Advisory Committee on the Management and Protection of the State's Water Resources

Final Report

May 28, 2004

M. Gordon Wolman, Chairman

ROBERT L. EHRLICH, JR.
GOVERNOR

MICHAEL S. STEELE
LIEUTENANT GOVERNOR

Acknowledgements

Preparation and completion of the report of the Advisory Committee on the Management and Protection of the Water Resources of the State of Maryland would have been impossible without the extraordinarily dedicated work of members of the staff of the Water Supply Program in the Maryland Department of the Environment. The staff devoted countless days and hours, including nights and weekends, to the task. The burden of developing the report was borne in addition to many of their continuing responsibilities in the Department. The Committee expresses its deep appreciation for this remarkable service.

In addition to those within the Department of the Environment, many individuals in government as well as those in the private sector have made indispensable contributions to the report. They have not only provided essential information but have served as commentators and critics during the progress of the study. The Advisory Committee is greatly indebted to these individuals.

As Chairman of the Committee, it is a pleasure to acknowledge the active interest and participation of the members of the Committee. On a very tight schedule, members from all over the State attended nine meetings of the full committee, and a number of subcommittee sessions.

The Committee is well aware of Benjamin Franklin's adage that "people only think about water when the well goes dry." It is hoped that yet another drought will not be necessary to stimulate action needed to assure Marylanders of an adequate supply of water to meet their aspirations, and that this report will lend urgency to the task.

M. Gordon Wolman
Chairman

ADVISORY COMMITTEE ON THE MANAGEMENT AND PROTECTION OF THE STATE'S WATER RESOURCES

Gordon Wolman, Ph.D.
Advisory Committee Chairman
Division of Environmental Engineering
Johns Hopkins Bloomberg School
of Public Health

Alan Brench, Ph.D.
Maryland Department of Health
And Mental Hygiene

Russell B. Brinsfield, Ph.D.
Maryland Center for Agro-Ecology Inc.
University of Maryland

David A.C. Carroll
Department of Environmental Protection
And Resource Management
Baltimore County

The Honorable Galen R. Clagett
Delegate, Frederick County
Maryland House of Delegates

Emery Cleaves, Ph.D.
Maryland Department of Natural Resources

Walter S. Finster
Environmental Health Division
Allegany County Department of Health

James M. Gerhart
Maryland District
U.S. Geological Survey

Roy Hancock
Department of Planning and
Growth Management
Charles County

George O. Hanson
Chesapeake Ranch Water Company

Anwarul Huq, Ph.D.
Center of Marine Biotechnology
University of Maryland

Gary L. Mangum
Bell Nursery, Montgomery Co.

Patricia A. McCants
Department of Public Works
City of College Park

The Honorable Thomas M. Middleton
Senator, Charles County
Maryland Senate

Louise Lawrence
Maryland Department of Agriculture

William P. Stack
Water Quality Management Section
Baltimore City Department of
Public Works

Robert Summers, Ph.D.
Maryland Department of the Environment

Joseph Tassone
Maryland Department of Planning

David D.R. Thomey
Maryland Aggregates Association

Frank L. Wise
Division of Environmental Health
Prince George's County
Department of Health

C. Victoria Woodward, Esquire
Safe Waterways in Maryland

STUDY CONTRIBUTORS

Maryland Department of the Environment

Donna Burke	Richard Lucas	Jeffrey Rein
Lorraine Ellenberg	Barry O'Brien, P.E.	Michael Richardson
Paul Emmart	Janice Outen	Herbert Sachs
John Grace	Matthew Pajerowski	Mohammad Sarai, Ph.D.
Clara Jablonski	Karen Pecorino	John Smith, P.E.
Saeid Kasraei	Lyn Poorman	Travis Sterner
Andrea Korsak	Nancy Reilman	Elizabeth Wheeler

Maryland Department of Agriculture
Fred Samadani, P.E.
Jennifer Schafsma

Maryland Department of Natural Resources
David Bolton
Diane Brown
David Drummond

Maryland Department of Planning
Stephanie Fleck-Martins
Larry Fogelson
Richard Hall
Jane Traynham

University of Maryland
Gary Felton, Ph.D

U.S. Geological Survey
Andrew Lamotte
Judith Wheeler
Michael Wieczorek
Douglas Yeskis

Interstate Commission on the Potomac River Basin
Eric Hagen
Deborah Tipton

Johns Hopkins University
John Boland, Ph.D

Delegate Galen Clagett's Office
Carol Krimm

Allegany County Department of Health
Elayne Warren

Table of Contents

List of Appendices

List of Figures

List of Tables

EXECUTIVE SUMMARY

WATER, OUR MOST VALUABLE RESOURCE, is essential to our daily life. Protecting and managing our water resources is paramount to the continued economic vitality of the State of Maryland, the health of our residents, and the viability of our environment.

Although water resource indicators for Maryland suggest that there is an abundance of water to meet present and future needs, in recent years some communities have suffered serious water supply shortages. The 2002 drought experienced throughout Maryland ignited widespread concern for the adequacy of the State's water resources to meet the future demand. There was an alarming realization that unless and until adequate measures are taken, Maryland will have great difficulties in the future in meeting its growing water demand, which could lead to a water crisis of significant proportions. The drought was a powerful confirmation of the need for long term planning to support the management of Maryland's water resources.

In response to the drought, a letter endorsed by 72 legislators called attention to the decline of water levels in Southern Maryland ground water aquifers and recommended a statewide assessment of laws, regulations, and governmental resources available for the protection, conservation, and management of water resources. Governor Robert L. Ehrlich Jr. issued Executive Order 01.01.2003.08, which created the Advisory Committee on the Management and Protection of the State's Water Resources, and charged it with several responsibilities, principally to evaluate the sustained ability of the State to meet its projected water needs.

This report provides insight into the wide range of water resource issues identified by the Advisory Committee, and it concludes with recommendations that are of paramount importance to the vitality of Maryland's economy and to the well-being of its citizens. In submitting this report to Governor Ehrlich, the Advisory Committee strongly believes that implementation of these recommendations will enable the State to responsibly manage Maryland's water resources for the present and future generations.

PRINCIPAL FINDINGS

Population Growth and Water Demand in Maryland

Maryland's population grew by 1.374 million people from 1970 to 2000, a 35% increase. The State population is projected to increase another 1.066 million (20% increase) by 2030. Approximately 545,000 new households will be created to accommodate the increased population. While half of these households will be located in the "older" suburban counties (Montgomery, Prince Georges, Anne Arundel and Baltimore), 39% will be located in the "newer" suburban areas of Howard, Harford, Frederick, Carroll, Charles, Calvert and St. Mary's Counties.

The Maryland Department of Planning (MDP) reports that the percent of residential development constructed on large lots (0.5 acre or larger) has been increasing over the past 30 years and is projected to continue growing. This decentralized growth pattern has resulted in forest and agricultural land being consumed for new homes and roads at an unprecedented rate. In relation to water supply management, the increase in low-density residential development can increase the demand for new infrastructure (water supply lines and water treatment facilities) and can increase the amount of non-point pollution, resulting in water quality degradation of the rivers and reservoirs used for water supply.

While recognizing the important interrelationship of water quantity and water quality, this report focuses on the quantity of water available to meet Maryland's needs. The Advisory Committee was able to consider water quality only as it directly impacted water supply. However, to achieve fully integrated water management, the recommendations contained in this report must be considered in conjunction with existing water quality programs, such as the Source Water Assessment and Protection Programs, and with the work of several other committees concentrating on water quality issues. These include the State Advisory Council on Water Security and Sewerage Systems, and the Interagency Technical Assistance Committee on Waste Water Treatment Systems.

Water use (defined in this report as withdrawals from sources, not consumption) is analyzed using the following categories: public supply, commercial, industrial, domestic self-supplied, thermoelectric, mining, and agriculture (the latter is further categorized as livestock, aquaculture and irrigation). In the year 2000, an average of 1.45 billion gallons per day of fresh water was withdrawn from streams, reservoirs and aquifers in Maryland. The largest withdrawals in the year 2000 were for public water supply, which totaled 824 million gallons per day (mgd), or 57% of the State total, followed by water for thermoelectric generation totaling 379 mgd (26%). When comparing use in the four major regions of the State (Western, Central, Southern and Eastern), a considerable amount of variance is noted. In the Central and Southern regions, water use for public supplies dominated. In the Western region, thermoelectric (39%) and industrial (35%) uses were the largest ones. In the Eastern region, irrigation was the largest use with 36% of the regional total. Population and water use projections through 2030 are indicated in the following table.

Table ES-1. Population and Water Use Projections 2000-2030						
	Population			Fresh Water Use in MGD		
Area	Year 2000	Year 2030	% Change	Year 2000	Year 2030	% Change
Baltimore Metropolitan[1]	2,512,431	2,799,700	11.4%	371	397	7.0%
Washington Suburban[2]	1,870,133	2,382,400	27.4%	805	901	11.9%
Southern Maryland[3]	281,320	437,000	55.3%	32	45	40.6%
Western Maryland[4]	236,699	254,650	7.6%	140	137	-2.1%
Upper Eastern Shore[5]	209,295	263,700	26.0%	51	52	2.0%
Lower Eastern Shore[6]	186,608	224,650	20.4%	49	64	30.6%
Projected Statewide Irrigation Increase[7]					84	
Total	5,296,486	6,362,100	20.1%	1,447	1,680	16.1%

[1]Baltimore Metropolitan Area: City of Baltimore; and Anne Arundel, Baltimore, Carroll, Harford and Howard Counties.

[2]Washington Suburban Area: Frederick, Montgomery and Prince George's Counties.

[3]Southern Maryland: Calvert, Charles and St. Mary's Counties.

[4]Western Maryland: Allegany, Garrett, and Washington Counties.

[5]Upper Eastern Shore: Caroline, Cecil, Kent, Queen Anne's and Talbot Counties.

[6]Lower Eastern Shore Area: Dorchester, Somerset, Wicomico and Worcester Counties.

[7]Total includes the statewide irrigation projection for 2030 in an average precipitation year. Regional irrigation projections are not available.

Public Water Supply

Public water supply systems in Maryland serve 4.5 million people, 84% of the State's population. Of this amount, 3.19 million people (60% of the State's population) are served by the Baltimore Metropolitan System or the Washington Suburban Sanitary Commission (WSSC). Demand projections indicate that water used for public water supplies will increase from 824 mgd to 882 mgd in 2030. Over the past several decades, industrial water use provided by public systems has significantly declined. A more thorough examination of this change in use may result in a higher projection of per capita use of water and in turn, an increase in the total projected demand for public water supply due to population growth.

Domestic Self-Supplied
An estimated 847,000 Maryland residents (16% of the State population) use private wells for their water supply. From 1985 to 2000, domestic water use withdrawals increased by almost 22% from 63 to 77 mgd. Future demand for self-supplied water is expected to increase with population increases, to a demand of 94 mgd by 2030.

Agricultural Water Use
Increases in agricultural water use are projected to occur predominantly on the Eastern Shore and as a result, regional issues related to this trend will need to be addressed. Since 1980, the total agricultural fresh water use has averaged 3% to 5% of the State's fresh water use. Agricultural water use in Maryland is partitioned into three use categories: irrigation, livestock and aquaculture. Water use increases for livestock, aquaculture and horticultural irrigation are projected to be nominal due to increased management efficiencies. Expansion of irrigation systems is expected to be driven by a desire to reduce crop production risks. For purposes of managing water resources, agricultural irrigation demand estimates are based on highest demand years. However, projections indicate water use demand for agricultural irrigation by 2030 to vary between 60 mgd to as much as 225 mgd under drought conditions.

Accounting for all agricultural uses and managing for highest demand years results in a projected use of 285 mgd statewide for agriculture. Adequate planning and management of the State's water resources must balance agricultural water use with future competition for the resource caused by growth and land use change. Research needs include evaluation of appropriate irrigation technology, nutrient reduction/loss under irrigation, and how management changes influence the efficiencies and economics of irrigation.

Thermoelectric Generation
The production of thermoelectric power in Maryland will nearly double by the year 2030. During this period, many older "once through" cooled generation units will be retired while newer, more efficient, "closed loop" cooled generation units will be constructed. The new units (which utilize evaporative cooling) often require higher quality cooling water. Therefore, it is anticipated that the use of brackish water in thermoelectric production will decrease rapidly (70% decrease by 2030) while the use of fresh ground water (100% increase) and surface water (6% increase) will grow. The consumptive use of fresh water and better quality brackish water will double from roughly 50 mgd to over 100 mgd by 2030.

Commercial, Industrial, Mining
With inadequate data to make projections, 2030 use was assumed to be the same as 2000. It is noted that withdrawals for these uses have declined, which may reflect a decline in industrial activity, or could reflect the fact that public water systems have expanded to serve commercial and industrial sites that were previously self-supplied.

Water Conservation and Efficiency Technology
Water efficiency technologies and behavior modifications along with public education can have a significant influence on demand and may be a supplement as well as an attractive alternative to seeking new water sources. While conservation and drought management are not the same thing,

drought conditions experienced from 1999 to 2002 elevated the importance of considering this alternative by both public and private water utilities.

Approaches that communities throughout the country have used to reduce demand include: educational programs; residential water audits; rebate or other incentive programs; meter upgrades; revised rate structures; leak detection and repair; and reuse.

The potential for even greater savings may be achieved by providing further pricing incentives for consumers to conserve, such as a differential pricing structure that charges higher rates for higher water use. Government-sponsored programs to assist water utilities in implementing these programs, or regulations requiring utilities to meet certain demand reduction goals, may be needed to encourage water systems in the State to undertake these activities. Some have already done so.

Effects of Climate Change

While a number of climate change modeling studies have been undertaken, the study authors cite many reservations and difficulties inherent in the process of directly translating the output of these models into management. Nevertheless, changes in climate could impact both demand and availability, and require continuing evaluation.

Availability of Resources for Water Supply

Maryland is fortunate to have relatively abundant water resources, and historically has been able to meet its water needs. Shortages occur because of inadequate planning for extreme climatic conditions (drought); lack of adequate infrastructure; inadequate plans for growth; stricter drinking water regulations; and pollution of sources. However, increasing demands for water to support population and economic growth are expected to result in greater challenges to supplying adequate water of acceptable quality.

In very general terms, the State can be divided into two regions: the Coastal Plain, where ground water from confined aquifers serves as the main source of water supply; and the Piedmont/Ridge and Valley/Allegheny Plateau Region, where surface water is the primary source for the largest water users, and ground water from unconfined fractured-rock and carbonate aquifers is extensively used for small to mid-sized water users.

While the methodologies for determining availability from these various sources are different, all are dependent on data derived from networks of surface water stream gages, ground water monitoring wells, and rain gages maintained through the cooperative effort of the federal and State agencies. The networks are not adequate to provide the data necessary for proper management of the State's water supply sources.

An immediate concern is the absence of funding in the budget of the Department of Natural Resources to continue operation of the Maryland ground water monitoring network outside Southern Maryland, and to adequately fund the stream gage network after July 2004. The Maryland ground water network includes the Central Maryland area (Piedmont/Ridge and Valley/Allegany Plateau) where many small towns depend on ground water as their source of water supply. The area is particularly vulnerable to the impact of drought, and monitoring data is paramount to proper management of water supply. Funding for these ground water monitoring stations is needed immediately in order to maintain the continuity of ground water level data. To maintain the stream-gage network at its 2004 level, State funding is also needed to retain the 12 stream gages that will be lost in the 2005 budget.

One of the most vexing and complex water resource issues in the State of Maryland is the decline of ground water levels in the seven major confined Coastal Plain aquifers. All seven aquifers are inter-related and are affected by what happens in their distant outcrop areas. A comprehensive approach is needed that assesses all the aquifers of the Maryland Coastal Plain as a whole. Critical to this task is the development of an accurate model representation of the hydrogeologic framework of the aquifer system.

Water availability is considered in the context of several planning or regulatory activities. Water and sewer plans are prepared by county and local governments to assure the orderly development of community water systems. While the plans describe the planned infrastructure needed to withdraw, treat and distribute potable water, these plans do not address whether the water sources will be adequate to meet expected demands. In addition, adequate drought management plans have been developed for only a few communities in Maryland.

Through the State water appropriation permit process, specific proposed water uses are reviewed to determine if the resource is adequate, and whether the impacts of a withdrawal are reasonable. It is a reactive process addressing a specific request and does not assess the availability of water for future, projected uses, or plan for their development. A separate process is needed to plan for the orderly development of available water resources and to assure that growth and development plans are commensurate with available resources.

County and local governments also have responsibilities related to assessing water availability. State law requires local or county authorities to ensure that adequate water is available before approving a building permit, and to ensure that adequate capacity will be available in time to serve a proposed development before approving a subdivision plat. How these authorities are carried out varies among jurisdictions, and is the subject of a review being conducted by the Maryland Department of the Environment (MDE) in cooperation with County Environmental Health Directors.

Water Supply and Demand Pilot Studies

The determination of water adequacy requires analysis of availability for the particular area of concern. For this reason, the Advisory Committee embarked upon two pilot projects to establish an approach toward determining water adequacy in all watersheds and aquifers that are or could be significant water sources. The pilot studies were conducted in rapidly growing regions of the State to examine the relationship between the demand for water and the available supply. The Monocacy River Watershed, which is partly in Frederick, Carroll and Montgomery Counties as well as in Pennsylvania, was chosen for one pilot study. This study considered water supply issues in an area that relies on both ground water and surface water in a hydrologic system that is directly influenced by annual precipitation. The Southern Maryland Counties (Anne Arundel, Prince George's, Calvert, Charles and St. Mary's) were chosen as a second pilot study area to demonstrate the very different water supply issues encountered in an area that relies almost solely on ground water from deep aquifers that are more sensitive to changes in water use than to variations in annual precipitation.

While there was some effort to compare projected demand with available water, the principal goal was to demonstrate the information needed and potential approaches to use in such an analysis. In the process of completing the pilot studies, several shortcomings were recognized such as the shortage of available monitoring data, the lack of information on the adequacy of the water supply, and insufficient analytical tools.

Monocacy Watershed Pilot Study

The Monocacy Watershed drains an area of approximately 969 square miles and includes significant portions of Frederick and Carroll Counties in Maryland and Adams County in Pennsylvania. Water demand in the Maryland portion of the watershed is expected to increase from 48 mgd in 2000 to 61 mgd in 2030, equally divided between surface and ground water sources. The assumption that the proportion of ground water and surface water uses will remain constant needs to be confirmed or revised by comparing information from water and sewer planning with the projected growth.

Ground water in the watershed comes from shallow aquifers that are recharged by precipitation and discharged to the streams in the watershed. Ground water availability can be estimated through a water balance approach that considers recharge and demand. This approach is extremely simplified considering the complexity of the fractured-rock aquifers. A general assessment that ground water is available in a watershed does not guarantee that it will be readily available in adequate amounts at any given location in that watershed. The pilot study supports the need for additional observation wells and stream gages discussed in Section 5.1 of this report.

Streams are an important source of water in the Monocacy watershed. However, if minimum stream flows are to be protected, then users of streams without reservoirs or other storage will not be able to meet their needs at all times. Provision for storage or alternative sources is fundamental to the reliable use of surface water. More refined analysis is necessary to fully evaluate the reliability of the surface water supply. The analysis did indicate that the water needs of the City of Frederick could be met during an average year using a combination of water purchased from Frederick County along with the City's existing resources. More detailed analysis is needed to determine how well the City's needs would be met during a drought.

Southern Maryland Pilot Study

The Southern Maryland region is dependent almost entirely on ground water for its water supply. The aquifers that underlie the region generally provide an abundant supply of good quality water, however these aquifers are vulnerable to overuse and a thorough understanding of the ground water system is necessary to ensure a reliable supply in the future.

Water levels in the confined aquifers have declined in the last 50 years due to the increasing use of these resources. MDE regulates ground water withdrawals for major water users and manages these aquifers to maintain acceptable water levels. Water levels in some aquifers in several areas in Southern Maryland are approaching the minimum sustainable management level. Existing modeling studies indicate that the major aquifers have the potential to handle future demands in the localized areas in which they were examined. However, significant management measures are needed to ensure that sustainable water levels are maintained throughout the region. A multi - aquifer ground water flow model is essential to address management issues associated with increased water usage and regional stresses.

Program Management

Monitoring and Modeling

Water supply management depends on data provided by the surface water gaging and the ground water monitoring networks. The existing networks are not adequate to meet management needs. A Sub-Committee of this Advisory Committee recommended an increase in stream gages from 115 to 157 gages. The Sub-Committee also recommended that the Maryland network of observation wells be increased from 141 to 240 wells. An immediate and critical need is the restoration of funding for existing observation wells in the Piedmont/Ridge and Valley area of Central Maryland.

A major water issue is the declining ground water levels in the seven major confined Coastal Plain aquifers. Because of their variability and the complex interrelationships among recharge, discharge, leakage, and pumpage, there is no simple way to evaluate the water supply potential of these confined aquifers. A more comprehensive approach is needed to analyze cumulative effects on all the aquifers of the Maryland Coastal Plain as a whole, as opposed to the individual aquifer studies conducted to date.

Water Resource Planning

The State is responsible by statute for developing a comprehensive statewide water resource program "which contemplates proper conservation and development of the waters of the state...on a watershed or aquifer basis…" (Environment Article §5-203). This mandated function has not been fully developed, resulting in serious consequences for the management programs. MDE has recently established a unit to begin addressing this mandate. However, it will need resources to act on the recommendations of the Advisory Committee. High priority should be placed on completion of the assessment of the State's water resources by preparing water demand/supply studies for each watershed or aquifer that is a significant water source. Further, a procedure for updating these assessments with new demand data should be established.

Water and Sewer Planning

Under State law, counties and Baltimore City are required to prepare and maintain Water and Sewer Plans to ensure the orderly development of community water and sewer systems in accord with local comprehensive plans. These Plans provide the nexus between land use planning, source water protection, and water supply planning. However, some counties are struggling to meet the State mandate to keep these Plans up to date and effective. There is a need to provide technical and financial support to some jurisdictions to assist these jurisdictions in preparing current, effective Water and Sewer Plans.

Non-Tidal Potomac River Basin

Managing the water supply needs for the Potomac Basin will be particularly challenging because it is shared with other jurisdictions and also because significant growth is projected in the Washington Metropolitan Area. While Maryland has traditionally taken the lead in addressing the water management issues in the Potomac, the situation has dramatically changed with the

December 2003 Supreme Court ruling that citizens of Virginia need not obtain regulatory approval from Maryland for construction of water intake structures and withdrawals from the Potomac. With both jurisdictions now able to make independent water use decisions and issue permits, a coordinated review process is needed. Once that process is established, attention should be focused on water use and drought management, issues that will become more significant with increased use of the River and reduced flows due to consumptive losses. As water demand continues to grow, the jurisdictions will also need to consider additional water supply sources for the Washington Metropolitan Area.

Source Water Assessment and Protection

As required by federal law, a source water assessment must be completed by MDE for every public water system, which is to include an inventory of potential contaminants in the assessment area and an analysis of the susceptibility of the drinking water source to contamination. One purpose of the assessment process is to provide recommendations on appropriate strategies to protect the wide variety of water supply sources across the State. The development and implementation of source water protection programs for communities is a labor-intensive process not funded by the federal government. It is important that local governments incorporate source water protection measures into their respective comprehensive plans. Because water supply sources are part of hydrologic systems that cross political boundaries, it is also imperative for planning agencies to take into account how land use upstream of large regional water supplies will impact drinking water sources that serve residents outside of their jurisdiction. This is especially important to the communities served by the Baltimore Metropolitan and WSSC water supplies, which are experiencing water quality problems related to non-point source pollution originating from urbanization and other sources. Local planners must coordinate with neighboring jurisdictions and stakeholders and commit to water quality goals.

Outreach

An educational outreach effort must be developed to enlighten both public officials and citizens about the State’s water supply resources and its management program. None currently exists. Some additional, minimal staffing effort would be required, and the effort should develop appropriate educational material for use across the State.

Regulation

Public Drinking Water Supplies

Regulated public drinking water systems in Maryland fall into three categories: community (year-round residents) of which there are 501; non-transient, non-community (serving regular customers everyday such as schools with their own individual wells) of which there are 570; and transient, non-community (serving different customers each day such as rest areas or gas stations) of which there are 2,676.

Inspection and monitoring of these facilities by MDE generates a significant amount of laboratory work, which is partially performed by the Department of Health and Mental Hygiene. Public water systems are required to sample for up to 91 regulated contaminants, an increase from 21 in 1976 and 35 in 1989. In addition to routine testing, the laboratories test for other contaminants based on localized water quality problems identified by MDE such as radium in Anne Arundel County and arsenic in Dorchester, Calvert, St. Mary's, Talbot and Queen Anne's Counties. In spite of partial funding by MDE, existing DHMH facilities are inadequate to handle all of this workload. DHMH is in the process of evaluating its laboratory needs to support the public health activities of MDE and the county health departments.

Appropriation Permits

In 2002, 1,621 appropriation permits (including new permits and renewals) were issued. Review of the permit data indicates 85% of permits for ground water use are issued for about 5% of the total withdrawals. A similar situation exists for surface water withdrawals. Because these small withdrawals have little collective impact on the source waters at the present time, these withdrawals should be exempted from permit requirements, and the resources used to review and track these withdrawals should be re-directed to uses with potentially greater impact. A regulatory exemption of 5,000 gpd is recommended.

Compliance and Enforcement

Enforcing permit conditions is a serious challenge. At present, MDE must first take a permit violator to court and secure a conviction. It is a lengthy and litigious process that has resulted in no fines being assessed for violations of the water appropriation laws during the past 20 years. MDE should be granted legal authority to issue administrative penalties in order to improve the effectiveness and efficiency of enforcement actions.

SUMMARY OF RECOMMENDATIONS

The Advisory Committee was charged with recommending the actions necessary to ensure that the management of the State's water resources will provide for their long-term sustainable use and protection. While time constraints did not allow a thorough review of each subject in the Executive Order, the Advisory Committee was able to identify the programmatic needs for monitoring, comprehensive planning, and enforcement that are necessary to meet the projected demands on the water resources of the State. These needs provide the basis for the following recommendations. Each major recommendation is followed by a brief explanation and the specific actions required for implementation.

1. Continue the Comprehensive Evaluation of Watersheds and Aquifers that are Significant Sources of Water Supply. Continue an Advisory Committee to Provide Guidance in Implementing the Recommendations.

Executive Order 01.01.2003.08 recognizes the importance of assessing the adequacy of the quantity and quality of the State's water supply resources to meet projected needs. Our understanding of the ability of available water resources to meet expected water needs is constantly changing as future water demand projections are updated and the analysis of water availability is refined. Therefore, it is most important to complete the evaluation process and to provide for updating the assessments on a routine basis. The Advisory Committee's specific recommendations include directing and enabling the Department of the Environment to:

- Continue conducting, in cooperation with the other participating agencies (Agriculture, Health and Mental Hygiene, Planning, and Natural Resources), the statewide evaluation of water supply sources, and repeat the evaluations at regular intervals to ensure consistency with changing demographics and resource conditions.
- Develop a comprehensive multi-aquifer model for the Coastal Plain to be used for ground water management purposes such as issuing permits for wells and developing appropriate County Water and Sewerage Plans.
- Establish an Advisory Committee to provide periodic evaluation of implementation of the recommendations.

2. Restore Funding for Existing Observation Wells and Stream Gages Deleted from the FY2005 Budget; Expand Monitoring Networks as Funding Becomes Available.

As the State's water supply sources experience heavier demands, monitoring their availability to meet projected needs will become increasingly important. The primary monitoring tools are statewide networks of stream gages to measure surface water flow and of ground water observation wells to monitor ground water levels. The collection of this most basic water resource information is indispensable to the ability of water resource managers to make sound decisions. Without adequate water resource data, it will become difficult or impossible to determine the availability of surface water or ground water, to assess and react to droughts, to determine the potential interference of competing water users, and to assess the impacts of water use on the State's aquifers and streams, while maintaining minimum stream flows. The required expansion of stream and ground water monitoring networks is outlined in the report. At this time, no funds have been allocated to continue operation of the existing Maryland ground water monitoring network and for the stream flow monitoring network in the FY 2005 State budget.

- Promptly restore funding for the statewide stream flow and ground water monitoring networks so that there is no interruption in the essential continuity of the data collection.
- Prioritize expansion of the two monitoring networks and phase in new monitoring stations as funding becomes available.

3. Improve Coordination Between Maryland and Virginia Regarding Water Allocations from the Potomac River.

Managing water resources in the Potomac Basin will be particularly challenging because the watershed is shared with other jurisdictions (Virginia, West Virginia, Pennsylvania and the District of Columbia) and because of the significant growth projected for the Washington Metropolitan Area. Another factor adding to the complexity of management in the watershed resulted from the recent Supreme Court decision in the case of <u>Virginia v. Maryland</u>, 540 U.S. ____(2003). The Court decision removed Virginia from the regulatory management authority of Maryland. With two states exercising authority over the same waters, there is an obvious need for a coordinated review process that will provide consistency in the issuance of permits.

- Initiate discussions with Virginia to establish a coordinated permit review process.
- Coordinate with Virginia to update drought management procedures relative to the Potomac River Basin.

4. Support Water and Sewer Planning at the State and Local Government Levels.

The significant role played by local governments in water supply management is derived primarily from State agency delegations. State support for these activities, both in grants and in technical assistance, has been significantly reduced over time, making it extremely difficult for local jurisdictions to meet the expectations of the State agencies providing oversight of these programs.

As an example of the reduced State support, MDE had at one time a staff of nine and MDP had a staff of four providing assistance to local jurisdictions in preparing the State-mandated Water and Sewer Plans. To maximize the benefit of these Plans to the public and to the water suppliers who rely on them, the Plans must be made in concert with local comprehensive plans, consistent with the water supply and water use data generated from the monitoring networks and the watershed/aquifer studies. These Plans are intended to provide for the orderly development and extension of community water supply and sewer systems. State staffing has been reduced to one position each at MDE and MDP, which is woefully inadequate for the work required. Because the capacity for comprehensive planning varies among the counties, the State had previously provided partial funding to those counties in need of assistance in preparing the Water and Sewer Plans. This funding is no longer available to the counties.

- Restore staff support at the State level to provide technical assistance for development of Water and Sewer Plans at the local level.
- Restore financial assistance where needed for counties to prepare the Water and Sewer Plans.
- Consider changes to enhance the utility of the water and sewer planning process, such as incorporation of source protection plans and assessments of available water resource.

5. Implement a Comprehensive Outreach Program to Educate Maryland Citizens and Create Partnerships for Stewardship of the State's Water Resources.

Too often, citizens are not fully aware of the issues related to the water they use. In order to ensure that the importance of efforts to manage water resources is recognized and supported, an educational outreach effort must be developed to enlighten both officials and the public about the water resource challenges facing the State, and the management options that are available. Outreach efforts can be initiated at the State level as was practiced in the past within the Water Supply Program. Waiting "until the well goes dry" means crisis management, engendering a reactive stance to urgent problems. Educational outreach and the support of the public is needed to ensure proper attention to water resource issues in a timely manner. Restoring staffing in the Water Supply Program would be necessary to continue this important effort.

In addition, water conservation and water use efficiency technologies are not used extensively in Maryland, due to the relative abundance of water resources in Maryland, coupled with the desire to maintain a comparatively low cost for drinking water. Encouraging an efficient level of conservation may be economical and lessen the likelihood of a water supply crisis.

- Include outreach as one of the responsibilities for additional State staffing.

- Encourage water utilities to employ water conservation and efficient water use technologies to meet their resource needs.
- Encourage water utilities to conduct routine water audits, identify unaccounted losses, and pursue leak detection and repair programs.

6. Exempt Withdrawals below a Minimum Threshold in the Appropriation Permit Law.

A review of the appropriation permit data indicates that a significantly large number of permits are issued for very small withdrawals, so small that even their cumulative impact on water sources is minimal at the present time. Exempting these smaller permits (less than 5,000 gpd) could remove an unnecessary regulatory burden from the business community. Exempting smaller permits would also allow staff to focus their attention on the review of large permits with potentially more serious impacts, to address compliance issues more effectively, and to review and issue permits in a more timely manner. The Advisory Committee recommends exempting permits less than 5,000 gpd.

- Modify State statutes and regulations.

7. Review Laws, Regulations, Funding Resources, and State Laboratory Capacity Relative to Comprehensive Management of the State's Water Resources.

Time constraints have not permitted a comprehensive review of existing laws, regulations, and funding resources pertinent to water supply management. Several other issues have been raised that could not be adequately addressed in this report. For example, HB 113, which proposed to modify the 1-gallon per minute minimum test standard for new wells, was introduced during the 2004 legislative session. The bill was later withdrawn with the understanding that while MDE was reviewing the existing requirement for possible modification, the Department would keep the bill sponsor advised on the status of the review.

In addition, it has been well documented that laboratory capability for drinking water analysis has not adequately expanded to meet statewide needs as mandated by the federal government. In 1990, only 35 contaminants were regulated for drinking water. Public water systems are now required to test for up to 91 different contaminants in addition to special monitoring for emergency and security related testing. No provision for the increased workload has been provided.

Funding the recommendations will be a major challenge. As one possibility, the Advisory Committee suggests legislation be considered that would establish fees related to water appropriation permit applications and on annual withdrawals.

Other topics identified for further study include:

- Establish a process to ensure that local governments approve new developments based on the adequacy of the water supply for the new developments.
- Establish administrative penalties to ensure compliance with water appropriation permits.
- Encourage consistency among jurisdictions in the implementation of the water and sewer planning process.

- Incorporate source water protection measures into the comprehensive plans developed by each county.
- Establish a process to ensure that abandoned wells are properly sealed.
- Review the well constructions standard and modify if necessary in order to enhance protection of the quality and quantity of ground water.
- Provide sufficient laboratory capability for drinking water analysis to accommodate the additional workload.

1.0 INTRODUCTION: WATER IN MARYLAND

Water, Maryland's most important natural resource, is essential to the well being of the people of the State. Growing communities, industries, agriculture, energy production, and critical ecosystems depend upon water being available in adequate quantity and suitable quality. Protecting and managing our water resources is therefore vital to maintaining the health of Maryland's citizens, environment, and economy. Nature provides Marylanders with abundant water, which, if well managed, could meet present and future needs. However, as population grows and land use intensifies, threats to water quantity and quality are increasing. Providing for Maryland's future water supply needs will require a committed, sustained, and supported effort by local governments, water providers, water users, and State and federal agencies working together to implement appropriate monitoring, planning, and regulation.

The landscape of Maryland is striking in its geographic diversity, ranging from the subdued landscape of the Coastal Plain in the east through the rolling hills of the Piedmont, the Blue Ridge Mountains, the Appalachian Valleys and Ridges, to the Appalachian Plateau in the west (Figure 1-1). While the average precipitation across the State varies little, from 38 inches in western Maryland to 46 inches in Central Maryland, the hydrologic system, controlled by the underlying geology and topography, differs markedly from one physiographic region to another. The diverse landscape is underlain by an equally diverse geology, which can be divided into three different, basic rock types that greatly influence water supply opportunities, and provide water supply managers with challenges unique to each rock type. In the Coastal Plain, the rock consists of unconsolidated sediments, with sand and gravel layers forming the aquifers that can supply ground water. In the Piedmont and westward to the Appalachian Plateau water supplies come from either fractures in hard rock (as ground water) or from reservoirs on streams and rivers. Washington and its suburban surroundings obtain water from the Potomac River, and Baltimore and its suburbs from three reservoirs and the Susquehanna River. The third rock type is limestone-marble, which

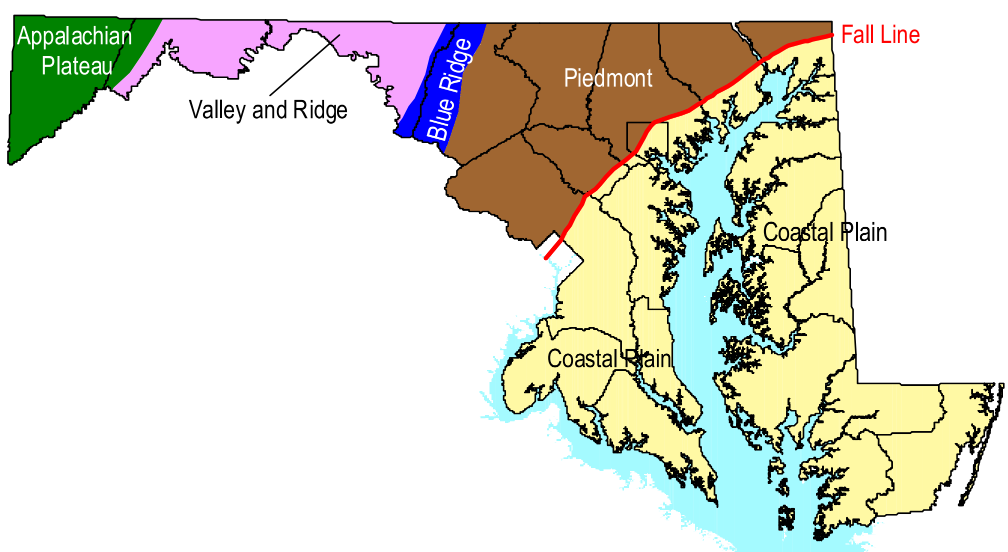

Figure 1-1. Maryland's Physiographic Provinces

underlies areas such as the Hagerstown and Frederick Valleys as well as the Wakefield and Timonium Valleys in the Piedmont. Especially in the Hagerstown and Frederick Valleys, cavities in the soluble limestone produce complicated ground water conditions, and pollution may more readily compromise water quality.

In every case, basic hydrologic principles apply. That is, precipitation is equal to the stream flow plus evaporation and transpiration by plants, plus or minus any changes in ground water storage. At the same time, the flow in streams is highly variable in time and in space. Rainfall varies seasonally and annually, and both ground and surface water vary from place to place. Thus, an adequate knowledge of water supply requires continuous observation of stream flow and ground water levels over long periods.

Similarly, as ground and surface water are hydrologically inseparable, so too are water quantity and quality. A given quantity of pollutants from point and non-point sources can have very different impacts on small streams than on large rivers. Ground water may be unusable due to contamination by naturally occurring minerals or by saltwater intrusion caused by immoderate pumping. Recharge of ground water may be reduced as urbanization leaves the ground surface impermeable to infiltration of precipitation.

Water availability issues are apparent throughout the State, and frequently differ from region to region. The impacts of growth affect most areas of the State, with increased burdens on the resource as well as increased impacts on water quality from land development and industry. Some areas of the State are more likely to face water shortages during dry periods, other areas may experience impacts from urbanization, and yet others are more likely to be concerned about naturally-occurring contaminants in their water supplies.

The hydrologic variability of the State of Maryland has a profound effect on the availability and use of water throughout the State. Water supply from individual wells, or sewage disposal from septic systems, at one end of the spectrum, and large water and sewage treatment plants at the other end of the spectrum, demand planning, development, and management appropriate to their local hydrologic environment. This means that in Maryland, protecting the health and ecosystems of the State requires coordination and cooperation at every level of government.

To accommodate a growing population and economy requires thoughtful planning and management of the State's water resources. The requisites include: measuring the water supply; estimating future demands in space and time; relating supply and demand; and developing laws and regulations designed to assure the availability of water in sufficient quantity and quality to protect public health and environmental quality. Coordination of water management efforts is an enormous challenge, but one that must be undertaken in order to ensure the well-being of Maryland's citizens and environment.

The Executive Order charged the Advisory Committee with the following responsibilities:

(1) Review the latest information from State, local and federal agencies concerning assessments of the quality and quantity management and protection of the State's ground and surface water resources;

(2) Review the results of ongoing scientific research regarding climate change and its regional impacts on aquifer depletion and recharge models;
(3) Review local, State and federal laws and regulations and policies related to the management, development, conservation and protection of ground and surface water resources;
(4) Assess the adequacy of existing governmental resources, regulatory enforcement and monitoring programs that are available for the management, development, conservation and protection of the State's ground and surface water resources;
(5) Develop models to assess trends regarding the State's major aquifers; and
(6) Recommend additional actions, studies, policies, regulations or laws necessary to assure that the management and protection of the State's surface and ground water resources is conducted in a manner consistent with their long-term sustainable use and protection. Within the recommendations, the Advisory Committee was asked to provide a cost estimate and funding alternatives for implementation of each recommendation.

This report addresses these fundamental issues under three broad areas: the demand for water, the available supply of water, and the role of government in managing the resource. While recognizing the importance of ambient water quality, this report focuses upon water supply. Eventually, the recommendations of this Committee must be considered along with those of the State Advisory Council on Water Security and Sewerage Systems, and the Interagency Technical Assistance Committee on Wastewater Treatment Systems to improve management of the waters of the State. In addition to identifying a number of important questions related to demand and supply, the Advisory Committee developed two pilot studies, one from Southern Maryland, a region depending primarily upon ground water, and the other from the Monocacy Watershed, which depends heavily on surface water for larger uses, while also relying on ground water for small to moderate uses. These case studies illustrate the approach needed to demonstrate the relationship between demand and supply. Along with the study of supply and demand for the Potomac completed by the Interstate Commission on the Potomac River Basin (ICPRB), these studies serve to illustrate how a recommended study for the State as a whole should proceed. The discussion of the role of government delineates a number of important functions performed at the State, county, and local level calling for review at greater depth. Among these is the need for an analysis of an appropriate design for continuing the planning and permitting of water withdrawals from the Potomac River in light of the recent decision of the Supreme Court in Virginia v. Maryland denying Maryland's claim to exclusive jurisdiction.

The Advisory Committee envisions development of a comprehensive, integrated water resource management program that will characterize the resource; evaluate existing tools and options; and develop strategies for ensuring sustainable beneficial water use. Development of such a program will require the use of integrated hydrologic monitoring networks to characterize water availability and quality, and accurate water demand projections based upon population growth, agricultural needs, industrial use, energy production, ecological resource needs, and the projected impact of climate change. To assure the development of sustainable water management policies, the framework of State, local, and federal responsibilities and activities as well as the current system of regulations, permits and water appropriations, must be evaluated and modified as needed.

2.0 WATER DEMAND

In order to evaluate whether Maryland's water resources will be able to meet the State's water use needs, it is important to fully understand what those needs are likely to be. The Advisory Committee reviewed current and past water demand trends, and attempted to forecast future demand based on the available information. Although demand for water in Maryland has generally increased over the past 50 years, the data suggests that overall use of water has leveled off in the past twenty years (Figure 2–1). Furthermore, some categories of water use have declined, while others, notably crop irrigation and public supply, have increased significantly. In addition, some areas of the State, for instance Frederick County (Figure 2–2), have seen an increase in water demand. To better understand these seemingly contradictory trends, the Advisory Committee reviewed existing data on current levels of water use, as well as projections prepared by MDE staff and other agencies of expected water demands through the year 2030.

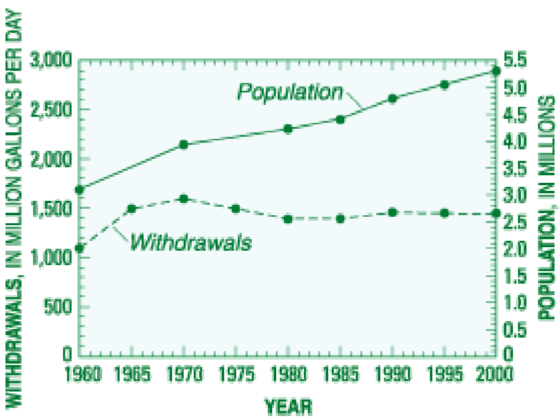

Figure 2–1. Population and Fresh Water Withdrawal Trends in Maryland (Wheeler, 2003)

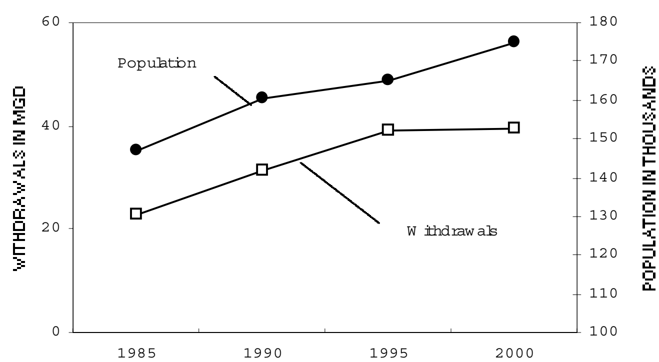

Figure 2–2. Fresh Water Withdrawals in Frederick County (Wheeler, 2004)

As the number of residents in the State continues to grow, so will sanitation and safe drinking water needs. The State's population grew by about 35% between 1970 and 2000, and water use trends for public water supply and domestic wells correlated closely with this growth pattern. In addition, if current patterns of growth continue, much of the future growth in the State will be concentrated in suburban and low-density residential areas. As a result, in addition to the added amounts of water needed to sustain the population, the amount of pervious land available for recharging ground water supplies will be reduced.

The Advisory Committee's analysis of agriculture also indicates the potential for a significant increase in water use for irrigation in high demand years. Although the total acreage of farms and cropland has decreased, the number of irrigated acres have nearly doubled. Despite this growth trend, only 6% of cropland acres are currently irrigated utilizing 3% to 5% of the State's fresh water resources. Ground water provides most of the water used for irrigation, and further study is needed to determine whether the State will be able to continue to meet the growing water use demands of large agricultural users as population competes for available resources.

Another factor the Advisory Committee considered was the potential impact of climate change on water demand. A study that was conducted in 1990 for the Potomac River Basin concluded that there is the possibility of substantial water use increases during the summer months as a result of climate change. Further study is needed to determine the statewide impacts of climate change on water demand.

Currently, water utilities in Maryland do relatively little to manage or reduce demand. Dramatic water use savings have been demonstrated in other areas of the country using water efficiency technologies and behavior modification to reduce demand. Conservation technologies could also play an important role in helping the agricultural sector meet future water needs.

In summary, the Advisory Committee found that water use trends indicate water demand will continue to rise over the next 30 years. Additional research is needed to fully understand these data trends, and the potential impacts that climate change and demand management might have on future water demands.

2.1 Current, Historical, and Projected Demand

The USGS compiles water-use data annually and prepares a report of water withdrawal and use in Maryland every five years. The USGS water use data are acquired from MDE, which maintains a database of water use reported under its water appropriation permit system. Water users who withdraw more than 10,000 gallons per day (gpd) are required to report monthly total water use to MDE as a condition of their permit. For users who withdraw less than 10,000 gpd, the USGS uses the permitted amount as an estimate of the actual use. Domestic use for those with private wells is estimated based on a per capita use of 80 gpd, using an estimate of the number of people on individual wells. The most recent year for which the USGS has published estimates of water use is 2000. Table 2–1 presents the existing water-use data by County, using the following categories of water use: public supply, commercial, domestic self-supplied, industrial, thermoelectric, mining, and agriculture (livestock, aquaculture, and irrigation).

Future water demand was projected for the years 2020 and 2030 using various methods for each category of water use (Tables 2–2, 2–3). The categories of public water supply, domestic self-supplied, and aquaculture were projected based on population projections, since past trends showed a good correlation with population. Future projections of power generation and water use were provided by the Power Plant Research Program of the Department of Natural Resources. The Maryland Department of Agriculture (MDA) provided the projected water use data for agricultural water use. Future demands were not projected for the remaining categories (commercial, industrial, and mining) due to the lack of an identified factor that correlates with water use trends.

In the year 2000, the most recent year with complete, available data, an average of 1.45 billion gallons of fresh water per day were withdrawn from streams, reservoirs, and aquifers in Maryland. The largest category of withdrawals was for public water supply at 824 million gallons per day (mgd), followed by water for thermoelectric generation at 379 mgd. The relative sizes of all water use categories are shown in Figure 2–3. Saline and brackish water uses were not considered for the purposes of this report.

Table 2–1. Total Water Withdrawals by Category and County in 2000

	Water withdrawals (MGD)														
	Public Supply	Commercial	Domestic	Industrial		Thermoelectric		Mining		Livestock	Aquaculture		Irrigation	Total	
County	Fresh	Fresh	Fresh	Fresh	Saline	Fresh	Saline	Fresh	Saline	Fresh	Fresh	Saline	Fresh	Fresh	Saline
Allegany	**0.73**	0.21	**0.93**	46.80	0.00	**0.00**	**0.00**	0.02	0.00	0.08	**0.01**	0.00	0.10	**48.88**	0.00
Anne Arundel	**31.23**	3.48	**10.93**	1.78	0.60	**0.00**	**778.21**	0.55	0.00	0.04	**0.01**	0.01	0.55	**48.57**	778.82
Baltimore	**271.05**	0.66	**4.08**	5.05	217.18	**0.00**	**402.44**	0.09	0.00	0.23	**0.13**	1.48	0.84	**282.13**	621.10
Calvert	**2.30**	0.50	**3.69**	0.05	0.00	**0.41**	**3,270.70**	0.00	0.00	0.02	**0.00**	0.00	0.06	**7.03**	3,270.70
Caroline	**1.04**	0.16	**1.57**	0.33	0.00	**0.00**	**0.00**	2.16	0.00	0.64	**0.00**	0.00	15.48	**21.38**	0.00
Carroll	**6.71**	0.43	**6.54**	0.73	0.00	**0.00**	**0.00**	0.00	0.00	0.81	**0.00**	0.00	0.31	**15.53**	0.00
Cecil	**3.66**	1.16	**3.79**	0.10	0.00	**0.00**	**0.00**	0.27	0.00	0.26	**0.02**	0.00	1.04	**10.30**	0.00
Charles	**7.48**	1.69	**3.29**	0.01	0.00	**0.60**	**1,192.55**	1.13	0.00	0.05	**0.00**	0.00	0.08	**14.33**	1,192.55
Dorchester	**2.47**	0.34	**0.94**	0.99	0.00	**0.02**	**0.73**	0.02	0.00	0.33	**0.03**	0.02	8.71	**13.85**	0.75
Frederick	**15.18**	0.70	**6.99**	1.88	0.00	**0.00**	**0.00**	0.00	0.00	1.80	**12.34**	0.00	0.55	**39.44**	0.00
Garrett	**2.96**	0.67	**1.80**	0.11	0.00	**0.00**	**0.00**	1.71	0.00	0.51	**1.76**	0.00	0.04	**9.56**	0.00
Harford	**8.87**	2.95	**6.13**	0.98	0.00	**0.00**	**0.00**	0.90	0.00	0.40	**0.00**	0.00	0.42	**20.65**	0.00
Howard	**0.00**	0.35	**2.81**	0.02	0.00	**0.00**	**0.00**	0.00	0.00	0.13	**0.00**	0.00	0.51	**3.82**	0.00
Kent	**1.11**	0.29	**0.88**	0.45	0.00	**0.00**	**0.00**	0.03	0.00	0.30	**0.02**	0.00	1.63	**4.71**	0.00
Montgomery	**380.22**	1.29	**3.20**	0.04	0.00	**322.41**	**0.00**	0.04	0.00	0.17	**0.00**	0.00	1.44	**708.81**	0.00
Prince George's	**52.15**	0.82	**1.24**	0.02	0.00	**0.75**	**569.45**	0.92	0.00	0.05	**0.01**	0.00	0.57	**56.53**	569.45
Queen Anne's	**1.47**	0.49	**2.40**	0.33	0.00	**0.00**	**0.00**	0.00	0.00	0.29	**0.00**	0.06	3.70	**8.68**	0.06
St Mary's	**3.68**	1.44	**4.40**	0.01	0.00	**0.00**	**0.00**	0.44	0.01	0.10	**0.00**	0.79	0.16	**10.23**	0.80
Somerset	**1.71**	0.78	**1.16**	0.02	0.00	**0.00**	**0.00**	0.00	0.00	0.66	**0.00**	0.73	0.40	**4.73**	0.73
Talbot	**2.32**	0.36	**1.58**	0.64	0.00	**0.00**	**0.00**	0.01	0.01	0.24	**0.01**	0.00	0.84	**6.00**	0.01
Washington	**13.88**	0.41	**3.63**	2.38	0.00	**54.71**	**0.00**	0.03	0.00	1.14	**5.28**	0.00	0.18	**81.64**	0.00
Wicomico	**6.14**	0.53	**4.19**	1.04	0.00	**0.00**	**0.00**	0.01	0.00	1.21	**0.00**	0.00	3.70	**16.82**	0.00
Worcester	**7.74**	0.63	**0.89**	1.93	0.00	**0.00**	**0.00**	0.01	0.00	0.90	**0.00**	0.00	1.12	**13.22**	0.00
Baltimore City	**0.00**	0.11	**0.00**	0.12	8.87	**0.00**	**45.96**	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.23**	54.83
Total:	**824.10**	20.45	**77.06**	65.81	226.65	**378.90**	**6,260.04**	8.34	0.02	10.36	**19.62**	3.09	42.43	**1,447.07**	6,489.80

(Source: Wheeler, 2004)

Table 2–2. Total Withdrawals by Category and County, Projected to 2020

	Water withdrawals (MGD)														
	Public Supply[1]	Commercial[2]	Domestic[1]	Industrial[2]		Thermoelectric[3]		Mining[2]		Livestock[2]	Aquaculture[1]		Irrigation	Total	
County	Fresh	Fresh	Fresh	Fresh	Saline	Fresh	Saline	Fresh	Saline	Fresh	Fresh	Saline	Fresh	Fresh	Saline
Allegany	0.64		0.90			1.90	0.00				0.00			50.66	
Anne Arundel	34.67		11.92			0.00	564.00				1.20			54.19	
Baltimore	273.28		4.72			0.35	5.00				0.90			286.13	
Calvert	3.45		4.02			0.40	3,200.00				0.40			8.90	
Caroline	1.26		1.63			0.00	0.00				0.08			21.74	
Carroll	9.01		7.20			0.00	0.00				0.79			19.29	
Cecil	4.61		4.06			0.01	0.00				0.35			11.86	
Charles	10.91		4.27			0.35	1,226.00				1.18			19.68	
Dorchester	2.51		0.95			0.35	5.00				0.04			14.25	
Frederick	19.92		8.35			7.30	0.00				13.98			54.48	
Garrett	3.12		1.85			5.25	0.00				1.82			15.08	
Harford	10.56		6.62			0.23	6.20				0.59			23.65	
Howard	2.55		3.54			0.00	0.00				0.88			7.99	
Kent	1.19		0.90			0.00	0.00				0.05			4.84	
Montgomery	389.87		5.97			359.00	0.00				3.34			761.16	
Prince George's	59.36		3.31			6.46	570.00				2.50			74.01	
Queen Anne's	2.30		2.64			0.00	0.00				0.29			10.04	
St Mary's	5.24		4.85			0.00	0.00				0.54			12.78	
Somerset	1.82		1.19			0.00	0.00				0.04			4.90	
Talbot	2.52		1.64			0.00	0.00				0.08			6.33	
Washington	14.62		3.84			43.00	0.00				5.53			71.13	
Wicomico	7.05		4.45			0.00	0.00				0.31			18.30	
Worcester	8.22		1.03			0.00	0.00				0.17			14.01	
Baltimore City	0.54		0.16			0.00	26.00				0.19			1.12	
Total:	869.24	*20.45*	90.03	*65.81*		424.60	5,602.20	*8.34*		*10.36*	35.24		*42.43*	1,566.51	
											Projected Average		108	1632[4.]	
											Projected Drought		166	1690[5.]	

[1] Public Supply, Domestic, and Aquaculture are projected based on population projections.
[2] Categories were not projected in this report. Numbers shown are 2000 withdrawals.
[3] Thermoelectric data provided from the Department of Natural Resources, Power Plant Research Program.
[4.] Total includes 2020 projected irrigation use in an average year (see table C–2)
[5.] Total includes 2020 projected irrigation use in a worst case drought year (see table C–2)

Table 2–3. Total Withdrawals by Category and County, Projected to 2030

	Water withdrawals (MGD)														
	Public Supply[1]	Commercial[2]	Domestic[1]	Industrial[2]		Thermoelectric[1]		Mining[2]		Livestock[2]	Aquaculture[1]		Irrigation	Total	
County	Fresh	Fresh	Fresh	Fresh	Saline	Fresh	Saline	Fresh	Saline	Fresh	Fresh	Saline	Fresh	Fresh	Saline
Allegany	0.55		0.88			1.90	0.00				0.00			50.54	
Anne Arundel	35.70		12.21			0.00	564.00				1.56			55.87	
Baltimore	274.18		4.98			0.35	5.00				1.21			287.58	
Calvert	3.93		4.16			0.40	3,200.00				0.56			9.68	
Caroline	1.34		1.66			0.00	0.00				0.10			21.86	
Carroll	9.62		7.38			0.00	0.00				1.00			20.28	
Cecil	4.91		4.15			8.01	0.00				0.45			20.35	
Charles	12.09		4.62			0.35	1,236.00				1.59			21.61	
Dorchester	2.52		0.96			0.35	5.00				0.05			14.27	
Frederick	22.30		9.04			7.40	0.00				14.80			58.46	
Garrett	3.18		1.86			5.25	0.00				1.84			15.17	
Harford	10.74		6.67			0.23	6.20				0.65			23.93	
Howard	2.73		3.60			0.00	0.00				0.95			8.29	
Kent	1.21		0.91			0.00	0.00				0.05			4.87	
Montgomery	391.51		6.44			359.00	0.00				3.90			763.83	
Prince George's	61.72		3.99			6.83	385.00				3.32			78.25	
Queen Anne's	2.52		2.70			0.00	0.00				0.36			10.40	
St Mary's	5.94		5.05			0.00	0.00				0.78			13.92	
Somerset	1.84		1.20			0.00	0.00				0.05			4.95	
Talbot	2.60		1.66			0.00	0.00				0.11			6.46	
Washington	14.82		3.90			43.00	0.00				5.60			71.46	
Wicomico	7.43		4.56			0.00	0.00				0.45			18.93	
Worcester	8.34		1.06			0.00	0.00				0.21			14.20	
Baltimore City	0.59		0.17			0.00	30.00				0.20			1.19	
Total:	882.31	*20.45*	93.79	*65.81*		433.07	5,431.20	*8.34*		*10.36*	39.79		*42.43*	1596.35	
												Projected Average	126	1680[4.]	
												Projected Drought	224	1778[5.]	

[1] Public Supply, Domestic, and Aquaculture are projected based on population projections.
[2] Categories were not projected in this report. Numbers shown are 2000 withdrawals.
[3] Thermoelectric data provided from the Department of Natural Resources, Power Plant Research Program.
[4.] Total includes 2030 projected irrigation use in an average year (see table C–2)
[5.] Total includes 2030 projected irrigation use in a worst case drought year (see table C–2)

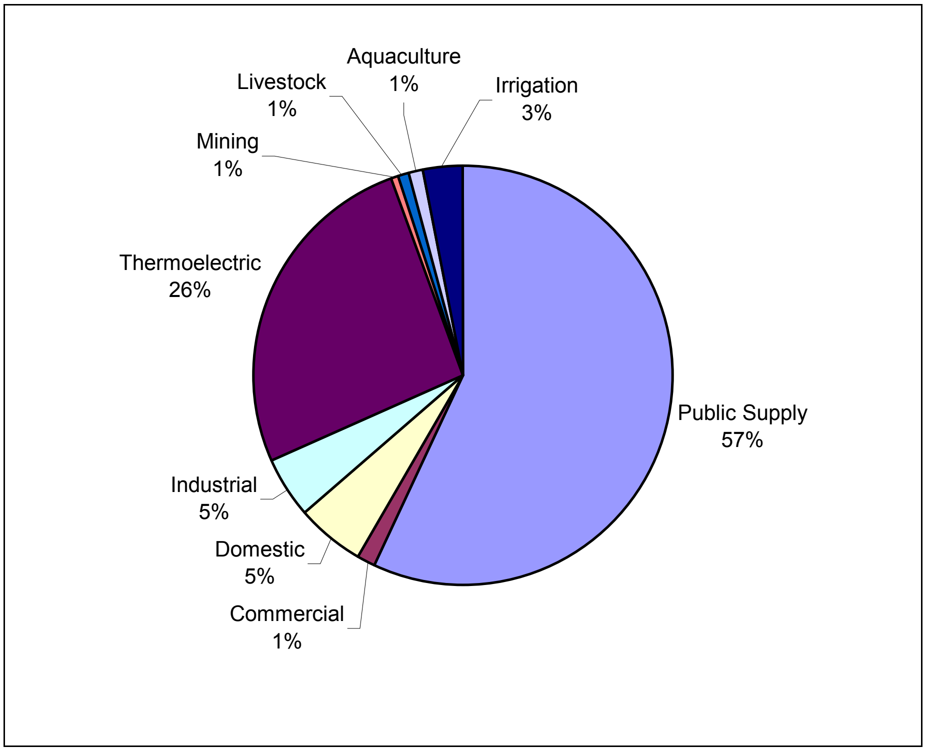

Figure 2–3. Statewide Water Use by Category in 2000

It is important to note that the water use by category varies by region as shown in Figure 2–4. In Western Maryland, thermoelectric use is the largest use, followed closely by industrial use, with public supply accounting for only 13% of fresh water withdrawals. In Central Maryland, public supply is the largest use, comprising almost 60% of all withdrawals. In Southern Maryland, public supply equates to 72% of withdrawals, with individual domestic wells as the second largest use at 17%. The Eastern Shore is the only region where the dominant water use is irrigation, which used 36% of water withdrawn, followed by public supply (28%).

While overall fresh water withdrawals have leveled off in the past twenty years, a closer examination of water use by category reveals varying trends over the last 15 years for which data is available. The categories of public supply, domestic self-supplied, and aquaculture each show a steadily increasing trend in use (Figure 2–5). Annual withdrawals for irrigation are highly variable because the amount of water needed for irrigation is dependent on precipitation, but there appears to be an overall increase in this category, which is supported by the increase in withdrawal requests over this period. Commercial and industrial withdrawals show a decreasing trend in use, while thermoelectric and livestock withdrawals show no observable trend (Figure 2–6). The decline in commercial and industrial water uses can be partially explained by the incorporation of these users into public water supply systems. Possible additional factors contributing to the decline in industrial water withdrawals include increased water reuse and a decline in the number of large industrial plants in the State. The manner in which mining water use is reported has changed over this period, thus a trend in consumption for this category cannot be inferred from the data.

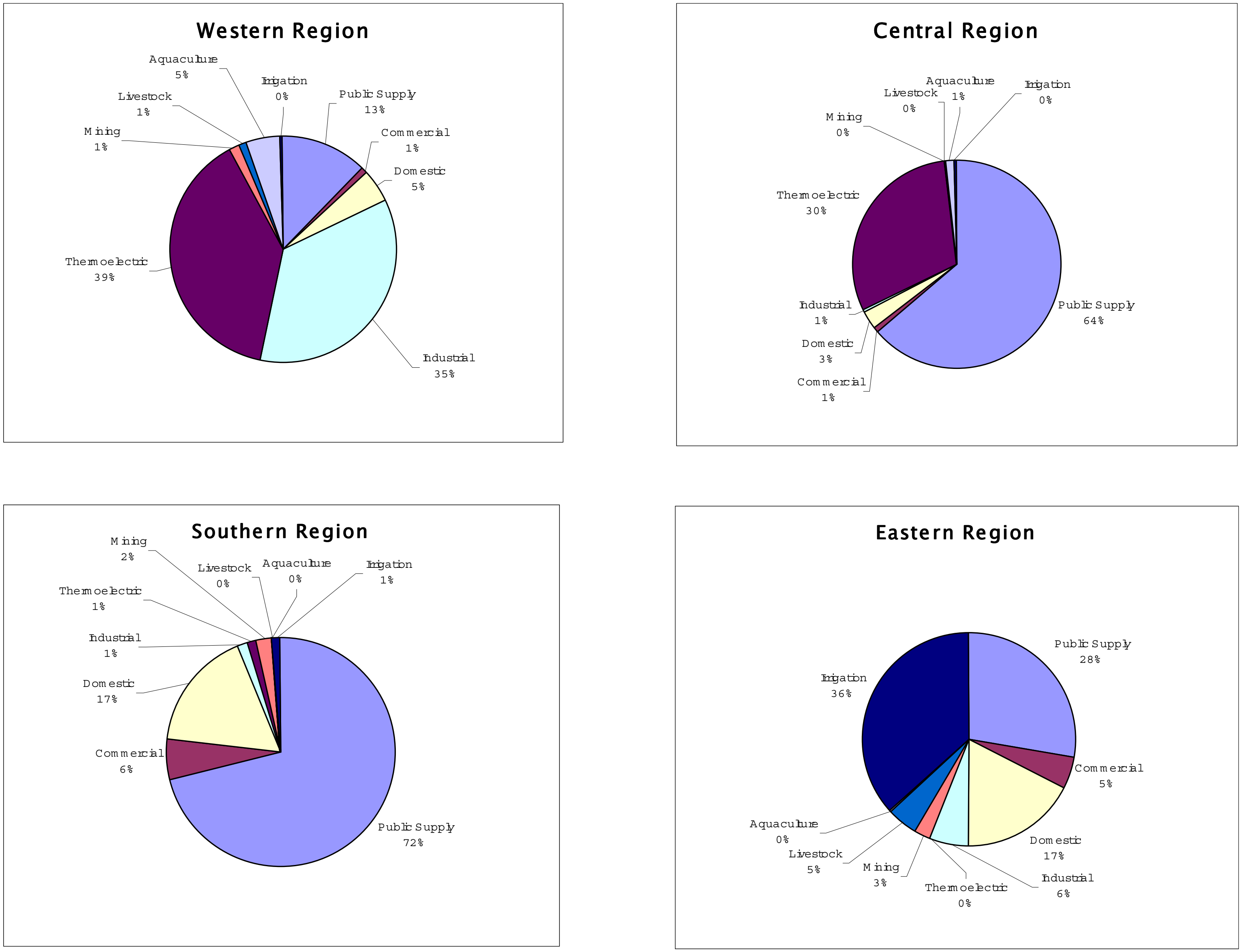

Figure 2–4. Regional Water Use by Category, Year 2000

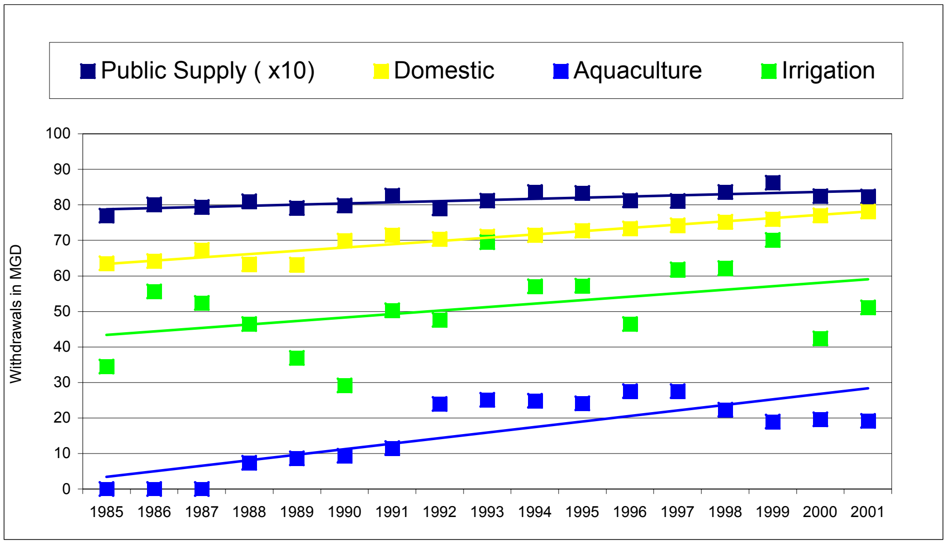

Figure 2–5. Fresh Water Withdrawal Categories that show an increasing trend from the period, 1985-2001.

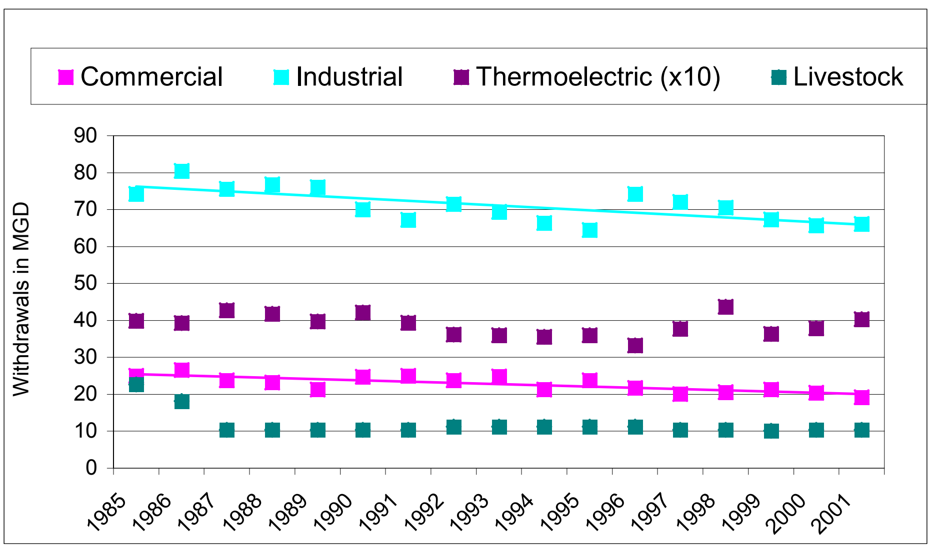

Figure 2–6. Fresh Water Withdrawal Categories that show a decreasing trend or no observable trend for the period 1985-2001.

2.1.1 Public Water Supply

The relative importance of public water supply across the State is illustrated by Figure 2–7, which shows the percent of population served by public water for each county. Ninety percent of all public supply withdrawals are from surface water sources, most of which are withdrawn by the two largest public water systems in Maryland. The Washington Suburban Sanitary Commission (WSSC) and the Baltimore Metropolitan System provide water to more than 85% of the population

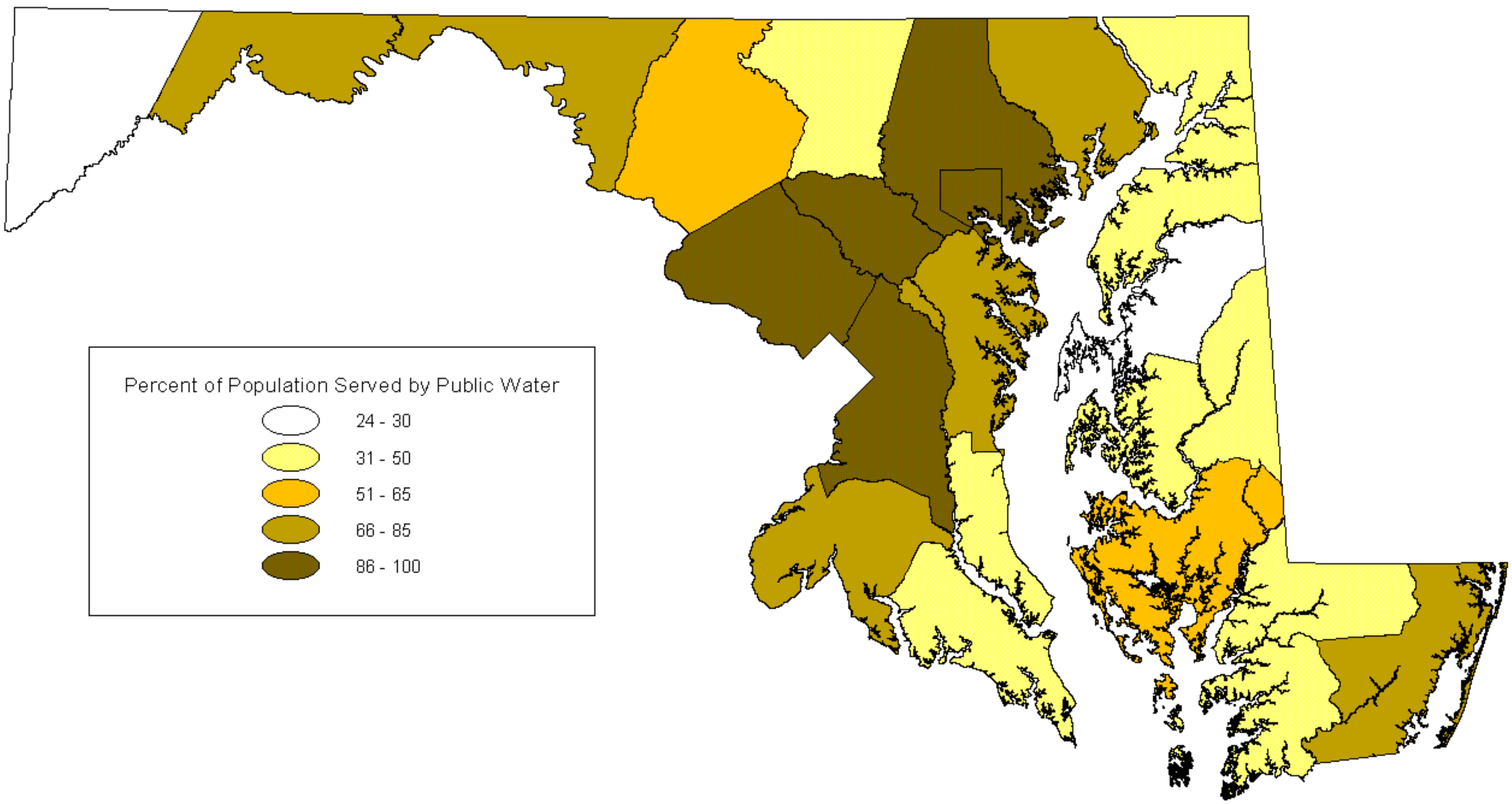

Figure 2–7. Percent of County Population Served by Public Water

in Montgomery, Prince Georges, Howard, and Baltimore Counties and Baltimore City (Figure 2–8). The water supply sources for these large systems include a system of reservoirs (Figure 2–9) as well as intakes on the Potomac and Susquehanna Rivers. These two public supply systems serve 3.19 million of Maryland's 5.4 million residents. In 2000, total withdrawals from the Baltimore Metropolitan System averaged 265 mgd and total withdrawals by WSSC averaged 170 mgd.

An additional 500 public water supplies, serving 1.3 million residents statewide, use water from a variety of surface water and ground water sources. While surface water withdrawals make up the largest proportion of total withdrawals, ground water is heavily relied upon by small and mid-sized communities across the State. Ground water withdrawals have increased by 21% from 1985 to 2000, compared with a 6% increase in surface water withdrawals.

Future demand for water use in the public supply category is expected to continue to increase as Maryland's population grows. The projected demands shown in Tables 2–2 and 2–3 for public supply were computed based on correlation coefficients derived from an analysis of past water use in relation to population. The derived correlation was applied to population projections obtained from the Department of Planning to project future water demand in these categories. Over the past several decades, however, the percentage of industrial usage within the public supply sector has decreased, while the population has grown. For example, in Baltimore City and County, industrial flows (as reported by the MDE Pretreatment Program) totaled about 9.4 mgd in 1988, but declined to 7.22 mgd in 2001. If not accounted for, this trend would result in an underestimate of the future demand in the public supply category. The demand projections for public supply may increase with a better evaluation of the impact on public water systems that the decrease of industrial water withdrawals will have.

2.1.2 Domestic Self-Supplied

Approximately 900,000 residents in Maryland obtain their water supply from private wells. Domestic water use was approximately 77 mgd in 2000, which represents approximately 32% of total ground water withdrawals statewide. Domestic water use withdrawals have increased by almost 14 % from 1985 to 2000.

Future demand for water use in the domestic category is expected to increase as population increases, in a pattern similar to public supply. The projected demands shown in Tables 2–2 and 2–3 for domestic water use were computed based on correlation coefficients derived from an analysis of past water use in relation to population. The derived correlation was applied to population projections obtained from the Department of Planning to project future water demand in this category.

2.1.3 Commercial and Industrial

Commercial and industrial fresh water uses are relatively small statewide, comprising a cumulative 6% of total withdrawals in 2000. In the western region of the State industrial water use was 35% of total fresh water withdrawals in 2000. However, 95% of industrial water use in the Western region is attributed to a single user. Commercial and industrial uses have decreased during the

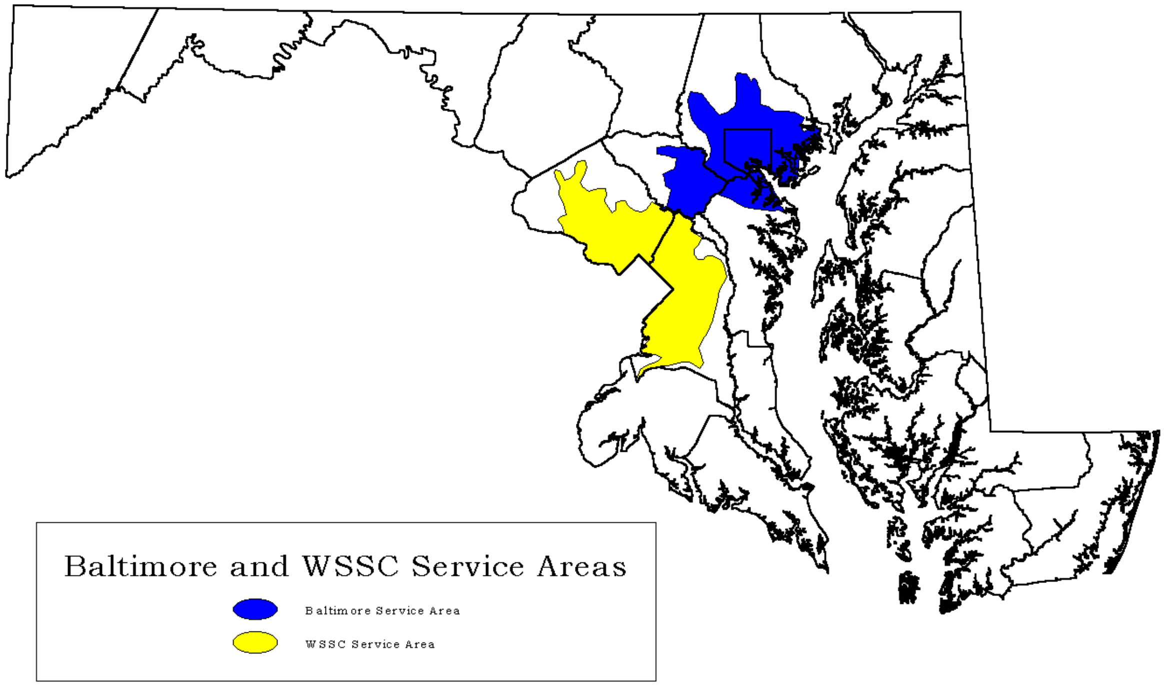

Figure 2–8. Baltimore and WSSC Water Service Areas

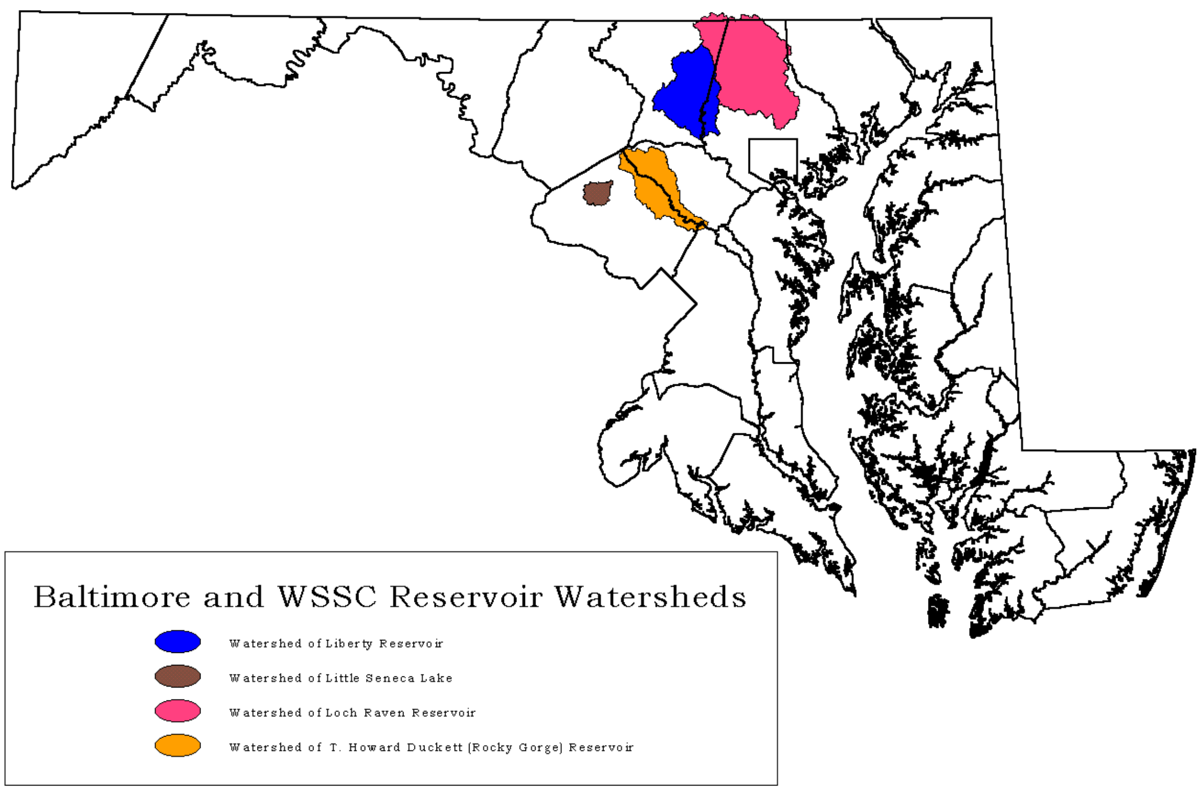

Figure 2–9. The Baltimore and WSSC Reservoir Watersheds

period from 1985 to 2000. This may be due to several factors, the most significant of which is likely the incorporation of some business and industry into public water supply systems. Projected water use demands were not made for commercial and industrial water uses, because no factor was identified with which to predict future trends. However, these two categories represent a relatively small percentage of overall water use, and therefore changes in their use are not expected to be significant relative to other categories.

2.1.4 Thermoelectric

Water use in the thermoelectric generation category has been variable over the period from 1985 to 2000. Average fresh water use for thermoelectric during this period was 387 mgd. An additional 6,260 mgd of saline water is used in this category. Currently, a large majority of thermoelectric water use is non-consumptive. Trends in the industry indicate that these water use patterns will change significantly in the future.

The Power Plant Research Program (PPRP) of the Department of Natural Resources provided analyses of present and future water demands for thermoelectric generation, based on estimates of projected demand for electricity. This report did not consider water demand for hydroelectric generation, which is non-consumptive. As shown in Tables 2–1 and 2–4, the current demand for brackish water for cooling during thermoelectric generation is extremely large at several locations, comprising some of the single largest water uses in the State. However, the Advisory Committee focused on demands for ground water and fresh surface water, since demand for tidal brackish water withdrawals do not compete with water demands for potable supplies.

The amount of brackish tidal water use for the generation of thermoelectric power is expected to decline sharply by 2030, while the use of fresh water is expected to increase during this period (Table 2–4). Data supplied by the PPRP indicates that fresh water use will increase due to the incorporation of new “closed-loop” generating units. The use of brackish tidal water for cooling will decline as old “once-through” cooled generating units are retired, since the “once-through” units are less efficient and pose a risk of thermal water pollution. As more efficient, less thermally-polluting “closed loop” cooled generating units are added, the use of fresh water will increase. The increasing use of “closed loop” cooled generating units, which increases the amount of evaporation during the process, requires a higher quality of cooling water and this results in a rise in both the withdrawal and the consumptive use of fresh water.

Industry projections show that total thermoelectric power generating capacity will nearly double from 2004 to 2030, while the use of brackish water for this use will decline by roughly 70%. The use of fresh ground water for thermoelectric generation is expected to more than double (to 3.6 mgd), the use of fresh surface water to increase by 6% (to 429.5 mgd), and the consumptive use of water, via evaporation, to more than double (to 100.8 mgd). This is due to the expected changeover to closed loop cooling, which uses far less total water but may evaporate roughly 90 % of the total cooling water. Therefore, a larger percentage of the additional 50+ mgd of added water consumption will come from fresh water sources.

Table 2–4. Thermoelectric Water Use and Water Consumption						
County	**Year**	**Total Generating Capacity (MW)**	**Ground Water Withdrawals (Fresh) (avg mgd)**	**Fresh Surface Water Withdrawals (avg mgd)**	**Brackish Surface Water Withdrawals (avg mgd)**	**Estimated Total Water Consumption (avg mgd)**
Allegany	2004	229.00	-	1.90	-	1.75
	2020	229.00	-	1.90	-	1.75
	2030	229.00	-	1.90	-	1.75
Anne Arundel	2004	2413.00	-	-	748.00	10.20
	2020	2139.00	-	-	564.00	9.10
	2030	2139.00	-	-	564.00	9.10
Baltimore County	2004	472.00	0.00	-	348.00	2.43
	2020	1080.00	0.35	-	5.00	4.50
	2030	1080.00	0.35	-	5.00	4.50
Calvert	2004	1829.00	0.40	-	3200.00	17.40
	2020	1829.00	0.40	-	3200.00	17.40
	2030	1829.00	0.40	-	3200.00	17.40
Cecil	2004	680.00	0.01	-	-	-
	2020	680.00	0.01	-	-	-
	2030	1880.00	0.01	8.00	-	7.20
Charles	2004	1336.00	0.35	-	1226.00	2.60
	2020	1336.00	0.35	-	1226.00	2.60
	2030	1336.00	0.35	-	1226.00	2.60
Dorchester	2004	162.00	0.02	-	0.35	0.23
	2020	1080.00	0.35	-	5.00	4.50
	2030	1080.00	0.35	-	5.00	4.50
Frederick	2004	-	-	-	-	-
	2020	1920.00	0.20	7.10	-	6.20
	2030	2600.00	0.30	7.10	-	6.20
Garrett	2004	-	-	-	-	-
	2020	400.00	0.25	5.00	-	4.50
	2030	400.00	0.25	5.00	-	4.50
Harford	2004	192.00	0.03	-	-	-
	2020	1292.00	0.23	-	6.20	5.60
	2030	1292.00	0.23	-	6.20	5.60
Montgomery	2004	588.00	-	359.00	-	1.50
	2020	1328.00	-	359.00	-	8.10
	2030	1328.00	-	359.00	-	8.10
Prince George's	2004	4982.00	0.91	1.50	570.00	13.30
	2020	5922.00	0.91	5.50	570.00	16.90
	2030	5544.00	1.33	5.50	395.00	25.10
Washington	2004	110.00	-	43.00	-	0.50
	2020	110.00	-	43.00	-	0.50
	2030	110.00	-	43.00	-	0.50
Baltimore City	2004	291.00	-	-	49.50	0.21
	2020	665.00	-	-	26.00	3.72
	2030	1195.00	-	-	26.00	3.72
State Totals*	2004	13,284.00	1.72	405.40	18,129.85	50.12
	2020	20,010.00	3.05	421.50	5,602.20	85.37
	2030	22,042.00	3.57	429.50	5,427.20	100.77

Note: The above table is adapted from data provided by the Power Plant Research Program of the Department of Natural Resources (Brown, D. 2004).
*Includes the counties in which there are current or future projected power generations.

2.1.5 Mining

Water use in the category of mining totaled 8.34 mgd in 2000. Mining water use includes water for washing material, dust suppression, and other process water, but does not include water removed from the ground to facilitate mining operations (mine dewatering). Water used for dewatering is considered non-consumptive since it is discharged to surface streams where it is available for subsequent use. It should be noted that mine dewatering has the potential to impact local wells, and should continue to be assessed by the State's water appropriation permit process. The problem of the impact of mine dewatering on local wells has been addressed legislatively by a requirement to establish "zones of dewatering influence" around quarries in carbonate aquifers. Water demand for mining does not correlate well with population, nor was any reliable predictor of demand identified. Thus, future demands were not projected for this water use category.

2.1.6 Agricultural Water Use in Maryland

Maryland initiated efforts to permit and track agricultural water use only in the last 15 years. Estimates of agricultural water use for years prior to 1990 are based on surveys conducted by the Maryland Cooperative Extension Service. Although agricultural water uses in excess of 10,000 gpd were permitted by MDE beginning in 1990, tracking and reporting of actual use was not required until 1996. USGS utilizes MDE permit information and combines it using a variety of techniques to provide estimates of agricultural water use. Agricultural fresh water use is estimated in three use categories: irrigation, livestock, and aquaculture. Since 1980, the total agricultural fresh water use has been on average about 3% to 5% of the State's fresh water use.

2.1.7 Irrigation

Historical trends of the last decade indicate that the total number of acres in farms and cropland are decreasing. The number of irrigated acres, however, has steadily increased in the same time. In the last 20 years, irrigated acres have increased from 40,000 to 70,000 acres representing 6% of cropland acreage, with ground water sources providing 65% to 70% of the water supply.

Farmers install irrigation systems to reduce risk. The amount of precipitation together with its distribution during the summer growing season determine the seasonal need for supplemental irrigation. Although the monthly rainfall in an average year is almost evenly distributed throughout the year, the amount of evaporation from soil and transpiration from crops, together known as evapotranspiration, varies widely. During the growing season, evapotranspiration is greater than precipitation. Irrigation reduces the risk of crop loss for farmers, and as a result, the total area of irrigated acres is likely to decrease less than the total area for non-irrigated acres. Irrigated acres are more likely to stay in agricultural use when unimproved parcels are sold or converted. Therefore, future demand trends for agricultural water withdrawals are correlated with irrigated acres rather than with total farmland or cropland acres.

In dry years, farmers will rely more heavily on irrigation. In addition to reducing economic risk, irrigation systems may also be a tool for controlling non-point source pollution from agricultural lands, by ensuring the uptake of nutrients during the growing season of dry years.

Analysis indicates that water use trends for agricultural irrigation are not consistent across the State. The Eastern Shore accounts for over 80% of agricultural water withdrawals and this trend is increasing. Remaining areas of the State show no growth in agricultural irrigation.

Estimates for irrigation requirements address times of peak demands rather than average use. During times of low demand or adequate rainfall, there may be recovery and recharge of the water table. An average year may or may not require irrigation depending on the distribution of the rainfall. Data from the Eastern Shore for rainfall and evapotranspiration were analyzed and ten simulations were evaluated for the period from 1992-2030. A more complete discussion of the methodology used to develop projections for agricultural irrigation data is in Appendix C. Based on this analysis, by the year 2030, statewide water demand from cropland irrigation is projected to be 225 mgd in the highest demand year.

Horticultural water use ranges from 0% to 8% of county totals statewide. Industry experts confirm a trend of increased efficiencies for horticultural irrigation systems that should counter growth and increased demand from the industry. Therefore, the analysis does not project significant demand increases from this sector. In 2002, statewide water use for horticulture was seven mgd. Projected demand for a high demand year over the next thirty years is 10 mgd.

The efficiency of agricultural irrigation can be improved through technology innovations as well as improved management. Management measures that could be implemented include proper scheduling based on moisture measurement and crop stress assessment. Outreach to farmers about improving water conservation and irrigation management should be provided through existing venues such as workshops and winter meetings and web-based delivery.

2.1.8 Livestock

Livestock water use has varied from 10 to 13 mgd since 1980. It is estimated that 80% of the water used for watering livestock in the Coastal Plain is from ground water and 20% is from surface-water sources. In other physiographic provinces, 70% is from surface water and 30% from ground water sources. Available data shows a decline in the number of cattle and hogs. This decline, coupled with more efficient watering systems for livestock operations, leads to a presumption for a flat trend in future water for livestock. The estimated livestock water use for 2030 is projected to be 15 mgd.

2.1.9 Aquaculture

State oversight of Maryland's aquaculture industry was formalized in 1990 under the Maryland Department of Agriculture. The major methods of aquafarming include pond, flow-through, and cage culture, which use surface water with intake structures from rivers and streams, and recirculating systems using ground water. Presently there are about 120 permitted facilities involved in aquaculture in Maryland. About 30 facilities are commercial operations. The remaining facilities are educational or research facilities. The USGS estimated fresh water use for the year 2000 to be 19.62 mgd. As a result of efficiency improvements through the use of recirculating systems and the outflow of ponds to surface waters, the consumptive water use should be lower than the estimated water use.

At the national level, aquaculture production is growing at a rate of 5% annually. Factors limiting future growth include higher capital costs of shifting to recirculating systems, environmental constraints, and profitability of the operations. Although the number of commercially operated aquaculture systems is projected to be 90 in 2030, estimated water use is projected to be 35 mgd because of increased efficiencies. There is also a need for further studies to provide better estimates on aquafarming water use.

2.1.10 Agricultural Water Use Conclusions

A number of assumptions were made to project agricultural water demand through 2030. Since the most recent data for 2002 is not yet available, the 1997 data was used. Results are preliminary because of limitations in available data. Accounting for all uses and managing for highest demand years results in a total agricultural need of 285 mgd statewide by the year 2030. Eastern Shore agricultural withdrawals are expected to significantly increase and may experience conflicts in the future with water supply needs of a growing population.

Adequate planning and management of the State's water resources to accommodate agricultural water use now and into the future will require additional information and research. Research needs include evaluation of appropriate irrigation technology; evaluation of nutrient reduction/loss under irrigation; and evaluation of management impacts on the economics of irrigation (Tompkins et. al., 1994).

2.2 Population Data and Trends

Maryland's population grew significantly between 1970 and 2000. The State's population grew by 1,374,000 people, representing a 35% increase from 1970 to 2000. During this same period, the number of new households grew by 806,000, representing a 69% increase. It is estimated that an additional 1,066,000 people will be living in Maryland by 2030, representing an additional 20% increase over the 2000 population. Approximately 545,000 new households will be created to accommodate this increase in population by 2030, representing an additional 28% increase in households since 2000. Overall, Maryland's population is projected to grow from 3,922,400 people in 1970 to approximately 6,362,000 people in 2030, representing a 62% increase since 1970. Likewise, the number of households in Maryland is projected to grow from 1,175,000 households in 1970 to approximately 2,526,000 households in 2030, representing a 115% increase since 1970.

There were 806,000 new households created in Maryland from 1970 to 2000. The greatest increases in total number of households during this period were in Montgomery, Prince George's, Anne Arundel, and Baltimore Counties. These "older" suburban Counties received 59% (474,000 households) of the new households constructed. However, the "newer" suburban counties of Howard, Harford, Frederick, Carroll, Charles, Calvert, and St. Mary's Counties received 33% (266,837 households) of the new households constructed during this period.

It is projected that another 545,000 new houses will be added from 2000 to 2030 to accommodate Maryland's growing population. The "older" suburban Counties are projected to receive 48% (approximately 263,000 households) of the new households constructed. However, the "newer" suburban counties are projected to receive 37% (approximately 200,000 households) of the new households constructed.

The Maryland Department of Planning reports that the percent of residential development constructed on large lots (0.5 acre or larger) has been increasing over the past 30 years, and is projected to continue growing. This decentralized growth pattern has resulted in forest and agricultural land being consumed for new homes and roads at an unprecedented rate. The percent of residential land developed in a low-density development pattern has increased from 47% (241,061 acres) in 1973 to 58% (489,540 acres) in 1997 and is projected to reach 62% (719,475 acres) by 2020. The conversion of forest and agricultural land to low-density residential development results in the loss and fragmentation of this resource land as well as an increase in the amount of impervious cover.

In relation to water supply management, the increase in low-density residential development increases the demand for new infrastructure (water supply lines and water treatment facilities) and increases the amount of non-point pollution, which results in the water quality degradation of the rivers and reservoirs used for water supply. Appendix B includes county and regional data on population, household numbers, and household size as well as residential development projections for the Monocacy watershed and Southern Maryland area.

2.3 Demand Management through Water Conservation and Efficiency Technologies

Water efficiency technologies and behavior modifications can have a significant influence on demand and represent an attractive alternative to seeking new water sources. Managing demand has typically not been a priority for most Maryland water systems because of the relative abundance of water supplies throughout the State. Drought conditions experienced from 1999 to 2002, however, forced many system managers to consider demand management in order to meet their water supply needs. As population growth and water use demand increase, some areas of the State may turn to demand reduction as one way to meet their water quantity needs.

There are a number of approaches that both the public and utilities have used to reduce demand, such as: educational programs; revised rate structures; residential water audits; leak detection and repair; rebate or other incentive programs; and meter upgrades. Additional water conservation tips and information can be found on MDE's website at www.mde.state.md.us. The Massachusetts Water Resources Authority was able to reduce daily demand by approximately 20% using these conservation technologies (MWRA, 2004). Gallatin, Pennsylvania reported water use reductions of 60% following the implementation of a comprehensive leak detection and corrosion control program (US EPA, 2002). Other water systems have developed alternative approaches that include reclamation and reuse of wastewater, which can also result in substantial savings. The City of St. Petersburg, Florida, for example, serves about 10,400 customers a day with reclaimed water for irrigation purposes, saving approximately 36 million gallons per day (St. Petersburg, Florida, 2004)

One of the most difficult obstacles to overcome when promoting wise water use is the wide discrepancy between the value of water and the price that consumers actually pay for its use. A number of factors contribute to this discrepancy, in particular the fact that for many citizens, the costs of building, maintaining, and operating their water systems is not fully evident in their water utility bills. These costs are less evident to ratepayers because the costs are cloaked in federal, state, or local taxes and may be obscured by grant programs that transfer the costs of infrastructure upgrades from the ratepayers to the taxpayers. Costs such as resource depletion or negative ecological impacts are frequently not considered at all. "Full cost pricing", or incorporating all of the costs of building, maintaining, and operating a water system into the price paid by the consumer, could have a substantial impact on water use. Beyond the non-discretionary use of water (i.e., the minimum needed for sanitation), there is considerable room for consumers to reduce their water use. Stronger price signals directly related to individual consumption could encourage conservation. Even greater savings may be possible through further pricing incentives for consumers to conserve, such as differential pricing structures that charge higher rates for higher water use.

Substantial water use reductions through water conservation and water use efficiency improvement technologies may be achieved in those regions of Maryland where existing water resources may not be able to meet future demands. Reducing demand can be an effective approach to meeting water quantity needs, but can require a significant investment of time and resources and can also negatively impact water system revenues. Government-sponsored programs to assist water utilities in implementing these programs, or regulations requiring utilities to meet certain demand reduction goals, may be needed to encourage water systems in the State to undertake these activities.

2.4 Possible Effects of Climate Change

The Interstate Commission on the Potomac River Basin (ICPRB), in collaboration with Johns Hopkins University and the U.S. Army Corps of Engineers Institute for Water Resources, conducted a study of climate variability and its potential effects on resources and demands in the Potomac Basin in the mid-1990s (Steiner et. al., 1997). Model output from five atmospheric circulation models was examined. Forecasts from the five climate scenarios produced a range of climate conditions that bracket current normal (historical) conditions.

The output from these models is monthly temperature and precipitation. The study authors translated this information into estimated effects on stream flow and water demand. The study authors cited many reservations and difficulties inherent in the process of translating the output of these models (i.e., monthly temperature and precipitation) into estimates of stream flow and water demand.

The study was conducted ten years ago, specifically for the Potomac River Basin. The effects of climate variability in other areas within Maryland were not studied. The study authors suggest that an updated climate variability study be conducted for the Potomac Basin, in light of better tools that have since been developed (i.e., a watershed runoff model), and that can be used to translate the output of the atmospheric circulation models into estimates of Potomac stream flow. An updated study should also be extended to cover the remaining areas of Maryland.

The results of the study suggest that compared to the stationary climate assumption, there is a possibility of a substantial increase in year 2030 summer water use as a result of climate change under assumptions of several of the atmospheric circulation models. Of the five atmospheric model scenarios examined, the greatest change was a 19% increase in the July, August, and September demands in the Washington Metropolitan Area when compared to the increase in water use calculated under historical climate.

Selected climate change scenarios produced a range of results, bracketing those results under historical climate. For reservoirs in the Potomac Basin, refill for the critical operating "season" varied from between -32% to +26% for climate change scenarios as compared to that calculated for historical climate. (It should be noted that all but one of the climate change scenarios reduced reservoir refill. Only one scenario increased inflow.) The range of flow of the Potomac River at Point of Rocks varied from between -49% to +33% for the climate change scenarios.

2.4.1 Policy Implications of Climate Change

Both water demand and water resources would be affected by changes in climate. Water demand and resources move in opposite direction under the influence of climate change, confounding the ability of resources to meet demands. Under all scenarios examined, conservation (demand management) is a potential means to reduce water use and thus contribute to the mitigation of future deficits.

A range of potential climate change scenarios was selected for this study. Water resource managers need to be aware that water resources may be more (or less) fully utilized in the various scenarios than under a continuation of historical climate conditions. At this time, water management decisions should involve consideration of whether or not to plan for the mitigation of the most severe climate change impacts determined in this study.

2.5 The Effects of Drought on Demand

Maryland experienced an extended period of precipitation deficits from 1999 through 2002, highlighting the potential impacts of weather and climate on the environment and economy of the State. Drought conditions affect not only the amounts of water that are available for use, but also the demand for water. During dry summer months when stream and aquifer resources may be low, farmers, landscapers, and homeowners need more water than during normal rainfall periods. Crops require supplemental irrigation that may not be needed during a normal year. Homeowners, businesses, nurseries, and golf courses tend to increase the amounts of water used to maintain their landscapes. At the same time, high temperatures and dry weather add to the amount of evaporation from streams and other water bodies. Swimming pools also lose more water to evaporation than usual, and require replenishment from ground water or other sources. Drought can result in much greater peak demand periods than during normal weather conditions. Peak demands are much more difficult to plan for than average demands.

The high peak demand during drought periods can be offset somewhat by using mandatory or voluntary water use restrictions, as were imposed in Maryland in both 1999 and 2002. For example, Maryland's drought management plan calls for restricting water use for lawn maintenance, car washing, golf course irrigation, and washing of paved surfaces. During 2002, some Maryland communities were able to reduce water use by as much as 20% for limited periods of time. Without proper planning, however, water use restrictions can be ineffective, or can have a negative fiscal impact on water systems, homeowners, businesses and industry. Maryland's restrictions were designed with input from private sector businesses and industry in order to minimize the fiscal impacts.

3.0 AVAILABILITY OF RESOURCES FOR WATER SUPPLY

Two primary considerations will determine whether Maryland can meet its water supply needs over the next thirty years: whether or not there is an adequate supply of water available to be withdrawn, and whether that water is of a quality that serves the intended use. In order to determine if Maryland's available supplies can meet the projected demands, it is also important to evaluate other considerations such as whether the State's water supply infrastructure can adequately treat, store, and distribute that water.

Water suppliers and citizens across the State experience a variety of water supply issues that impact the availability of the resource. Water availability can be affected by limited natural availability, heavy usage of the resource, or activities that compromise the quality of water. Because of Maryland's geographic, hydrogeologic, and cultural diversity, water supply issues range from those having a statewide impact to those impacting a region or even a single water supply. Growth is a pervasive concern that threatens to have far-reaching impacts on water supplies throughout most of the State. Another issue that crosses regional lines is the need to protect the sources of community water supplies. In many cases, communities need to establish control of land beyond their service area and/or undertake other protective efforts to achieve water balance requirements and/or protection from contaminants. The adequacy of available water supply infrastructure is also an important factor when considering water availability.

The Advisory Committee found that the resources currently available for evaluating water supplies across the State are not adequate to determine whether supplies will be able to meet future demands. Although simple water balance calculations can provide adequate information in some areas, more complex evaluations that include monitoring of water levels and modeling of ground water flow are required for other situations. Existing monitoring networks, especially for ground water supplies, are inadequate to provide a detailed picture of water availability and staffing is not currently available to undertake complex modeling evaluations.

Additional issues, in particular those related specifically to the operation of public water systems, will impact the ability of Maryland's water supplies to meet future needs. The adequacy of existing public water system infrastructure, as well as a growing regulatory burden will prove to be formidable challenges for the public utility industry.

3.1 Regional Water Supply Issues

Western Maryland relies on surface water sources as well as fractured rock aquifers for water supply. In some areas, there is limited availability of ground water supplies and it can sometimes be difficult to locate a viable supply. These areas can be particularly vulnerable during periods of drought, and water suppliers need to focus on building redundancy into their systems to avoid shortfalls during dry periods. Other ground water areas, particularly in the limestone regions of Washington County, while supplying ample quantities of water, are locally contaminated with fecal coliform and thus are unsuitable for human consumption without treatment. Some Western Maryland water systems using surface water sources are experiencing disinfection by-product levels in their finished water that exceed current or future standards.

In Central Maryland, many water supply issues revolve around growth. The six central region counties experienced 52% of the population growth for the State from 1970 to 2000. With well over two million residents dependent on the Baltimore and WSSC reservoir systems, it is essential that these systems maintain the resources needed to control eutrophication in the reservoirs, plan for alternative water sources, and meet water quality requirements. More than 400,000 individuals in this region use domestic ground water supplies, which are vulnerable to contamination from nitrates, pesticides, organic chemicals and fecal contamination. Some smaller community systems in the region do not have adequate storage or reserve supplies, and may violate their appropriation permit requirements during periods of drought. Continued growth and development in the region presents a host of issues, including the impacts of withdrawals and discharges on downstream users, the impacts of development on the hydrology of streams, the impacts of various industrial activities that can pollute water supplies, and the cumulative impacts of consumptive use, especially during dry periods.

Eastern Maryland has its own set of water supply problems. A recent change in federal drinking water standards lowered the standard for arsenic from 50 parts per billion (ppb) to 10 ppb. A number of water suppliers using the Aquia aquifer exceed the new standard, and compliance will require additional treatment, at substantial cost to consumers. High arsenic levels also impact a relatively large number of private well users. Many water suppliers and private wells also experience high levels of nitrate, a contaminant that presents a special risk for infants. Fluoride and iron, both naturally occurring, are present in some areas at levels that cause concern. Another problem in some areas is the prevalence of older "telescoping" wells drilled for domestic use. These wells do not allow homeowners to lower pumps as water levels decline, potentially rendering the wells useless. Brackish water intrusion may also be a concern for certain areas. Increased growth and increased used of water for agricultural purposes may eventually lead to conflict over water resources in areas where these activities are in close proximity.

Water resource issues are also a concern in Southern Maryland, and are discussed in more depth in Section 4.2 of this report. Growth is again of concern, and additional studies are needed to identify the limitations of the water resource in the region, primarily deep confined aquifers. Additional issues include the presence of elevated levels of arsenic, gross alpha radiation, and sodium. In Prince George's County, much of which is served by WSSC, the Patuxent River will not be able to meet the needs of the growing area and the County will increasingly rely on the Potomac River for its water supply. Whether or not the Potomac River can support this and other growth areas is a question that needs to be addressed. Further discussion of growth issues in the Potomac River basin is provided in section 5.2 of this report.

3.2 Natural Occurrence and Factors Affecting Availability

Maryland is fortunate to have relatively abundant water resources, and historically has been able to meet its water needs. Shortages occur when climatic conditions are extreme (drought) or there is a lack of adequate infrastructure to withdraw, treat or deliver water. However, increasing demands for water to support population and economic growth are expected to result in greater challenges to supplying adequate water of acceptable quality.

Despite the overall abundance of water resources in a typical year, the natural occurrence of the State's water resources is not evenly distributed either in space or in time. Some areas receive more rainfall than others do, and rainfall can vary greatly with the seasons and from year to year. Topography, soil type, and other factors interact to affect the amount of rainfall that runs off as storm flow or infiltrates into the ground to recharge aquifers and eventually discharge as baseflow to streams. In very general terms, the State can be divided into two regions: the Coastal Plain, where ground water from confined aquifers serves as the main source of water supply, and the Piedmont/Ridge and Valley/Appalachian Plateau, where surface water is the primary source for the largest water users, and ground water from fractured-rock and carbonate aquifers is extensively used for small to mid-sized water users. The dividing line between these two regions is known as the "Fall Line".

In unconfined aquifers, which are the dominant aquifer type north and west of the Fall Line in Central and Western Maryland, ground water recharge is a relatively local phenomenon, and water travels relatively short distances before being discharged to a stream or withdrawn. Recharge occurs rather quickly in response to precipitation, due to the direct percolation of water into the aquifer. In confined aquifers, which are the dominant aquifer type in Southern Maryland and on the Eastern Shore east and south of the Fall Line, ground water may travel great distances across several counties after it infiltrates in a recharge area. Due to confining layers of clay or silt that isolate aquifers from direct infiltration (except in their recharge areas), precipitation does not have an immediate effect on ground water levels. In both types of aquifers, managing ground water withdrawals to a sustainable level depends on limiting withdrawals to a rate less than the long-term recharge rate.

In both regions, base stream flow is directly related to the discharge of ground water from unconfined aquifers. Confined aquifers in the Coastal Plain are not linked to surface streams. These deep aquifers serve as a primary water source due to their capacity to store large quantities of water and their protection from surface water contaminants, thus leaving surface water as a minor source for potable uses, although it is an important source for agriculture. By contrast, surface water is used more heavily in areas underlain by consolidated rock. Due to the limited ability of the fractured-rock aquifers to yield large quantities of ground water, community supplies and other large uses rely more heavily on surface water.

3.3 Methods for Determining Availability

In unconfined aquifers, a water balance analysis (or water budget) performed on a watershed basis is an appropriate method for determining water availability. A water balance involves the estimation of ground water recharge rates. Recharge rates are estimated for both an average year and a drought year in order to provide a conservative estimate. Recharge rates in unconfined aquifers are derived using stream baseflow records, underscoring the need for reliable, long-term stream gages for proper water resource planning.

Recharge rates in confined aquifers are not readily measured or estimated, rendering a water balance approach ineffective. In lieu of a direct measure of recharge rates, MDE has attempted to limit withdrawals in a confined aquifer by limiting the amount of drawdown (the water level decline due to pumping) to an acceptable level. Because lowering water levels in a confined aquifer below the top of the aquifer is associated with permanent loss of aquifer yield, MDE has adopted a policy encoded in regulation that attempts to limit withdrawals so that water levels do not decline from their pre-pumping levels any more than 80% of the distance to the top of the aquifer. See Figure 3–1 below.

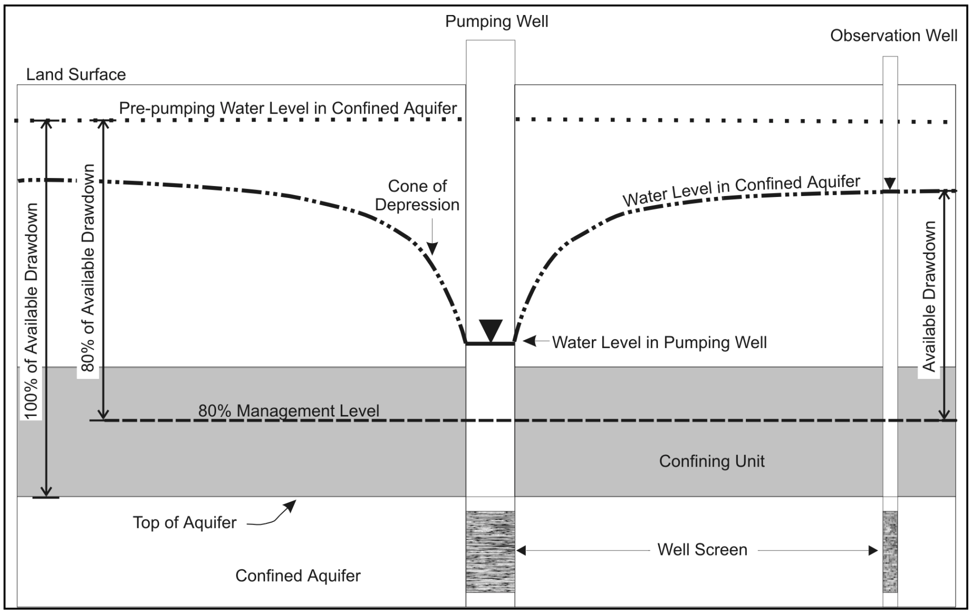

Figure 3–1. Schematic Illustration of the 80% Management Level for Confined Aquifers. The water level rises above the top of the aquifer because it is under pressure and is lowered due to withdrawals from the pumping well. The water level measured at the pumping well is much lower than the water level in the observation well due to the formation of a cone of depression.

Recent advances in computerized ground water modeling have presented a promising new method of estimating recharge in confined aquifers. With sufficient data on the size, extent, and other characteristics of an aquifer, along with records of withdrawals and water level changes over time, it is possible to model the effects of ground water withdrawals, and to infer estimates of recharge. This method has been used by the MGS and the USGS on a case-by-case basis for certain aquifers in selected areas of interest, but has the potential for wider and more comprehensive application for all of the confined aquifers in the State. The main hurdles to wider use of the methodology are the availability of reliable aquifer data and ground water level data, as well as the resources to perform the modeling (i.e., software, hardware, personnel, and funding).

3.4 <u>Existing Data Sources</u>

Some of the data necessary for proper estimation of sustainable withdrawals, and therefore adequate planning and management of water resources, is available from existing sources. For surface water, the USGS, in cooperation with the MGS and many other federal, state, and local agencies, maintains a network of stream gages in Maryland. The stream network, together with precipitation data from a network of rain gages, provides the key monitoring data. However, the stream gage network is far from adequate in its coverage of major and minor streams in Maryland that are used for water supply (Figure 3–2). It is even more inadequate in its coverage of watersheds for which ground water withdrawals require the calculation of ground water recharge rates (Figure 3–3). The stream gage network needs to be greatly expanded.

The USGS and MGS maintain and operate a network of observation wells throughout the State, in order to monitor trends in ground water levels. A discussion of the needs of this observation well network is presented in Section 5.1 and Appendix F of this report. The network should be expanded in order to assure the collection of data critical to sound management decisions for the State's ground water resources.

Aquifer characteristics, critical to modeling the behavior of aquifers and estimating drawdown impacts, can only be derived from aquifer tests. An aquifer test involves sustained pumping of a well to determine an area of impact. These tests are expensive, and may be performed as part of a hydrogeological investigation performed by the MGS or the USGS. These tests may also be required as a requirement of a permit application.

3.5 Existing Regulatory Process for Assessing Water Availability and Permitting Use

Presently, water availability is considered in the context of several planning or regulatory activities. Water and Sewer Plans are prepared by county governments, with input from municipal governments, to assure the orderly development of community water systems. The Plans delineate areas intended for public water service, and describe the available and planned infrastructure needed to withdraw, treat and distribute potable water in those areas. However, the Plans generally do not address whether the water resources (e.g., wells, streams, etc.) will be adequate to meet expected demands.

Through the Water Appropriation Permit process, specific proposed water uses are reviewed to determine if the resource is adequate, and whether the impacts of a withdrawal are reasonable. The permit process is intended to review specific proposals, and therefore, reviews are specific to the requested need. While an attempt is made to consider the cumulative effect of existing permits during an application review, the regulatory permit process is not intended to assess the availability of water for future, projected uses, or to plan for their development. A separate process is needed to plan for the orderly development of available water resources and to assure that growth and development plans are commensurate with available resources.

County and local governments also have responsibilities related to assessing water availability. Through the delegation of authority under the laws related to Water and Sewer Plans (Env. Article §9-512), appropriate local or County authorities must assure that adequate water capacity is available before approving a building permit, and that adequate capacity will be available in time to serve a proposed development before approving a subdivision plat. How these responsibilities are carried out varies among jurisdictions, and is the subject of a review being conducted by MDE in cooperation with county Environmental Health Directors. Recent experience with certain municipalities and a preliminary summary of the responses of the Environmental Health Directors indicate that a more formal or standard method of determining remaining available system capacity

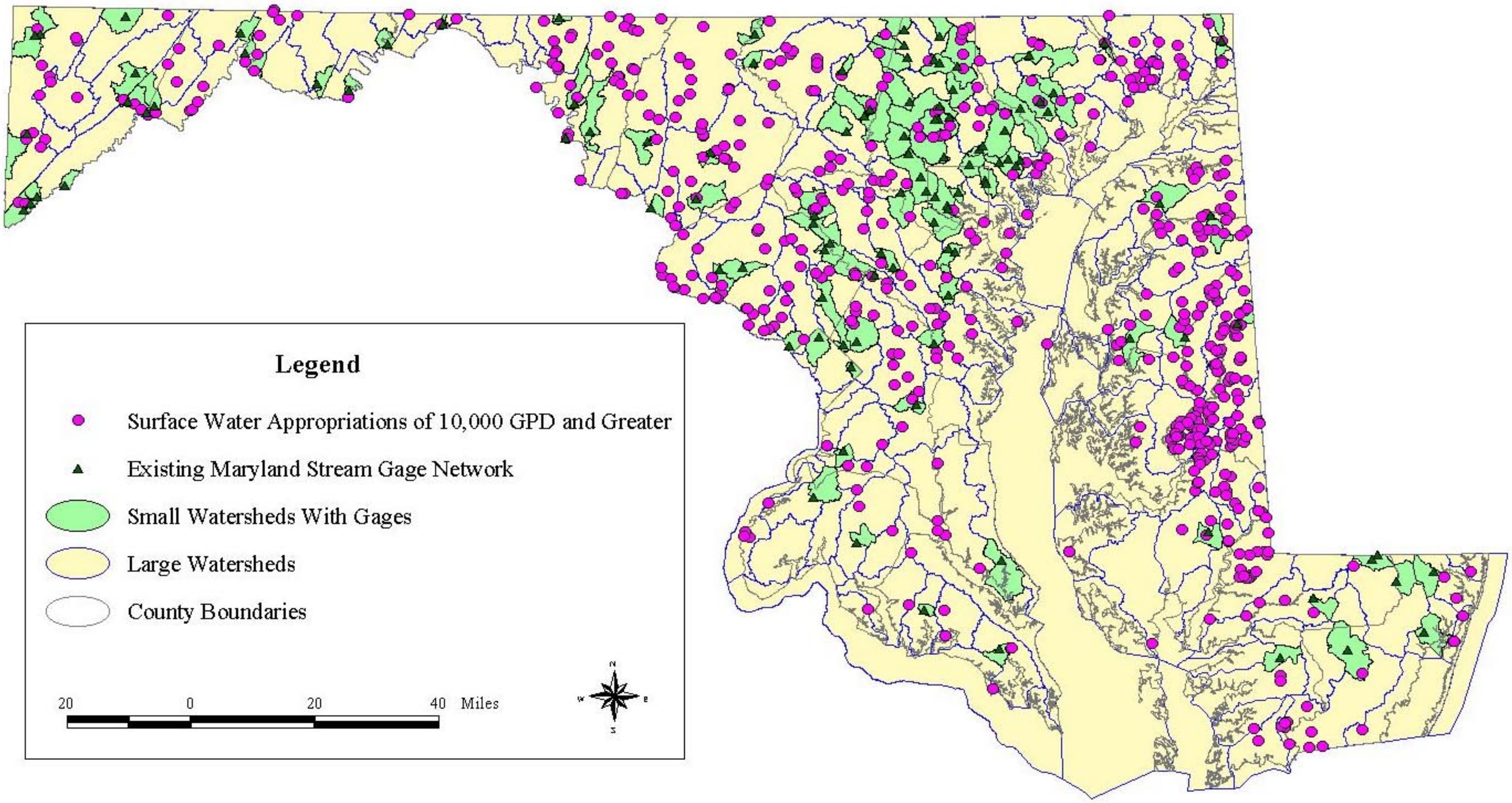

Figure 3–2. The Maryland Stream Gage Network in relation to Large Surface Water Appropriations. The small watersheds in green are the Maryland twelve-digit watersheds that currently have an operating stream gage. There are a total of 569 surface water appropriation permits of 10,000 GPD or greater, sixty-eight of which are located within a small watershed with an operating stream gage.

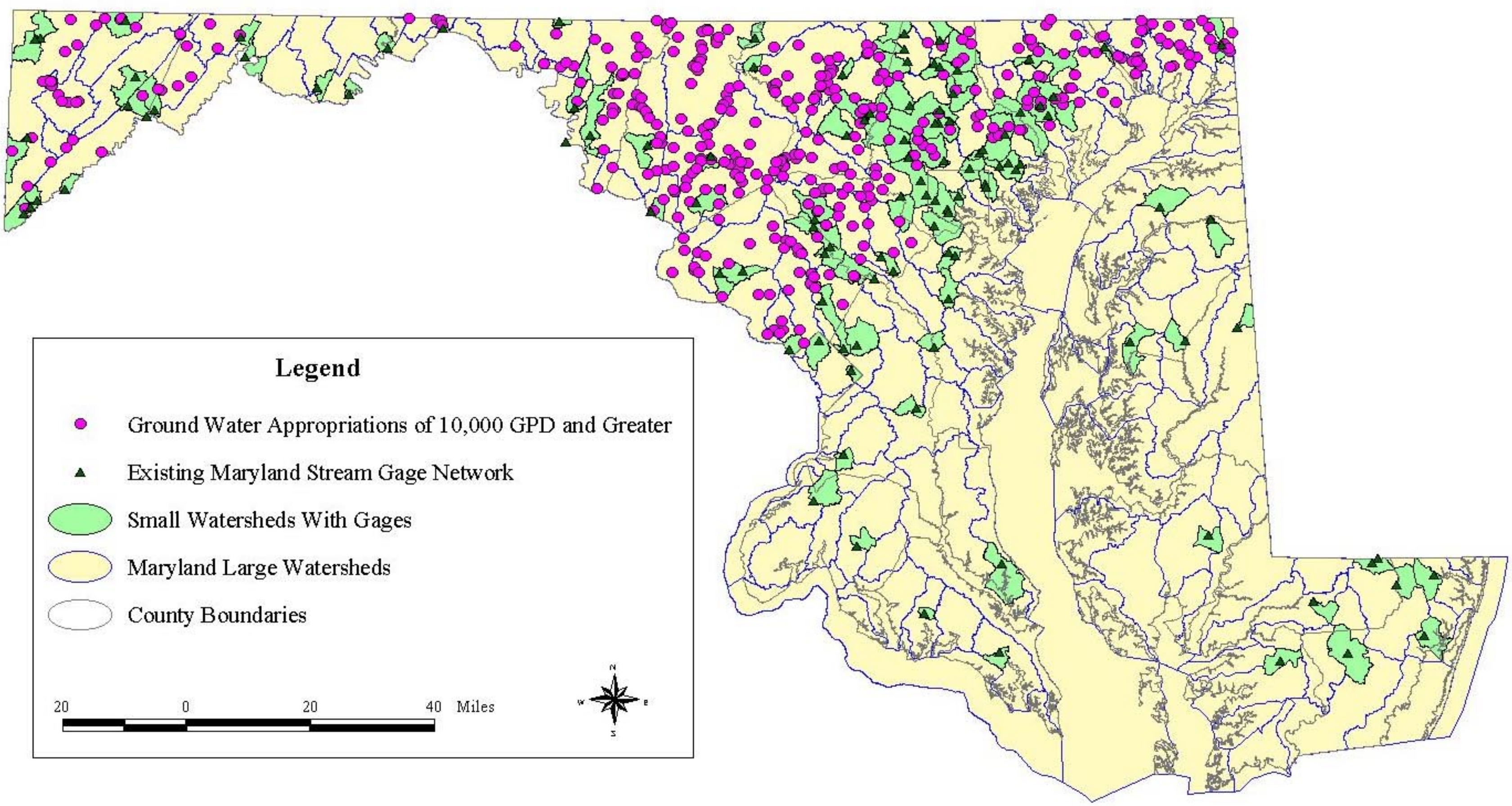

Figure 3–3. The Maryland Stream Gage Network in relation to Large Ground Water Appropriations West of the Fall Line. Ground water permits west of the Fall Line require a ground water recharge calculation, which is determined from baseflow analysis of stream gage data. There are 407 ground water permits of 10,000 GPD or greater in this area, eighty-one of which are located within a small watershed with an operating stream gage.

may be needed to assure that public water systems do not commit to serve new development beyond their means.

3.6 Water Supply and Drought

The variability of climate and weather complicate the process of planning for water supply. The drought that impacted the State from 1999 through 2002 demonstrated the potential severity of impacts that could occur from an extended dry period. In 2002, record low water levels were observed in several Maryland water-level monitoring wells. Because most streams rely heavily on baseflow from ground water to maintain normal water levels during summer months, a large number of streams also experienced record low levels during 2002. Counties across Maryland reported increased numbers of applications for replacement wells, and there were a number of public water systems in the State that experienced water supply shortages due to drought. Although most of the wells that went dry due to drought were older shallow wells, it was clear that an extended drought could have far-reaching impacts on Maryland's citizens. The costs of drilling replacement wells, replacing damaged landscapes, and loss of business can result in significant fiscal impacts to homeowners, businesses, and industries in the State.

Fortunately, a drought management plan that was developed after dry conditions began in 1999 resulted in a coordinated approach for communication and response to drought conditions, including implementation of water use restrictions for some areas of the State. Further planning is needed to improve the coordination of drought response with the agricultural community as well as to identify additional responses that might be needed if conditions become more severe than they were during 2002. With agricultural irrigation needs predicted to increase, Maryland must explore ways to assist farmers in reducing water consumption without increasing crop losses, especially during times of peak demand such as during drought conditions.

3.7 Public Water Supply Issues

In addition to considering the amounts of water available for water supply, it is also important to look at the adequacy of public water supply infrastructure for treating, storing, and distributing water to Maryland's citizens. The federal Safe Drinking Water Act governs requirements for public water systems, and these systems are now required to monitor for up to 91 contaminants and to meet a host of technical, managerial, and financial requirements outlined under the Act. A number of issues threaten to impact the ability of Maryland water systems to meet these needs.

The first issue is the actual availability of infrastructure, especially in areas where population growth is high or where naturally occurring contaminants impact the safety of domestic well water supplies. For example, federal and State regulations recently lowered the drinking water standard for arsenic from 50 parts per billion (ppb) to 10 ppb. As noted earlier, several counties in the

Coastal Plain region of Maryland have large numbers of domestic wells that use aquifers where arsenic levels may exceed the standard. Further research and consideration must be given to whether the development of community water supplies for certain areas might be the best way to protect public health. Similar situations exist for areas of Anne Arundel County where radionuclides in ground water exceed drinking water standards, and for areas in the western and central regions of the State where geologic conditions result in elevated levels of bacterial contamination in ground water.

A second issue relates to aging distribution systems, especially in older urban areas of the State. In many areas, distribution pipes are beginning to reach their natural life limit. As a result, these older systems may be losing large amounts of water through leaks in the distribution systems. Replacement of the pipes represents an enormous financial undertaking, but could result in a substantial savings of water, as water demand increases for these systems.

Third, new information related to the health impacts of disinfection byproducts may have a major impact on some surface water systems' ability to meet drinking water standards. Disinfection byproducts are formed when the chemicals used to disinfect drinking water combine with naturally occurring organic materials in the water source to form new chemicals that are now known to present health risks. New federal regulations place even more stringent requirements on water systems to limit the production of disinfection byproducts.

A fourth issue relates to the ability of Maryland's State Laboratory to continue providing the necessary analytic services required to ensure that public water systems meet water quality requirements. The substantial increase in numbers of regulated contaminants and numbers of required samples has placed considerable demand on laboratory resources. Improved laboratory infrastructure and increased personnel are needed to guarantee that the State's laboratory capacity is sufficient to meet routine analytic requirements as well as the additional capacity needed in the case of water system emergencies.

4.0 PILOT STUDIES

In accordance with the Executive Order, the Advisory Committee directed staff to initiate a review of the latest information concerning assessments of the quantity and quality of the State's ground and surface waters. Staff found much relevant available information, but no recent efforts to assess the adequacy of the water resources to meet expected needs on a statewide level. A comparison of available water supply resources with expected water demands is a critical and basic analysis that is essential to assessing not only the adequacy of the State's water resources, but also the adequacy of water use plans, and the legal and administrative mechanisms in place to properly manage those resources. A statewide assessment was beyond the limited timeframe of the Advisory Committee. Therefore, the Advisory Committee directed the completion of two pilot studies in selected areas of the State, in order to demonstrate the methodologies that could be used in a statewide assessment, to identify the needed information, and to draw preliminary conclusions about the utility of extending the analysis across the State.

Two pilot studies were conducted in an effort to examine the relationship between demands for water and the available supply in rapidly growing regions of the State, and are included as appendices to this document. The pilot study areas were selected to represent two distinct hydrogeologic regions of the state in order to demonstrate the broad range of water supply issues. The Monocacy River Watershed, which includes parts of Frederick, Carroll, and Montgomery Counties, was chosen to demonstrate ground water and surface water supply issues in a hydrologic system that is directly influenced by annual precipitation. (see Appendix D). The Southern Maryland Counties (Anne Arundel, Prince George's, Calvert, Charles, and St. Mary's) were chosen as a second pilot study area to demonstrate different water supply issues, i.e., in areas dependent on ground water from deep aquifers that are more sensitive to changes in water use than to variations in annual precipitation. (see Appendix E).

The overall goal of each pilot study was to demonstrate the methods that could be used in an analysis of water supply and demand. The objective of each pilot study was to determine if the water supply would be able to meet water demands projected to 2030. However, conclusions pertaining to this objective were not made, because in the process of completing the pilot studies, several shortcomings were recognized such as availability of monitoring data, the quality of information, or the adequacy of analytical tools. Due to the distinct hydrologic systems in each region, two significantly different approaches were taken to assess the water supply. The methods and results of each are summarized in this section and explained in further detail in the appendices.

4.1 Monocacy River Watershed Pilot Study

The Monocacy Watershed drains an area of approximately 969 square miles. The watershed includes significant portions of Frederick County, Maryland; Carroll County, Maryland; and Adams County, Pennsylvania as well as smaller portions of other counties (Figure 4–1).

This region has experienced significant growth in the last 30 years and the population living in the Maryland portion of the watershed is expected to increase by 57% in 2030. This continued population increase has raised questions concerning the availability of water to support the anticipated growth. Frederick County has recognized this concern and plans to accommodate much of their future growth with an increased withdrawal from the Potomac River. Nonetheless, an analysis of the water availability within the watershed is useful to demonstrate where demand locally may exceed available supply within the watershed.

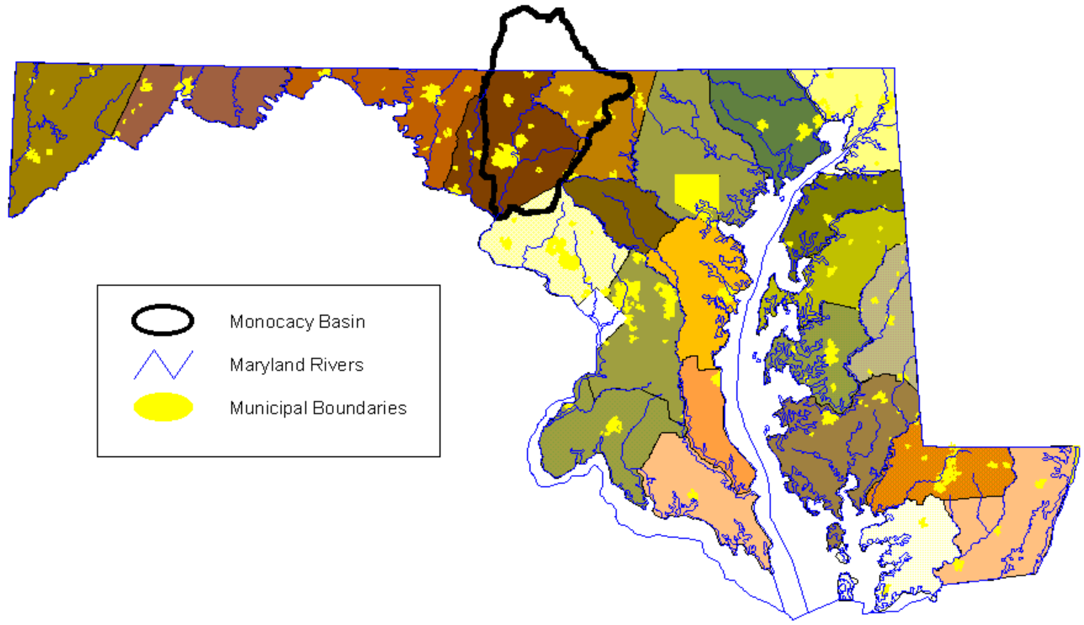

Figure 4–1. Monocacy Watershed Vicinity Map

The Monocacy River Watershed pilot study demonstrated some of the techniques that can be used to evaluate the reliability of both ground water and surface water supplies in the watershed. The pilot study proceeded through the following steps:

- The Monocacy Watershed was divided into fifteen sub-watersheds (Figure 4–2) in an attempt to address the variability in population, hydrogeology, and water use across the watershed.

- Historical and current water use data was evaluated with population data and used to estimate future water demand for each sub-watershed.

- Aquifer recharge was estimated for normal and drought years based on geology and baseflow. Ground water budgets were developed for each of the fifteen sub-watersheds using the estimated recharge and the annual average demand.

- Three simulation models of surface water flows, based on historical records and annual average water use, were used to provide a rough estimate of surface water availability and to evaluate several alternatives under consideration for the Monocacy-Lower Monocacy sub-watershed.

- Analysis techniques were evaluated in order to identify limitations, the need for additional data, and opportunities for modifying the analysis to adequately address the unique characteristics of supply and demand in the watershed.

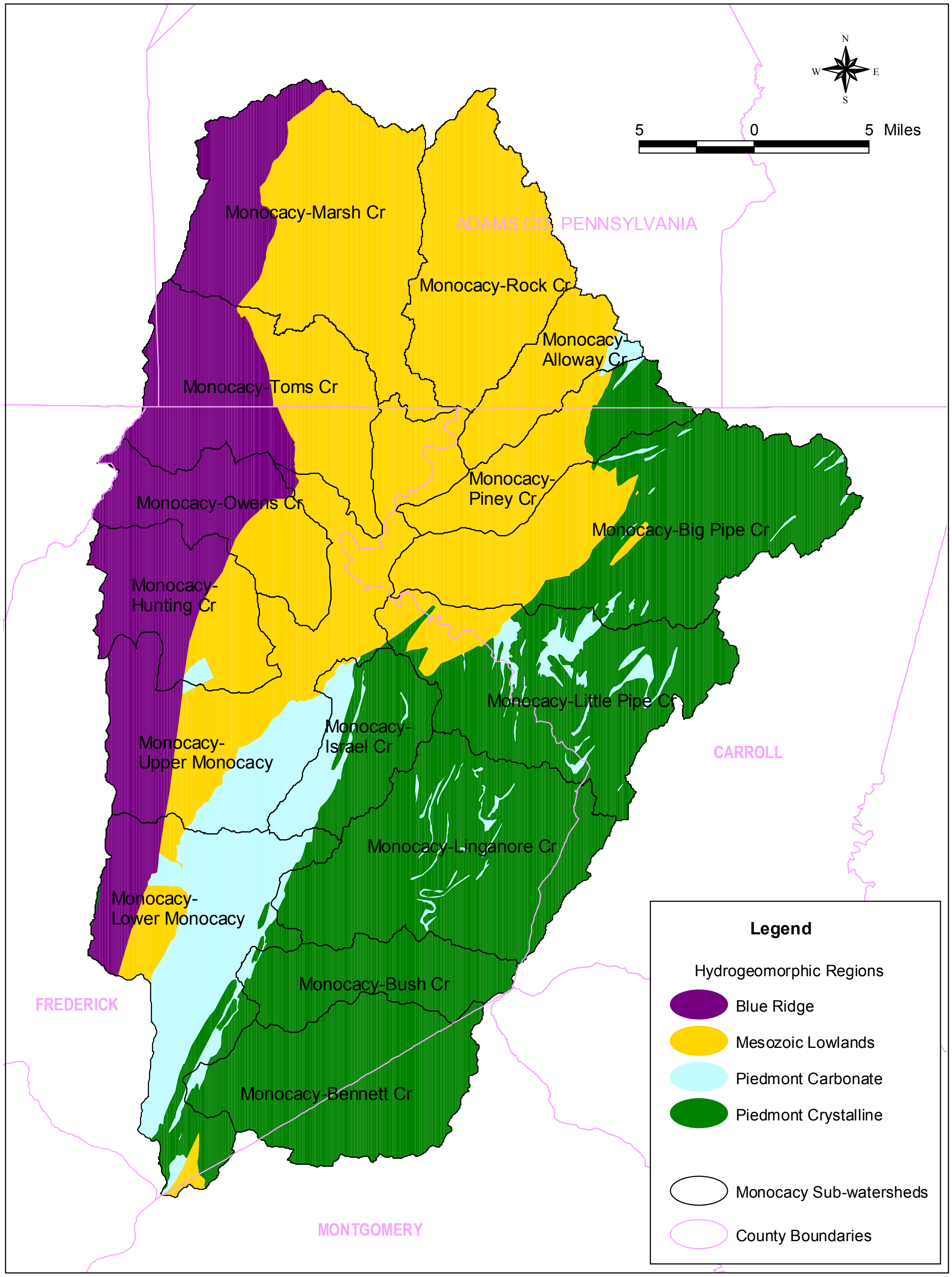

Figure 4–2. The Fifteen Sub-Watersheds and Hydrogeomorphic Regions in the Monocacy Watershed Pilot Study. The sub-watersheds are aggregations of the DNR twelve-digit watersheds in Maryland, created for the express purpose of analyzing water supply and demand for this pilot study. The naming convention is used to avoid confusion with sub-watershed names recognized in other watershed classifications. Hydrogeomorphic regions are adapted from the USGS GIS Coverage entitled "Hydrogeomorphic Regions of the Chesapeake Bay Watershed." (Brakebill and Kelly, 2000)

4.1.1 Projected Demand

Water use in the Maryland portion of the Monocacy watershed in 2000 was approximately 47 mgd, including roughly 3 mgd that is transferred into the watershed from the Potomac River via the New Design water treatment plant. The total water demand in the watershed is equally divided by surface water and ground water uses. The current water demand by use class in the Maryland portion of the Monocacy watershed was determined from analysis of water appropriation permits, public water systems, and census data. Current and projected populations within each sub-watershed were determined based on 2003 Metropolitan Washington Council of Governments Traffic Analysis Zone (TAZ) data and GIS files (Metropolitan Washington Council of Governments, 2003).

USGS provided a yearly breakdown of water use by type and county in Maryland for the period from 1985 through 2001, which was analyzed for correlation with population for Frederick, Carroll and Montgomery counties. This analysis was used to project water demand within the Maryland portion of the fifteen sub-watersheds. Because municipal and industrial discharges in Maryland were explicitly considered in the analysis, demand figures cited in the Maryland portion of the watershed represent the total demand and not just consumptive use. Discharge data in Pennsylvania was not available to MDE and most water appropriations in Pennsylvania do not require a permit. Therefore, in the Pennsylvania portion of the watershed, consumptive use estimates generated for 2000, 2020 and 2030 by the Interstate Commission on the Potomac River Basin (ICPRB) (Steiner et. al., 2000) were distributed to each sub-watershed using 2000 census data (U.S. Census Bureau, 2001). The 1995 proportions of surface and ground water use within the Pennsylvania portion of the Monocacy Basin determined by ICPRB were maintained in the water demand projections.

A significant assumption of these projections is that the current relative proportions of ground water and surface water use will remain the same for each category of use (e.g. public supply). This assumption could be confirmed, and the proportions of ground water and surface water use refined, if the information were available to incorporate water and sewer planning with projected growth. The projected proportions of population growth that will be served by public water and sewer, as opposed to individual well and septic, could also be improved by incorporating water and sewer plan information.

4.1.2 Determining Ground Water Availability

Ground water within the watershed comes from shallow aquifers that are recharged by precipitation and discharge to the streams in the watershed. The reliable yield of these aquifers is the recharge less the quantity needed to sustain minimum streamflow.

The underlying geology in the Monocacy Watershed is composed of four major rock types that can be grouped based on their common hydrogeologic characteristics. These four hydrogeologic classifications were used to estimate recharge rates (Tipton, 2004) for both average years and drought years in each of the sub-watersheds (Figure 4–2). A reasonable estimate was made that 80% of the water used for households on individual wells is returned to the aquifer via recharge from onsite wastewater treatment systems. This estimate could be confirmed or refined with research on consumptive use of water. The quantity of ground water recharge needed to maintain minimum base flow in streams was estimated from published values for the 7-day, 10-year low flow (7Q10) for stream gages representing each hydrogeologic region.

The total ground water available is estimated from the recharge and minimum base flow in streams in each sub-watershed, and the values can then be compared to the demand figures to estimate the adequacy of the ground water supply. A limitation of the analysis is that it only provides an annual average of water availability and does not incorporate seasonal variations in either recharge or demand. In addition, an underlying assumption is that reserving an amount of ground water recharge equivalent to the 7Q10 streamflow will be sufficient to maintain acceptable minimum streamflows. The adequacy of the 7Q10 as an appropriate reserve flow needs to be evaluated. Any increase in the amount of ground water needed to maintain base flow will decrease the amount of ground water available for withdrawal. The relationship between recharge, discharge, and storage to ground water availability also needs further study to increase the confidence in the analysis of the ground water supply.

4.1.3 Determining Surface Water Availability

Streamflows vary from day to day and from season to season. Appropriations from streams and rivers are required to leave a minimum amount of water in the stream, known as the flowby, to meet minimum biologic needs of the stream. The smallest formally calculated flowby that Maryland considers for a new surface water appropriation would be the 7-day, 10-year low flow (7Q10). Absent a reservoir, even a stream with no appropriations in its watershed will not have adequate water to provide its minimum 7Q10 flow at all times.

Due to the requirement for an absolute minimum streamflow, appropriators from streams without reservoirs or other storage will not be able meet their needs at all times, regardless of other uses of the resource. Provision for storage and other sources are fundamental to appropriation from surface water. Two important questions are therefore: 1) To what extent will growth in the region increase the number of days that flow will be inadequate to meet all needs? and 2) What can be done to provide for days in which no appropriation can be made? Three related surface water models were evaluated as possible ways to address these questions. Surface water availability was estimated by a series of model simulations using stream gage data from 1947 through 2003.

Once the daily values of available streamflow are calculated for each sub-watershed, they can then be compared to demand figures generated in the demand analysis to interpret the reliability of the surface water supply. In general, the results of the modeling show that the number of days where flows will not be sufficient to meet demands will increase in 2030. However, due to the multiple shortcuts and simplifications employed, it is clear that a more refined analysis is necessary to fully evaluate the reliability of the surface water supply. For example, wastewater discharge flows were obtained from permit data and only project flows on an annual basis. Improved discharge flow data and flow projections, including monthly or seasonal estimates would improve confidence in the model output. A more detailed model, using a simulation package and using monthly and, where available, daily demand estimates would provide more reliable conclusions about surface water availability.

4.1.4 Conclusions: Meeting Projected Demand and Identification of Needed Management Resources

The results of the Monocacy Watershed pilot study demonstrate the limitations of an analysis based on annual averages. When implemented on an annual average basis, the water balance approach is not well suited to indicate whether ground water resources will be adequate for extreme climatological conditions outside the norm. The model should be refined to reflect seasonal variations in use and recharge. The pilot study supports the need for additional observation wells and stream gages discussed in section 5.1 of this report.

In addition, neither this nor any other analysis can fully incorporate the complexity of the fractured rock system. Because of the highly variable nature of the fractured rock aquifers and the limestone aquifers, a general assessment that ground water is available in a sub-watershed does not guarantee that it will be readily accessible in adequate amounts at any given location within the sub-watershed. For example, the City of Taneytown cannot use one of their wells at full capacity because it has an unreasonable impact on nearby users, which became apparent only after the well was in use.

With regard to surface water, the analysis provided an evaluation of several of the alternatives under consideration for the Lower Monocacy, but far more detail needs to be added to the model if it is to be a useful management tool. The surface models indicate that the water needs of the City of Frederick could be met during an average year with water purchased from Frederick County (from the proposed pipeline and expansion of the New Design treatment plant), together with appropriations from the existing intakes at Fishing Creek Reservoir, Linganore Creek and the Monocacy River. A more detailed study is needed to establish how well the City's needs would be met during a drought. Subsequent study also needs to consider the interstate aspects of water use in the Monocacy watershed, including the impact on quantity and quality of water used in the Pennsylvania headwaters of the Monocacy, and drought management requirements that may be imposed on withdrawals from the main stem of the Potomac.

In the course of this study, several issues arose that point to a need for additional information and resources to perform an adequate assessment and to extend this analysis to other areas of the State. More research is needed to better determine what portion of appropriated water is consumptively used and how much is returned to streams or aquifers and is available for reuse. Furthermore, research is needed to 1) refine ground water recharge and discharge estimates, 2) to better estimate the streamflow reduction that can be expected from ground water appropriations, 3) to refine the estimate of ground water reserves that must be left unappropriated in order to assure acceptable base flow to streams, and 4) to understand the relationship of well yields in fractured rock to changes in ground water in storage. The adequacy of current minimum streamflow requirements to protect aquatic life needs to be evaluated. A change in the minimum streamflow requirements would have an impact on the amount of water that is available for use. Improved wastewater discharge flow data (current and projected) is needed to properly evaluate available surface water. Lastly, a detailed surface water model that incorporates reservoir operations and daily variations in flow is needed as a management tool to properly evaluate the effect of appropriations on the Monocacy Watershed.

4.2 Southern Maryland Pilot Study

The Southern Maryland Counties were chosen as a second pilot study area to demonstrate the water supply issues in an area that relies almost solely on ground water from deep aquifers (See Appendix E). The population in the region has grown significantly and the corresponding increase in water use has resulted in declining water levels in the region's aquifers. The projected growth in the region raises concerns about the ability of the aquifers to sustain the anticipated demand on the water resources.

The Southern Maryland pilot study evaluates the ground water supply in the five-county region and projects future demand on the aquifers. The pilot study proceeded through the following steps:

- An analysis of the current status of the water supply in the region based on the existing uses and current management strategies;
- An analysis of water demand trends and projections of future water demands in the region;
- An evaluation of the water supply potential in the region (as documented in previous studies) and the ability for the supply to meet projected demands; and
- A discussion of the methods currently used for predicting water supply potential and the sufficiency of this for water management and planning.

4.2.1 Ground Water and the Major Aquifers in Southern Maryland

The Southern Maryland region is dependent almost entirely on ground water for its water supply. The aquifers that underlie the region generally provide an abundant supply of good quality water for domestic, commercial, military, and light-industrial needs. However, the ground water resources in Southern Maryland are vulnerable to overuse, and a thorough understanding of the ground water system is necessary to ensure a reliable water supply into the future.

The geology of the Southern Maryland region is made up of layers of unconsolidated sediments of sand, clay, silt, and gravel, which gradually become deeper and thicker to the southeast. The sand and gravel layers form the major water-bearing aquifers in the region, which include (from shallow to deep) the Piney Point, Aquia, Magothy, Upper Patapsco, Lower Patapsco, and Patuxent aquifers (Figure 4–3).

The Aquia aquifer is currently the chief source of ground water in Calvert, St. Mary's, and southern Anne Arundel Counties; the Piney Point aquifer is also used in St. Mary's and southern Calvert Counties. The Magothy aquifer is used in Anne Arundel County, northern Calvert County and northern and eastern Charles County, but is absent in the rest of Southern Maryland. The Patapsco aquifer system is the major source of ground water in Charles and Anne Arundel Counties. The Upper Patapsco aquifer is used by municipal production wells throughout the region, but not for domestic use in Calvert and St. Mary's Counties. The Patuxent aquifer is used in Anne Arundel and Charles Counties for public supply and is used moderately for domestic supplies in northern Anne Arundel County. The Lower Patapsco aquifer and the Patuxent aquifer are not currently in use in Calvert and St. Mary's Counties, but are likely to be potential sources of water.

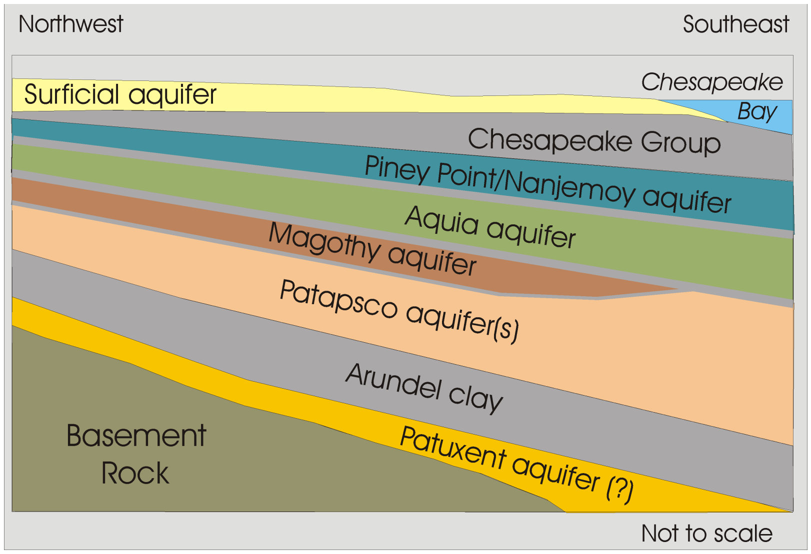

Figure 4–3. Generalized Cross-section of Southern Maryland Showing the Major Aquifers

4.2.2 Water Levels

The Coastal Plain aquifers of Maryland are replenished with water from precipitation, however water levels in the confined portions of the aquifers are not directly affected by precipitation due to confining layers of clay or silt that isolate aquifers from direct infiltration. Water levels in the confined aquifers have declined in the last fifty years due to the increasing use of these resources (Table 4–1), and the magnitude of decline in each aquifer varies with location. Water levels measured in an aquifer provide an indication of the impact of pumpage on the aquifer's water-producing capabilities. As pumpage from an aquifer increases, water levels will decline; the amount of decline for a given time period is called the drawdown. Measured water levels in an aquifer, when related to sea level and plotted on a map, show the potentiometric surface of the aquifer, which is the level to which water in a given aquifer rises in a well that is screened in that aquifer. Each aquifer has its own potentiometric surface and these are mapped annually through cooperative programs of the U.S. Geological Survey, Maryland Geological Survey, and participating agencies. The deep water levels near large pumping centers produce an inverted cone shape in the potentiometric surface, which is referred to as a cone of depression. MDE regulates ground water withdrawals for major water users by prohibiting water levels from declining below an 80% management level. (Figure 3-1)

Hydrograph records of 27 monitoring wells in the five major aquifers were examined in order to demonstrate the status of water levels in the pilot study area with respect to the 80% management levels. The review of monitoring well data as well as published reports indicate that some areas of Southern Maryland are of concern regarding management of sustainable ground water levels. One example of this is in western Charles County from the Waldorf area to Indian Head. Characteristics such as large use coupled with shallower aquifer depth of the Magothy and Patapsco aquifers in this area has resulted in water levels approaching the 80% management level in this area. In another example, water levels near the outcrop area of the Aquia aquifer in southern Anne Arundel County near Waysons Corner are approaching 80% management levels due to the combination of localized domestic use and large users in neighboring Calvert County.

Aquifer	Average Drawdown Rate in Pilot Study Monitoring Wells (feet/year)*	Range of Drawdown Rates in Monitoring Wells (feet/year)*
Piney Point	-0.3	+0.2 to –0.6
Aquia	-1.6	-0.9 to –4.4
Magothy	-1.4	-0.5 to –2.8
Patapsco – Upper Patapsco – Lower	-3.0 -1.8	-0.4 to –7.4 -0.4 to –3.6
Patuxent	-1.9	-0.8 to –3.8

Table 4–1. Drawdown rates observed in the Southern Maryland confined aquifers.
*In twenty-seven monitoring wells chosen for the pilot study, see Appendix E for hydrograph data.

4.2.3 Predicting Water Supply Potential: Ground Water Flow Modeling

Ground water flow models are used to simulate water-level changes in response to increasing ground water withdrawal rates. To develop a flow model, data are collected for historical water levels, pumpage rates, and aquifer characteristics. The data are entered into the flow model, and it is calibrated by matching simulated water levels with measured water levels. Future pumpage scenarios are entered into the flow model, with the model results presented as simulated potentiometric surfaces, which are estimated for several future periods. Because the rates of future ground water withdrawals from each aquifer are uncertain, several pumping scenarios are simulated to cover a range of conditions and to predict the impacts of various potential uses of ground water.

Ground water managers can use the results of the flow-model simulations to determine optimum withdrawal rates from existing well fields, the best locations for new production wells, and which aquifers to tap in the new wells. The time and effort required to produce a ground water flow model for the entire region is well beyond the scope of the pilot study. Therefore, a review was conducted of four recent studies (Fleck and Wilson, 1990, Achmad and Hansen, 1997, Andreason, 1999 and 2002) that provide estimates of the effects of future water demands in localized areas of the pilot study area. In each study, the modeling results are limited to local projections of changes in water levels. Due to the increasing use of two or more aquifers in locations where they are available, there is an increasing need for multi-aquifer models. An initial effort to construct a multi-aquifer model in Calvert, Charles, and St. Mary's counties is currently underway by the MGS and is scheduled for completion in September 2005.

4.2.4 Projected Demand for Water in Southern Maryland

The pilot study focused on the ground water resources within Southern Maryland. Public supply and self-supplied domestic water withdrawals make up 86% of the current fresh water withdrawals in Southern Maryland. Additional water transported to Prince George's County by WSSC, which is withdrawn from the Potomac River and Patuxent Reservoir, was not considered in the demand projections. A significant amount of water is used in thermoelectric power generation in the region, however this is predominantly saline water and is not taken into consideration for the purpose of this pilot study. In order to project water demand in the future, historical records of water use by county were analyzed relative to changes in population. The public supply and self-supplied domestic categories correlated well in most counties with changes in population, and future water demand projections were made based on Maryland Department of Planning's population projections for each county.

Total demand for ground water used as public or domestic supply in the pilot study region is projected to be 88 million gallons per day in 2030. Projected demands for each aquifer, based on current proportions of use and projected population growth, are shown in Figure 4–4. These projections are based on the assumption that the aquifers will continue to be used in the same relative proportions as they are currently used. This may not be a realistic assumption, since there may be a need to utilize the deeper aquifers at a higher rate to reduce the impacts of drawdown in the shallower aquifers. In addition, it is anticipated that some growth in Charles County will be accommodated by purchased water from WSSC, which was not factored into the demand projections.

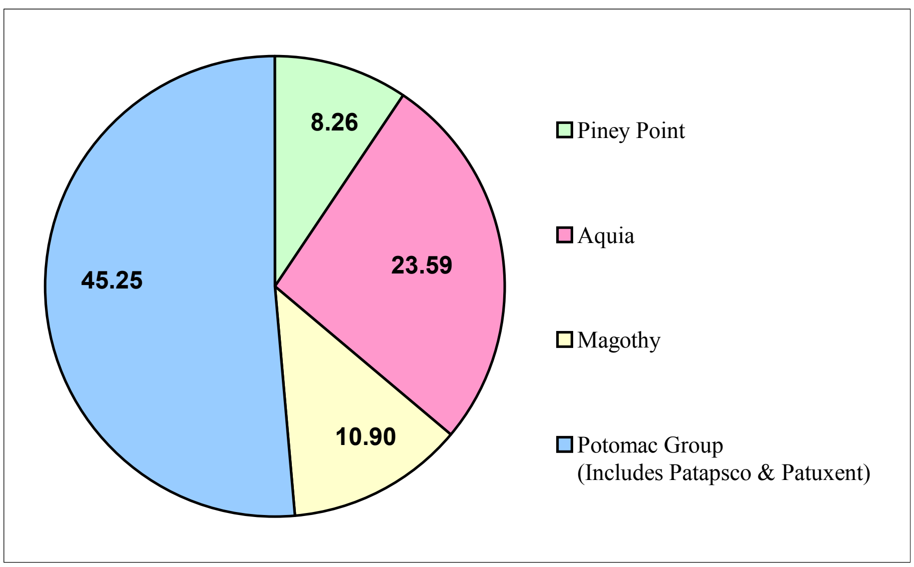

Figure 4–4. Projected Ground Water Demand in 2030 for the Southern Maryland Pilot Study Region Aquifers (in mgd)

4.2.5 Conclusions: Meeting Projected Demand and Identification of Needed Management Resources

A regional, multi-aquifer ground water flow model for the major aquifers is needed to address the management issues associated with regional stresses and increased use in Southern Maryland. Additional data, collected over space and time, is critical to build models that can adequately assess the water supply potential of the confined aquifers. The existing modeling results do not provide sufficient information to assess the ability of the water supply to meet the projected demands for the region as a whole. While existing models can account for future water use in localized areas within the five-county region, they cannot adequately incorporate regional stresses on the aquifers. It is important to recognize that the accuracy of each predictive scenario is limited by the amount of data and the validity of the assumptions made. Therefore, a regional model can only be relied upon when it is built with sufficient water level measurements and reasonable, scientifically based assumptions.

The existing modeling studies demonstrate that the major aquifers have the potential to handle future demands in the localized study areas; however, it will take significant management measures to ensure that sustainable water levels are upheld. For example, ground water managers can use the results of the flow-model simulations to make decisions about suitable well locations and pumping rates. Where the models predict water level declines that are unacceptable in one aquifer, water users have often assumed that a deeper aquifer can be explored. However, the availability of water in deeper aquifers in such situations may be unknown, the interaction of the deeper aquifers with shallow aquifers is not completely understood, and these topics require further study. The potential use of two or more aquifers in locations where they are available attests to the need for multi-aquifer models. MGS is currently constructing a multi-aquifer model in three counties in Southern Maryland. An ideal modeling solution would incorporate the entire Coastal Plain physiographic province and would be a tool that ground water managers could update and use as withdrawal requests are being evaluated.

5.0 PROGRAM MANAGEMENT

The Water Supply Program (WSP) is a part of the Water Management Administration within the Maryland Department of the Environment. The mission of the Water Supply Program is to ensure that public drinking water systems provide safe and adequate water to all present and future users in Maryland, and that appropriate usage, planning and conservation policies are implemented for Maryland's water resources. This mission is accomplished through proper planning for water withdrawal, protection of water sources that are used for public water supplies, oversight and enforcement of routine water quality monitoring at public water systems, regular onsite inspections of water systems, and prompt response to water supply emergencies. In addition to ensuring that public drinking water systems meet federal and State requirements, the WSP also oversees the development of Source Water Assessments for water supplies, and issues water appropriation permits for both public drinking water systems and commercial entities statewide. Because all of these activities reside together in the WSP, Maryland has the unique opportunity to evaluate and regulate public drinking water systems from a broad perspective that includes an evaluation of the resource for both quantity and quality. The Water Supply Program's activities help to ensure safe drinking water for more than four million Marylanders.

Many additional programs both within and outside of the Department of Environment seek to protect and/or restore water resources. For example, other programs in the Water Management Administration regulate ground water and surface water discharges, oversee well construction activities statewide, and ensure proper oversight of septic installations for rural areas of the State. Waste Management Administration activities, including solid waste and hazardous waste permitting, and superfund oversight, have ground water protection and restoration as a primary goal. In the Department of Natural Resources, the Maryland Geological Survey provides investigative analysis of existing resources and the impacts of various activities on the resources. Coordination among these varying programs for the purpose of establishing priorities and synchronizing efforts is essential to the success of managing Maryland's water resources.

There are several areas, however, where enhancement of existing program efforts are needed to improve water management protection in the State. This report presents the programmatic needs under the three headings of monitoring, program development, and enforcement.

5.1 Monitoring

As the State's water supplies experience heavier use, it becomes increasingly important to closely monitor the condition of the water supply resources. The primary tools for monitoring water quantity are statewide networks of stream gages that measure surface water flows and of observation wells that monitor ground water levels. As illustrated by the pilot studies described in this report, these monitoring networks provide the data necessary to determine water availability and to assess the impacts of increased use on water resources. Both pilot studies described in this report indicate the need for additional monitoring data to more accurately determine water availability. An in-depth review of the current physical and financial status of the existing monitoring network, as well as recommendations for improving the existing network and associated costs, is provided in Appendix F and is summarized in this section.

Streamflow and ground water are not separate water resources; they are inextricably connected because ground water contributes on average 50% of total streamflow. Rivers and streams are fed by precipitation and ground water from aquifers, and aquifers are recharged by precipitation and sometimes streamflow. A comprehensive, integrated water monitoring network that includes stream gages, observation wells, and precipitation gages is an essential tool for decision-making based on sound data and science.

The optimal streamflow and ground water level monitoring networks described in the next two sections are presented as separate networks with separate design criteria. However, in implementing these two networks, every effort must be made to site observation wells and stream gages coincident with each other to achieve an integrated monitoring network for Maryland.

5.1.1 Streamflow Monitoring Network

The USGS, with funding support from many federal, State, and local agencies, currently operates a streamflow-monitoring network of 115 stream gages in Maryland. The data are used for water-supply assessments; watershed management; stream restoration; bridge design; flood warning; sediment and contaminant loadings; assessment of development impacts; water-quality improvements; and support of recreational activities.

One example of the value of streamflow data is that they provide the basis for allocation of water from rivers and streams for various competing purposes. A river or stream can supply water for many purposes along its length, including supply for drinking water, industries, and businesses; and sufficient flow for recreational activities and to dilute sewage effluent. These uses cannot be properly balanced without consistent and accurate measurement of the amount of water flowing in rivers and streams.

A workshop sponsored by the Maryland Water Monitoring Council in 1997 resulted in a commitment to develop a comprehensive network and a subsequent report (Cleaves and Doheny, 2000) showed a need for 157 stream gages in Maryland. The stream-gage report describes an optimal, multi-purpose, streamflow-monitoring network for Maryland. The report recommends additional stream gages to:

- Provide a core network that would include all major rivers and streams in Maryland;
- Provide a network of stream gages on streams in small watersheds in the various settings in Maryland; and
- Provide a network of stream gages to fill the remaining geographic gaps in the monitoring of streamflow in Maryland.

Maps of the current stream gage network and of proposed enhancements to the stream gage network are shown as Figures 5–1 and 5–2 respectively.

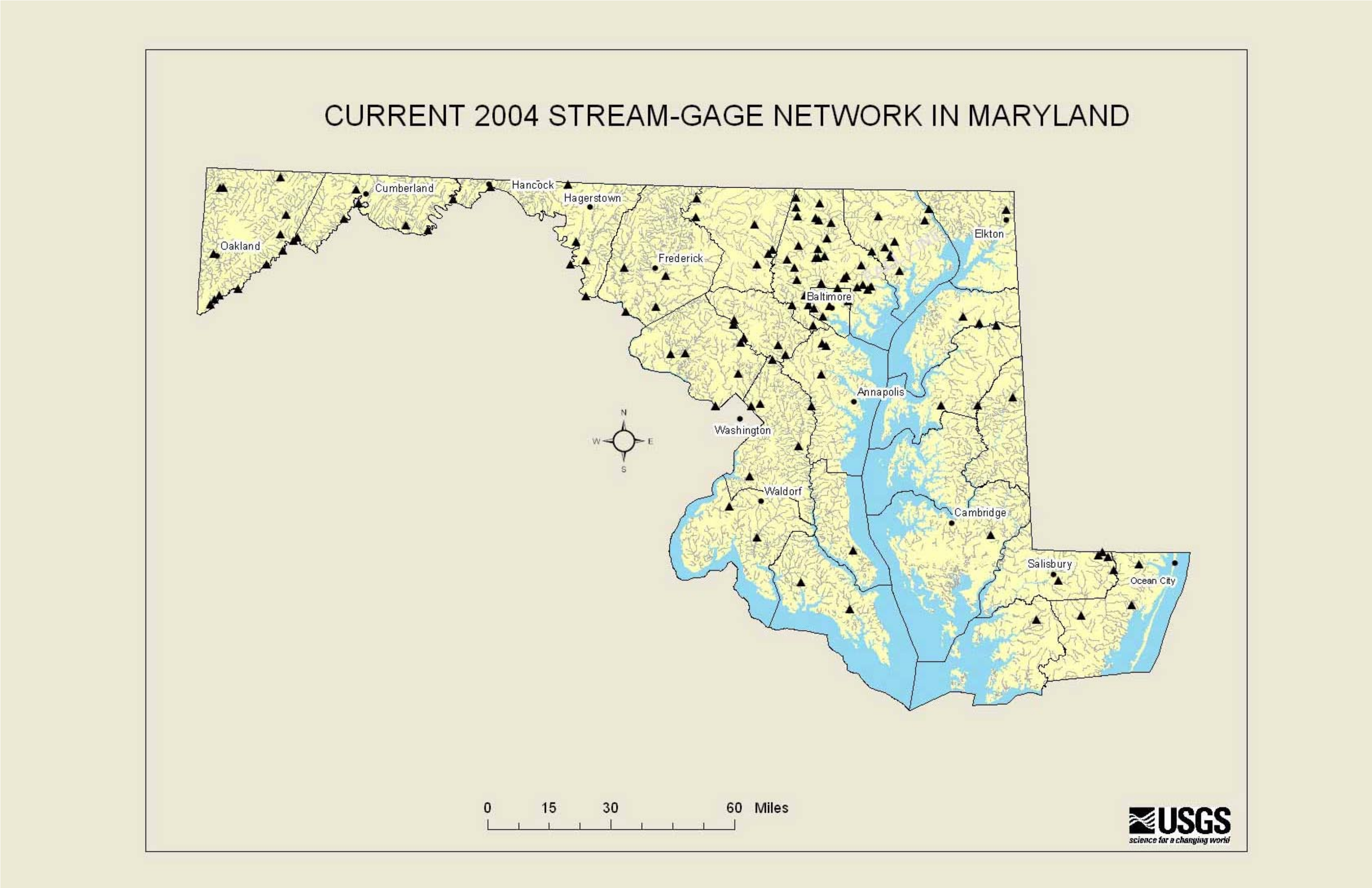

Figure 5–1. Current (2004) Stream Gage Network in Maryland

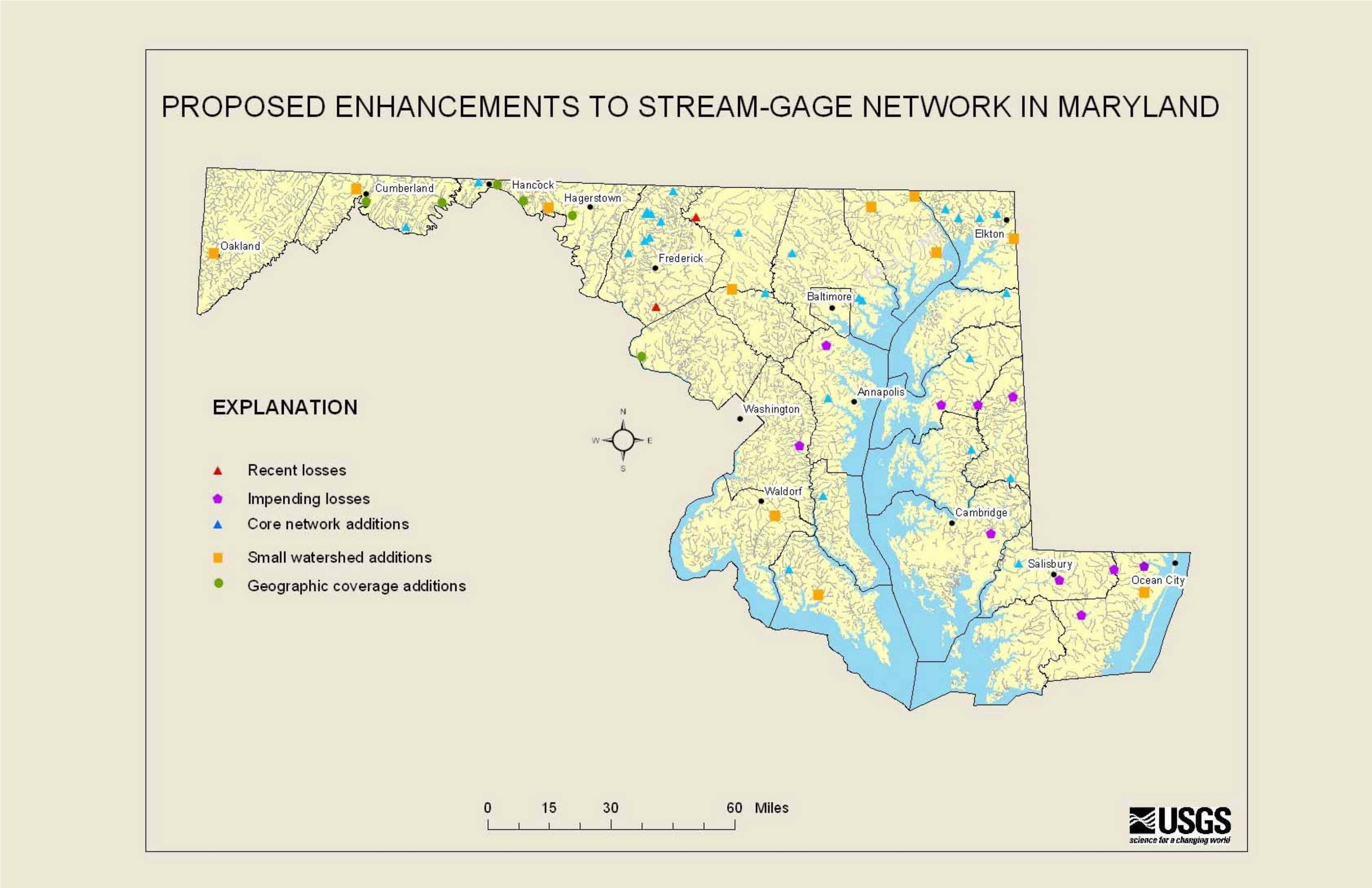

Figure 5–2. Proposed Enhancements and Impending Losses to Stream Gage Network

5.1.2 Ground Water Level Monitoring Network

The Maryland observation-well network consists of 141 wells throughout the State's aquifers and is currently funded and operated by the USGS and the MGS. In addition, there are six sub networks - five county ones and the Southern Maryland sub-network, consisting of over 155 observation wells. The Maryland observation-well network provides the only direct measurement of the status of Maryland's aquifers. Ground water level data are used to assess long-term trends due to natural or human influences, for drought monitoring and tracking, and in decision-making for the ground water appropriation permitting process.

One recent example of the value of ground water level data is its use as one of the major indicators of the progress of the drought of 2002. Ground water level data indicated when the drought was approaching, when it equaled and exceeded previous droughts, and when it ended. Moreover, having ground water level data from different geographic areas and geologic settings provided essential data to the State for applying water-use restrictions at different times and levels in certain areas, thereby reducing the impacts to the people and the economy of Maryland.

A multi-agency workgroup sponsored by the Maryland Water Monitoring Council has completed an evaluation of the statewide Maryland observation-well network and has recommended an optimal network for monitoring the surficial aquifer and the seven major confined aquifers of Maryland. The workgroup determined that 240 observation wells are needed to adequately monitor the condition of Maryland's ground water resources. This represents an additional ninety-nine observation wells that will have to be added to the network. The goals of the optimal network are to:

- Monitor the effects of climate variability, particularly drought, on the shallow ground water resources of Maryland; and
- Monitor the effects of ground water pumpage on the seven major confined aquifers of the Maryland Coastal Plain.

5.1.3 Needs and Recommendations for Monitoring Networks

Reduction of State general fund support for monitoring networks in FY2005 will eliminate 12 stream-flow gaging stations and 141 wells from the USGS-MGS Maryland ground water level observation well network. Further declines are likely as State and county funding sources are increasingly stressed, and as USGS matching funds also continue to decline. In addition, the optimal observation-well network that has been recommended is in jeopardy, and the ground water level trends apparent only through decades of data will be truncated.

A long-term, stable source of funding is needed to ensure that Maryland's existing networks continue to operate. Additional funding is needed to expand each of the networks in order to provide water resource managers with the data needed to make sound, scientifically based decisions.

5.1.4 Funding Needs for Monitoring Networks

To maintain the stream-gage network at its 2004 level, State funding is needed to retain the 12 stream gages that have been lost or are about to be lost in 2004-2005 (Figure 5–2). The necessary State funding would be $75,000, which would be matched by $75,000 of USGS funding. To enhance the stream-gage network by adding the 47 new gages recommended in the 2000 workshop report would require that State funding cover the cost of establishing these 47 new gages and 50% of the cost of the annual operation of these new gages. Under this scenario, State funds on the order of $300,000 per year would be needed to add these 47 new stream gages over a 5-year period. If funding were available from the State, it would be incumbent on the USGS and selected counties to provide the necessary funds to match the State contributions for annual operation costs.

Should only some, but not all, of the above State funding be available for the 47 new gages needed, the addition of new stream gages would proceed at a slower pace as funding allows based on the following priorities. The highest-priority new gages to be added would be the core-network gages, of which there are 30. Following those new gages, the small-watershed (11) and spatial-gap (6) gages would be the next priorities. The number of new stream gages that could be added would be in direct proportion to the amount of State funding available.

To maintain that portion of the recommended Maryland observation-well network that already exists (141 observation wells), State funding on the order of $150,000 per year is needed, which would be partially matched by $100,000 in USGS funding. To implement the entire optimal 240-well network that the network workgroup has recommended would require the addition of 99 new observation wells (most by drilling) and would require additional State funds on the order of $600,000 per year over a 5-year period.

Should only some, but not all, of the above State funding be available to enhance the observation-well network, the addition of new wells could proceed at a slower pace as funding allows based on the following priorities. The highest-priority new wells to be added would be those located near major pumpage centers in the Maryland Coastal Plain, to be followed by new wells in the shallow aquifers west of the Fall Line in physiographic units without sufficient coverage to address drought conditions. The number of new observation wells that could be added would be in direct proportion to the amount of State funding available.

5.1.5 Coastal Plain Aquifer Modeling and Management

One of the most vexing and complex water-resources issues in the State of Maryland is the declining ground water levels in the seven major confined Coastal Plain aquifers in the Southern and Eastern Shore areas of Maryland. These seven aquifers (Chesapeake, Piney Point, Aquia, Magothy, Upper Patapsco, Lower Patapsco, and Patuxent) are heavily used for water supply - about 80 million gallons per day of ground water is being withdrawn for various uses. Ground water levels are declining by an average of about 2 feet per year in these aquifers. As noted in the Southern Maryland pilot study, a comprehensive approach that assesses all the aquifers of the Maryland Coastal Plain and that includes the entire extent of each aquifer from the Fall Line to the Atlantic Coast is needed to adequately plan for future water withdrawals and to manage water level declines.

The computational methods and tools needed to manage the variability in aquifer geometries and characteristics and the complex interrelationships among recharge, discharge, leakage and pumpage over a large area are now available. Ground water flow models can be built in a Geographic Information System (GIS) context, and the models can solve the necessary complex ground water flow equations in large numbers of grid cells much more quickly than was previously possible. In addition, it is possible to build a single model to simulate both regional and local aquifer conditions. Furthermore, it is possible to link stream-routing models in the recharge areas to ground water flow models in the confined portions of the aquifers. These advances now permit the undertaking of a single large ground water flow model of the Coastal Plain aquifers of Maryland.

Certain gaps in the data would need to be addressed before a comprehensive model could be built. The presence of some aquifers, and their water-yielding characteristics, particularly in the deeper portions of the aquifers, are data that are still needed. This data could be acquired by selective drilling and aquifer testing that would provide key information to complete the aquifer framework. In addition, it is absolutely critical to understand the processes that govern recharge and leakage. Detailed studies of recharge and leakage processes are needed to provide the necessary data to ground-truth the models. These studies would necessarily involve the full array of field and analytical tools currently available, including the installation of new wells, long-term aquifer testing, installation of other instrumentation such as stream and rain gages, application of analytical solutions, small-scale flow models, water-quality sampling, age-dating of ground water, and other similar approaches.

With all the above information in hand, a comprehensive, multi-aquifer, ground water flow model could be developed, calibrated, and used to test scenarios of ground water pumpage in the seven major aquifers of the Maryland Coastal Plain. The scenarios could be optimized to determine the spatial and temporal distribution of pumpage that produces the least amount of water-level decline. This optimization approach has not yet been attempted on a large scale in Maryland, and would provide a major enhancement over previous modeling studies.

The final step toward a comprehensive, multi-aquifer model that could be used for ground water management purposes would be the development of a set of tools that would facilitate the incorporation of flow model results into the management decision-making process. Optimization software is available that will automatically provide modeling results in the form of management options that can be used as the basis for decision-making. In this way, the ground water flow model can be maintained and updated every time more aquifer data are available and every time there is a change in pumpage. Current climatic conditions also can be incorporated. Such a model can be used in a dynamic, real-time fashion to simulate current aquifer conditions, enabling ground water managers to immediately test the impact of any proposed increase in ground water withdrawals and determine whether a ground water appropriation should be granted. To develop this model as a tool for water management, including the necessary ground water studies, data collection, and model construction, would require seven to eight years and would cost between $10 and $12 million (see Appendix F).

5.2 Program Development

MDE is charged with the responsibility for developing a statewide water resource program as follows:

> The Department shall exercise to the fullest extent possible the State's responsibility for its water resources by planning and supervising multiple purpose development and conservation of the waters of the State for the State's best interests and benefit. The Department shall develop a general water resources program, which contemplates proper conservation and development of the waters of the State, in a manner compatible with multiple purpose management on a watershed or aquifer basis, or any other appropriate geographical unit. The program shall recognize and be consistent with functions of other State units. The Department shall be guided by the program in the performance of its duties. (Environment Article §5-203).

The State's activities under this mandate have been diffuse and not comprehensive. The development of water resources has been supervised and regulated through the water appropriation permit process, but regulation has not been complemented by comprehensive planning. While counties prepare Water and Sewer Plans to describe their plans for water use, no system exists to assure that the water resources will be available to support local plans. Efforts at promoting water conservation have been intermittent at the State level, ebbing and flowing with the public's interest raised by droughts, and with available funding. A distinct unit to plan for the management, conservation and development of water had not existed at MDE until early this year, when a Water Policy and Security Division was created. This small unit, created with staff reassignment from other units, has been assigned the lead in staffing the Water Resources Advisory Committee established by the Governor's Executive Order (01.01.2003.08). It forms a core group that will require additional staffing and resources if it is to act on recommendations of the Advisory Committee and begin planning for the orderly development and management of the State's water resources.

5.2.1 Water Supply/Demand Studies

Consistent with the legislative mandate in Environment Article 5-203, and to complete an assessment of the quantity and quality of the State's water resources (for which the Executive Order called for a review), a water supply and demand study for each significant watershed and aquifer should be undertaken. This task is a multi-year activity that will describe the water supply sources, project demands through 2030, and address specific management issues for each area.

Given the limited time available to fulfill the Advisory Committee's charge, two pilot projects were initiated to develop a model for additional studies. The Monocacy Watershed in Frederick and Carroll Counties was selected as one of the pilot projects because it demonstrated the interrelationship between surface and ground water sources. The Southern Maryland area was chosen for the second pilot project because it exemplified the confined aquifer geology typical of the Coastal Plain. Both studies justified the need for improvements in the monitoring networks. These assessments should continue until all of the State's significant water supply sources are assessed. Equally important, a procedure should be established whereby the studies are updated periodically, and incorporated into both local plans for water development and State planning and oversight of water use.

5.2.2 Water and Sewer Planning

With MDE supervision, counties are required by law to develop and maintain Water and Sewer Plans to provide for the orderly development and extension of community water supply and sewer systems. A review of the current status of Water and Sewer Plans indicates that there is a need for significant improvement in many of these Plans in order to better fulfill their important potential as a water supply and resources planning tool. Many county governments are struggling to meet the State mandate to keep these Plans up to date, relevant, and effective. There is a need to provide meaningful technical and financial support to some local governments to assist them in preparing stronger and more comprehensive Water and Sewer Plans.

State law (Environment Article §9-501 to §9-521) requires every county and Baltimore City to prepare and maintain a Plan that sets out the "where, when, and how" of providing for the orderly development of community and individual water and sewer service within each jurisdiction. The purpose of these Plans is to provide for safe and adequate systems for at least the following 10 years in a manner that integrates water quality, public health, and county and municipal comprehensive plans; supports the Priority Places Program; and utilizes capital programming, sound engineering, and fiscal management. These Plans should address the adequacy and protection of water resources and systems for conveying those resources in a manner consistent with local needs. However, since water resources are generally interjurisdictional and interstate in nature, and since the State has primary regulatory responsibility for managing all the waters of the State, State guidance and technical support is clearly important to assisting the counties in preparing effective local plans.

The Water and Sewer Plans are an important State mandate that, if well executed, could make a significant contribution to addressing many of the Governor's charges to this Advisory Committee. These Plans are the voice of local governments that collectively reflect the water demands, capital needs, and operating needs of Maryland's growing population and economy. When prepared and maintained, these Plans could be the foundation for improving State programs and compiling local needs. Water and Sewer Plans are a vital State and local management tool. These Plans form the basis for many day-to-day decisions that must be made by local officials with various regulatory responsibilities for approving proposed development at various stages leading to construction. Safe and adequate water for sanitation and fire protection should be available before subdivision plats, site plans, and building permits are approved. These Plans also provide the basis for State regulatory decisions related to issuance of water appropriation permits and construction permits for water treatment and distribution systems.

The consequences of land use and of water use are inextricably linked, affecting and compounding each other. A recent study of the relationship between land use planning and water management notes not only that land use decisions in Maryland are delegated to local government but that, "local governments are actually required to make specific development approvals contingent on the adequacy of the local water supply systems. This requirement, however, appears directed primarily at the *infrastructure* [italics in the original] needed to serve individual developments rather than the *long-range adequacy of water supply* [italics in the original] to serve all development contemplated under a master plan" (Cohen, 2003, p.65)

Water management and land use planning should be closely coordinated, an objective that could be accomplished through the Water and Sewer Planning process. In the past, MDE had a staff of nine to assist the counties in preparing Water and Sewer Plans. That staffing has been reduced to one individual. MDE is recommending that additional staffing positions be created to provide the necessary assistance and integration of related programs.

5.2.3 Non-Tidal Potomac River Basin

The non-tidal portion of the Potomac River Basin (all of Allegany, Washington, Frederick, Montgomery, and Prince George's Counties as well as parts of Garrett and Carroll Counties) encompasses 27% of Maryland's land area and includes 40% of its population. The tidal portion of the Potomac Basin is discussed in the Southern Maryland pilot project. Managing the water supply for the Potomac Basin will be particularly challenging because it is shared with other jurisdictions (Virginia, West Virginia, Pennsylvania and the District of Columbia) and because of the significant growth projected for the Washington Metropolitan Area. While there are numerous intrastate issues in the Maryland portion of the Basin, water supply for the Washington Area is the issue that has dominated water management efforts for the past 40 years.

As it existed in the 1970s, the Washington Metropolitan Area consisted of Montgomery and Prince George's Counties in Maryland, Fairfax County in Virginia, and the District of Columbia, with their respective extended service areas. Location of new employment centers, expanded transportation corridors, and inter-county agreements for water and sewerage services have expanded the Metro Area to now include Frederick County in Maryland and Loudoun County in Virginia. Both population and water use in the expanded Metro Area are expected to increase over 30% by 2030. Meeting that demand will be made more challenging by increased consumptive losses of water on the main-stem Potomac and in the tributary watersheds as water use increases.

Maryland has traditionally taken the lead in addressing water management issues in the Potomac Basin. The State did so under the understanding that its boundary extended to the Virginia-West Virginia shoreline and therefore, it had full authority over all in-stream activity including construction and withdrawals. In the exercise of that authority, Maryland required Virginia and West Virginia users to obtain the same permits as were required of Marylanders. Maryland used that authority to initiate inclusion of water supply storage in the Corps of Engineers' Bloomington Reservoir (now named Jennings Randolph) in the North Branch Potomac and to develop a payment strategy that allowed the project to proceed. The State's authority later played an important part in the development of the Potomac River Low Flow Allocation Agreement (LFAA) for the Washington Metropolitan Area including a flow-by restriction in the area between Great Falls and Little Falls. Permits issued by Maryland to water appropriators in the Washington Metropolitan Area included language implementing both the LFAA and the flow-by requirements.

As a result of a dispute over a waterway construction permit, Virginia challenged Maryland's autonomy over the Potomac River and subsequently won its case before the Supreme Court. The Court determined that Virginia and its citizens had equal access with Maryland to the River for waterway construction and water withdrawals and could not be required to obtain approvals from Maryland. The single, unified set of rules for managing the waters of the Potomac was eliminated as a result of this decision. Virginia, however, has now adopted regulations and guidance procedures that enable the Commonwealth to issue permits for Virginia users seeking to withdraw water from the Potomac and its Virginia tributaries. These permits will include provisions necessary to comply with the Potomac River LFAA. With both jurisdictions now authorized to issue permits, a coordinated review process is needed. This process could be initiated by a conference of the States, perhaps brokered by the Interstate Commission on the Potomac River Basin (ICPRB), a role it is ideally suited to perform. Once a coordinated permit review process is established, attention should be focused on drought management, an issue that will become more prominent with increased use of the river and reduced flow due to consumptive losses.

Another task of extreme importance to all of the jurisdictions bordering the Potomac is to find additional sources of water for the Washington Metropolitan Area, which is expected to continue growing through at least 2030. Alternatives for further investigation include: expanding the water supply storage in the Jennings Randolph Reservoir, construction of new dams, use of existing quarries as offsite reservoirs, pumping from the Potomac estuary, and possibly even desalinization projects. New conservation measures and use of "gray water" (i.e. treated effluent) should also be considered as ways to reduce demand and maximize use of available supplies.

The extent and complexity of the issues related to the Potomac River require additional staffing dedicated to these program development activities.

5.2.4 Source Water Assessment and Protection Needs

Since the approval of Maryland's Source Water Assessment Plan by the US EPA in 1999, MDE has been completing source water assessments for public water systems across the State. As required by the 1996 Safe Drinking Water Act Amendments, a source water assessment for every public water system must include the delineation of an area that contributes water to the drinking water source, an inventory of potential contaminants within the source water assessment area, and an analysis of the susceptibility of the drinking water source to contamination. Maryland's plan includes different methods and approaches for the wide variety of drinking water sources used across the State (reservoirs or river intakes, unconfined or confined aquifers), as well as the size of the water withdrawal. The assessments have been reported in varying formats, based on the similarities of water sources and the available resources of the water system owners. The common denominator for each source water assessment is a list of recommended approaches that stakeholders - including water system owners, residents, county planners and health officials, or interstate commissions where applicable - can take to protect the water quality of the water sources.

The source water assessments have demonstrated that some water sources are vulnerable to contamination and their continued use as a reliable water supply in the future may be dependent on diligent efforts to protect the source. In this sense, water availability and water quality are inseparable. Many state laws and programs exist to protect the waters of the state, but coordination to ensure that they are implemented and enforced in a manner that best protects the vulnerable drinking water sources is an area that needs improvement.

MDE has stressed the importance of implementing a source water protection program in each source water assessment and has a long history of participating in drinking water protection programs with individual water systems and municipalities. The development and implementation of a source water protection program is made difficult in communities and counties that are already stretched for resources. MDE has been able to alleviate some of the financial burden for development of wellhead protection programs through participation in federally funded grant projects. However, this is not a sufficient resource to fund programs for every water system in the State, nor does this funding apply to systems relying on surface water. Furthermore, the implementation of protection programs is made difficult by different jurisdictions having authority over land use decisions in another jurisdiction's source water assessment area.

The watersheds of the large metropolitan water supplies in Central Maryland have been dominated by agricultural and forested lands. Recent and future growth patterns in Central Maryland, associated with the expansion of suburban areas, will result in greater development upstream of these major water supply sources. These land use changes in the watersheds raise concerns about water quality impacts such as increased stormwater runoff and sewage effluent, and eutrophication in reservoirs. Water supply sources are part of hydrologic systems that cross political boundaries. To carry out the source protection recommendations in the assessment, local planning agencies need to coordinate with neighboring stakeholders and jurisdictions and commit to water quality goals. A State role in facilitating inter-jurisdictional agreements is a necessary component in the implementation of source protection programs for these water supply sources. Such agreements could be facilitated by existing organizations such as the Baltimore Metropolitan Council, ICPRB, the Tributary Strategy Teams, and other groups charged with protecting water quality.

An essential way of implementing source water protection measures is by incorporating them into the comprehensive plans developed by each of the counties. The measures would vary considerably from county to county depending on the predominant types of water sources. For example, in Frederick County where vulnerable surficial aquifers are used by many of the municipalities and smaller private communities, the plan could detail land use or zoning conditions in source water protection areas. In the Southern Maryland Counties, where the predominant sources are the naturally protected confined aquifers, source protection measures might include a program to seal and abandon unused wells in the contributing areas of the water supply aquifers. Local governments also need to consider how land use decisions upstream of large regional water supplies will impact drinking water sources that serve residents outside of their jurisdiction. This is especially important to the communities served by the Baltimore Metropolitan and WSSC water supplies, which are experiencing water quality problems related to non-point source pollution originating from urbanization and other sources. Each county would have the ability to take into consideration the recommendations made in the source water assessments and incorporate the measures they deem appropriate into the already existing water planning structure.

5.2.5 Outreach Needs

Benjamin Franklin is quoted as saying "when the well's dry, they know the worth of water." This quote aptly describes the general lack of concern for water supply matters that exists because Marylanders think we are water rich with a never-ending replenishment cycle of our water resources. Adding to this complacency is the fact that only occasionally are restrictions imposed on our use of water.

The protection of the quality of our water sources is likewise a non-issue for most Marylanders. The public interest in water quality relates primarily to achieving "fishable" and "swimmable" waters but hardly a mention about protecting water supply sources. Public perception assumes that the technology to adequately treat our water regardless of its quality is available.

Public complacency will diminish as greater demands and impacts of growth begin to stress our water resources. Communities are already placing moratoriums on development until water issues are addressed. The Washington Metropolitan Area is looking for new sources in western Maryland and West Virginia to meet projected needs. The adequacy of our water sources in southern Maryland can not be ascertained without additional monitoring. There is concern for protecting the recharge areas necessary to refurbish our ground water sources. Wells constructed in the limestone formations of Washington and Frederick Counties are extremely susceptible to surface pollution. Our monitoring of water supply facilities now includes 95 contaminants, an increase over a list of 35 in 2000. While these problems do not represent a crisis, addressing and properly managing the total array of water supply activities requires program resources, for which there are numerous competing needs.

To ensure that the importance of water supply management is recognized and supported, an educational outreach effort must be developed to enlighten both public officials and the public about the water resource challenges facing the State, and the management options that are available. Outreach efforts can be initiated at the State level (within the Water Supply Program), and at county and municipal levels. Waiting "until the well goes dry" means crisis management, engendering a reactive stance to urgent problems. Educational outreach and the support of the public results in a pro-active stance whereby water resource issues can be anticipated, planned for, and pre-empted from becoming crises. Minimal additional staffing in the Water Supply Program would be required to initiate a modest educational outreach effort. State universities and colleges, as well as elementary, middle, and high schools, should be encouraged to include Maryland water supply issues in their environmental studies courses.

5.3 Regulation

5.3.1 Public Drinking Water Systems

MDE is responsible for regulating public drinking water systems in Maryland. The systems fall into three categories: community (year-round residents); non-transient, non-community (serving regular customers everyday, such as schools); and transient, non-community (serving different customers each day, such as rest areas or gas stations). Maryland currently regulates 501 community water systems; 570 non-transient, non-community water systems; and 2,676 transient, non-community water systems.

MDE regulates the community and non-transient, non-community water systems. Transient, non-community systems are regulated by county environmental health departments through delegation agreements with MDE except in Montgomery, Prince George's and Wicomico Counties, which continue to be regulated directly by MDE.

The Department of Health and Mental Hygiene (DHMH) provides laboratory support for the Maryland Department of Environment and the local county health departments for testing drinking water. The Laboratory Administration has the capability of testing for bacteriological, inorganic, volatile organic, synthetic organic, and radiological contaminants. Public water systems are required to sample for up to 91 regulated contaminants based on the population served and the type of source water. This has resulted in a significant increase in laboratory demand since 1976 and 1989 when 21 and 35 contaminants were regulated in drinking water, respectively.

The Department of Health and Mental Hygiene's activities with drinking water focus on water quality; the analytical laboratory routinely tests for the federally mandated contaminants in drinking water. The new surveillance and monitoring efforts have placed a considerable demand on the laboratory infrastructure and created a need to replace some of the laboratory equipment currently in use, or to ensure that back-up equipment is available to guarantee laboratory capacity in the event of water system emergencies. This will require additional funding.

County health departments approve private wells for potable use based on test results from DHMH and other State-certified laboratories. The raw water testing has expanded from nitrate and bacteriological testing to include other contaminants based on localized water quality problems such as radium in Anne Arundel County, and arsenic in Talbot and Queen Anne's counties. Monitoring drinking water in private homes for anthropogenic contaminations from leaking underground storage tanks and landfills is also performed to assist the counties in evaluating ground water contamination.

Following Tropical Storm Isabel, it became evident that the State laboratory resources were not sufficient to meet the needs in an emergency. Many homes and businesses with wells are located in low-lying areas, and the well casings are not constructed to an elevation that prevents flooding. The laboratories must be capable of promptly testing wells that might have been contaminated by storm surges.

DHMH has evaluated the resources needed by the laboratory to support public health activities by the MDE and local county health departments. Without additional resources, DHMH expects difficulties in meeting an increased demand for drinking water analyses.

5.3.2 Water Appropriation Permits

In 2002, the Water Supply Program issued 1,621 appropriation permits (both new and renewals). Issuance of the permit involves evaluating the potential needs of the user and the probable impact of the withdrawal on neighboring users and the point source. The evaluation may involve conducting pump tests to measure the adequacy of an aquifer, or measuring stream flow to determine the adequacy of a surface water source. Appropriation permits are reviewed on a triennial basis. Current staffing is inadequate to review and issue permits on a timely basis. Lack of staffing also limits the ability to field check water used by permittees.

Review of the permit data indicates 85% of permits for ground water use are issued for about 5% of the total withdrawals. A similar situation exists for surface water withdrawals. Because these small withdrawals have little impact even collectively on the source waters, water appropriations for small withdrawals should be exempted from permit requirements. A regulatory exemption of 5,000 gpd is recommended. The reduction in the number of permits processed would allow staff to shift their attention to the review of permits for large withdrawals with more potential for serious impacts, to address permit compliance more effectively, and to review and issue permits in a more timely manner.

5.3.3 Compliance and Enforcement

The success of the water appropriation permit system as a tool for effective water management is predicated on the compliance of permittees with both general and site-specific permit conditions. An example of an important general condition is the reporting of water use on an annual or semi-annual basis. Compliance with water use limits is the most fundamental requirement. Any assessment of impacts associated with a water withdrawal is dependent on the amount of water used. The Water Supply Program has an existing procedure for collecting and compiling the data, but lacks the staff and resources to track down delinquent permittees and force their compliance with reporting requirements, or to identify over-appropriators and enforce permitted water use restrictions. In addition, many permits have conditions unique to the specific water use or water source, such as minimum stream flow requirements on a surface water withdrawal. Additional resources are needed to assure compliance with all permit conditions.

Even when a violation is identified, enforcing permit conditions is still a challenge. The Department's enforcement ability is hampered by the lack of authority to impose administrative penalties. Because violation of a permit condition is defined as a misdemeanor, it is subject to a fine not exceeding $500 per day of the offense, with a maximum of $25,000. However, in order to assess a penalty, the Department must first take a permit violator to court and secure a conviction of the violator. The costs of any associated fine are determined by the court. This lengthy and litigious process has resulted in no fines being assessed for violations of the water appropriation laws within at least 20 years. Authority to impose administrative penalties would provide an essential enforcement tool and a credible disincentive to those who would flaunt or ignore permit conditions designed to protect public health and the environment.

5.3.4 Other Regulatory Issues

Time constraints have not permitted a comprehensive review of laws and regulations pertinent to the Water Supply Program. Some topics, however, have been considered for further study, as follows:

1. Incorporation of source water protection measures into the comprehensive plan developed by each county, consistent with specific vulnerabilities of locally predominant water sources. Each county would have the ability to take into consideration the recommendations made in the source water assessments and incorporate the measures they deem appropriate into the already existing water planning structure.

2. Implementation of a process to assure that local governments do not approve new developments until the adequacy of the proposed water supply for the new developments has been determined.
3. Addressing problems of abandoned wells near the Chesapeake Bay that are now submerged because of shoreline erosion and sea level rise. These wells may be creating a pathway for contaminants and Bay water to enter aquifers used for water supply. Because lands lost to erosion are no longer private property, landowners and even some local governments contend they are not responsible for adequately sealing these wells.
4. Reviewing construction standards to determine the adequacy of minimum yield test requirements of private wells; reviewing how private wells are constructed with respect to aquifer management issues such as protecting yield capacity of aquifers through drawdown limitations; and reviewing provisions related to telescoping wells, which may be at greater risk as a result of aquifer management strategies.

As the water supply/demand studies proceed, it is likely that other regulatory changes may need to be considered.

6.0 RECOMMENDATIONS

The Advisory Committee was charged with recommending the actions necessary to assure that the management of the State's water resources will provide for their long-term sustainable use and protection. In its assessment, the Advisory Committee identified the programmatic needs for monitoring, comprehensive planning, and enforcement that will be necessary to meet the projected demands on the water resources of the State. These needs provide the basis for the following recommendations. Each major recommendation is followed by a brief explanation and the specific actions required for implementation.

1. Continue the Comprehensive Evaluation of Watersheds and Aquifers that are Significant Sources of Water Supply. Continue an Advisory Committee to Provide Guidance in Implementing the Recommendations.

Executive Order 01.01.2003.08 recognizes the importance of assessing the adequacy of the quantity and quality of the State's water supply resources to meet projected needs. The Advisory Committee has concentrated its efforts on water quantity and considered quality only to the extent that quality impacts available water supply. Our understanding of the ability of available water resources to meet expected water needs is constantly changing as future water demand projections are updated and the analysis of water availability is refined. Therefore, it is most important to complete the evaluation process and to provide for updating the assessments on a routine basis.

In response to the requirement to review the latest information concerning such assessments, the Advisory Committee initiated pilot projects of water supply and demand analysis for two distinct areas. The Monocacy Watershed was selected because of known current water supply issues and because it is typical of the way ground water occurs in hard-rock aquifers throughout the State, and provides a good example of the inter-relationship between surface and ground water sources. Southern Maryland was chosen as the second pilot project because of existing concerns about declining ground water levels, and because its confined aquifers are characteristic of most of Maryland's Coastal Plain geology. The two pilot projects were intended to illustrate the types of information needed and the process that could be followed for evaluating watersheds and aquifers in the State, a process that should be continued until every significant water supply source is studied. The pilot projects undertaken for the Monocacy and Southern Maryland regions illustrate the limitations of the existing networks. Approximately 99 additional monitoring wells and 47 additional stream gages are needed statewide to complete the networks.

The Advisory Committee's specific recommendations include directing and enabling the

Department to:

- Continue, in cooperation with the other participating agencies (Agriculture, Health and Mental Hygiene, Planning, and Natural Resources) with the statewide evaluation of water supply sources and repeat the evaluations at regular intervals to ensure consistency with changing demographics and resource conditions.

- Develop a comprehensive multi-aquifer model for the Coastal Plain to be used for ground water management purposes such as issuing permits for wells and developing appropriate County Water and Sewerage Plans.
- Establish an Advisory Committee to provide periodic evaluation of implementation of the recommendations.

2. Restore Funding for Existing Observation Wells and Stream Gages Deleted from the FY 2005 Budget; Expand Monitoring Networks as Funding Becomes Available.

As the State's water supply sources experience heavier demands, monitoring their availability to meet projected needs will become increasingly important. The primary monitoring tools are statewide networks of stream gages to measure surface water flow and of ground water observation wells to monitor ground water levels. The collection of this most basic water resource information is indispensable to the ability of water resource managers to make sound decisions. Without adequate water resource data, it will become difficult or impossible to determine the availability of surface water or ground water, to assess and react to droughts, to determine the potential interference of competing water users, and to assess the impacts of water use on the State's aquifers and streams, while maintaining minimum stream flows. The required expansion of stream and ground water monitoring networks is outlined in the report. At this time, no funds have been allocated to continue operation of the existing ground water monitoring network and for the stream flow monitoring network in the FY 2005 State budget.

- Promptly restore funding for the statewide streamflow and ground water monitoring networks so that there is no interruption in the essential continuity of the data collection.
- Prioritize expansion of the two monitoring networks and phase in new monitoring stations as funding becomes available.

3. Improve Coordination Between Maryland and Virginia Regarding Water Allocations from the Potomac River.

The non-tidal Potomac River Basin in Maryland (which encompasses all of Allegany, Washington, Frederick, Montgomery, and Prince George's Counties as well as parts of Garrett and Carroll Counties) comprises 27% of the State's area and provides drinking water for 40% of the State's population. (The tidal portion of Maryland Potomac drainage is in Southern Maryland and is discussed in that pilot project.) Managing water resources in the Potomac Basin will be particularly challenging because the watershed is shared with other jurisdictions (Virginia, West Virginia, Pennsylvania and the District of Columbia) and because of the significant growth projected for the Washington Metropolitan Area. Another factor adding to the complexity of management in the watershed resulted from the recent Supreme Court decision in the case of Virginia v. Maryland, 540 U.S. ____(2003). Until that 2003 decision, Maryland exercised exclusive jurisdiction over the main-stem Potomac to its landward boundaries in Virginia and West Virginia. Water users in these jurisdictions obtained the same appropriation and waterway construction permits as Maryland users, thereby providing a single, unified set of rules for managing the waters of the Potomac. The Court decision removed Virginia from the regulatory management authority of Maryland. Virginia has subsequently adopted its own rules and procedures for issuing permits to Virginia users. With two states exercising authority over the same waters, there is an obvious need for a coordinated review process that will provide consistency in the issuance of permits. Once that process is established, the States should coordinate their efforts in developing consistent drought procedures within their respected jurisdictions. With its current activity in drought management, the Interstate Commission on the Potomac River Basin should be an extremely useful participant.

- Initiate discussions with Virginia to establish a coordinated permit review process.
- Coordinate with Virginia to update drought management procedures relative to the Potomac River Basin.

4. Support Water and Sewer Planning at the State and Local Government Levels.

The significant role played by local governments in water supply management is derived primarily from State agency delegations. State support for these activities, both in grants and in technical assistance, has been significantly reduced over time, making it extremely difficult for local jurisdictions to meet the expectations of the State agencies providing oversight of these programs.

As an example of the reduced state support, MDE had at one time a staff of nine and MDP had a staff of four providing assistance to local jurisdictions in preparing the State-mandated Water and Sewer Plans. These Plans are intended to provide for the orderly development and extension of community water supply and sewer systems. To maximize the benefit of these Plans to the public and to the water suppliers who rely on them, the Plans must be made in concert with local comprehensive plans, consistent with the water supply and water use data generated from the monitoring networks and the watershed/aquifer studies. The Plans must also take into account the information produced from other State programs (e.g., source water assessments, water quality studies, development capacity analysis, statewide population and demographic projections, etc). This integration cannot occur without State assistance. However, the previous State staffing has been reduced to a single position each at MDE and MDP, which is woefully inadequate for the work required. Because the capacity for comprehensive planning varies among the counties, the State in past years provided partial funding to assist the counties in preparing the Water and Sewer Plans. This funding is no longer available to the counties.

- Restore staff support at the State level to provide technical assistance for development of Water and Sewer Plans at the local level.
- Restore financial assistance where needed for counties to complete the Water and Sewer Plans.
- Consider changes to enhance the utility of the water and sewer planning process, such as incorporation of source protection plans and assessments of available water resources.

5. Implement a Comprehensive Outreach Program to Educate Maryland Citizens and Create Partnerships for Stewardship of the State's Water Resources.

Too often, citizens are not fully aware of the issues related to the water they use. In order to ensure that the importance of efforts to manage water resources is recognized and supported, an educational outreach effort must be developed to enlighten both public officials and the public about the water resource challenges facing the State, and the management options that are available. Outreach efforts can be initiated at the State level as was practiced in the past within the Water Supply Program. Waiting "until the well goes dry" means crisis management, engendering a reactive stance to urgent problems. Educational outreach and the support of the public are needed to ensure proper attention to water resource issues in a timely manner. Restoring staffing in the Water Supply Program would be necessary to continue this important effort.

Some water systems in Maryland have reported that more than 30% of the total amount of treated water they produce is unaccounted for when compared to metered customer use. Unaccounted water can be from uncalibrated meters, which over time tend to be read low, unmetered connections, flushing, and leakage. Water systems exceeding a population of 10,000 are currently asked by MDE to conduct annual water audits, and if losses exceed 10% to prepare a water loss reduction plan. Most water systems with population less than 10,000 do not undertake routine accounting of their water use and losses. All water systems should be encouraged to conduct routine water audits, identify unaccounted water losses, and aggressively pursue leak detection.

In addition, water conservation and water use efficiency technologies are not used extensively in Maryland, due to the relative abundance of water resources in Maryland, coupled with the desire to maintain a comparatively low cost for drinking water. Encouraging an efficient level of conservation may be economical and lessen the likelihood of a water supply crisis.

- Include outreach as one of the responsibilities for additional State staffing.
- Encourage water utilities to employ water conservation and efficient water use technologies to meet their resource needs.
- Encourage water utilities to conduct routine water audits, aggressively pursue leak detection and repair programs, and identify unaccounted water.

6. Exempt Withdrawals below a Minimum Threshold in the Appropriation Permit Law.

Except for domestic and agricultural water withdrawals that are less than 10,000 gpd, all other water users are required to obtain a water appropriation permit. Permits are required to be reviewed on a triennial basis and after a maximum of 12 years unless renewed. Current staffing is inadequate to process permits on a timely basis. A review of the appropriation permit data indicates that a significantly large number of permits are issued for very small withdrawals, so small that even their cumulative impact on water sources is minimal at the present time. Exempting these smaller permits (less than 5,000 gpd) could remove an unnecessary regulatory burden from the business community. Exempting smaller permits would also allow staff to re-focus their attention on the review of large permits with potentially more serious impacts, to address compliance issues more effectively, and to review and issue permits in a more timely manner. The Advisory Committee recommends exempting permits less than 5,000 gpd.

- Modify State statutes and regulations.

7. Review Laws, Regulations, Funding Resources, and State Laboratory Capacity Relative to Comprehensive Management of the State's Water Resources.

Time constraints have not permitted a comprehensive review of existing laws and regulations pertinent to water supply management. Several other issues have been raised that could not be adequately addressed in this report. For example, HB 113, which proposed to modify the 1-gallon per minute minimum test standard for new wells, was introduced during the 2004 legislation. The bill was later withdrawn with the understanding that while MDE was reviewing the existing requirement for possible modification, the Department would keep the bill sponsor advised on the status of the review.

In addition, it has been well documented that laboratory capability for drinking water analysis has not adequately expanded to meet statewide needs as mandated by the federal government. In 1990, only 35 contaminants were regulated for drinking water. Public water systems are now required to test for up to 91 different contaminants in addition to special monitoring for emergency and security related testing. No provision for the increased workload has been provided.

Funding the recommendations will be a major challenge. As one possibility, the Advisory Committee suggests legislation be considered that would establish fees related to water appropriation permit applications and on annual withdrawals.

Other topics identified for further study include:

- Establish a process to ensure that local governments approve new developments based on the adequacy of the water supply for the new developments.
- Establish administrative penalties to ensure compliance with water appropriation permits.
- Encourage consistency among jurisdictions in the implementation of the water and sewer planning process.
- Incorporate source water protection measures into the comprehensive plans developed by each county.
- Establish a process to ensure that abandoned wells are properly sealed.
- Review the well constructions standard and modify if necessary in order to enhance protection of the quality and quantity of ground water.
- Provide sufficient laboratory capability for drinking water analysis to accommodate the additional workload.

7.0 REFERENCES

Achmad, G. and Hansen, H.J., 1997. *Hydrogeology, Model Simulation, and Water Supply Potential of the Aquia and Piney Point-Nanjemoy Aquifers in Calvert and St. Mary's Counties, Maryland*, Maryland Geological Survey Report of Investigations No. 64, 197 pp.

Achmad, G. and Hansen, H.J., 2001. *Ground-Water Levels and Pumpage Trends in the Major Coastal Plain Aquifers of Southern Maryland Between 1970 and 1996*, Maryland Geological Survey Open File Report No. 2000-02-12,149 pp.

Andreason, D.C., 1999. *Geohydrology and Water Supply Potential of the Lower Patapsco and Patuxent Aquifers in the Indian Head-Bryans Road Area, Charles County, Maryland*, Maryland Geological Survey Report of Investigations No. 69, 110 pp.

Andreason, D.C., 2002. *Hydrogeology, Water Quality, and Water Supply Potential of the Aquia and Magothy Aquifers in Southern Anne Arundel County, Maryland*, Maryland Geological Survey Report of Investigations No. 74, 119 pp.

Boland, J.J., 1998. *Water Supply and Climate Uncertainty. Water Resources Update: Global Change and Water Resources Management,* The Universities Council on Water Resources. Southern Illinois University at Carbondale, Carbondale, IL.

Brakebill, J.W. and Kelly, S.K., 2000. *Hydrogeomorphic Regions of the Chesapeake Bay Watershed*, Electronic GIS Layer, USGS Open File Report Number 00–424.

Brown, D., 2004. Data from the Power Plant Research Program of the Maryland Department of Natural Resources.

Chapelle, F.H. and Drummond, D.D., 1983. *Hydrogeology, Digital Simulation, and Geochemistry of the Aquia and Piney Point-Nanjemoy Aquifer System in Southern Maryland*, Maryland Geological Survey Report of Investigations No. 38,100 pp.

Cleaves, E. T. and Doheny, E.J., 2000. *A Strategy for a Stream-Gaging Network in Maryland*, Maryland Gological Survey Report of Investigations 71., 72 pp.

Cohen, J.R., 2004. *Water Supply as a Factor in Local Growth Management Planning in the U.S.: A Review of Current Practice, and Implications for MD,* Urban Studies and Planning Program, University of MD, College Park, 83 pp.

Curtin, S.E., Andreasen, D.C., and Wheeler, J.C., 2002. *Potentiometric Surface of the Aquia Aquifer in Southern Maryland*, 1 p., Scale 1:250,000.

Curtin, S.E., Andreasen, D.C., and Wheeler, J.C., 2002. *Potentiometric Surface of the Lower Patapsco Aquifer in Southern Maryland*, 1 p., Scale 1:250,000.

Fleck, W.B. and Vroblesky, D.A., 1996. *Simulation of Ground-Water Flow of the Coastal Plain Aquifers in Parts of Maryland, Delaware, and the District of Columbia*, United States Geological Survey Professional Paper 1404-J, 41 pp.

Fleck, W.B. and Wilson, J.M., 1990. *Geology and Hydrologic Assessment of Coastal Plain Aquifers in the Waldorf Area, Charles County, Maryland*, Maryland Geological Survey Report of Investigations No. 53, 137 pp.

Mack, F.K. and Achmad, G, 1986. *Evaluation of the Water-Supply Potential of Aquifers in the Potomac Group of Anne Arundel County, Maryland*, Maryland Geological Survey Report of Investigations No. 46, 111 pp.

Mack, F.K. and Mandle, R.J., 1977. *Digital Simulation and Prediction of Water Levels in the Magothy Aquifer in Southern Maryland*. Maryland Geological Survey Report of Investigations No. 28 1977, , 42 pp.

Maryland Department of the Environment Website, 2004. www.mde.state.md.us

Maryland Department of Planning, 2001. *Maryland's Changing Land: Past, Present and Future*, 83 pp.

Maryland Department of Planning, 2004. *Socio-Economic Projections*.

Maryland Department of Planning, 2004. *Monocacy Watershed - Residential Development on Septic and Sewer*, unpublished data, 1 p.

Maryland Department of Planning, 2004. *Southern Maryland - Residential Development on Septic and Sewer*, unpublished data, 1 p.

Massachusetts Water Resources Authority (MWRA) Website, 2004. Section concerning Water Supply and Demand, http://www.mwra.state.ma.us/04water/html/wsupdate.htm

Metropolitan Washington Council of Governments, 2003. *Round 6.3 Cooperative Forecasting: Employment, Population and Household Forecasts to 2030 by Traffic Analysis Zone*, Department of Human Service, Planning and Public Safety, Metropolitan Washington Council of Governments.

St. Petersburg, FL website, 2004. Section concerning water system, http://www.stpete.org/wwwrecla.htm

Steiner, R.C., Ehrlich, N.N., Boland, J.J., Choudhury, G.S., Teitz, W., McCusker, S., and Yamamoto, A, 1997. *Water Resources Management in the Potomac River Basin Under Climate Uncertainty*, ICPRB Report 94-3. Rockville, MD. Prepared for Institute for Water Resources, Water Resources Support Center, Corps of Engineers, Department of the Army.

Steiner, R.C., Hagen, E.R., and Ducnuigeen, J., 2000. *Water Supply Demands and Resources Analysis in the Potomac River Basin*, ICPRB Report No. 00–05

Tompkins, M.D., Cooper, F.F., Drummond, D.D., 1994. *Ground Water and Surface Water Data for Kent County, Maryland*. Maryland Geological Survey Basic Data Report No. 20.

U.S. Census Bureau, 2001. *Census 2000 Summary File 1 (SF 1) 100 Percent Data*, U.S. Census Bureau.

US EPA, 2002. *Cases in Water Conservation: How Efficient Programs Help Water Utilities Save Water and Avoid Costs*. US EPA website, http://www.epa.gov/ow/yearofcleanwater/docs/utilityconservation.pdf

Wheeler, J.C., 2003. *Freshwater Use Trends in Maryland, 1985–2000,* USGS Fact Sheet FS112–03.

Wheeler, J.C., 2004. *DRAFT Water Withdrawal Report for Maryland.* USGS unpublished data report.

Wheeler, J.C., 2004. *Maryland Water Withdrawal Reports* for 1985 thru 2001.

Acronyms and Abbreviations

Advisory Committee – Advisory Committee on the Management and Protection of the State's Water Resources

Avg – average

Bmsl – below mean sea level

Cfs – cubic feet per second

CO2 – carbon dioxide

DE – Delaware

DHMH – Maryland Department of Health and Mental Hygiene

EHD – Environmental Health Directors

ET – Evapotranspiration

EX – annual precipitation excess

Feet/year – feet per year

Feet2/day – feet squared per day

GCM model – General Circulation Model

GCMs – General Circulation Models

GFDL – Geophysical Fluid Dynamics Laboratory, new version

GIS – Geographic Information System

GISS-A – Goddard Institute for Space Studies, version –A

GISS-B – Goddard Institute for Space Studies, version-B

Gpd – gallons per day

HB – House Bill (no.___)

HYSEP – Hydrograph Separation Program

ICPRB – Interstate Commission on the Potomac River Basin

IWR-MAIN – a detailed demand-forecasting model

LFAA – Potomac River "Low Flow Allocation Agreement"

MDA – Maryland Department of Agriculture

MDE – Maryland Department of the Environment

MDP – Maryland Department of Planning

Metro Area – Washington Metropolitan Area (Montgomery, Prince George's, Frederick Counties in Maryland; Fairfax, Loudoun, Prince William Counties in Virginia; and the District of Columbia

MGD – million gallons per day

MGS – Maryland Geological Survey

MLM – Monocacy–Lower Monocacy sub-watershed

MPI – Max Planck Institute, Germany

MW – mega watts

NASS – National Agriculture Statistic Service

POS – complete "period of simulation"

Precip – precipitation

(Precip-ET) – precipitation minus evapotranspiration

r^2 values – values for "square of correlation coefficient"

R.I. – Report of Investigations

sq miles – square miles

Std. Dev. – Standard deviation

TAZ – Traffic Analysis Zone

UKMO – United Kingdom Meteorological

University of MD – University of Maryland

U.S. – United States

U.S. Census Bureau – United States Census Bureau

U.S. EPA – United States Environmental Protection Agency

USGS – United States Geological Survey

WMA – Water Management Administration (of MDE)

WSP – Water Supply Program (of WMA of MDE)

WSSC – Washington Suburban Sanitary Commission

YRS – Years

7Q 10 – 7-day, 10-year low flow

Glossary of Terms

Appropriation permit: A permit issued by the Maryland Department of the Environment for an intentional withdrawal, movement, or diversion of water for use from its source of natural occurrence which is caused by human activity.

Aquaculture: The regulation and cultivation of water plants and animals for human use or consumption.

Aquifer: A geologic formation, group of formations, or part of a formation capable of yielding a significant amount of ground water to wells or springs.

Aquifer test or pump test: A process in which the yield of an aquifer is measured through pumping at a sustainable rate and measuring water level response.

Base flow: That part of the stream discharge that is not attributable to direct runoff from precipitation or melting snow; it is usually sustained by ground water discharge.

Base flow separation analysis: An analytical technique by which that part of a total stream flow hydrograph that consists only of base flow is determined.

Brackish water: Water of low salinity (typically between 5 and 25 parts per thousand) produced by mixing of fresh water and saltwater.

Build out: A planning term used to indicate the final maximum population or development potential of an area, such as may be indicated in a county or city master plan.

Cone of depression: A depression of the potentiometric surface in the shape of an inverted cone that develops around a well that is being pumped.

Confining layer or confining unit: A hydrogeologic unit of impermeable or distinctly less permeable material bounding one or more aquifers and is a general term that replaces aquitard, aquifuge, aquiclude

Confined aquifer: An aquifer bounded above and below by confining units of distinctly lower permeability than that of the aquifer itself.

Consumptive use: That portion of water used or withdrawn from an aquifer, stream or water body that is not returned to its source because it is "used-up," such as by evaporation or by being incorporated into a product and being shipped away, etc.

Correlation coefficient: A statistical measure of the interdependence of two or more random variables. Fundamentally, the value indicates how much of a change in one variable is explained by a change in another.

Dip: The angle that a stratum is inclined from horizontal.

Discharge: (1) The natural flow of water from ground water to a surface water body, also refers to the water that leaves. (2) The point on a stream where treated water from wastewater plants is added, also refers to the water that enters the stream.

Drawdown: The decline in potentiometric surface at a point caused by the withdrawal of water from a hydrogeologic unit

Drought: A period of time when natural or managed water systems do not provide enough water to meet established human and environmental uses because of natural shortfalls in precipitation or stream flow.

Eighty percent (80%) management level: The water level or potentiometric surface in a confined aquifer that represents eighty percent of the available drawdown from pre-pumping conditions, which is used as a method of determining the "reasonableness" of an impact of a water withdrawal granted under a ground water appropriation permit.

Evapotranspiration: The combined loss of water from a given area by evaporation from the land and transpiration from plants.

Fall Line: The boundary between the Coastal Plain and Piedmont Plateau physiographic provinces, so named due to the formation of rapids and waterfalls where streams have eroded the harder crystalline formations of the Piedmont.

Flowby: The required minimum flow past the point of appropriation to protect other users of the water and to protect flora and fauna within the watercourse, which is used in regulation of surface water appropriations.

Fractured-rock aquifer. A general term for a consolidated rock formation that lies beneath soil, loose sediments, or other unconsolidated material in which ground water flows through cracks or fissures.

General Circulation Models: Computer models that numerically solve equations describing the conservation of mass, energy, momentum, and account for the transfer of those quantities, in order to describe or predict the physical processes occurring in the atmosphere and their relation to climate.

Geographic information system: An automated system composed of hardware, software, data and people used to create, store, display and analyze spatial data and related attributes.

Ground water: Subsurface water that fills available openings in rock or soil materials to the extent that they are considered water-saturated.

Hydraulic conductivity: (1) A proportional constant relating hydraulic gradient to specific discharge which for an isotropic medium and homogeneous fluid, equals the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. (2) The volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Hydrogeologic unit: Any soil or rock unit or zone, which by virtue of its hydraulic properties has a distinct influence on the storage or movement of ground water.

Hydrologic cycle: The cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, via infiltration to ground water, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.

Hydrograph: A graphical depiction of water levels with respect to time, at either a given point in a stream or in an aquifer.

Instream reserve flow: This is the minimum flow needed in a stream to preserve stream life. In the Monocacy River Pilot Study of this report this flow is equated with the seven-day, ten-year low flow.

Karst: A landscape or terrain in which the topography is formed by the dissolution of limestone and is characterized by the formation of sinkholes, sinking streams, closed depressions, and subterranean drainage.

Leakage: (1) The flow of water from one hydrogeologic unit to another. The leakage may be natural, as through a semi-impervious confining layer, or human made, as through an uncased well. (2) The natural loss of water from artificial structures as a result of hydrostatic pressure.

Leaky aquifer: Aquifers, whether artesian or water-table, that lose or gain water through adjacent less permeable layers.

Maryland Most Common Flow Method: A technique used to determine a flow-by that will be required to pass a surface water intake. The required minimum flow-by is generally about one standard deviation below the mean flow value for a particular month or other time period.

Model: A conceptual description and the associated mathematical representation of a system, subsystem, components, or condition that is used to predict changes from a baseline state as a function of internal and/or external stimuli and as a function of time and space.

Monitoring well or observation well: A well that is used for the express purpose of measuring water level in an aquifer or making other scientific observations.

Outcrop area: The area in which a geologic formation or an aquifer is exposed at the land surface. This is often the most important area of recharge of ground water to the aquifer.

Physiographic province: A geographical area that can be defined by its common landscape, land forms, and/or topography. The physiography of an area is, in large part, a product of the geology. The five physiographic provinces of Maryland from east to west are the Coastal Plain, the Piedmont Plateau, the Blue Ridge, the Valley and Ridge and the Appalachian Plateau.

Potentiometric surface: An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a tightly cased well.

Pre-pumping potentiometric surface: The level to which water would have risen in a tightly cased well prior to the historic removal of any substantial amount of water from an aquifer by man.

Public water supply: A water supply system that provides water for human consumption to the public through pipes or other constructed conveyances, if the system has at least 15 service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

Recharge: The process of addition of water to the saturated zone; also refers to the water added.

Recharge area: An area in which water reaches the saturated zone by surface infiltration.

Recharge rate: The rate at which an aquifer is replenished by water.

Regression equation: A statistical technique used to explain or predict the behavior of a dependent variable.

Reliable yield or safe yield: The amount of water that can be pumped from an aquifer or stream at a sustained level without causing excessive drawdown or dewatering of streams.

Reservoir: an artificial lake where water is collected and kept in quantity for use.

Reservoir safe yield: The amount of water that can be extracted from a reservoir that is limited by storage capacity of reservoir and the average annual recharge in the reservoir drainage basin.

Saline water: Water that generally is considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids. Commonly expressed as milligrams per liter (mg/L) of dissolved solids, with 35,000 mg/L defined as equivalent to sea water, slightly saline as 1,000 - 3,000 mg/L, moderately saline as 3,000 - 10,000 mg/L, very saline as 10,000 - 35,000 mg/L, and brine has more than 35,000 mg/L.

Saltwater intrusion: The movement of salt water into fresh water aquifers.

Saturated zone: That part of the earth's crust beneath the water table in which all voids, large or small, are ideally filled with water under pressure greater than atmospheric.

Seven-day, Ten-year low flow (7Q10): The lowest mean daily flow in stream recorded over a period of seven consecutive days, recurring once every ten years. The 7Q10 is often used as a minimum flow requirement or flowby for streams.

Source water assessment: The assessment of the contributing area of a public drinking water supply in relation to its susceptibility to contamination, as required by Federal Safe Drinking Water Act, 1996 Amendments.

Source water protection program or wellhead protection program: A program designed to manage and protect drinking water sources, generally designed by local governments to address land use issues that may impact the contributing area of a drinking water supply.

Stream gage or gaging station: a site on a stream where observations and hydrologic data are obtained: Specifically stream discharge is measured on a stream gage.

Synthetic stream flow: A representation of the hydrograph of a stream, which is created via a computer model from areally proportioned stream gage data from another stream or streams.

Transmissivity: The capacity of a rock to transmit water under pressure. Specifically, the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Unconfined Aquifer: an aquifer in which the upper surface of the saturated zone forms a water table under atmospheric pressure.

Water and Sewer Plan: A plan developed by each County in the State, to be consistent with the comprehensive plan, that shall be used as a tool to implement the county development policy so that: (1) An ample supply of water may be collected, treated, and delivered to points of use; (2) Waste water may be collected and delivered to points best suited for waste treatment and disposal or for re-use; (3) Waste water can be either treated before any discharge to State waters, in compliance with applicable water quality standards and discharge permit conditions, or disposed of to minimize most effectively adverse effects on legitimate water uses.

Water balance or water budget or hydrologic budget: A method for determining water availability in a watershed or aquifer by taking into consideration all inputs (recharge) and outputs (discharge, withdrawals) to the system.

Water Table: The upper surface of the saturated zone on which the water pressure in the porous medium equals atmospheric pressure.

Watershed: The land area that drains water to a particular stream, river, or lake.