are projected to increase to 10.3.mgd and 14.9 mgd for average and maximum day design conditions.

D. Total Harford County System Demands

Table IV-2 summarizes the projected total Harford County system demands for average day and maximum day demands. The Year 2005 average and maximum day demands for Harford County (combined First, Second, Third and Fourth Zones) are 14.3 mgd and 15.9 mgd, respectively. By the Year 2025, these demands are projected to increase to 27.0.mgd and 38.3 mgd for average and maximum day design conditions.

E. Total Harford County System Demands Including BRAC

The total Harford County average day demands for Zones 1, 2, 3 and 4 for combined residential/commercial and industrial users are 25.74 mgd for 2010, 27.97 mgd for 2015, and 38.26 mgd for 2025. The phasing of the BRAC demands, 4.5 mgd to the Aberdeen APG and 4.0 mgd to the Edgewood APG, or 4.0 mgd to Edgewood APG alone is expected to follow the schedule below:

1. Aberdeen APG
   a. Initially 1.5 mgd in 2010
   b. 3.0 mgd with 0.3 mgd increments added each year from 2010 through 2020

2. Edgewood APG
   a. Initially 2.0 mgd in 2010
   b. 2.0 mgd with 0.2 mgd increments added each year from 2010 through 2020

With the additional BRAC demands the total Harford County demands will be 29.2 mgd for 2010, 34.0 mgd for 2015, and 46.8 mgd for 2025 if 8.5 mgd is required to Aberdeen and Edgewood APG areas. If only the Edgewood APG requires 4.0 mgd, the total demands for the County will be 27.7 mgd for 2010, 31.0 mgd for 2015, and 42.3 mgd for 2025.

F. Other Design Parameters

1. Harford County Design Standards

The primary criterion for evaluating the County's water distribution system is its capacity to meet the demands placed on it, i.e., maintaining adequate flow and pressure to all users at all times. Demands taken into account when evaluating system hydraulics include average day, maximum day, peak hourly demands, and fire flow demands. For this evaluation the County established general standards for minimum and maximum system pressure, flow velocity and fire flow criteria that are discussed below. These design standards are included in Table IV-3. Where

appropriate these standards were included in the hydraulic model so that areas of the distribution system that do not meet the general standards can be identified, and the necessary modifications to the system or its operation can be made in order to satisfy the standards over the range of demands modeled from 2010 to 2025.

As requested by the County, the pressures used to evaluate the maximum day demand model range from a minimum of 28 pounds per square inch (psi) to 120 psi during average and maximum day demand conditions at the customer's curb-stop. During fire flow events the minimum pressure at the curb-stop is 20 psi. In a typical water distribution system, pressures normally range from 40 psi to 80 psi on an average day basis. If pressures exceed 80 psi, the County's plumbing code as well as other codes including the Uniform Plumbing Code requires that pressure reducing devices be provided on the affected customer's service line. In general, pressures that are higher than 80 psi are undesirable because they can result in wasted water through leaks, wasted energy, and excessive main breaks. Pressures lower than 20 psi can interrupt service to fixtures above the first floor and potentially allow contaminants to enter the water supply through illegal cross connections.

In addition to these minimum and maximum water pressure standards, the County also specified that water velocity in the distribution system's pipelines generally be 6 feet per second (fps) or less. This criterion was established to limit the friction loss in pipelines which occurs with higher velocities.

The County also developed general design guidelines for the First Zone Water System Evaluation concerning locations of

pipelines within rights-of-way, preferred criteria for siting proposed storage tanks and selection of pumping equipment for compatibility with the County's existing mechanical equipment. These guidelines are provided in Table IV-4.

2. Pumping Facility Capacity Requirements

"Safe" pumping capacity of a given pumping station is defined as the total pumping capacity of the facility assuming the largest pump is out of operation. Pumping station capacity requirements are sized to meet the maximum day demands.

3. Storage Capacity Requirements

Distribution system storage facilities normally provide both equalization storage and fire flow storage for the system's users. Water treatment plants and pumping stations normally deliver water to the distribution system at a fairly constant rate during the day. However, water consumption rates and usage patterns in a service area vary during the day depending on the level and type of water consumption activities of the population being served. The distribution system's equalization storage allows it to meet the peak hourly demands that exceed the pumping and water treatment plant outputs. When the system demands fall below the pumping and treatment plant outputs, the equalization storage is replenished until storage tank levels return to the tank overflow elevation. Required equalization storage typically ranges from 15 to 30 percent of the maximum day demand depending upon the mix of residential, commercial and industrial development.

An analysis of the First Zone Hydraulic Model Diurnal Pattern Factors for Years 2005 through 2025 indicates that, the equalization storage for the First Zone should be a minimum of 14 percent of the maximum day demand. For planning purposes, the criteria for equalization storage has been set at 20 percent of maximum day demands for this evaluation.

4. System-Specific Fire Flow Criteria

In addition to equalization storage for meeting the normal diurnal demand, storage for fire fighting must also be provided. Required fire flow storage capacity is normally based on one or more fixed fire flow rates and fire durations. The Insurance Services Organization and American Water Works Association establish criteria for fire fighting capacity of water systems based on the number and type of structures served by the system. Under these criteria the system's storage and pumping facilities must be capable of supplying the additional water demand for fire-fighting, and the piping system must have the necessary capacity to deliver the fire flow to the fire location while maintaining a minimum residual pressure at all points in the distribution system. When pumping facilities are used in addition to storage in meeting fire flow demands, the largest pump in the pumping facility is assumed to be out of service.

As stated above the County's design standard for minimum residual system pressure during a fire event coincident with maximum day demand conditions is 20 psi or greater. The County specified that the analyses of the distribution system for this water distribution system evaluation utilize the fire flow rates and fire flow withdrawal locations listed in Table IV-5. Figure IV-1 identifies the

locations of the various fire demand locations used in the model. Further, the County specified that two-hour fire duration be used for the system fire flow evaluation simulations. The County also specified that no simultaneous fireflow analyses were required.

5. Head Loss Gradients for Water Transmission Mains

Another general indicator of the adequacy of a distribution system is the head loss gradient in the system's mains. Head loss in a pipe is caused by energy dissipation due to frictional or surface resistance of the pipe's inner wall to the passage of water through the pipe. The head loss gradient in a pipe is usually measured in feet of head loss for 1,000 feet of pipe length. High head loss gradients will reduce the flow efficiency in pipelines with resultant increases in pumping costs. For these reasons it is prudent to design water transmission or conveyance systems in a manner that minimizes head losses. For hydraulic modeling purposes, head loss gradients greater than 2 to 3 feet per 1,000 feet are generally considered excessive when evaluating water transmission main capabilities.

SECTION V

ANALYSIS OF COUNTY'S PROPOSED PHASED CAPITAL IMPROVEMENT PLAN

A. General

The initial task of this evaluation of the First Zone water distribution system was to identify the capital and operational improvements necessary to meet the projected future demands on the system through 2025 *"without"* BRAC demands. To assist in this effort the County's computer hydraulic model was used to confirm the County's proposed CIP and phased staging, identify any additional hydraulic deficiencies in the system under the anticipated future conditions, and determine and recommend system improvements to remedy those deficiencies. In order to ensure that the recommended improvements do not result in unsatisfactory water quality, water quality analyses were also conducted.

In addition to confirming the County's CIP, simulations of various operating scenarios were performed with different combinations of the three WTPs in operation. These simulations included the County's Abingdon, Perryman and Havre de Grace WTPs. Simulations with fireflows at selected locations in the system were also performed. Each of the operating scenario simulations were conducted for average day and maximum day demand conditions for the 5-year periods beginning in 2010 and running through 2025. Fireflow simulations were performed under maximum day demand conditions, again for the 5-year periods beginning in 2010 and running through 2025.

Certain design parameters were employed as criteria for identifying hydraulic deficiencies in the system under the various scenarios and fireflow conditions. These criteria, described in Section III, included

minimum pressures, maximum headloss gradients and velocity, and operating parameters including storage tank level fluctuations, maximum tank level drawdown and refilling time, pumping cycles, and WTP operating cycles. Pumping and storage analyses were also conducted to identify any deficiencies in the planned storage and pumping facilities.

The following includes descriptions of the hydraulic and water quality models used to evaluate the distribution system and the recommended improvements. Also discussed are the scenarios and fireflow simulations that were evaluated. Water quality simulations that were used to evaluate the recommended improvements are described. Finally, recommended piping, storage and pumping improvements needed to achieve the County's goals of a balanced system which meets the design parameters are described with their estimated costs and year of implementation. A comparison of the County's proposed CIP and the recommended CIP is also provided.

B. Hydraulic Modeling

1. Model Descriptions

a. County's Base Model

The First Zone water distribution system hydraulic model used for the evaluation was developed in 2006 by Harford County using EPANET hydraulic modeling software. EPANET is a water system simulation model developed by the USEPA for water utilities and consultants. It performs steady-state and extended period simulations for networks of junctions, pipes, pumps, valves, and storage structures,

calculating flow of water, pressures, tank elevations, concentration of chemical species, and water age using detailed system-specific design and operation data inputs. In constructing its base distribution system model in EPANET the County used as-built construction drawings of its existing facilities, and conducted field tests of major transmission mains to evaluate their hydraulic flow characteristics. Calibration of the model was conducted using actual pressure, flow and storage tank elevation data collected in the field at various locations in the distribution system. Demands based on water meter locations and billing addresses were assigned to all model demand nodes.

b. Updated/Modified Model

The County conducted an evaluation of its entire water distribution system using its EPANET model in 2006. As a part of this effort the County developed a long range CIP for the First Zone, which identified capital improvements that would be required to be made to the system to enable it to meet the projected demands for growth within the First Zone development envelope through 2025. The physical improvements in the distribution system identified in the County's CIP were incorporated into the base model.

The County recently initiated planning and design for several new projects at the Abingdon WTP that affect the First Zone distribution system performance but are not yet part of the CIP developed in 2006, and were not included in the County's 2006 model. These improvements include a new 48-inch connection to the 108-inch Susquehanna River

raw water main, and two phases of expansion of the clearwell, finished water piping and pumps at the Abingdon plant. Also included in this project is a new 36-inch parallel transmission main from the Abingdon plant to feed the First Zone system. To ascertain an accurate reflection of the system's configuration as planned by the County through 2010, the base model was updated to include these improvements. The improvements were timed in the updated model to come on line in the following three phases:

1) 2007 to 2010
2) 2010 to 2015
3) 2015 to 2020

Following the development of the distribution system model in EPANET by the County, this base model information was converted to WaterCAD. WaterCAD is a software package similar to EPANET but with enhanced capabilities. Files can be transferred between the two software programs. WaterCAD was used to conduct the modeling scenarios for the First Zone system both *"without"* and "w*ith"* the BRAC demands. The hydraulic analyses *"with"* BRAC demands are discussed in Section VII.

The various sub-zones comprising the First Zone system are described in Section III and depicted in Figure III-1. In the WaterCAD and EPANET models, Sub-zones 1A and 1B were modeled as separate sub-zones except for scenarios where either the Perryman or Havre de Grace WTPs was out of service. Sub-zones C, D and E demands were modeled as parts of Sub-zone IB. Sub-zones F & G

were modeled as point demands in Sub-zone IA. These sub-zones represent interconnections with the City of Aberdeen (Sub-zone F) and the Aberdeen APG (Sub-zone G).

2. Model Scenarios

As described in Section III, the First Zone is supplied with finished water from the Abingdon, Havre de Grace and Perryman water treatment plants. One of the County's objectives in this study was to evaluate the effects of operating the system with either the Havre de Grace or the Perryman plants out of service for an extended time period. To accomplish this objective, the hydraulic model simulations were conducted using the following three operating conditions:

- All three water treatment plants are in operation
- The Abingdon and Perryman WTPs are in operation and the Havre de Grace WTP is taken out of service for an extended time period. During this period of time the Abingdon WTP operates at a rate necessary to make-up the water supply deficit.
- The Abingdon and Havre de Grace WTPs are in operation and the Perryman WTP is taken out of service for an extended time period. During this period of time the Abingdon WTP operates at a rate necessary to make-up the water supply deficit.

These simulations were made for the projected average day and maximum day demands for 2010, 2015 and 2025 for Sub-zones 1A and 1B. In order to assess the performance of the

system under fireflow demands, simulations were also performed using the designated fire demand locations shown in the previous section on Figure IV-1 and in Table IV-4 under maximum day demand conditions. Typically, the fireflow events were simulated during the 9 AM to 11 AM period, which was determined to be a period during which demands approximate the average of the flow over a 24-hour maximum day demand period. In accordance with the County's request, analyses were not made of combinations of two simultaneous fireflow events.

Over one hundred models using the updated/modified distribution system configuration were developed representing the various design years, WTP operating scenarios and fireflow conditions. The models were used to identify hydraulic modifications required in the two sub-zones, 1A and 1B, based on the design and operating parameters described earlier in Section IV. Typical modifications involved adding parallel mains to existing transmission mains exhibiting lower than desired pressure, or velocities, or head loss gradients exceeding the design standards. Other modifications to the modeled systems included increasing the size of planned transmission main improvements, or changes in pumping schedules to increase or decrease flow rates. Iterations of the model were performed with successive improvements to the piping system until the simulated hydraulic system successfully achieved compliance with the design and operating criteria.

The models allowed storage tank levels to be observed to determine if they fluctuated within a range that ensured that sufficient turn-over occurred to prevent the development of extended water age conditions that could result in water quality problems during typical average day demand conditions. Also

used as indicators of storage tank performance were excessive tank draw-down levels and time required to re-fill tanks after being drawn down to meet maximum day demands. These same conditions were observed during simulated fire flows.

3. Hydraulic Model Results

Successive model runs were made under the various conditions and design years discussed above until each run produced results that satisfied the design parameters and maintained a balanced distribution system. The only exceptions occurred in areas where lower pressures were observed; typically, these areas were generally beyond the normal design service limits of the system by their ground elevation relative to the system's hydraulic grade line. The results of the modeling showed that additional capital improvements beyond those identified in the County's CIP were required to be made during the design periods in order to satisfy design parameters under all of the conditions that were evaluated. These improvements are listed below and depicted in Figure V-1:

a. Year 2010 Additions and Upgrades

Upgrades are required to the existing Abingdon Road transmission main to enable demands in the 2010 to 2015 period to be met. These upgrades involve larger diameter replacement mains for smaller existing mains and parallel mains.

In addition to these upgrades, the 1-MG Swan Harbor elevated tank and transmission main will need to be

constructed sooner than anticipated in order to provide sufficient storage for fireflow conditions. This tank was proposed in the County's CIP to be constructed in 2015. The schedule for construction of the 1-MG Swan Harbor elevated tank will need to be accelerated, moving it from the 2015 plan to the 2010 plan. The recommended 20,400 lf parallel 16-inch Route 40 transmission main from the Swan Harbor tank to Philadelphia Road will also need to be added to the 2010 plan in order to enable the Abingdon and Perryman WTPs to supply Sub-zone 1A when the Havre de Grace WTP is out of service for an extended period. Also, the Oak Grove Booster Station needs to be upgraded during this period.

b. Year 2015 Additions and Upgrades

Transmission main projects recommended for 2015 include the following:

- 16-inch Route 7 Transmission Main between Harford Town Road to Route 543
- 16-inch Route 7 Transmission Main, SW of Mountain Road
- 12-inch Route 7 Transmission Main, Edgewood Road to Fashion Way
- 20-inch transmission main parallel to existing main in Route 7 from Abingdon Rd and Harford Town Rd
- 12-inch Route 40 Transmission Main from Edgewood Road

Construction of the 16-inch main from Harford Town Road to Route 543 was to allow service to Zone 1A when the Havre de Grace WTP is out of service. The 16-inch main southwest of Mountain Road was to decrease headloss into the Joppa Tank.

In addition to these projects the 2-MG Trimble Storage Tank and Magnolia Booster Station upgrade will need to be completed.

c. Year 2020 Additions and Upgrades

One additional transmission main, the 7,500 lf 12-inch Route 7 main from Fashion Way to Clayton Road Route 40 is included in the recommended CIP for 2020. This main is required in order to provide adequate flow and pressure during peak hours in sub-zones 1C and 1D, and to maintain Trimble and Joppa Tank levels.

In addition to the need for these improvements, the model for 2015 maximum day demand with fire flow indicates that the new Trimble or Swan Harbor elevated tanks experience difficulty recovering to overflow elevation before the end of the 72-hour simulation period when the Havre de Grace WTP is out of service for an extended period either. However, both tanks recover fully within 24 hours of the fireflow events staged from 9 AM to 11 AM in the model simulation.

4. Storage Analysis Results

An analysis was made of the First Zone system's total storage requirements and total planned usable storage for the 5-year design periods, 2005 through 2025. Three analyses were made, one each for Sub-zone 1A and Sub-zone 1B, and one for both sub-zones combined. Maximum day demand conditions were used without point demands. Equalization storage requirements were calculated at 20% of the maximum day demand for each year. Fireflow storage requirements for a two hour duration period were 2,800 gpm for Sub-zone 1A and 3,500 gpm for Sub-zone 1B. These fireflows are the maximum rates assigned to each sub-zone by the County. The fireflow analyses simulated for this period of 9 AM to 11 AM.

The total planned usable storage available for each year was based on existing usable storage in each tank for 2005 and the proposed storage in the recommended CIP for 2010 through 2025. It included the usable storage in the existing and proposed storage tanks less the usable volume of those planned to be de-commissioned. The results of the analysis are summarized in Tables V-1 through Table V-3.

Under the demands and operating conditions described above the analysis of Sub-zone 1A showed that the total existing usable storage for 2005, 0.30 MG, is less than the required total storage of 0.66 MG for the period. However, if the 1-MG Swan Harbor tank is constructed as indicated above, usable storage in Sub-zone 1A will be adequate through the period of 2025. The analysis also showed that a deficit will exist in storage in Sub-zone 1B for 2010. The total storage requirements were 2.75 MG with a

total planned usable storage of 2.30 MG, a deficit of 0.45 MG. After 2010, planned construction of the 2-MG Trimble storage tank will provide usable storage above the storage requirements through 2025. Looking at Zone 1 as a whole, total storage requirements exceeded planned usable storage in 2005. In the 2010 to 2015 period, total usable storage is greater than the storage required, and continues to be adequate through 2025.

With construction of the 1-MG Swan Harbor Tank proposed for 2010, system modeling indicates that fluctuations in water levels in the existing 0.3-MG Stepney tank will be minimal. This condition may cause water quality problems in the Stepney tank as a result of excessive water age. Also, because of its relatively low volume, it is not cost -effective to operate and continue to maintain this tank over the long run. For these reasons it is recommended that the Stepney tank and booster station be de-commissioned and demolished following construction of the Swan Harbor tank. The estimated project cost for demolition of the tank is approximately $25,000.

The existing 0.1-MG Joppatowne Tank capacity is also small relative to the new 2-MG Trimble Tank that is planned to be constructed in the 2010 to 2015 period. As with the case of the Stepney Tank discussed above, it will not be cost-effective to continue to operate and maintain this tank. It is recommended that the Joppatowne Tank be taken off line and demolished once the Trimble Tank is put in service. The estimated project cost for demolition of the tank is approximately $25,000.

5. Pumping Analysis Results

An analysis was conducted of the First Zone's available pumping capacity for each design period through 2025 beginning with the Year 2005. Three analyses were made for Subzone 1A and Subzone 1B, and one for both subzones combined. Maximum day demand conditions were used with point demands. The results of the three analyses are included in Tables V-4 through V-6.

Using the system demands previously identified, an analysis was made of the safe pumping capacity for Subzone 1A. The analysis assumed that all of the supply of water to the subzone was from the Havre de Grace WTP with no supply provided from Perryman and Abingdon WTPs. However, under actual operating conditions, division valves between Subzones 1A and 1B can be opened in an emergency to supply water from the Abingdon and Perryman WTPs. Under maximum day demand for Subzone 1A from 2005 through 2025, the total planned safe pumping capacity was adequate.

An analysis was also made of the Subzone 1B pumping capacity through 2025. This analysis assumed that the sources of supply were limited to the Abingdon and Perryman WTPs with no contribution from the Havre de Grace WTP. However, under actual operating conditions, division valves between Subzones 1A and 1B can be opened in an emergency to provide water from the Havre de Grace WTP. The safe capacity at the Perryman WTP of 2.9 mgd was held constant over the period of the analysis because there are no plans to increase capacity due to limitations on groundwater withdrawals imposed by MDE. The Abingdon WTP safe pumping capacity assumes an increase from 4.0 mgd in 2005 to 8.6 mgd in

2010, and to 17.3 mgd in 2020 based in the current capital improvements plan.

The analysis of Subzone 1B showed that in the 2005 to 2010 period, a deficit of 3.4 mgd exists between the projected maximum day demand of 10.4 mgd and the safe pumping capacity of 7.0 mgd. In 2010, planned expansion of the Abingdon WTP pumping capacity effectively reduces the deficit to a nominal 0.1 mgd. However, by 2015, a deficit of 1.2 mgd exists between the safe pumping capacity mgd and the projected maximum day demand. By 2020, Abingdon WTP pumping capacity will be increased under a planned WTP upgrade which should satisfy maximum day demand through 2025.

Based on these results, it is recommended that one of the existing pumps be retrofitted with a larger impeller and an additional pump be added at the Abingdon WTP pumping station. These measures should satisfy maximum day demands projected to occur between 2005 and 2010. A pump curve for the proposed additional pump is provided in the Appendices. Further, it is anticipated that modification of the pumping station operating scheme can be made to overcome the 0.1 to 1.2 mgd deficit that is projected to occur between 2010 and 2020.

C. Water Quality Model Description

Water quality modeling was conducted using EPANET to evaluate the effects of implementing the County's CIP on the residence time of water in the distribution system in 2005 and with the recommended CIP in 2025. Once the hydraulic model of the system was upgraded to where all

of the design parameters were met, the system was modeled using average day demand conditions in 2025.

Using the hydraulic results from an extended period simulation, EPANET tracked the movement of water particles through the distribution system under the different scenarios and conditions, and calculated the length of time that each particle was in the system. Water age was used as an indicator of water quality. The modeling was conducted with all three water treatment plants in service.

Each water quality simulation began with an assumed initial age of zero for the water in all the pipes and tanks. The water age at supply sources remained at zero throughout an extended period simulation. The water age at other locations increased with each hour of the simulation until fresh water from the source arrived at a given node. The fresh water from the source mixed with the older water until the water age stabilized.

Nodes with zero or very small demands, especially at dead ends, did not receive fresh water and water age predictions did not stabilize; these nodes were excluded from the final water age analysis. Water age predictions for tanks increased slowly until the entire volume of each tank was replaced with fresh water from the sources.

To overcome the effects of initial water age assumptions, it was important to simulate a sufficiently long period of time that produced a consistent, repeating pattern of water age in each storage facility. A period of 720 hours (30 days) was used as the simulation time for the Harford County system.

Because of the length of the simulations, the pump controls in the hydraulic model were carefully checked to ensure stable operation. Water

age simulations also are sensitive to the time steps used for the calculations. In general, the accuracy of the simulation increases as the time step is decreased, however, small time steps result in longer processing time. A sensitivity analysis was conducted with different time steps which indicated that 5 minutes was the optimum period for the final simulations.

D. Water Quality Model Results

Average water age in the system was developed using water age predictions for the last 24 hours of each simulation, after system equilibrium was established. These average water age predictions were exported from the EPANET model into ArcView GIS. The analysis results are provided graphically in Figures V-1and V-2 for the 2005 and 2025 average day demand conditions. The results of the analyses are shown in color with the average water age in hours, in increments of 0 to 20 hours, 20 to 50 hours, 50 to 120 hours and greater than 120 hours.

The results of the average water age analysis for the existing system model show that the average water age in the majority of the First Zone is less than 20.0 hours. Exceptions to these results are areas of Joppatowne and in the community of Hidden Ridge at Box Hill South in Sub-zone 1A where water age exceeds 120 hours, and small areas with dead-end distribution mains. In Sub-zone 1B the Swan Harbor Dell Trailer Park and Glenn Heights areas, the analysis indicates average water age greater than 120 hours for the 2005 model. Also in Sub-zone 1B, the Route 40 transmission main exceeds 120 hours. This main connects Sub-zones 1A and 1B where two division valves are normally maintained in a closed position. The sub-zone separation creates two dead-ends which account for the excessive water age in this location. Other scattered dead-ends in Sub-zone 1B exhibit water age greater than 120 hours

including the Joppatowne area. The remainder of the system exhibits average water age less than 50 hours.

In 2025, as additional storage, pumping and transmission mains are constructed some improvement in the water age in the Joppatowne area can be observed, where water age is primarily on the order of 50 to 120 hours rather than greater than 120 hours. The remainder of the areas with longer age identified above for the 2005 model remains essentially unchanged. Overall, the recommended capital improvement program slightly improves existing areas with excessive water age and does not create any new areas where water age is excessive.

E. Recommended Plan

1. Project Cost Derivations

Project costs have been derived for the recommended capital improvement plan. The project costs include estimated construction costs at Year 2008 prices; a 20% contingency allowance for construction; engineering, construction phase services, administrative costs, and right of way costs at 35% of the total construction cost. The project costs also include a 10% contingency allowance for the aggregate of the aforementioned non-construction costs. Tables with the derivation of these costs are provided in the appendices.

2. Plan Description

As a result of recently scheduled upgrades to the plant and piping at the Abingdon WTP, and the results from hydraulic modeling of the County's current base plan with modifications to

enable the system to perform so that it is meeting the County's design parameters and other standards, a recommended capital improvements plan has been developed. The modifications include the addition of new transmission mains, reinforcement of existing mains by constructing parallel mains, construction of storage facilities and pumping upgrades. The plans for each design period, 2010, 2015 and 2020 are depicted and identified in Figure V-3. The estimated project costs by year of implementation for each project are shown in Table V-7. The total estimated cost of the recommended CIP program is $44.4 million.

This plan enables the First Zone to meet average and maximum day demands in 2010, 2015 and 2025 with coincident fireflows of 2800 gpm in Sub-zone 1A or 3500 gpm in Sub-zone 1B for durations of two hours while maintaining a minimum 20 psi pressure at curb stops. The improvements in the plan also enable the system to meet these demands when all three water treatment plants are in operation; the Abingdon and Perryman WTPs in operation and the Havre de Grace WTP is taken out of service for an extended time period; and when the Abingdon and Havre de Grace WTPs are in operation and the Perryman WTP is taken out of service for an extended time period.

a. Year 2010 Improvements

The recommended 2010 to 2015 CIP includes construction of the Oak Grove Booster Station to be constructed and financed by a developer, and the 1-MG Swan Harbor elevated tank and transmission main will be constructed. This tank was proposed in the County's CIP to be constructed in 2015. The following

transmission main construction will also be completed during this period:

- 36-inch, 30-inch and 24-inch parallel and replacement transmission mains in Abingdon Road
- 16-inch Route 40 Transmission Main from the Swan Creek elevated tank to Philadelphia Road

The total estimated project cost for this phase of construction is estimated at $23,570,000.

b. Year 2015 Improvements

The recommended 2015 to 2020 improvement program includes construction of the 2-MG Trimble Elevated Tank at the Magnolia School on property already owned by the County. This program also includes upgrades to the Magnolia Booster Station. In addition, transmission main construction during this period includes the following mains:

- 12-inch Route 40 Transmission Main, Route 40 from Edgewood Road
- 12-inch Route 7 Transmission Main from Edgewood Road to Fashion Way
- 20-inch Route 7 Transmission Main parallel to the existing transmission main in Abingdon Road to Harford Town Road
- 16-inch Route 7 Transmission Main, Harford Town Road to Route 543
- 16-inch Route 7 Transmission Main, SW of Mountain Road

The total project cost for this construction phase is estimated at $16,650,000.

c. Year 2020 Improvements

The recommended 2020 to 2025 capital improvement program includes construction of a 12-inch Route 7 Transmission Main from Fashion Way to Clayton Road to Route 40.

The total project cost for this construction phase is $4,150,000.

3. Comparison of Harford County CIP and Recommended Plan

The recommended capital improvement plan accelerates several planned improvements, reinforces existing mains with parallel, and adds additional mains, and increases the size of mains already in planning stages. The plan improves the hydraulic performance of the system, enables the County's design parameters to be met for velocity, pressure and flow, provides adequate fire flow and residual system pressures to maintain service and reduce risk of contamination through illegal cross connections during fire events, and enables the system to perform adequately when either the Havre de Grace or Perryman WTPs are out of service for extended periods. This plan improves water age in certain areas of the distribution system and does not create any new areas where water age is excessive. The following projects are recommended:

a. The current CIP increased the capacity of the existing transmission main from the Abingdon WTP by constructing a parallel transmission main. This proposed parallel main consisted of 36-inch, 30-inch and 24-inch transmission main. Based on the hydraulic modeling of the system conducted for this study the proposed 24-inch transmission main is upgraded to a 36-inch main in the recommended CIP.

b. The schedule for construction of the 1-MG Swan Harbor elevated tank was accelerated, moving it from the 2015 plan to the 2010 plan. The recommended 20,400 lf parallel 16-inch Route 40 transmission main from the Swan Harbor tank connection to Philadelphia Road was added to the 2010 plan in order to enable the Abingdon and Perryman WTPs to supply the First Zone 1A when the Havre de Grace WTP is out of service for an extended period.

c. Three additional transmission main projects are recommended for 2015 including the 3,800 lf 20-inch Route 7 Transmission Main parallel to the existing transmission main in Abingdon Road to Harford Town Road, the 6,100 lf 16-inch Route 7 Transmission Main, Harford Town Road to Route 543, and the 250 lf 16-inch Route 7 Transmission Main, SW of Mountain Road.

d. One additional transmission main, the 7,500 lf of 12-inch Route 7 and Clayton Road transmission main was included in the recommended CIP for 2020. This main was not included in the County's CIP.

SECTION VI
ANALYSIS OF ADDITIONAL WATER SOURCES REQUIRED TO MEET BRAC DEMANDS

A. General

In addition to evaluating the County's proposed CIP and recommending additional improvements to the distribution system, another important objective of this study was to evaluate two different alternatives to increase the County's water supply for the additional demands anticipated as a result of the BRAC expansion of the Aberdeen and Edgewood APG facilities. At the present time, the County instructed that evaluation be based upon demands of the APG facilities, which will be either 4.5 mgd at the Aberdeen APG and 4.0 mgd at the Edgewood APG, or only 4.0 mgd at the Edgewood APG.

B. Alternatives Evaluated

For the purposes of the alternative source evaluation, the County elected to investigate additional supply from: 1.) Baltimore City through the Big-Inch raw water transmission main, and 2.) through a desalination plant constructed in the First Zone. Four sub-alternatives were identified by the County based on the anticipated future demands at the two APG facilities:

1A Additional raw water from the Big Inch with 4.5 mgd to Aberdeen APG and 4.0 mgd to Edgewood APG.

1B Additional raw water from the Big Inch with 4.0 mgd to Edgewood APG.

2A Additional raw water from a new desalination WTP in the First Zone with 4.5 mgd to Aberdeen APG and 4.0 mgd to Edgewood APG.

2B Additional raw water from a new desalination WTP in the First Zone with 4.0 mgd to Edgewood APG.

Although the evaluation of the alternatives was done on the maximum day demand for 2020/5 with no staging of the improvements, the actual phasing of the demands will be as follows:

- For Alternatives 1A and 2A, the 8.5 mgd to Aberdeen/Edgewood APG will be 5.0 mgd in 2010 and the other 2.0 mgd will be spread out over the next 10 years (2010-2020);

- For Alternatives 1B and 2B and the 4.0 mgd to Edgewood APG-only will be 2.0 mgd in 2010 and the other 2.0 mgd will be spread out over the next 10 years (2010-2020*).*

C. Description of Alternatives 1A and 1B - Baltimore City Big-Inch

3. Raw Water Supply

Selection of this alternative will require a new agreement between the County and Baltimore City to purchase an additional 10 mgd from the Loch Raven Reservoir and Susquehanna River sources via the Big Inch Transmission Main by 2025. The existing agreement between the City and the County allows the County to withdraw 20 mgd from these sources and allocates the cost of purchasing the water. The agreement includes an option for the

County to obtain up to 30 mgd if the option is exercised by no later than June 30, 2010. The City agreed to allow the County to purchase this additional 10 mgd if the City determines that it is able to supply the additional water without materially affecting its ability to meet the City's or other users' projected water demands. The County has notified the City of its intent to exercise this option, and is awaiting the City's response. In order for the County to obtain an additional 10 mgd above the current 30 mgd agreement for raw water supply, a separate or amended agreement will need to be reached with the City.

The City's withdrawal of water from the Susquehanna River is governed by the September 27, 2001 settlement agreement with the Susquehanna River Basin Commission (SRBC). This agreement limits the City's withdrawals and diversions from the Susquehanna River. During "Trigger Low Flow Events" the City may only withdraw 64 mgd as measured as a maximum 30-day average, and 107 mgd on any one day. Trigger Low Flow Events are seasonally-based flows in the Susquehanna River that are established by the Federal Energy Regulatory Commission, measured at the US Geological Survey's Marietta Gage. These trigger flows range from a low of 1,600 cfs from December 1 through February, to 10,000 cfs in April. During non-trigger flow periods, i.e., when Susquehanna River flows exceed the trigger levels, the City can withdraw up to a maximum of 250 mgd (162 cfs). The 2001 Raw Water Supply Agreement, which sets restrictions on the City's withdrawals from the Susquehanna River, will need to be restructured with SRBC to accommodate BRAC water supply demands.

2. Raw Water Pumping and Transmission Facilities

During non-drought conditions, the Abingdon WTP currently receives water supply by gravity from the Loch Raven Reservoir. During drought conditions, the Deer Creek Raw Water Pumping Station draws from the Susquehanna River and provides water supply to Abingdon and Baltimore City through the Big-inch. For the purpose of this study the worst case scenario of drought conditions were considered and Abingdon WTP would receive it's water supply from the Big-inch. The Abingdon WTP provides water to all four pressure zones in Harford County. The WTP provides complete surface water treatment with coagulation, flocculation, sedimentation and filtration.

The design of modification to Deer Creek Pumping Station will provide an ultimate hydraulic design capacity of 250 mgd. A two-phase project is currently under design to achieve this capacity. Phase 1 will increase the capacity of the pumping facility from a current safe capacity of 107 mgd to 190 mgd, and then to 250 mgd under Phase 2.

3. Treatment Facilities

In order to provide treatment for the anticipated BRAC demands, expansion of Abingdon WTP will be required beyond the capacity already planned. The current Abingdon WTP design capacity is 10 mgd. Design is underway to expand the plant to 20 mgd. The design includes expansion of certain plant components to capacities above 20 mgd, some to 30 mgd and others to 40 mgd. Ultimately, the County plans to expand the Abingdon WTP to 30 mgd by 2015 to meet projected non-BRAC related demands. An

additional 10 mgd to total of 40 mgd at Abingdon will be required by 2020 to meet all demands.

Improvements are also required to increase the capacity of the existing raw water transmission facilities from the Big Inch Transmission Main to the Abingdon WTP. The existing …-inch tap will be replaced with a 48-inch connection and new crossing under I-95. Bid-ready documents are being reviewed by the City of Baltimore. Following approval of the proposed improvements by the City this project will be advertised for construction bidding.

4. Abingdon WTP Capital Cost Estimates

It is estimated that the expansion of the Abingdon Water Treatment Plant from a 20 MGD capacity to 40 MGD capacity would cost $65,000,000. Additionally, a portion of the costs to increase pumping capacity at the Deer Creek Pumping Station was included in the capital cost of providing an additional 20 MGD from Abingdon. Of the estimated $34,000,000 cost for improvement at Deer Creek, $1,600,000 was attributed to Abingdon's capital cost.

5. Operation and Maintenance Cost

Harford County's 2008 Operations and Maintenance Budget for the Abingdon WTP was reviewed to determine the unit rate ($ per 1,000 gallons) of O & M costs. Based on this review it was determined that the Abingdon WTP operates with an O & M cost of $1.00 per 1,000 gallons.

D. Description of Alternatives 2A and 2B - Desalination WTP located in First Zone

1. Proposed Desalination WTP Site

Based on discussions with Harford County staff, a land parcel located east of Bush River, north of Canning House Road, and west of Perryman Road was identified as a potential location for the new desalination WTP. This parcel has been used for agricultural purposes in the past. The area is currently zoned as Agricultural and Light Industrial District (LI) under the Harford County zoning classifications. Based on an ultimate plant capacity of 20 mgd, a land parcel approximately 2,000 ft by 1,200 ft (55 acres) is required.

2. Desalination Raw Water Source Quality

The raw water source for the desalination WTP is the Bush River, with an average water depth ranging from 1 to 3 feet near the proposed site. A conventional passive intake typically requires a minimum water depth of 7 to 8 ft. Passive intakes are usually designed to allow one screen diameter below the intake for silt and sediment, and one screen diameter above to prevent vortexing. Alternatively, a passive intake could be buried in the river bed. However, siltation would need to be mitigated.

An alternate concept to obtain raw water from the shallow Bush River would be to install a horizontal collector well with screened arms buried in trenches excavated from the river bed and backfilled with sand.

Site conditions of the proposed site location present design limitations for obtaining raw water from Bush River. An additional detailed study will be necessary to determine the feasibility of the proposed location.

The proposed site is located at the head of Chesapeake Bay, where Church Creek flows into the Bush River. There is limited water quality data available for Bush River near the proposed site.

The Maryland Department of Natural Resources (DNR) monitors water quality in the Bush River at two Harford County locations near the proposed site: Otter Point Creek and Lauderick Creek. The water quality parameters monitored include dissolved oxygen (DO), salinity, temperature, pH, turbidity, water depth and total chlorophyll.

The Otter Point Creek site is the closest monitoring site to the proposed desalination WTP site. A summary of the Otter Point Creek water quality data for 2007 is presented in Table VI-1.

The proposed desalination WTP site is located upstream of the Otter Point Creek monitoring site. Hence, the Bush River water quality near the proposed site should be of higher quality since it will be less affected by the tidal action in Chesapeake Bay.

The high turbidity values (up to 900 ntu) indicate that full conventional pre-treatment will be required. Harford County staff has indicated that the Bush River is muddy brown in color near the proposed plant site during/after rain events (indicator of high turbidity). Rain events and tidal effects within the Chesapeake Bay

are expected to result in significant turbidity variations in Bush River.

A salinity classification is presented in Table VI-2. The water salinity at Otter Point Creek site is 0.1 to 4 ppt. Based on the classification, Bush River water near the proposed site is expected to be low concentration brackish water. Brackish RO membrane treatment will be required to reduce the salinity to less than 100 to 250 mg/L (0.1 to 0.25 ppt).

Since the raw water for the desalination WTP will have significant turbidity excursions and salinity (brackish water), the new plant includes a two-step treatment process: conventional pre-treatment followed by reverse osmosis (RO) membrane treatment. Conventional pre-treatment is expected to remove suspended and colloidal particles (turbidity) and a fraction of the natural organic matter. However, most of the dissolved solids (salinity) are expected to pass through the conventional treatment process. The brackish RO membrane treatment process is expected to remove most of the dissolved solids.

3. Conceptual Capital Cost Estimates

Conceptual cost estimates for the 10 mgd and 20 mgd desalination WTPS are $183,000,000 and $354,000,000. Table VI-3 provides details of the conceptual capital cost estimates for the 20 mgd desalination WTP. The conceptual capital costs were developed based on the assumptions listed in Table VI-4.

4. Conceptual Operation and Maintenance Costs

The annual operation and maintenance (O&M) costs were estimated based on a unit O&M cost of $2.10 per 1,000 gallons. This unit cost includes costs for conventional pre-treatment ($1.10 per 1,000 gallons) and brackish RO treatment ($1.00 per 1,000 gallons).

Harford County's Abingdon WTP (10 mgd capacity) has a unit annual O&M cost of approximately $1.00 per 1,000 gallons. The Abingdon WTP treats water from the Big-Inch where raw water flows by gravity to the plant, and has a low turbidity (less than 5 ntu). In the Desalination WTP, raw water will have to be pumped from the Bush River, and raw water turbidity can be as high as 800 ntu. Hence, the Abingdon WTP costs were modified to reflect additional O&M costs, resulting in a revised unit O&M cost of $1.10 per 1,000 gallons for conventional treatment.

The Tampa Bay seawater desalination plant is a 29 mgd plant that employs conventional pre-treatment followed by RO treatment. The unit O&M cost for the Tampa Bay desalination plant was estimated to be $1.90 per 1,000 gallons. This number is comparable to the unit O&M cost developed for Harford County's desalination water treatment plant.

A factor of 0.65 was used to estimate the average day flow. Hence, the average day flows for the 10 mgd and 20 mgd plants will be 6.5 mgd and 13.0 mgd, respectively.

Based on the above average day flows and a unit O&M cost of $2.10 per 1,000 gallons, the annual O&M cost for the 10 mgd

desalination water plant was estimated at $4.98 Million per year. The annual O&M cost for the 20 mgd desalination water plant was estimated at $9.96 Million per year.

E. Costs Analysis

1. Alternatives 1A and 1B

A Present Worth Cost Analysis for Water Source was performed for capital, O & M, connection charges, and water purchasing costs and fees. Costs, other than capital, are not constant but increase with the water demands serviced by Abingdon. The Present Worth analysis was extended out to the year 2025 for which flow demands were estimated which in turn effect costs.

The unit costs for O & M, fees to Baltimore City for obtaining water from Deer Creek PS and fees to the Susquehanna RIVER Basin Commission were increased over the period of the study by a adjustment factor index of 1.02 per year. The 1.02 index was determined in accordance wit the United States Army Corps of Engineers Technical Manual TM 5-802-1 “Economic Studies for Military Construction Design-Applications”. The costs and fees considered were not constant over the analysis period but increased with the water demands upon Abingdon. In the PW analysis these costs were assessed as an annual cost with a gradient factor.

Alternatives 1A and 1B water source have a present worth of $105,300,000 and $96,000,000 respectively. Table VI-5 presents

the present worth for capital, O & M, connection charges, and water purchasing costs and fees.

2. Alternative 2A and 2B

A Present Worth Cost Analysis for Water Source was performed for capital and O & M costs. As with the Abingdon analysis, costs other than capital, are not constant but increase with the water demands serviced by the Desalination Plant. The Present Worth analysis was extended out to the year 2025 for which flow demands were estimated which in turn effect costs.

The unit costs for O & M were increased over the period of the study by a adjustment factor index of 1.02 per year. Other fees for obtaining water will not be incurred by the Desalination Plant. The 1.02 index was determined in the same manner as that utilized for Abingdon. The costs and fees considered were not constant over the analysis period but increased with the water demands upon the Desalination Plant. In the PW analysis these costs were assessed as an annual cost with a gradient factor.

Alternatives 2A and 2B water source have a present worth of $433,000,000 and $419,000,000 respectively. Table VI-5 presents the present worth for capital and O & M.

F. Alternative Evaluation Considerations

Evaluating the two alternative water sources required identification of various factors, such as consideration of siting, engineering, regulatory and institutional, cost and time to implement the influence implementation of this alternative.

Based on input from the County and the County's Statement of Work, the following factors were used to evaluate the alternatives. In the alternative evaluation, these factors have an equal weight, whether it is providing 4.5 mgd to Aberdeen APG and 4.0 mgd to Edgewood APG (1A, 2A), or 4.0 to the Edgewood APG, (1B, 2B). Factors selected for analysis included:

a) Constructability
b) Environmental Impacts
c) Land Acquisition
d) Capital Costs
e) Operation and Maintenance Costs
f) Feasibility
g) Permitting Issues
h) Public Acceptance
i) Hydraulics
j) Raw Water Quality
k) Safety of Supply
l) Reliability
m) Time to Implement
n) Plant Wastewater and Solids Handling

G. Evaluation Methodology

A matrix was developed to compare Alternatives I and II against the consideration of criteria factors listed in the previous Subsection F. For each criteria factor such as Constructability, an Alternative Rating was provided on a scale of 0 to 3. The ratings given, i.e. for Constructability, ranging from 0 (reflecting an alternative would encounter great difficulty or cost, making the alternative undesirable) to 3 (reflecting lower cost and ease of construction) were assigned.

Each of the criteria factors were also assigned a weight (1 to 3) on their importance in evaluating the alternatives with 3 indicating the criteria factor has the highest importance level. The Alternative Ratings were multiplied by the assigned criteria factor weight to produce a Weighted Rating.

Table VI-6 reflects the rating of the Alternatives for water source as determined by our offices. One criteria not included in this matrix was the opportunity to have major water source availability from more than one source . It was our opinion that the importance of such an option needed to be assessed by the County.

H. Recommended Alternative

Our recommendation is based upon the consideration of factors affected by the water source alternative and the costs incurred by the water source alternative. It is our recommendation that Alternatives 1A and 1B be utilized as the water source option. The costs of these alternatives are substantially less and received a more favorable rating for the factors which influence the implementation of the alternative.

SECTION VII

DEVELOPMENT OF CAPITAL IMPROVEMENT PROGRAM REQUIRED TO MEET BRAC DEMANDS

A. General Overview

The objective of this task was to employ the results from Tasks 1 and 2, of which are respectively discussed in Sections V and VI of the report to identify and determine those additional capital improvements required to the First Zone water treatment, pumping and transmission mains to enable it to supply water to meet the needs of the APG Aberdeen and APG Edgewood area BRAC program and, at the same time, satisfy the County's ultimate 2025 demands for: a) maximum day demand conditions, b) maximum day demand with fireflow at designated locations and, c) average day demand conditions to satisfy the ultimate build-out of the First Zone.

B. Hydraulic Modeling

1. Hydraulic Model Description

The County's hydraulic model was modified to include the transmission main, storage and pumping improvements in the recommended capital improvement plan in Section V. The two additional source alternatives, the Big Inch Transmission Main (Abingdon Supply) and a proposed desalination WTP Desalination Supply, near Perryman were modeled under two demand conditions. In addition, four operating conditions were evaluated. The system models were evaluated to identify improvements

required to meet the County's design parameters described in Section III.

At the direction of the County, BRAC-related water delivered to APG was to be provided under normal operating pressures of the First Zone distribution system through existing system interconnections. The four existing interconnections between the First Zone system and the Aberdeen and Edgewood APG areas are listed below.

a) Aberdeen APG, 4.5 mgd to the Chapel Hill interconnection in Subzone 1A
b) Edgewood APG, 4.0 mgd through multiple interconnections in Subzone 1B:
    1) Van Bibber WTP at MD route 755, just south of the CSX Railroad,
    2) MD Route 755 at the APG property line,
    3) MD Route 152 at the entrance to APG.

In addition, it was stipulated by the County that the APG would be responsible for conveying the flows from the interconnections into the APG distribution system, and further, that the flow directed to the three Subzone 1B interconnections would minimize the need for additional improvements to the distribution system.

An evaluation was made to determine how the 4.0 mgd delivered to the Edgewood APG could be routed to the three points of entry to the APG distribution system in a manner that minimized the need for additional system improvements. Based on this evaluation the optimum allocation of flow among the three entry

points assumes a flow distribution of 2.0 mgd to the Van Bibber WTP interconnection, 0.5 mgd to the interconnection at Route 755 and 1.5 mgd to the Route 152 interconnection.

2. Model Alternatives

Four alternatives were evaluated including the following:

1A Additional raw water from the Big Inch (Abingdon supply) with 4.5 mgd to Aberdeen APG and 4.0 mgd to Edgewood APG.

1B Additional raw water from the Big Inch (Abingdon Supply) with 4.0 mgd to Edgewood APG.

2A Additional raw water from a new desalination WTP in the First Zone with 4.5 mgd to Aberdeen APG and 4.0 mgd to Edgewood APG.

2B Additional raw water from a new desalination WTP in the First Zone with 4.0 mgd to Edgewood APG.

In addition, four operating scenarios were evaluated including the following:

- All three water treatment plants are in operation in the case of Alternatives 1A and 1B.
- All four water treatment plants are in operation in the case of Alternatives 2A and 2B
- The Abingdon and Perryman WTPs are in operation and the Havre de Grace WTP is taken out of service for an extended time period. During this period of time the Abingdon WTP and the Desalination WTP operates at a rate necessary to make-up the water supply deficit.

- The Abingdon and Havre de Grace WTPs are in operation and the Perryman WTP is taken out of service for an extended time period. During this period of time the Abingdon WTP and Desalination operates at a rate necessary to make-up the water supply deficit.

3. Hydraulic Model Results

The model results show that significant additional or upgraded transmission mains are required to meet the BRAC demands. Due to the stipulations that flow to APG be delivered at the normal First Zone operating pressure, and that APG be held responsible for peak demand equalization and fire fighting storage, no additional pumps or storage tanks beyond those planned nor changes in construction schedule for the facilities recommended in Section V are anticipated to be needed.

The transmission main improvements required to meet the design parameters with BRAC demands in 2025 are summarized in Tables VII-1 through VII-4 and depicted in Figures VII-1 through VII-4 for each of the four alternatives.

The results of the water age and residual chlorine decay modeling for the four alternatives are depicted in Figures VII-5 through Figure VII-2.

In addition, these alternatives are described as follows:

a. Alternative 1A

In order to implement this alternative, four mains previously recommended to be constructed to meet the County's non-BRAC demands will need to be upgraded. Improvements previously recommended to the Abingdon Road transmission main will need to be upgraded including the replacement 2,060 lf of the proposed 30-inch main with 36-inch main, upgrading 6,100 lf of 16-inch main in Route 7 to 24-inch and 3,800 lf of 20-inch main to 24-inch main. In addition, the previously recommended 23,130 lf 16-inch Route 40 transmission main will need to be upgraded to 20-inch main. Several additional mains will need to be constructed, as well. All of the improvements required to be made to implement Alternative 1A are listed in Table VII-1.

b. Alternative 1B

This alternative only requires construction of two new 16-inch mains to enable flow to be delivered to the Edgewood APG and satisfy the design parameters. These improvements are the 16-inch Route 7 transmission main of 11,320 lf and the 16-inch Edgewood Road main of 3,810 lf in length. The two improvements are listed in Table VII-2.

c. Alternative 2A

Implementation of this alternative will require upgrading the previously recommended Route 40 transmission main from 16-inch to 20-inch main along its 23,130 lf of length. In addition, a substantial number of new mains will need to be constructed to enable the proposed desalination WTP improvements to deliver the

required flow to the Edgewood and Aberdeen APG areas. These improvements are listed in Table VII-3.

d. Alternative 2B

As with Alternative 2A above, this alternative will require a substantial number of new mains to be constructed to enable the proposed desalination WTP to deliver flow to the Edgewood APG. These recommended projects are listed in Table VII-4.

C. Water Quality Modeling

1. Model Description

Water quality modeling was conducted using EPANET to evaluate the effects of the additional BRAC demands on the residence time of water in the distribution system and the decay of residual chlorine between the entry points of water from the WTPs into the system and the points of water use or storage. The model of the system was modified with the recommended capital improvement plans required to meet all of the design parameters under average day demands for 2025. The modeling for water age and residual chlorine decay was conducted using the same methods employed in Section V, and with all three existing water treatment plants in service. Four alternatives, 1A, 1B, 2A and 2B as described above in Section VII. B. 2. were modeled.

The residual chlorine decay modeling used a warm weather bulk decay coefficient of 0.45 per day. This coefficient was estimated from laboratory-measured coefficients from water sources believed to be representative of Harford County's sources

of supply. The source or initial average warm weather residual chlorine concentrations used in the model for the Abingdon, Perryman and Havre de Grace WTPs were obtained from the County's water operations superintendent and are listed in Table VII-3.

2. Water Quality Model Results

The results of the water age and residual chlorine decay modeling for the four alternatives are depicted in Figures VII-1 through Figure VII-8.

D. Estimated Total Project Costs of Recommended Capital Improvements for the Alternatives

1. Cost Derivation

As presented in Section V, the project costs include estimated construction costs at 2008 prices; a 20% contingency allowance for construction; engineering, construction phase services, administrative costs, and right of way costs at 35% of the total construction cost. The project costs also include a 10% contingency allowance for the aggregate of the aforementioned non-construction costs. Tables with the derivation of the costs, including escalation where appropriate for each of the four alternatives are provided in the Appendices.

2. Estimated Project Costs

The estimated total project costs for the recommended capital improvements to the distribution system that enable the

County to supply water to the APG Aberdeen and APG Edgewood areas to meet the projected demands from the BRAC program are listed below. These costs are for the conveyance of water through the distribution system and do not include costs for water sources or treatment. The estimated costs for the four alternatives are shown in Tables VII-5 through VII-8 and are summarized as follows:

Alternative 1A – 8.5 mgd from the Big Inch
$22,620,000

Alternative 1B – 4.0 mgd from the Big Inch
$6,800,000

Alternative 2A – 8.5 mgd from the Desalination WTP
$39,980,000

Alternative 2B – 4.0 mgd from the Desalination WTP
$28,800,000

SECTION VIII

ANALYSIS OF PROPOSED CIP FOR FIRST ZONE DISTRIBUTION SYSTEM TO ACCOMMODATE ADDITIONAL BRAC DEMANDS

A. General

The objective of this task is to identify capital improvements required to be made to the First Zone distribution system to enable it supply water to the APG Aberdeen and APG Edgewood areas to meet demands from anticipated BRAC program activities program and satisfy the County's ultimate demands. In order to accomplish this task the County's hydraulic model was used with the transmission main, storage and pumping improvements for two alternatives, increased capacity at the Abingdon Water Treatment Plant or construct a desalination plant within the limits of Zone 1.

B. Conveyance

1. Abingdon WTP

If ultimate demands of the County and the BRAC program are to be met at the Abingdon WTP, improvements will be required to the distribution system along sections of the Pulaski Highway corridor. The cost of these improvements will be dependent upon ultimate demand provided to APG. The estimated costs of these improvements for providing either 8.5 MGD or 4.0 MGD to the APG facilities are $22,600,000 and $6,800,000 respectively.

2. Desalination Plant

The alternative of constructing a desalination plant will require the construction of a water transmission system from the plant's location to connect with existing transmission mains. The cost of constructing a new transmission system will also be dependent upon ultimate demand provided to APG. The estimated costs of these improvements for providing either 8.5 MGD or 4.0 MGD to the APG facilities are $40,000,000 and $28,800,000, respectively.

C. Water Source

As discussed previously in this study, the water source to meet the ultimate demands of the County and the BRAC program can be met by improvements to Abingdon WTP or the construction of a desalination plant. The costs for water source are also dependent upon ultimate demand provided to APG as shown in the following:

1. Abingdon – BRAC 8.5 MGD (1A) - $105,300,000

2. Abingdon – BRAC 4.0 MGD (1B) - $96,000,000

3. Desalination - BRAC 8.5 MGD (2A) - $433,000,000

4. Desalination - BRAC 4.0 MGD (2B) - $419,000,000

D. CIP Recommendation

It is the conclusion of this study that Alternative 1 (1A or 1B) be selected as the distribution system to meet the ultimate demands of the County and BRAC program. This alternative is significantly more cost effective while meeting the County's criteria for a desirable alternative.

SECTION IX
PROVISIONAL COST ALLOCATION

A. General

The objective of this task is to identify the cost allocations for providing ultimate water demands of either 8.5 MGD or 4.0 MGD to the APG facilities as part of the BRAC Program. This allocation analysis was evaluated for Alternatives 1A and 1B, the Abingdon water supply expansion. A tabulation of the cost allocation has been provided on Table IX-1.

B. Conveyance

The allocation of conveyance cost was based upon the hydraulic modeling of the ultimate demands to provide the necessary supply to the APG facilities. It was determined that conveyance costs of $22,620,000 and $51,170,000 are to be allocated to BRAC for Alternatives 1A and 1B respectively based upon the improvements required.

C. Water Source

The allocation of water source cost was based upon a ratio of the demand provided to BRAC to the total demand necessitating the expansion (i.e. 1A ratio 8.5/20, 1B ratio 4.0/20). Other charges which may be incurred, such as the City Use Fee and the Susquehanna River Basin Commission Fee, were not considered at this time. It was determined that water source costs of $41,530,000 and $38,680,000 are to be allocated to BRAC for Alternatives 1A and 1B respectively.