WATER RESOURCES TECHNICAL COMMITTEE
REGIONAL GROWTH AND WATER RESOURCES PLANNING WORKSHOP

April 23, 2007
(10:00 am to 2:00 pm)
COG Training Center, 1st Floor

Regional Growth, Planning and Tools: Attachments and Links

Provided below are some attachments and links to background information that should be helpful in providing you with a better understanding of the topics, tools and processes that will be discussed during the Workshop.

COG PLANNING

Attachment: Maps of *COG Membership Area and Transportation Modeling Area (Includes the Transportation Analysis Zones) and COG Membership Area and COG Planning Area*

Attachment: *Growth Trends to 2030 – Cooperative Forecasting in the Washington Region"*
Also available at: http://www.mwcog.org/uploads/pub-documents/8llaXQ20061010135838.pdf

COG's Cooperative Forecasting Committee prepares official forecasts of employment, population, and household growth at the traffic analysis zone (TAZ) level for the entire metropolitan Washington region, covering a period of 25 to 30 years. The last set of forecasts approved by the COG Board was Round 7.0a in October 2006. The Cooperative Forecasts are also the inputs for our Regional Wastewater Flow Forecast Model (RWFFM) and the National Capital Region Transportation Planning Board annual Air Quality Conformity Analysis. *Note: Currently Round 7.1 projections are under technical review and are not expected to be formally adopted until fall 2007.*

These forecasts are used as part of the region's formal transportation and air quality conformity planning. Several references regarding COG housing/economic planning and projections, transportation planning, transportation models, and air quality planning activities include:

http://www.mwcog.org/planning/planning
http://www.mwcog.org/transportation/activities
http://www.mwcog.org/transportation/activities/models
http://www.mwcog.org/transportation/activities/quality

CHESAPEAKE BAY PROGRAM MODELS and OTHERS

Attachment: *Chesapeake Bay Program Environmental Models*

The Bay Program utilizes five environmental models (see pdf below). However, the attachment only highlights three main models (Watershed, Estuary, and Airshed) which can simulate changes in the Bay's ecosystem due to population change, land use or pollution management. The model simulations can be used to predict the impact of changes in nutrient and sediment loads due to various environmental management actions.

For more detailed information on the various Bay Program Models visit:
http://www.chesapeakebay.net/pubs/iannewsletter11.pdf
Note: This pdf describes the current Phase 4.3 Watershed Model. *Note: The Phase 5.0 Watershed Model is currently under technical review.*

Attachment: *Phase 5.0 Description*

Phase V is the latest version of the Chesapeake Bay Program's Watershed Model. There are many improvements under development, the most significant being that the model can be used on a fine scale, which is "…consistent with the scale needed for State developed TMDLs."

For more information on the Phase V version of the Watershed Model, visit:
http://www.chesapeakebay.net/phase5.htm

Vortex Model

A Web-based Model Scenario Generator & Data Analysis System (aka Vortex) is another modeling tool being developed by the CBP that will provide an interface to the CBP's Watershed Model Phase 5.0 that would allow a full range of alternative planning scenarios to be utilized. COG staff is currently conducting testing on a Beta version. *Note: It is hoped that this system will be available to the public by the fall of 2007.*

Attachment: *Anne Arundel County Watershed Management Tool*

A local example of a modeling tool that "…not only looks at stormwater flow, it also looks at groundwater movement and its effect on septic tank impacts."

LAND USE / PROJECTIONS

Attachment: *"The Butterfly Effect: How Land Development Impacts Water Quality"*

Discusses how land development – construction and development activities, impervious surfaces, reductions in forested and agricultural lands, etc - impact the Bay.

Attachment: USGS Map *"Areas of Highest Development Pressure in the Chesapeake Bay Watershed (1990 – 2000)"*

REGULATION / LEGISLATION

Attachment: *Maryland HB1141*

Passed during the 2006 Legislative Session, this legislation requires all local jurisdictions to include a water resources element in their comprehensive plans on or before October 1, 2009 unless extensions are granted by MDP. The purpose of the element is to link the comprehensive plan to water resources issues by outlining how water and sewer will be provided for planned growth in each jurisdiction.

Note: MDE is currently reviewing the Implementation Guidelines for HB1141.

Attachment: *9 VAC 25-780. Local and Regional Water Supply Planning*

> Virginia's Title 9 regulation "…establishes a planning process and criteria that all local governments will use in the development of local or regional water plans."
>
> Under section '9 VAC 25-780-100. Projected water demand information,' the plan requires the estimation of water demand for a minimum of 30 to 50 years into the future; and an estimated future water use projected at the beginning of each decade.

ICPRB Water Supply Planning & Collaboration with NVRC

The three largest water utilities in the Washington, D.C. metropolitan area (WMA) rely on the Potomac River and its reservoirs for water supply. These utilities have committed to a periodic review of the system's adequacy to meet future demands. In 1990, 1995, 2000, and again in 2005 the utilities requested that the Interstate Commission on the Potomac River Basin (ICPRB) conduct a 20-year water demand and resource adequacy study to fulfill this need. The selection of the five-year interval provides multiple benefits. It allows regular updates and incorporation of recent demographic forecasts, and increases visibility and understanding of the adequacy of the region's water resources. It also provides adequate time to conduct research on the physical system and to incorporate modifications based on this research to subsequent studies. The work has been a natural outgrowth of a long history of cooperative water supply planning and management among the main WMA water utilities and ICPRB. *ICPRB is coordinating with Virginia DEQ to ensure that our next demand study will fulfill the needs of the planning regulation for the Virginia water suppliers that depend on the Potomac River and that are wholesale customers of Fairfax Water or the Washington Aqueduct.*

Attachment: *JAWRA Benefits of Iterative Demand Forecasting.pdf*

The ICPRB is also collaborating with the Northern Virginia Regional Council (NVRC) to address the specific demands of the Title 9 requirements, and plans to work with COG's Cooperative Forecasting Committee and COG staff to develop projections to 2040.

Figure 1
COG Member Boundary
and
Transportation Modeling Area

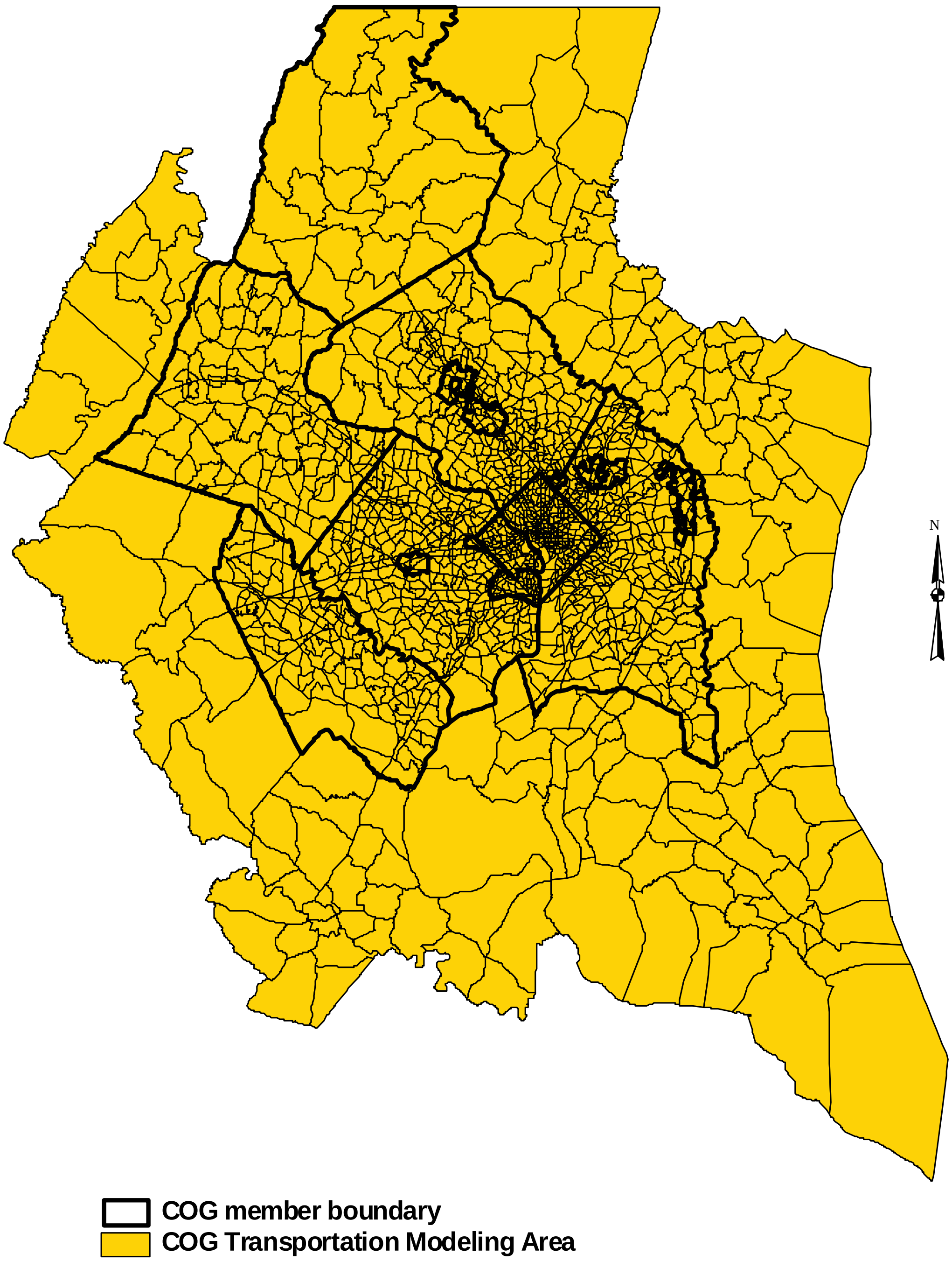
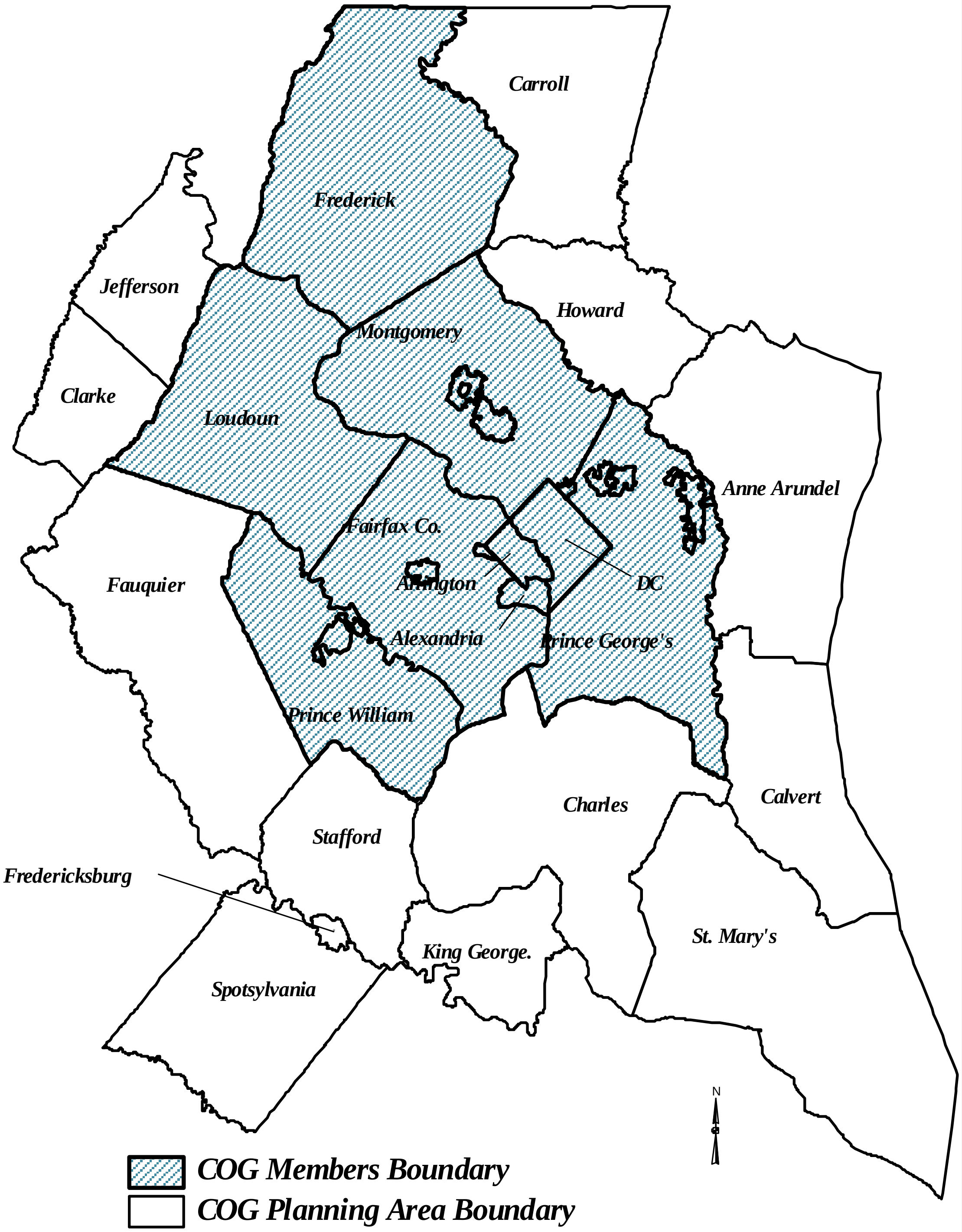


Figure 1
COG Memembership
and
COG Planning Area Boundary



What Are Environmental Models?

SEE ALSO

• Modeling Subcommitee

Environmental models are essential for simulating ecosystems that are either too large or too complex to isolate for experiments in the real world. Models allow scientists to simulate changes in an ecosystem due to changes in population, land use or pollution management. These simulations, called scenarios, allow scientists to predict positive, or negative, changes within our ecosystem due to management actions such as improved sewage treatment, reduced fertilizer or manure application on agricultural land or controlling urban sprawl.

Models use mathematical representations of the real world to estimate the effects of complex and varying environmental events and conditions. For example, the Chesapeake Bay Watershed Model estimates the delivery of nutrients and sediments to the Bay by simulating hydrologic and nutrient cycles, using inputs such as atmospheric nutrient deposition, precipitation, fertilizer application, and land cover or land use.

Why do we need Environmental Models?

Environmental models are essential for simulating ecosystems that are either too large or too complex to isolate for experiments in the real world. Models allow us to simulate changes in our ecosystem due to changes in population, land use, or pollution management. These simulations, called scenarios, allow us to predict positive, or negative, changes within our ecosystem due to management actions such as improved sewage treatment, reduced fertilizer or manure application on agricultural land, or controlling urban sprawl.

Why are the Bay Program Models important?

Models are one of the principal tools crucial to the Bay Program goals of reducing nutrients and sediments delivered to the Bay. In 1992, Bay Program partners agreed to reduce controllable loads of nitrogen and phosphorous delivered to the Bay by 40% of 1985 levels by the year 2000. From this goal, the Bay models were used to develop tributary nutrient allocations, or reductions, for each of the nine major tributaries in the Chesapeake watershed. In 2000, these tributary allocations became a nutrient cap, not to be exceeded even with future increases in population and growth. With the nutrient cap in place, Bay models are used to track nutrient loads to ensure the cap is not exceeded. Currently, the models are directed toward the examination of the need for further nutrient and sediment reductions to fully restore the water quality required for the Bay's living resources.

Models produce estimates, not perfect forecasts. They reduce, but do not eliminate, uncertainty in environmental decision making. Used properly, they are a tool that can assist in developing nutrient and sediment reductions that are most protective of the environment, while being equitable, achievable and cost effective

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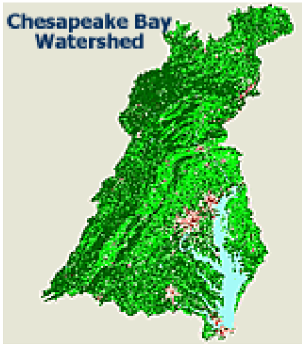
What Models do we have?

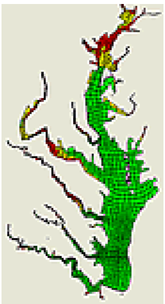
The Watershed Model



The Chesapeake Bay watershed.

The Watershed model divides the 64,000 square mile Chesapeake Bay drainage basin into 94 model segments. Each segment contains information generated by a hydrologic submodel, a nonpoint source submodel and a river submodel. The hydrologic submodel uses rainfall, evaporation and meteorological data to calculate runoff and subsurface flow for all the basin land uses including forest, agricultural and urban lands. The surface and subsurface flows ultimately drive the nonpoint source submodel, which simulates soil erosion and the pollutant loads from the land to the rivers. The river submodel routes flow and associated pollutant loads from the land through lakes, rivers and reservoirs to the Bay.

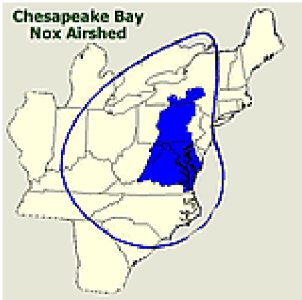
- Learn more about Phase 5 the latest version of the watershed model. (Note: the current version of the Watershed Model is Phase 4.3)


The Chesapeake Bay Estuarine model

The Estuary Model

The estuarine model, commonly referred to as the water quality model, examines the effects of the loads generated by the Watershed Model on Bay water quality. In the Estuary Model, the Bay is represented by more than 10,000 computational cells which average six miles long, two miles wide and five feet deep. The cells are stacked up to 15 layers in the deepest areas of the Bay. The Estuary Model is built on two submodels: the hydrodynamic submodel and the water quality submodel. The hydrodynamic submodel simulates the mixing of estuarine waters with coastal ocean waters, and the mixing of water within the Chesapeake. The water quality submodel calculates the chemical and physical dynamics of the Chesapeake.

The Airshed Model



The Chesapeake Bay Airshed.

The Airshed Model (Regional Acid Deposition Model - RADM) tracks nitrogen emissions from all sources in the airshed. The model is three-dimensional; it simulates movement both vertically and horizontally across a region. The Airshed Model covers the eastern United States from Texas and North Dakota eastward to Maine and Florida with 22,000 cells. Each cell measures eighty kilometers square. Stacked up, the cells make fifteen vertical layers reaching about fifteen kilometers high. The airborne nutrient loads are transported by the Airshed Model and linked to the Watershed Model through deposition to land surfaces and to the Estuary Model through deposition to the water surfaces of the tidal Bay.

For more information, contact the Chesapeake Bay Program Office:
410 Severn Avenue, Suite 109, Annapolis, MD 21403 / Tel: (800) YOUR-BAY / Fax: (410) 267-5777.

Phase 5, the latest version of the Chesapeake Bay Program's Watershed Model, is now under development. A number of improvements are being made from the previous version of the model, Phase 4.3; however, the most significant improvement is the scale in which the data are now available. We are developing a model that can be used on a fine scale, consistent with the scale needed for State developed TMDLs. In this way, watershed load analysis can be consistent between State-led basin and small tributary TMDLs, and the CBPO led overall assessment of Chesapeake Bay water quality. The level of collaboration with this model between the Environmental Protection Agency (EPA), the Chesapeake Bay Program (CBP), US Geological Survey (USGS), Interstate Commission on the Potomac River Basin (ICPRB), Maryland Department of the Environment (MDE), VA Department of Conservation and Recreation (DCR), and the University of Maryland (UMD) has allowed us to significantly improve the spatial and computational scale of the model.

Specific improvements include:

- Refined and updated rainfall, fertilizer, Best Management Practice (BMP), and landscape processes data. All data will be updated to 2002, allowing an 18 year simulation period from 1984 to 2002.
- Refined segmentation of land segments and river reaches including the simulation of all major reservoirs in the watershed.
- Additional land use simulations - there will be approximately 20 Phase 5 land uses, a two-fold increase from Phase 4.3. Phase 5 land use will include 12 different crop types, and several new BMP types will be directly simulated.

For more information see the model related publications by clicking on the publications tab on the top of this page. Featured publications include: the report *Cross-Media Models of the Chesapeake Watershed and Airshed* and *Watershed Model Application to Calculate Bay Nutrient Loadings: Final Findings and Recommendations* are particularly recommended as detailed background information on the Watershed Model

Draft Phase 5 Community Model Documentation

A preliminary working draft of the Phase 5 model is provided here for the user community. This draft documentation includes updates in October 2006, January 2007, April 2007, and July 2007. The documentation will be finalized by January 2008 when Phase 5 is approved for management application in Bay Program nutrient and sediment load assessments. Users of this draft information are warned that this information is preliminary, subject to change, and unsubstantiated by full and final reviews. These draft reports should be cited as "U.S. EPA, 2008. Chesapeake Bay Phase 5 Community Watershed Model In preparation EPA XXX-X-XX-008 Chesapeake Bay Program Office, Annapolis MD. January 2008."

Section 1: Watershed Model Overview

Section 1.1 – 1.10	Latest Draft: 2/13/07	12 MB .pdf	Download

Section 2: Meteorology and Precipitation

Section 2.1 – 2.31	Latest Draft: 3/17/07	4 MB .pdf	Download

Section 3: Land and River Segmentation

Section 3.1 – 3.7	Latest Draft: 8/18/05	8 MB .pdf	Download

Section 4: Land Use

Section 4.1 – 4.7	Latest Draft: 6/20/06	8.5 MB .pdf	Download

Section 7: Point Sources, Water Withdraws, and On-Site Waste Disposal Systems

Section 7.1 – 7.4	Latest Draft: 8/30/06	372 kb .pdf	Download

For more information, contact the Chesapeake Bay Program Office:
410 Severn Avenue, Suite 109, Annapolis, MD 21403 / Tel: (800) YOUR-BAY / Fax: (410) 267-5777.

Anne Arundel County
Maryland

Innovative Watershed Management Tool for Restoration and Preservation in Anne Arundel County

Mary L. Searing, P.E.
Watershed Management Program Manager
Office of Environmental & Cultural Resources
Anne Arundel County

September 13, 2004

Project Background

- **Anne Arundel County is developing a comprehensive Watershed Management Master Plan for the Severn River**
- **Project Team: CH2M HILL and KCI Technologies, Inc., and GeoNorth**
- **Two Main Parts to project:**
  - traditional watershed management plan activities
  - development of Watershed Management Tool (WMT)

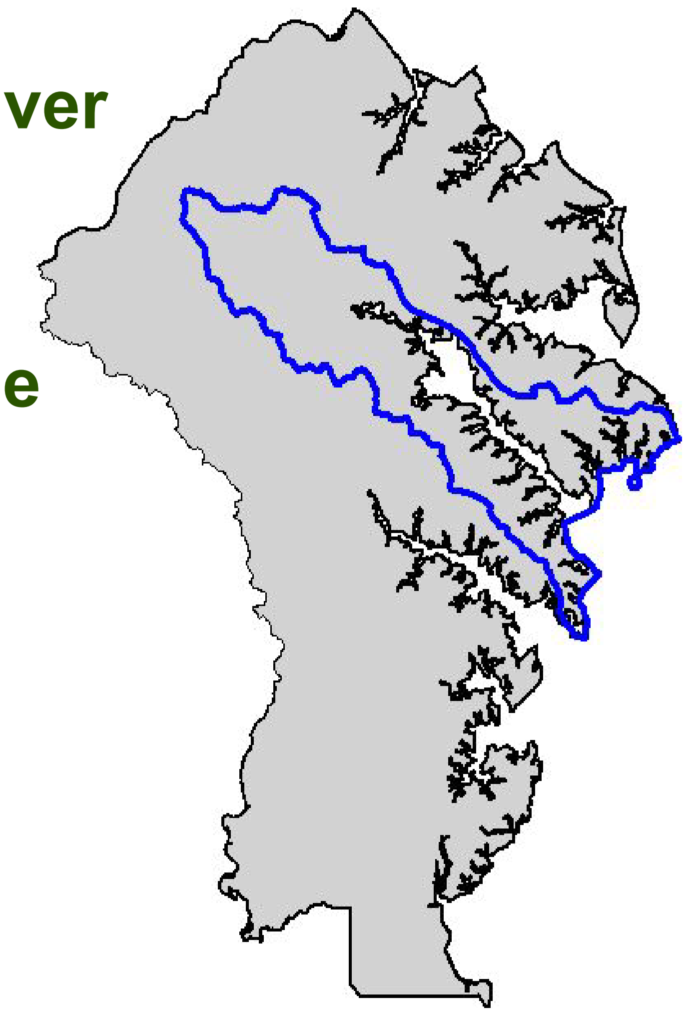
Vision

The Watershed Master Plan will provide a blueprint and tools to facilitate land use and infrastructure decisions by County Staff and Stakeholders to protect the resources of the Severn River.

Better Decisions for a Better Future

Project Area

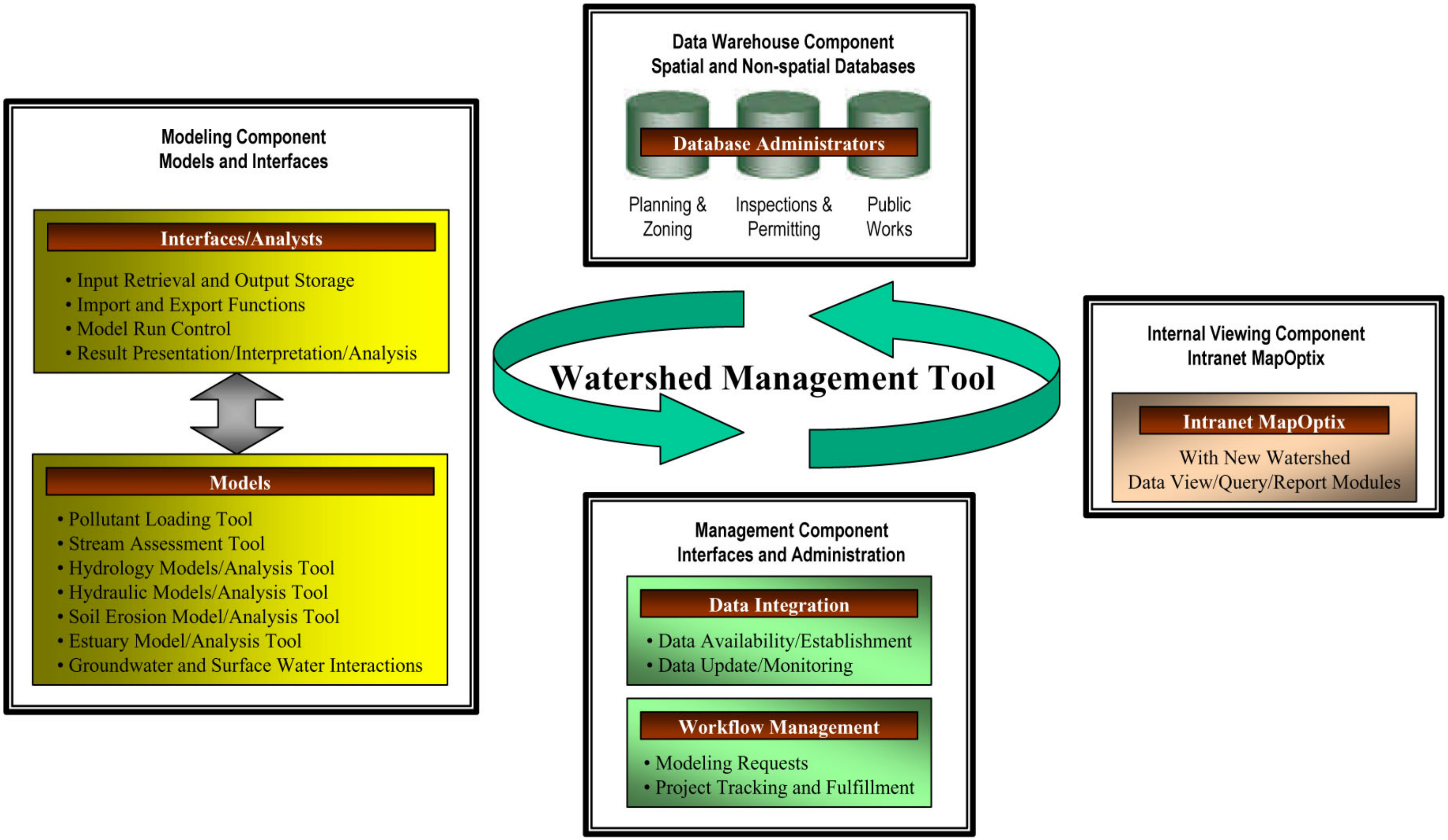
- Current project area is Severn River Watershed
- Eventually incorporate all 12 watersheds of the County into the Watershed Management Tool



Summary and Overview of Watershed Management Tool

- **Utilized for:**
  - NPDES Permitting and Compliance
  - Watershed-Based Land Management & Land Use Planning
  - Development Review
  - Capital Improvement Planning

Overview of Functional Components of WMT



Model Categories within WMT

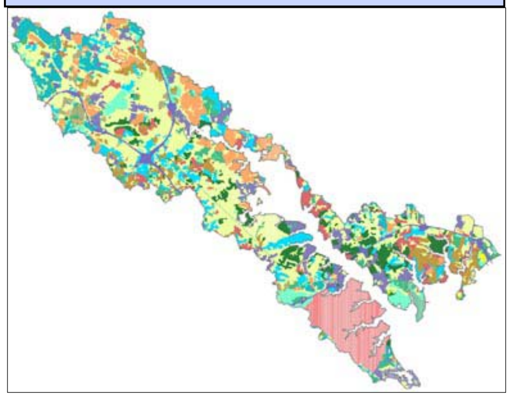
- **Water Quality Modeling - Pollutant Loading**
- Hydrologic & Hydraulic Modeling
- Soil Erosion Modeling
- Stream Assessment
- Groundwater / Surface Water Interactions

Pollutant Loading Model: PLOAD

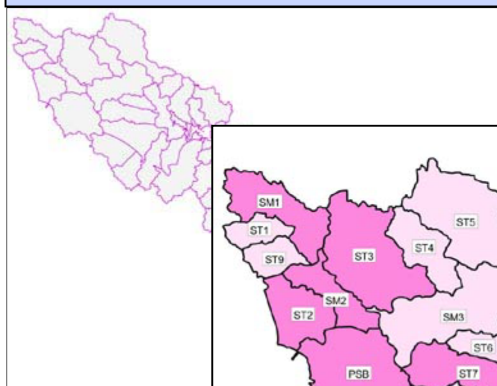
- Based on the Simple Method
- Uses Event Mean Concentrations (EMCs)
- Encompasses a BMP point coverage
- Encompasses a Point source coverage
- Modeled current conditions, future conditions, and what-if scenarios

Modeling Tool: Pollutant Load Modeling

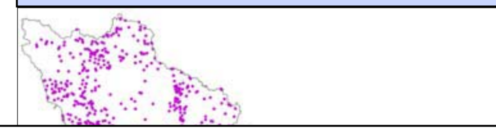
Land use

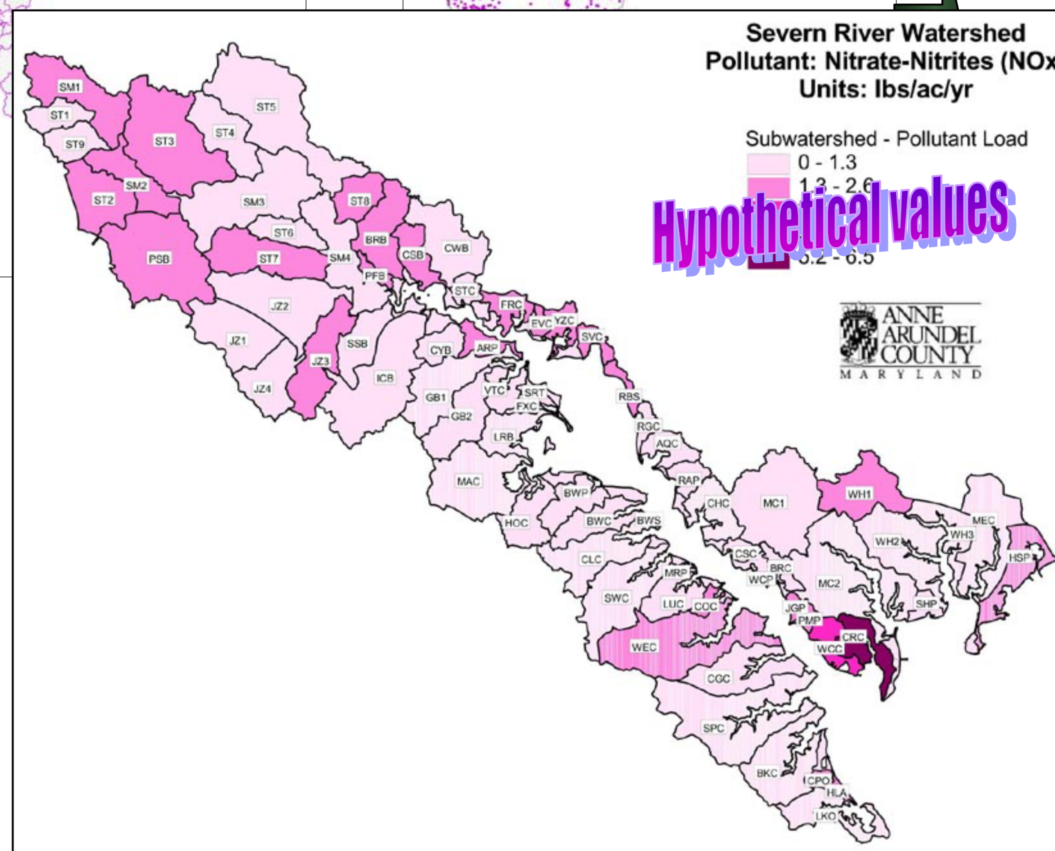


Subwatersheds

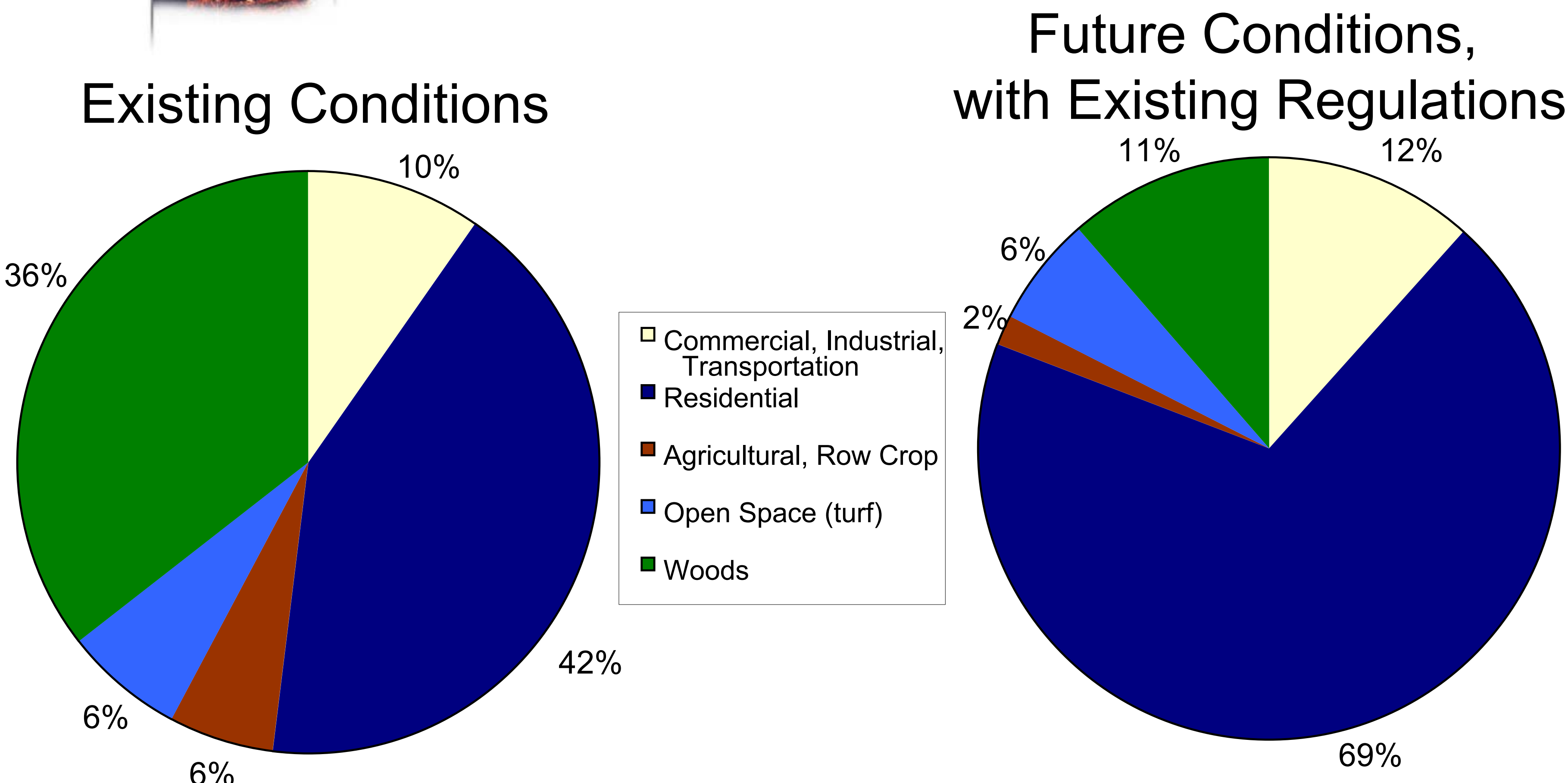


BMPs



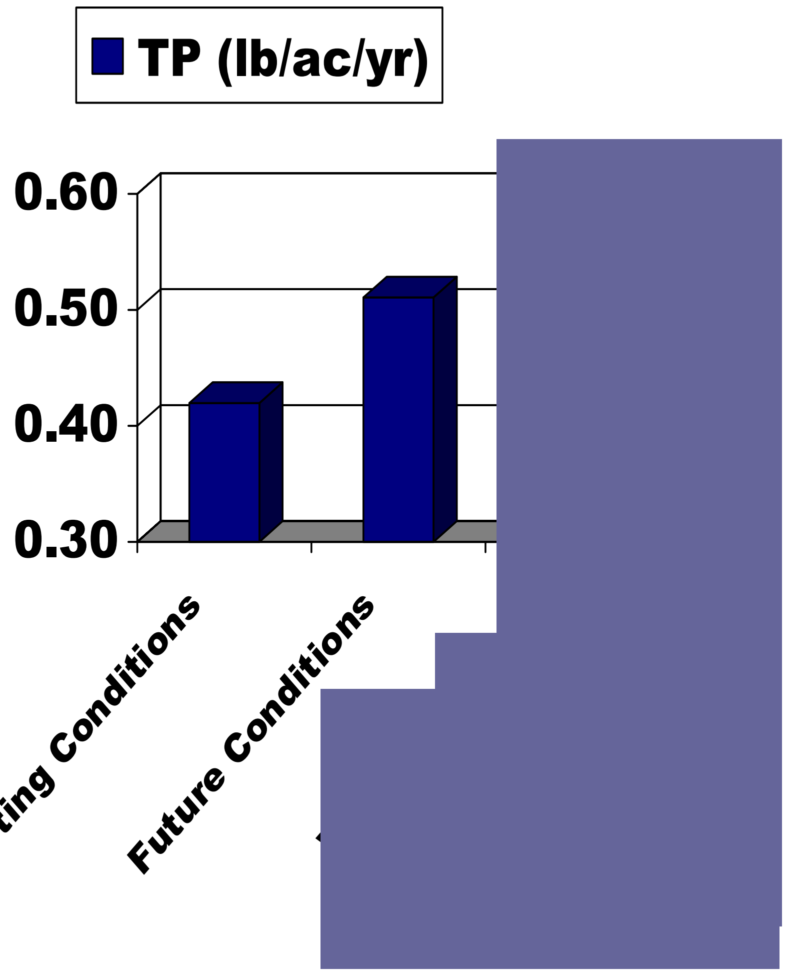


Existing Land Use Plan Projected Land Use Changes



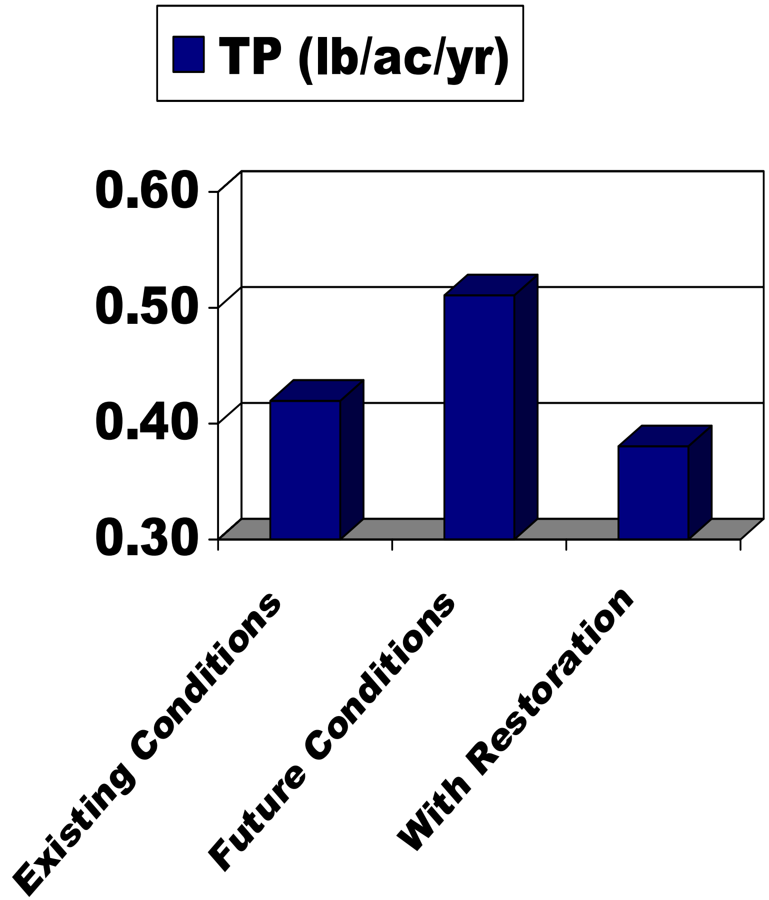
Note: Data does not include the City of Annapolis

Loading Rates of Total Phosphorus for Existing and Future Conditions



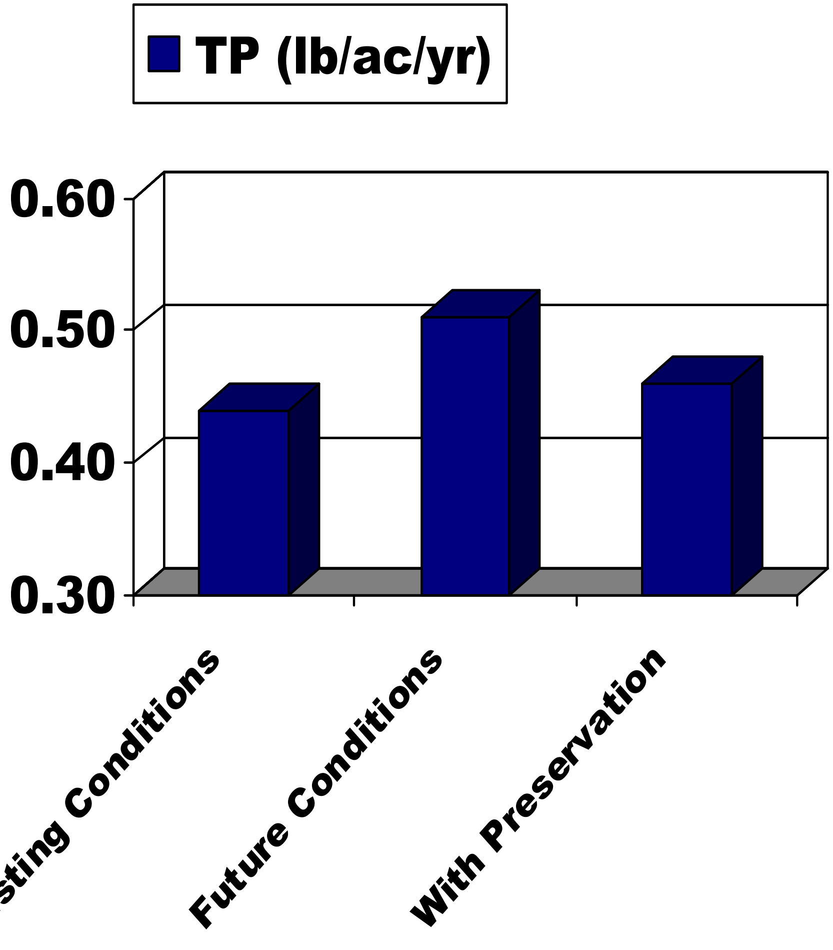
Considerations for Revised Land Use Plan - Possible Restoration Alternatives

- Bioretention
- Dry to Wet Pond Retrofits
- Wetland Mitigation
- Septic System Upgrades



Considerations for Revised Land Use Plan – Possible Preservation Alternatives

- Stream buffers and shoreline buffers (critical area)
- Greenways (100% of plan)
- Wetland mitigation sites
- Cluster zoning



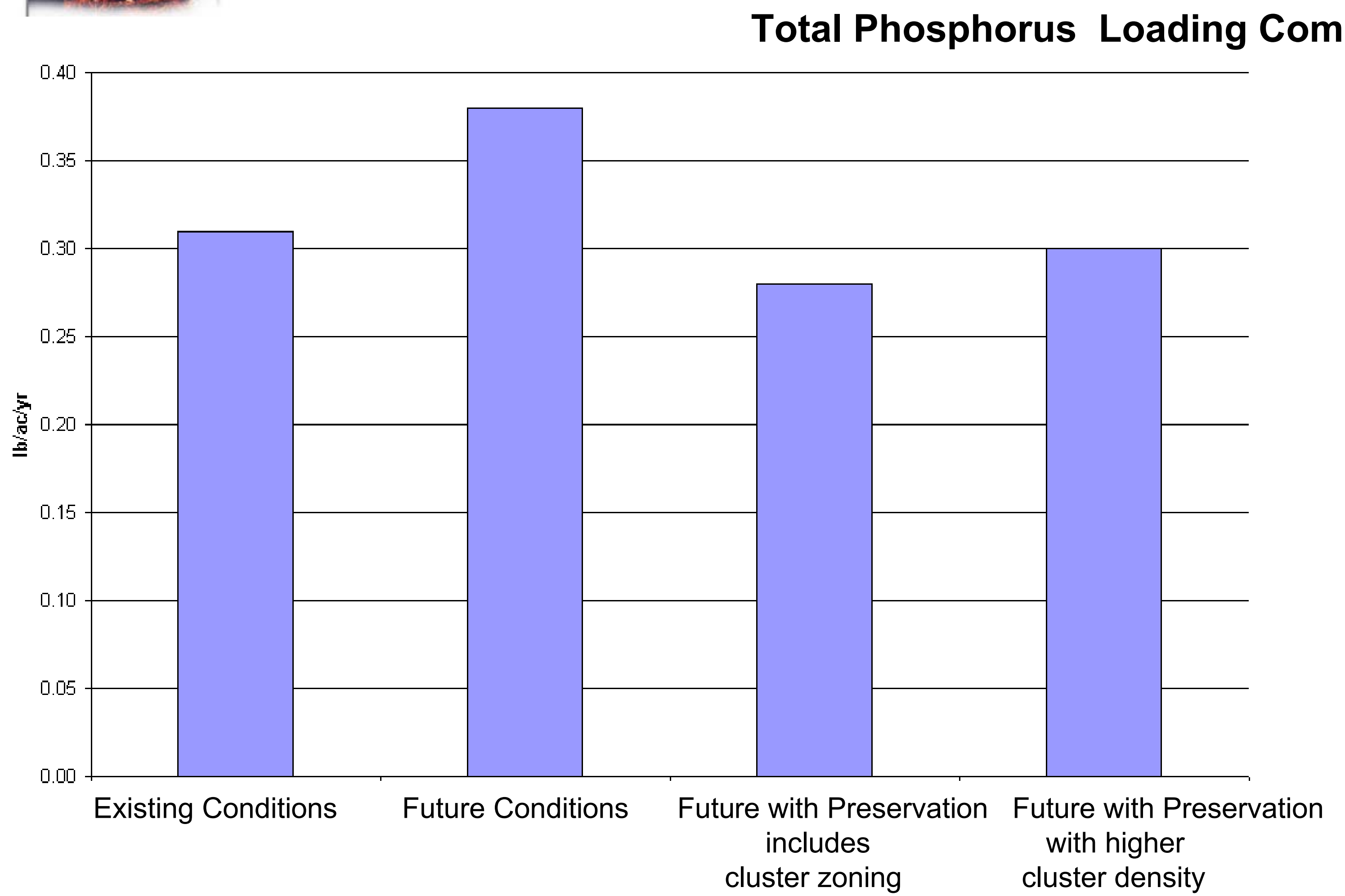
Potential Policy Considerations for Balancing Development and the Environment

WMT staff will investigate scenarios such as:

- **Cluster Zoning – decrease lot size while maintaining number of units on a site**
- **Septic System Alternatives – replace conventional septic systems with treatment systems having better pollutant removal**

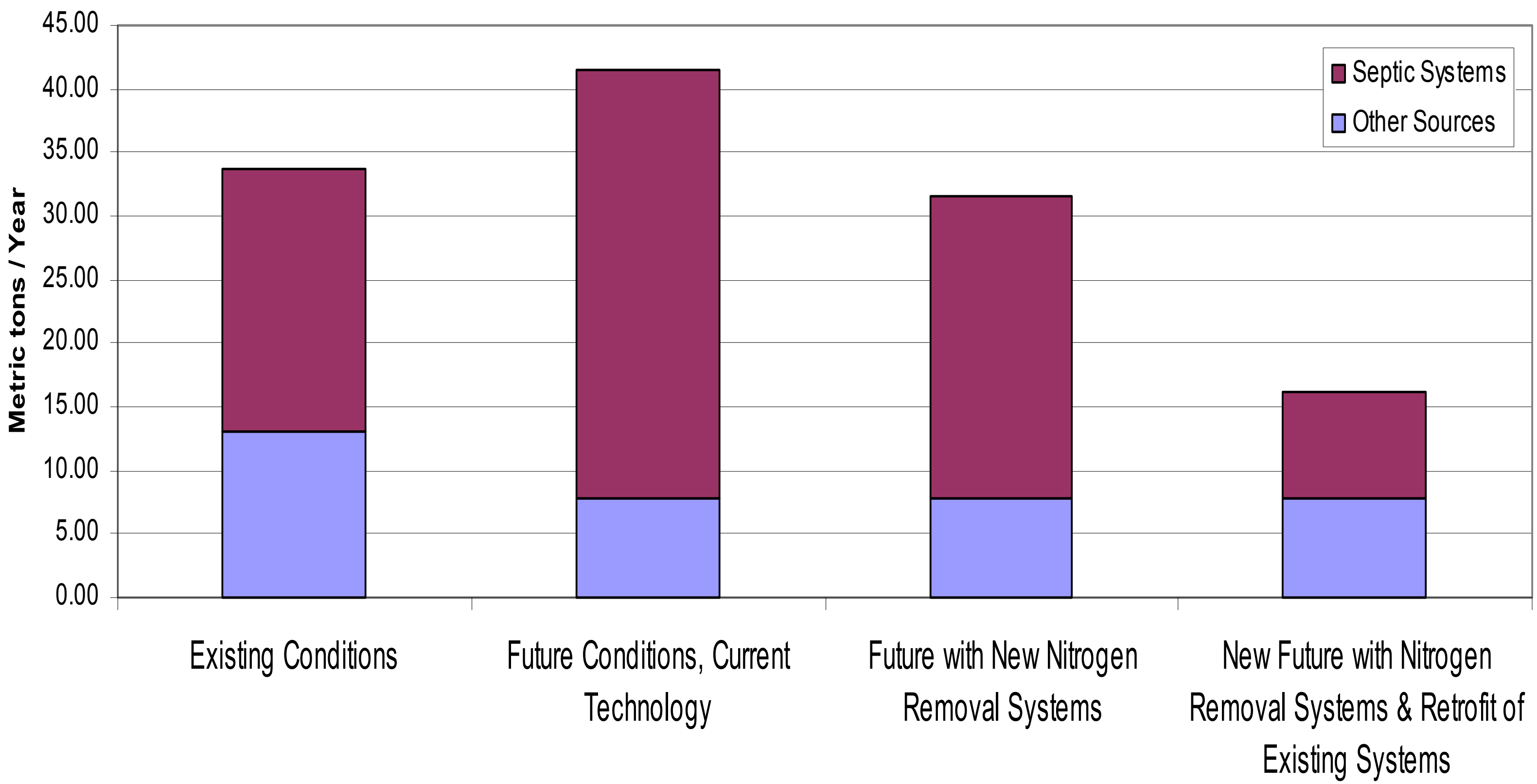
In order to facilitate better land use decisions.

Cluster Development



Septic System Alternatives

Total Nitrogen Loading Comparison



Summary and Final Thoughts

- Experiencing stressors and changes in land use
- Utilizing Watershed Studies and Technological Tools
- Increasing regulatory responsibilities, but decreasing resources
- Growing backlog of restoration projects
- Need for innovative methods to address these problems

Questions & Answers

The Butterfly Effect: How Land Development Impacts Water Quality

Covering over 64,000 square miles, the Chesapeake Bay watershed has the highest land area to water volume ratio of any large water body on Earth. Over 16 million people live throughout the Bay's watershed, and the population is growing by more than 1 million per decade. As the watershed population increases, so does the amount of developed land; researchers expect that if current trends continue, by 2030, developed land will increase by more than 60%. Although local growth may benefit the local economy, it can be taxing to the environment at the same time.

How does developed land impact the Bay?

All of the activities that take place on urban and suburban developed land -- construction activities, impervious surfaces, sewer and septic systems, residential fertilizer use and vehicle emissions -- contribute a significant amount of nutrients to the Bay, particularly when compared to other major land uses. Sprawling growth patterns have also led to losses of filtering forested and working agricultural lands in the watershed.

Construction and Development Activities
Urban development contributes substantial amounts of sediments to the Bay. Urban and suburban lands can contribute twice as much as sediment compared to natural landscapes. Most of these sediments are produced during the initial construction phases of a project. Particularly in the 1960's, construction activities throughout the northeastern United States caused a sharp increase in sediment. Bay Program partners have promoted a series of best management practices that construction operations may use to minimize the project's impact on the local environment.

Impervious Surfaces
Impervious surfaces, or surfaces that do not absorb water, compose roughly 17% of all urban and suburban lands in the Bay watershed. Impervious surfaces:

- **alter the natural flow of streams** because they typically carry rainfall directly into streams via gutters and storm sewers, bypassing wetlands and riparian forest buffers, both of which filter and slow down the flow of water. Impervious surfaces are sometimes built near streams and rivers, replacing existing riparian buffers, which can in turn degrade those streams.
- **limit the filtration of rainwater into the soil** , potentially reducing the amount of water reaching shallow streams and groundwater aquifers
- **help to carry airborne pollutants to streams** . In natural landscapes, some pollutants can be retained and broken down in the soil or plants that intercept water as it flows over the land and into streams.

Sewer and Septic Systems
When development occurs in urban and suburban areas, wastewater generated by new residents is typically treated through wastewater treatment plants. When new homes are built far from public infrastructure, their wastewater is usually treated by on-site septic systems. While discharges from these systems are dependent on a variety of technological and geographic factors, on average, septic systems annually deliver about 5 pounds of nitrogen per person to the Bay compared to an annual delivered load of about 3.1 pounds of nitrogen per person from municipal wastewater treatment plants.

Residential Fertilizer Use
According to The Fertilizer Institute, between 1994 and 2004, non-agricultural fertilizer sales increased over 50%. Unlike many farmers using nutrient management plans, suburban residents often over apply fertilizer to their lawns and gardens. The soils in residential developments are also highly compacted, so less fertilizer is absorbed into the ground, and more fertilizer runs off of the lawns, into storm sewers, where they are carried to the Bay and its tributaries.

Vehicle Emissions
Approximately 32% of the all nitrogen inputs to the Bay come from atmospheric sources. In the Bay watershed, vehicle emissions account for one-third of all atmospheric nitrogen emissions deposited to the Bay.

Reductions in Forested and Agricultural Lands
Forest lands provide abundant ecosystem services such as wildlife habitat, air pollutant removal, carbon sequestration, timber resources, and recreational opportunities. The conversion of forests to urban lands may fragment and therefore degrade the quality of remaining forests lands. Conversion of agricultural lands to residential and commercial developments can adversely impact the long-term sustainability of farming because many operations affect nearby residents, limiting their support of local farms. Animal operations are particularly impacted by the loss of nearby farms because there is less area available for applying manure as a fertilizer.

What are current trends in development?

New development patterns are based on consumer preferences: homebuyers oftentimes look for large houses on large lots near open space, jobs, and good schools, while commercial organizations look for larger, less expensive office spaces. These preferences have caused a sprawling pattern of development and a growing human footprint on the landscape (Figure 1 2.6 MB). Smaller families, larger homes, and “big box” retail outlets with accompanying parking areas have contributed to a 41% increase in impervious surfaces during the 1990's compared with an 8% increase in population.

Residents are also opting for longer commutes in exchange for living in more rural areas. Between 1970 and 1997, the number of vehicle miles traveled in the Bay watershed increased at four times the rate of the area's population growth. Some commuters to the Baltimore-Washington, D.C. region drive from northern Virginia, the panhandle of West Virginia, southern Pennsylvania, and Maryland 's Eastern Shore .

Consumer preferences have combined with low mortgage interest rates to fuel record increases in building permits (Figure 2 16 kb). Much of this growth has occurred in exurban and rural areas, which often lack the policies, regulations, and resources to manage growth.

What is the Chesapeake Bay Program doing to limit the effect of development on the Bay?

To address the adverse impacts of growth, Bay Program partners are promoting ecologically based site designs (187 kb) to minimize stormwater runoff and fall lawn fertilization to minimize the loss of excess nutrients. The Partners have developed a Resource Lands Assessment to help local and state planning agencies identify valuable lands to protect for habitat, water quality, timber management, and farming purposes. Most recently, Bay Program partners have committed to assess the cumulative impacts of future urban growth and land use change on the health of the Chesapeake Bay by projecting land use changes and nutrient loads out to 2030.

Are there any restoration projects that limit the impact of development on local waterways?

Riparian forest buffers are critical for preserving streams by filtering excess nutrients and sediment from developed land. Learn more about the current health of riparian forest buffers.

How is the Bay Program involved in restoring riparian forest buffers?

Bay Program partners have supported riparian forest buffer restoration in many local communities throughout the watershed. Learn more about these locally implemented restoration projects.

Also See:

- Virginia's Erosion and Sediment Control Program – Information from the Virginia Department of Conservation and Recreation
- Keystone Principles for Growth, Investment & Resource Conservation – An article about the guidance that Pennsylvania 's state agencies will follow for new development
- Growing Greener II Program – Pennsylvania 's coordinated effort to revitalize communities in an environmentally-conscious manner
- Smart Growth Program – Maryland 's guiding program for development with minimal environmental impact
- Urbanization and the Loss of Resource Lands in the Chesapeake Bay Watershed - An Environmental Management journal article about urbanization in the watershed

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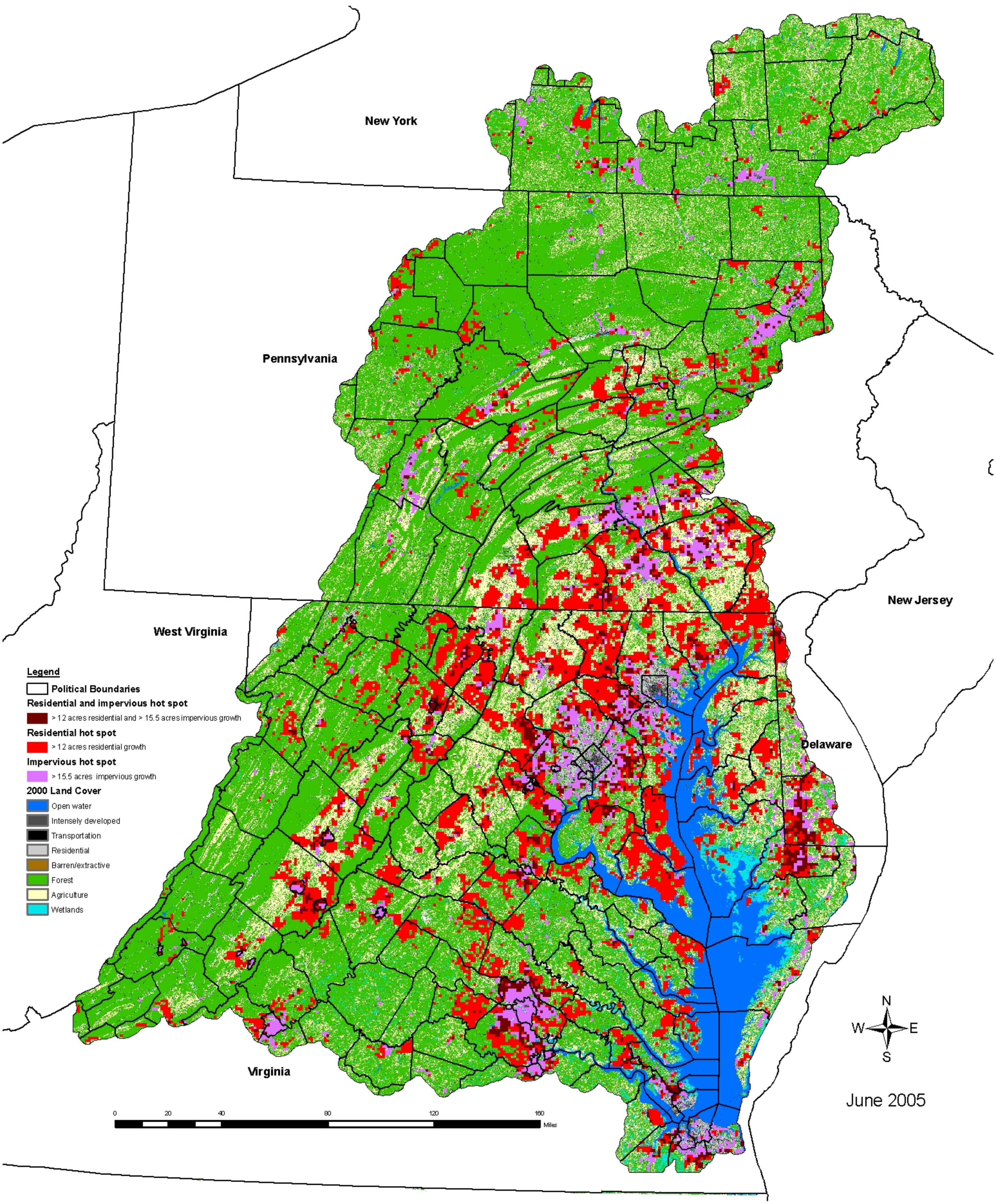
To bookmark this page, please use this URL: http://www.chesapeakebay.net/newsdevelopment121205.htm

For more information, contact the Chesapeake Bay Program Office:
410 Severn Avenue, Suite 109, Annapolis, MD 21403 / Tel: (800) YOUR-BAY / Fax: (410) 267-5777.

Areas of Highest Development Pressure in the Chesapeake Bay Watershed (1990 - 2000)



TITLE 9. ENVIRONMENT

STATE WATER CONTROL BOARD

Title of Regulation: **9 VAC 25-780. Local and Regional Water Supply Planning (adding 9 VAC 25-780-10 through 9 VAC 25-780-190).**

Statutory Authority: §§ 62.1-44.15 and 62.1-44.38:1 of the Code of Virginia.

Effective Date: November 2, 2005.

Agency Contact: Scott Kudlas, Department of Environmental Quality, P.O. Box 1105, Richmond, VA 23218, telephone (804) 698-4456, FAX (804) 698-4347, or e-mail scott.kudlas@deq.virginia.gov.

Summary:

The regulation establishes a planning process and criteria that all local governments will use in the development of local or regional water plans. These plans will be reviewed by the Department of Environmental Quality and a determination will be made by the State Water Control Board on whether the plans comply with this regulation. Within five years of a compliance determination by the board, the plans will be reviewed to assess adequacy and significant changes will require the submission of an amended plan and review by the board. All local programs will be reviewed, revised and resubmitted to the Department of Environmental Quality every 10 years after the last approval.

Summary of Public Comments and Agency's Response: A summary of comments made by the public and the agency's response may be obtained from the promulgating agency or viewed at the office of the Registrar of Regulations.

CHAPTER 780.
LOCAL AND REGIONAL WATER SUPPLY PLANNING.

9 VAC 25-780-10. Application.

A. All counties, cities and towns (hereinafter "local governments") in the Commonwealth of Virginia shall submit a local water supply plan or shall participate in a regional planning unit in the submittal of a regional water supply plan to the board in accordance with this chapter.

B. The provisions of this regulation shall not affect any water supply project for which a permit application was submitted prior to January 1, 2003, to any state or federal agency. The provisions of this regulation shall not affect any water supply project for which an application for grant, loan or other funding has been made to a state or federal agency prior to January 1, 2003. All projects shall remain subject to applicable federal and state regulatory requirements.

C. Nothing in this chapter shall be construed as altering or authorizing any alteration of any existing surface, ground water or common law water rights of any property owner within the Commonwealth, except as required by federal or state law.

D. The review required by 9 VAC 25-780-140 shall not be a prerequisite for applying for a permit from the Commonwealth of Virginia for a water supply project.

9 VAC 25-780-20. Purpose of chapter.

The purpose of this chapter is to establish a comprehensive water supply planning process for the development of local, regional, and state water supply plans. This process shall be designed to (i) ensure that adequate and safe drinking water is available to all citizens of the Commonwealth; (ii) encourage, promote, and protect all other beneficial uses of the Commonwealth's water resources; and (iii) encourage, promote, and develop incentives for alternative water sources, including but not limited to desalinization.

This chapter establishes the required planning process and criteria that local governments shall use in the development of the local and regional plans.

9 VAC 25-780-30. Definitions.

Unless otherwise defined in this chapter or unless the context clearly indicates otherwise, the terms used in this regulation shall have the meanings ascribed to them by the State Water Control Law, Chapter 3.1 (§ 62.1-44.2 et seq.) of Title 62.1 of the Code of Virginia; the Ground Water Management Act of 1992, Chapter 2.5 (§ 62.1-254 et seq.) of Title 62.1 of the Code of Virginia; the Virginia Water Protection Permit Regulation, 9 VAC 25-210 (2004); and the Surface Water Management Area Regulation, 9 VAC 25-220 (2004), including any general permits issued thereunder.

"Beneficial use" means both in-stream and off-stream uses. In-stream beneficial uses include, but are not limited to, the protection of fish and wildlife habitat, maintenance of waste assimilation, recreation, navigation, and cultural and aesthetic values. Off-stream beneficial uses include, but are not limited to, domestic (including public water supply), agricultural, electric power generation, and commercial and industrial uses.

"Board" means the State Water Control Board.

"Community water system" means a waterworks that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents, and is regulated by the Virginia Department of Health Waterworks Regulation (12 VAC 5-590).

"Conservation" means practices, techniques, and technologies that improve the efficiency of water use.

"Department" means the Department of Environmental Quality.

"Local government" means a city, incorporated town or county.

"Local program" means the combined water plan, resource conditions, and drought response and contingency plan developed in compliance with this regulation. The term "local program" will be used in this regulation to mean either local or regional programs. The term "program" implies the institution of a continuous planning process for maintenance of these documents.

"Planning area" means the geographical area as defined by local government boundaries that is included in a local or regional water supply plan.

"Planning period" means the 30- to 50-year time frame used by the locality to project future water demand in accordance with 9 VAC 25-780-100 B.

"Regional planning unit" means a collection of local governments who have voluntarily elected to develop and submit a regional water plan. A regional planning unit may be composed of all local governments located within the bounds of a planning district, any subset of local governments within the bounds of a planning district, or any group of local governments within multiple planning districts.

"Regional water plan" means a water plan developed and submitted by two or more cities or counties or both. A town and an adjacent county may develop a regional water plan. Two or more towns may develop and submit a regional water plan where the plan results in the proposed development of future water supply projects that supply the water supply demands of the affected towns. Such plans developed by two or more towns may be included in regional water plans developed and submitted by counties or cities. Regional water plans shall be developed and submitted in conjunction with all public service authorities operating community water systems within the regional planning unit, if applicable.

"Self-supplied user" means any person making a withdrawal of surface water or ground water from an original source (e.g., a river, stream, lake, aquifer, or reservoir fed by any such water body) for their own use. Self-supplied users do not receive water from a community water system.

"Service area" means the geographical area served by a community water system.

"Technical evaluation committee" means a committee of state agencies, including but not limited to the Department of Health, the Department of Conservation and Recreation, the Marine Resources Commission, the Department of Historic Resources, and the Department of Game and Inland Fisheries, convened by the Department of Environmental Quality in accordance with subdivision 8 of 9 VAC 25-780-60 to provide comments on the impacts to or conflicts among in-stream and off-stream uses resulting from proposed alternatives for meeting projected water demands.

"Unaccounted for losses" means the difference between a community water system's billing records for volumes of water distributed and production records for volumes of water treated.

"Water demand management" means plans for water conservation, reuse, and reducing unaccounted for water losses contained in a local program.

"Water plan" means a document developed in compliance with this regulation. The term "water plan" will be used in this regulation to mean either local or regional water plans.

"Water sources" means wells, stream intakes, and reservoirs that serve as sources of water supplies.

9 VAC 25-780-40. Program development.

Local governments shall develop programs for local or regional water plans that are necessary to comply with this chapter. Local governments shall consult and coordinate with all community water systems in the planning area during the preparation of local or regional programs. Community water systems within the planning area shall cooperate and participate with the locality during preparation of the local program. Counties, cities, and towns are encouraged to develop regional programs. Local programs shall be designed to (i) ensure that adequate and safe drinking water is available, (ii) encourage and protect all beneficial uses, (iii) encourage and promote alternative water sources, and (iv) promote conservation.

9 VAC 25-780-50. Preparation and submission of a program.

A. Local governments must adopt a local program as defined in this section, including any revisions to comprehensive plans, water supply plans, water and sewer plans, and other local authorities necessary to implement this chapter. A local public hearing consistent with § 15.2-1427 of the Code of Virginia is required during the development of the local program. The public hearing may be combined with other public hearings that may be required.

B. All local governments shall submit a local program to the department in accordance with the following schedule:

1. Local governments with populations in excess of 35,000 persons based on the most recent U.S. Census shall do so no later than November 2, 2008.

2. Local governments with populations in excess of 15,000 persons but no more than 35,000 persons based on the most recent U.S. Census shall do so no later than November 2, 2009.

3. Local governments with populations less than or equal to 15,000 persons based on the most recent U.S. Census shall do so no later November 2, 2010.

4. Notwithstanding the above, local governments may elect to participate in the submittal of regional water supply plans By November 2, 2008, local governments participating in a regional plan shall provide notice to the department of the intent to participate in a regional plan and shall include the names of the other participating localities. Such regional plans shall be submitted no later November 2, 2011.

Nothing in this section shall be construed as limiting the submittal of local or regional water supply plans before the date when such plans are due.

C. Local programs shall contain the elements listed below. This information may be derived from existing, readily available information and additional detailed studies shall not be required.

1. A description of existing water sources in accordance with the requirements of 9 VAC 25-780-70;

2. A description of existing water use in accordance with the requirements of 9 VAC 25-780-80;

3. A description of existing water resource conditions in accordance with the requirements of 9 VAC 25-780-90;

4. An assessment of projected water demand in accordance with the requirements of 9 VAC 25-780-100;

5. A description of water management actions in accordance with the requirements of 9 VAC 25-780-110 and 9 VAC 25-780-120;

6. A statement of need in accordance with the requirements of 9 VAC 25-780-130;

7. An alternatives analysis that identifies potential alternatives to address projected deficits in water supplies in accordance with the requirements of 9 VAC 25-780-130;

8. A map or maps identifying important elements of the program that may include existing environmental resources, existing water sources, significant existing water uses, and proposed new sources;

9. A copy of the adopted program documents including any local plans or ordinances or amendments that incorporate the local program elements required by this chapter;

10. A resolution approving the plan from each local government that is party to the plan; and

11. A record of the local public hearing, a copy of all written comments and the submitter's response to all written comments received.

D. All local programs shall be reviewed no later than five years after a compliance determination by the board in accordance with 9 VAC 25-780-140 F. Revised plans shall be submitted when this review indicates that circumstances have changed or new information has been made available that will result in water demands that will not be met by alternatives contained in the water plan. These circumstances may be caused by changes in demands, the availability of the anticipated source, cumulative impacts, in-stream beneficial uses, or other factors. In the case where the review by the local government or regional planning unit indicates that the circumstances have not changed sufficiently to warrant a revision of the water plan after five years, the locality shall notify the department that the existing plan is still in effect.

E. Notwithstanding subsection D of this section, all local programs shall be reviewed, revised and resubmitted to the department every 10 years after the date of last approval.

9 VAC 25-780-60. State role in program preparation.

To assist local governments in the development of local programs, the board will:

1. Provide technical and financial assistance;

2. Provide guidance on compliance options;

3. Facilitate acquisition of existing resource conditions (the department shall prepare and post on its website a list of readily available sources for the items identified in 9 VAC 25-780-90 B);

4. Facilitate acquisition of existing use information that has been reported to the department;

5. Facilitate acquisition of water management information (the department shall prepare and post on its website a list of acceptable practices that are used with regard to the topics in 9 VAC 25-780-110);

6. Identify acceptable methods for the projection of future water demands as per 9 VAC 25-780-100;

7. Provide any information regarding known conflicts relating to the development of alternatives;

8. At the request of the applicant, convene a technical evaluation committee meeting; and

9. Provide notice of local public hearings on the local program upon notification by the locality.

9 VAC 25-780-70. Existing water source information.

A. A water plan shall include current information on existing water sources.

B. A water plan shall include, for community water systems using ground water, the name and identification number of the well or wells, the well depth, the casing depth, the screen depth (top and bottom) or water zones, the well diameter, the design capacity for the average daily withdrawal and maximum daily withdrawal, the system capacity permitted by Department of Health, and the annual and monthly permitted amounts contained in ground water withdrawal permits for all wells located within ground water management areas.

C. A water plan shall include, for community water systems using surface water reservoirs, the name of the reservoirs, the sub-basins in which the reservoirs are located, the drainage area, the amount of on-stream storage available for water supply, the design capacity for average daily and maximum daily withdrawals from the reservoirs, the safe yield of the reservoirs, the capacity of any associated water treatment plant, the Department of Health permitted capacity of the systems, and any limitations on withdrawal established by permits issued by the board. For a community water system that operates a system of interconnected reservoirs, the reporting of the design capacity for withdrawals, designed average daily withdrawal, the designed maximum daily withdrawal and the safe yield may be for the entire system or may be reported as subsets of the system. The plan shall designate which reservoirs and which intakes constitute a system for the purposes of this paragraph. The plan must report the drainage area and amount of storage available for water supply from each reservoir independently.

D. A water plan shall include, for community water systems using stream intakes, the name of the stream or river, the drainage area of the intake, the sub-basin in which the intake is located, the design capacity for average daily and designed maximum daily withdrawal from the stream, the safe yield, the lowest daily flow of record the design capacity of the pump station, the design capacity of the water treatment plant, the capacity of the system permitted by the Department of Health, and any limitation on withdrawals established by permits issued by the board.

E. To the extent that information is available, a water plan shall include a list of all self-supplied users of more than 300,000 gallons per month of surface water for nonagricultural uses, the name of the water body utilized, the design capacity for the average daily and maximum daily withdrawal, and any limitation on withdrawals established by permits issued by the board, the Department of Health or any other agency.

F. To the extent that information is available, a water plan shall include, for all self-supplied users of more than 300,000 gallons per month of ground water for nonagricultural uses, the name and identification number of the well or wells, the well depth, the casing depth, the screen depth (top and bottom) or water zones, the well diameter, the design capacity for the average daily and maximum daily withdrawal and any limitation on withdrawal established by permits issued by the board.

G. A water plan shall include the amount of ground or surface water to be purchased from water supply systems outside the geographic boundaries of the planning area on a maximum daily and average annual basis, any contractual limitations on the purchase of the water including but not limited to the term of any contract or agreement, the recipient(s) or areas served by the water purchased, and the name(s) of the supplier(s).

H. A plan shall include the amount of water available to be purchased outside the planning area from any source with the capacity to withdraw more than 300,000 gallons per month of surface and ground water, reported on a maximum daily and average annual basis and any contractual limitations on the purchase of the water including but not limited to the term of any contract or agreement, the geographic region(s) that receive the water purchased, and the name(s) of the supplier(s).

I. A water plan shall include, to the extent possible, a list of agricultural users who utilize more than 300,000 gallons per month, an estimate of total agricultural usage by source, whether the use is irrigation or nonirrigation, and whether the source is surface or ground water.

J. A water plan shall include an estimate of the number of residences and businesses that are self-supplied by individual wells withdrawing less than 300,000 gallons per month and an estimate of the population served by individual wells.

K. When available, a water plan shall include a summary of findings and recommendations from applicable source water assessment plans or wellhead protection programs.

9 VAC 25-780-80. Existing water use information.

A. A water plan shall include, at a minimum, current information documenting existing water use as listed below. Water use information shall be obtained from Department of Health waterworks permit compliance reports, the department ground water permit compliance reports or department water use reports. Information shall be reported for the most recent previous annual compilation of such data that is available on the date of submission of the water plan.

B. A water plan shall include the following information for community water systems:

1. The population within the planning area served by each community water system.

2. The number of connections within the planning area for each community water system.

3. The average and maximum daily withdrawal for each community water system within the planning area.

4. The amount of water used within the planning area on an annual average basis, and on an average monthly basis for each community water system expressed in terms of million gallons per day.

5. The peak day water use by month for each community water system within the planning area.

6. An estimate of the water used on an average annual basis by self-supplied nonagricultural users of more than 300,000 gallons per month of surface and ground water within the service area of each community water system.

7. An estimate of the amount of water used on an average annual basis by self-supplied agricultural users of more than 300,000 gallons per month of surface and ground water within the service area of each community water supply.

8. An estimate of the number of self-supplied users of less than 300,000 gallons per month of ground water and an estimate of the total amount of water used by them on an annual average basis within the service area of each community water supply.

9. For each community water system included in the water plan, the plan shall include an estimate of the disaggregated amounts of water used in categories of use appropriate for the system. Typical categories may include:

a. Residential use;

b. Commercial institutional and light industrial (CIL) use;

c. Heavy industrial use;

d. Military water use;

e. Water used in water production processes;

f. Unaccounted for losses;

g. Sales to other community water systems and the names of such systems; or

h. Subtotals of the above categories for all community water systems

10. To the extent that information is available pursuant to 9 VAC 25-780-60 and other sources, for each community water system included in the water plan using stream intakes, the plan shall include a qualitative description of existing in-stream beneficial uses within the planning area or outside the planning area that may be affected by the point of stream withdrawal.

C. A water plan shall include an estimate of the water used on an average annual basis by self-supplied nonagricultural user of more than 300,000 gallons per month of surface and *ground water outside the service areas of community water systems.*

D. A water plan shall include an estimate of the amount of water used on an average annual basis by self-supplied agricultural users of more than 300,000 gallons per month of surface and ground water outside the service areas of community water systems.

E. A water plan shall include an estimate of the number of self-supplied users of less than 300,000 gallons per month of ground water and an estimate of the total amount of water used by them on an annual average basis outside the service areas of community water systems.

9 VAC 25-780-90. Existing resource information.

A. A program shall include a description of existing geologic, hydrologic, and meteorological conditions within the planning area, and in proximity to the point of withdrawal if it is outside the planning area.

B. A program shall include a description of existing environmental conditions that pertain to, or may affect, in--stream flow, in-stream uses, and sources that provide the current supply. This description of conditions may be provided in a distinct section of the plan document or as a part of the existing water sources information required pursuant to 9 VAC 25-780-70. This information may be derived from existing, readily available information and additional detailed studies shall not be required. The description of conditions shall include the following items, as they are applicable:

1. State or federal listed threatened or endangered species or habitats of concern;

2. Anadromous, trout and other significant fisheries;

3. River segments that have recreational significance including state scenic river status;

4. Sites of historic or archaeological significance;

5. Unusual geologic formations or special soil types;

6. Wetlands;

7. Riparian buffers and conservation easements;

8. Land use and land coverage including items such as percentage of impervious cover within a watershed and areas where new development may impact water quality of the source;

9. The presence of impaired streams and the type of impairment;

10. The location of point source discharges; and

11. Potential threats to the existing water quantity and quality, other than those from above.

9 VAC 25-780-100. Projected water demand information.

A. A water plan shall include projections of future water demand as listed below. Population in aggregate and disaggregate formulations should be estimated according to information from the U.S. Census Bureau, Bureau of Economic Analysis, the Virginia Employment Commission, or other accepted source of population information, including but not limited to, local or regional sources. Demand projection methodologies should be consistent with those outlined in the American Water Works Association or American Society of Civil Engineers manuals. Sources of information and methodologies used in projecting future water demand shall be documented.

B. A water plan shall estimate water demand within the planning area for a minimum of 30 to a maximum of 50 years into the future. While not required, localities are encouraged to plan for the maximum planning period to ensure that the most appropriate and sustainable alternatives are identified.

C. A water plan shall include an estimated future water use projected at the beginning of each decade (2010, 2020, 2030, etc.) within the planning period.

D. A water plan shall include the following projections for community water systems:

1. An estimate of population within the planning area served by each community water system;

2. A map depicting the proposed service area of each existing or proposed community water system;

3. Estimated water demand for each existing or proposed community water system on both an annual average and peak monthly basis;

4. Estimated water demand for each existing or proposed community water system disaggregated into categories of use appropriate for the system. Typical categories may include:

a. Residential use;

b. Commercial institutional and light industrial (CIL) use;

c. Heavy industrial use;

d. Military water use;

e. Water used in water production processes;

f. Unaccounted for losses;

g. Sales to other community water systems and the names of such systems; or

h. Subtotals of the above categories for all community water systems; and

5. Total projected water demand for all existing or proposed community water systems disaggregated into the categories used in subdivision 4 of this subsection.

E. A water plan shall include a projection of water demand within the planning area on an annual average basis for each existing and any proposed self-supplied nonagricultural user of more than 300,000 gallons per month of surface and ground water located outside the service areas of community water systems.

F. A water plan shall include a projection of the amount of water use on an annual average basis for each existing and any projected self-supplied agricultural user of more than

300,000 gallons per month of surface and ground water located outside the service areas of community water systems.

G. A water plan shall include a projection of the number of self-supplied users of less than 300,000 gallons per month of ground water and a projection of the amount of water used on an annual average basis outside the service areas of community water systems.

H. A water plan shall include, if available, any cumulative demand, use conflict, or in-stream flow information developed pursuant to 9 VAC 25-780-140 G.

I. A water plan shall explain how the projected needs of domestic consumption, in-stream uses, and economic development have been accounted for in the demand projection for the planning period.

9 VAC 25-780-110. Water demand management information.

A. As part of a long-term strategy, a water plan shall address conservation as a part of overall water demand management in accordance with the following requirements:

1. A water plan shall include information that describes practices for more efficient use of water that are used within the planning area. The type of measures to be described may include, but are not limited to, the adoption and enforcement of the Virginia Uniform Statewide Building Code sections that limit maximum flow of water closets, urinals and appliances; use of low-water use landscaping; and increases in irrigation efficiency.

2. A water plan shall include information describing the water conservation measures used within the planning area to conserve water through the reduction of use. The types of measures to be described may include, but are not limited to, technical, educational and financial programs.

3. A water plan shall include information that describes, within the planning area, the practices to address water loss in the maintenance of water systems to reduce unaccounted for water loss. The types of items to be described may include, but are not limited to: leak detection and repair and old distribution line replacement.

B. Current conservation practices, techniques, and technologies shall be considered in projecting water demand pursuant to 9 VAC 25-780-100 D.

9 VAC 25-780-120. Drought response and contingency plans.

A program that includes community water systems and self-supplied users who withdraw more than an average of 300,000 gallons per month of surface water and ground water shall contain drought response and contingency plans in accordance with the following requirements:

1. Drought response and contingency plans shall be structured to address the unique characteristics of the water source that is being utilized and the nature of the beneficial use of water.

2. Drought response and contingency plans shall contain, at a minimum, the following three graduated stages of responses to the onset of drought conditions:

a. Drought watch stage responses are generally responses that are intended to increase awareness in the public and private sector to climatic conditions that are likely to precede the occurrence of a significant drought event. Public outreach activities shall be identified to inform the population served by a community water system of the potential for drought conditions to intensify and potential water conservation activities that may be utilized.

b. Drought warning stage responses are generally responses that are required when the onset of a significant drought event is imminent. Voluntary water conservation activities shall be identified with the goal of reducing water use by 5-10%.

c. Drought emergency stage responses are generally responses that are required during the height of a significant drought event. Mandatory water conservation activities shall be identified with the goal of reducing water use by 10-15%.

3. Drought response and contingency plans shall include references to local ordinances, if adopted, and procedures for the implementation and enforcement of drought response and contingency plans.

9 VAC 25-780-130. Statement of need and alternatives.

A. A water plan shall determine the adequacy of existing water sources to meet current and projected demand by preparing a clear statement of need that is derived from an evaluation of the information required by 9 VAC 25-780-70 through 9 VAC 25-780-110. The statement of need shall contain, at a minimum, a determination of whether the existing source(s) is adequate to meet current and projected demands.

B. If the determination is that the existing source is inadequate to meet projected demands during the planning period, the program shall include an alternative analysis of potential sources that includes the following information:

1. A description of potential water savings from water demand management actions including an estimated volume for each action;

2. A description of potential sources for new supplies including an estimated volume from each source; and

3. A description of potential resource issues or impacts, identified in accordance with 9 VAC 25-780-140 G, known for each potential new source that any future water project will need to consider in its development.

C. Potential alternatives considered shall include water demand management alternatives as well as more traditional means of increasing supply, i.e., wells, reservoirs, impoundments and stream intakes. Where appropriate, the program shall consider nontraditional means of increasing supplies such as interconnection, desalination, recycling and reuse. The analysis of potential alternatives may include a *combination of short-term and long-term alternatives. The result of this analysis shall be provided as part of the submission required by 9 VAC 25-780-50 C 7.*

9 VAC 25-780-140. Review of local programs.

A. The board shall review all programs to determine compliance with this regulation and consistency with the State Water Resources Plan. The board will review adopted elements of a local program according to review policies adopted by the board. Copies of the adopted local program documents and subsequent changes thereto shall be provided to the board.

B. To assist in the review of the program, the board shall provide the Department of Health and other agencies listed in 9 VAC 25-780-150 B along with any other agency the board deems appropriate, 90 days to evaluate the program. Comments must be received from the Department of Health or other agency by the deadline stipulated in the written notification from the board.

C. The board will assess the compliance of submitted programs with these regulations. The board shall prepare a tentative statement of findings on whether the program has demonstrated compliance with the following:

1. All elements of a local program identified in 9 VAC 25-780-50 have been submitted;

2. The program was developed through a planning process consistent with this chapter;

3. The results of any evaluation conducted pursuant to subsection G of this section have been appropriately accommodated;

4. The existing sources information complies with 9 VAC 25-780-70;

5. The existing water use information complies with 9 VAC 25-780-80;

6. The existing resources information complies with 9 VAC 25-780-90;

7. The projected water demand is based on an accepted methodology and complies with 9 VAC 25-780-100;

8. The water demand management information complies with 9 VAC 25-780-110;

9. The drought response and contingency plan complies with 9 VAC 25-780-120;

10. The statement of need complies with 9 VAC 25-78-130 A;

11. When required, the alternatives comply with 9 VAC 25-780-130;

12. The local program is consistent with 9 VAC 25-390-20, § 62.1-11 of the Code of Virginia and Chapter 3.2 (§ 62.1-44.36 et seq.) of Title 62.1 of the Code of Virginia.

D. If the board's tentative decision is to find the local program in compliance with subsection C of this section, the board shall provide public notice of its findings pursuant to 9 VAC 25-780-150.

E. If the tentative decision of the board is to find the local program in noncompliance with subsection C of this section, the board shall identify (i) the reason for the finding of noncompliance, (ii) what is required for compliance, and (iii) the right to an informational proceeding under Article 3 (§ 2.2-4018 et seq.) of Chapter 40 of the Virginia Administrative Process Act.

F. The board shall make a final decision on whether the local program is in compliance with this chapter after completing review of the submitted program, any agency comments received, and any public comment received from a public meeting held pursuant to 9 VAC 25-780-160.

G. In conjunction with the compliance determination made by the board, the state will develop additional information and conduct additional evaluation of local or regional alternatives in order to facilitate continuous planning. This additional information shall be included in the State Water Resources Plan and used by localities in their program planning. This information shall include:

1. A cumulative demand analysis, based upon information contained in the State Water Resources Plan and other sources;

2. The evaluation of alternatives prepared pursuant to 9 VAC 25-780-130 B and C;

3. The evaluation of potential use conflicts among projected water demand and estimates of requirements for in-stream flow; and

4. An evaluation of the relationship between the local plan and the State Water Resources Plan.

H. The board may facilitate information sharing and discussion among localities when potential conflicts arise with regard to demands upon a source.

I. A local program's information shall be included in the State Water Resource Plan when determined to be in compliance by the board.

9 VAC 25-780-150. Public notice and public comment period.

A. The board shall give public notice on the department website for every tentative and final decision to determine local program compliance.

B. The board shall give public notice to the Department of Health, the Department of Conservation and Recreation, the Marine Resources Commission, the Department of Historic Resources, and the Department of Game and Inland Fisheries for every tentative and final decision on program compliance. The agencies shall have 90 days to submit written comment. At the request of the applicant, the board will convene a technical evaluation committee meeting to facilitate receipt of these comments.

C. The board shall provide a comment period of at least 30 days following the date of the public notice for interested persons to submit written comments on the tentative or final *decision. All written comments submitted during the comment period shall be retained by the board and considered during its final decision.*

D. Commenters may request a public meeting when submitting comments. In order for the board to grant a public meeting, there must be a substantial public interest and a factual basis upon which the commenter believes that the proposed program might be contrary to the purposes stated in 9 VAC 25-780-20.

E. The contents of the public notice of a proposed program compliance determination shall include:

1. Name(s) and address(es) of the locality(ies) that submitted the local or regional water plan;

2. Brief synopsis of the proposed plan including any identified future alternatives;

3. The name(s) of the principal water supply sources;

4. A statement of the tentative determination to certify or deny consistency with the regulation;

5. A brief description of the final determination procedure;

6. The address, e-mail address and phone number of a specific person at the state office from whom further information may be obtained; and

7. A brief description on how to submit comments and request a public meeting.

9 VAC 25-780-160. Public meetings.

A. Public notice of any public meeting held pursuant to 9 VAC 25-780-150 shall be circulated as follows:

1. Notice shall be published on the department website;

2. Notice shall be published once in a newspaper of general circulation in the county, city, or town where the local or regional water plan is in effect; and

3. Notice of the public meeting shall be sent to all persons and government agencies that requested a public meeting or have commented in response to the public notice.

B. Notice shall be effected pursuant to subdivisions A 1 through 3 of this section at least 30 days in advance of the public meeting.

C. The content of the public notice of any public meeting held pursuant to this section shall include at least the following:

1. Name and address of the localities who prepared the program;

2. The planning area covered by the program;

3. A brief reference to the public notice issued for the comment period including the date of issuance unless the public notice includes the public meeting notice;

4. Information regarding the time and location for the public meeting;

5. The purpose of the public meeting;

6. A concise statement of the relevant water resources planning, water quality, or fish and wildlife resource issues raised by the persons requesting the public meeting;

7. Contact person and the address, e-mail address and phone number of the department office at which the interested persons may obtain further information or request a copy of the draft statement of findings prepared pursuant to 9 VAC 25 780-140 D; and

8. A brief reference to the rules and procedures to be followed at the public meeting.

9 VAC 25-780-170. Appeals.

All appeals taken from actions of the board or the director relative to the provisions of this chapter shall be governed by the Virginia Administrative Process Act (§ 2.2-4000 et seq. of the Code of Virginia).

9 VAC 25-780-180. Enforcement.

Enforcement of this chapter will be in accordance with §§ 62.1-44.15, 62.1-44.23, and 62.1-44.32 of the Code of Virginia.

9 VAC 25-780-190. Delegation of authority.

The executive director, or his designee, may perform any action of the board provided under this chapter, except as limited by § 62.1-44.14 of the Code of Virginia.

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BENEFITS OF ITERATIVE WATER SUPPLY FORECASTING IN THE WASHINGTON, D.C., METROPOLITAN AREA[1]

Erik R. Hagen, K. John Holmes, Julie E. Kiang, and Roland C. Steiner[2]

ABSTRACT: The three largest water utilities in the Washington, D.C., metropolitan area (WMA) rely on the Potomac River and its reservoirs for water supply. These utilities have committed to a periodic review of the system's adequacy to meet future demands. In 1990, 1995, 2000, and again in 2004 (for publication in 2005) the utilities requested that the Interstate Commission on the Potomac River Basin (ICPRB) conduct a 20-year water demand and resource adequacy study to fulfill this need. The selection of the five-year interval provides multiple benefits. It allows regular updates and incorporation of recent demographic forecasts, and it increases visibility and understanding of the adequacy of the region's water resources. It also provides adequate time to conduct research on the physical system and to incorporate modifications based on this research into subsequent studies. The studies and lessons learned are presented in this case study of the WMA. The work has been a natural outgrowth of a long history of cooperative water supply planning and management among the main WMA water utilities and ICPRB.
(KEY TERMS: water resources planning; water demand; demographic projections; demand forecasting; resource adequacy analysis; Potomac River; consumptive use.)

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INTRODUCTION

Water supply management in the Washington, D.C., metropolitan area (WMA) requires a high degree of interjurisdictional cooperation. The urban populations in Maryland, Virginia, and the District of Columbia share the Potomac River as their primary source for municipal supply. The three major metropolitan water supply utilities, the Washington Suburban Sanitary Commission (WSSC), the Fairfax Water (FW), and the Washington Aqueduct Division of the U.S. Army Corps of Engineers (Aqueduct Division) – collectively, WMA water suppliers – jointly own water storage in upstream Jennings Randolph and Little Seneca reservoirs that they have agreed to operate for their common benefit during droughts (Figure 1). Additional regional resources include the Triadelphia and Duckett reservoirs on the Patuxent River (Patuxent reservoirs), owned by WSSC, and the Occoquan Reservoir on the Occoquan River (a tributary to the tidal Potomac), owned by FCWA, all of which are operated to improve regional water supply reliability during droughts. Water quality releases from the Savage Reservoir, owned by the Upper Potomac River Commission, also benefit the downstream WMA water suppliers during droughts.

The WMA water suppliers have committed to a periodic review of the adequacy of the system to meet future demands, by formal agreement (i.e., Low Flow Allocation Agreement of 1981 among the U.S. Army, Maryland, Virginia, Washington, D.C., the WSSC, and FW; and Water Supply Coordination Agreement of 1982 among the U.S. Army Corps of Engineers, FW, the WSSC, Washington, D.C., and the ICPRB). The first study was conducted in 1990 (Holmes and Steiner, 1990), with subsequent studies in 1995 (Mullusky *et al.,* 1996), 2000 (Hagen and Steiner, 2000), and 2005 (Kame´enui *et al.,* 2005. By request of the WMA water suppliers, the ICPRB led the effort to forecast

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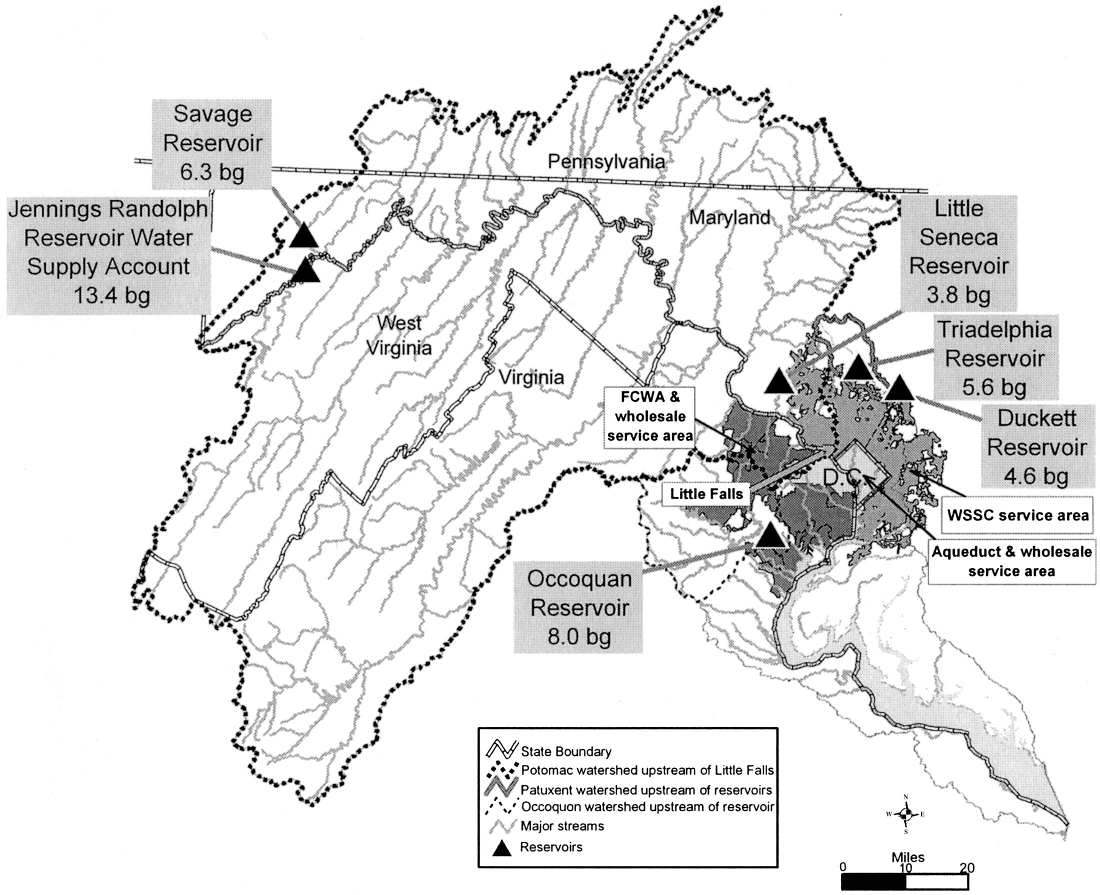

Figure 1. Potomac Basin, Patuxent Basin, Basin States, Water Supply Service Area, and Regional Supply Reservoirs.

water demand and assess resource adequacy. In cooperation with the WMA water suppliers, ICPRB developed a process to integrate the data inputs from the water utilities and regional and local planning agencies. The methods selected for both the demand forecasting and resource adequacy phases of these studies were intended to promote replication and transparency. The result is a process that is improved through periodic updates with new demographic forecasts, updated understanding of the physical system characterization, and enhancements in quantitative methodologies while relying on the same basic inputs and institutional collaborations.

THE GEOGRAPHICAL SETTING

One of the most famous landmarks of the WMA is the Potomac River. The drainage area of the Potomac includes 14,679 square miles (38,000 square km) in four states (Maryland, Virginia, West Virginia, and Pennsylvania) and the District of Columbia (Figure 1). The Potomac basin lies in five geological provinces: the Appalachian Plateau, the Ridge and Valley, Blue Ridge, Piedmont Plateau, and Coastal Plain. The majority of the basin is covered by forests at about 58 percent of the land area. Developed land makes up 5 percent of the basin, while agriculture covers 32 percent. Water and wetlands make up 5 percent of the basin.

The WMA water suppliers serve 4.1 million people in the city of Washington, D.C., and adjacent urban portions of Maryland and Virginia (Figure 1), covering an area of 1,073 square miles (2,800 square km or 7.3 percent of the watershed). The recent pattern of urban growth is similar to that of many metropolitan areas in the United States, with the suburbs and outlying towns experiencing most of the growth. The planning domain for water supply includes multiple municipalities, states, and the federal government.

DESCRIPTION OF WMA WATER SUPPLY

Most of the residents of the WMA rely on the Potomac River as their primary source of water supply. On average, the Potomac River accounts for about 75 percent of the water treated by the WMA water suppliers, with the remainder drawn from the Patuxent and Occoquan reservoirs. Average Potomac flow is about 7,000 million gallons per day (mgd; 26 million cubic meters per day or million m^3/d) with a one-day low flow (before water supply withdrawals) of 388 mgd (1.47 million m^3/d) on September 10, 1966. The annual average Potomac withdrawal for the WMA water suppliers from 2000 through 2002 was approximately 384 mgd (1.45 million m^3/d).

The WMA water suppliers collaborated to pay for storage in Jennings Randolph Reservoir and Little Seneca Reservoir, at an original cost of more than US$96 million plus annual operation and maintenance costs since construction. Costs for the Jennings Randolph Reservoir were allocated based on projections of future growth: WSSC assumed 50 percent of the costs of the new resources, FW 20 percent, and the Aqueduct Division 30 percent. The following are the major components of the metropolitan water supply system (also shown in Figure 1).

Jennings Randolph Reservoir

This reservoir provides supplemental releases to the Potomac to increase low flows and is owned and operated by the U.S. Army Corps of Engineers (USACE). The reservoir is divided into three accounts. The water supply account has 13.4 billion gallons (bg; 50.7 million m^3) that is available to the WMA water suppliers when needed. The water quality account has 16.6 bg (62.8 million m^3) that is managed by the USACE for multiple objectives including water quality and recreation. The flood control account has 11.8 bg (44.7 million m^3). Release recommendations from the water supply account are made by ICPRB based on existing and projected utility demand, status of other reservoirs, and weather conditions. The reservoir is some 200 miles (300 km) upstream of the utilities' intakes, and releases take more than a week to travel to the utilities during times of low flow.

Little Seneca Reservoir

This smaller reservoir, which stores 3.8 bg (14.4 million m^3) of water, is funded by the three utilities and is operated by WSSC. Located in Montgomery County, Maryland, releases take about a day to reach the utilities' intakes. Little Seneca is used to "fine tune" Jennings Randolph releases – without Little Seneca, water managers would have to make larger releases from Jennings Randolph to ensure adequate water supply at the intakes.

Savage Reservoir

Savage Reservoir is owned by the Upper Potomac River Commission and is operated by the USACE. This 6.3 bg (23.9 million m^3) reservoir is located in the headwaters of the basin near Jennings Randolph Reservoir. Savage Reservoir is operated primarily to maintain instream flow for industrial wastewater dilution in the North Branch Potomac. Together, Savage and Jennings Randolph reservoirs control about 3 percent of the Potomac watershed upstream of Washington, D.C. When water supply releases are made from this system, approximately 80 percent comes from Jennings Randolph Reservoir and 20 percent from Savage Reservoir.

Patuxent Reservoirs

The WSSC owns and operates two reservoirs in the neighboring Patuxent River watershed, Triadelphia Reservoir and Duckett Reservoir. Total usable storage at these reservoirs is about 10.2 bg (38.6 million m^3). The utility uses this stored water in tandem with Potomac withdrawals throughout the year.

Occoquan Reservoir

The FCWA owns and operates this reservoir on the Occoquan River, which is a tributary to the tidal Potomac estuary. The reservoir contains about 8.0 bg (30.3 million m^3) of total usable storage, which is used conjunctively with Potomac withdrawals.

This system presents opportunities for increasing efficiencies through cooperative management. Operating the reservoirs as part of a coordinated system allowed for improvement in estimated system yield via conjunctive management (Palmer, 1979). The associated synergistic gains in yield greatly increase the system's ability to meet growth. However, the system's physical characteristics also create operational difficulties. Travel times between the upstream Jennings Randolph Reservoir and the most downstream flow control point during low flows are much longer than originally assumed, making actual operations less efficient than prior model estimates (Trombley, 1982). In addition, the State of Maryland is considering a revision to the recommended minimum environmental flow at Little Falls, just downstream of the last metropolitan area water supply intake (MDNR, 2003). Any change in the recommendation could have an effect on system reliability.

HISTORY OF COOPERATION ON WATER SUPPLY

Population in the WMA grew from 672,000 in 1930 to 2 million in 1960, and forecasts in the early 1960s called for the population to grow to 5 million by 1985 (USACE, 1963). The actual MWA population realized in 1985 was less than forecast by the USACE, at approximately 3.1 million people (U.S. Census Bureau, 2004).

Drought induced rationing was a very real threat in the WMA through the 1960s and 1970s (ICPRB, 1982). In the 1963 USACE study and in subsequent water supply studies through the late 1970s, demands were forecast to exceed the low flow of the largely unregulated Potomac. Historical flows have ranged from a low of about 0.3 bgd to a high of approximately 300 bgd (Figure 2). Drought rationing in the WMA was avoided by virtue of luck, with no serious droughts threatening the water supply system in the 1970s. WMA demand levels exceeded the 1966 low flow of the Potomac River 41 times during 1971 through 1982 (Ways, 1993).

The first proposed solutions were structural, with the USACE releasing a report in 1963 recommending 16 potential reservoir sites in the Potomac River basin (USACE, 1963). The USACE study did not consider synergistic gains possible from conjunctive operation and instead calculated benefits based on independent reservoir operation. Other measures that were studied included estuary treatment plants, interconnections in the distribution systems, and interbasin transfers (Ways, 1993).

Because of financial and technical difficulties and public opposition to the structural options, the water utilities and local governments looked for other solutions. Research at Johns Hopkins University and ICPRB that began in the late 1970s showed that coordinated use of the stored water in the Potomac basin during droughts greatly alleviated the need for most new reservoirs (Sheer, 1977; Palmer *et al.,* 1979, 1982). Their research revealed that, by managing the Jennings Randolph Reservoir in coordination with the existing Occoquan and Patuxent Reservoirs, the region's projected demands could be met and adequate environmental flow could be maintained through about 2020 with only a fraction of the

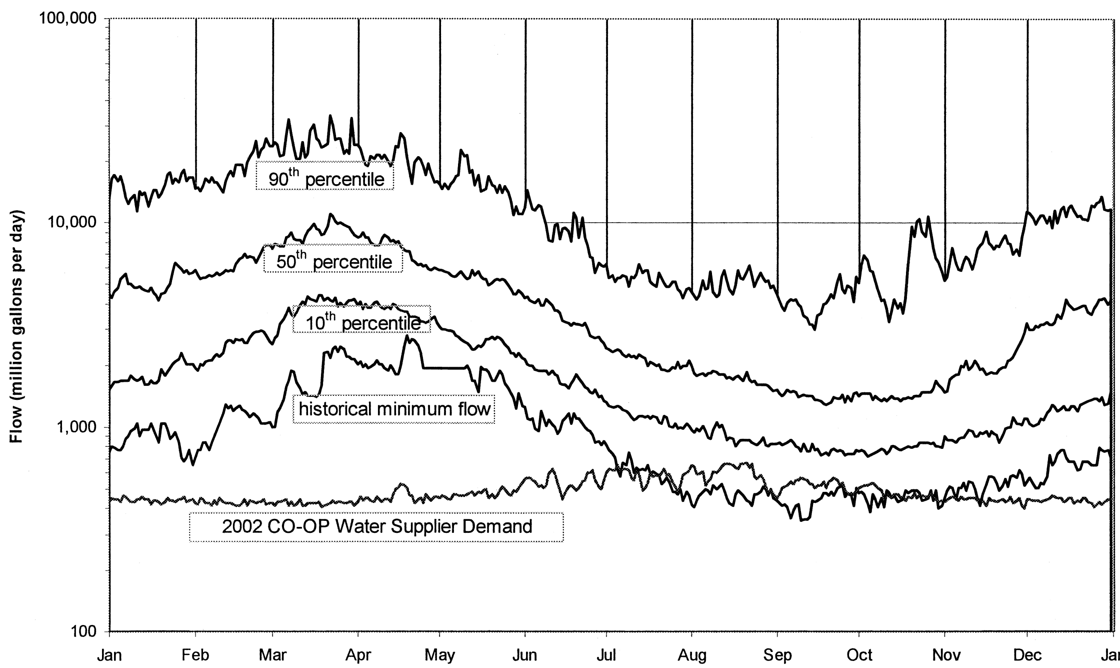

Figure 2. Flow on the Potomac River at Point of Rocks and Water Supplier Demand. Flow statistics are Based on 1895 through 2003 USGS gage flow (USGS, 2004). Data provided by T. Supple, WSSC, May 2004, unpublished data; J. Peterson, Aqueduct Division, May 2004, unpublished data; and T. Kammer-Goldberg, Fairfax Water, May 2004, unpublished data.

reservoir storage originally proposed by the USACE. Gains in reliability were obtained by operating rules that specified that the WMA water suppliers depend more heavily on the free flowing Potomac River during low flow winter and spring months in order to preserve storage in Patuxent and Occoquan Reservoirs. This strategy was physically possible because even during drought months, the winter and spring Potomac flow is more than adequate to meet water supply demands. This operating policy ensured that the Patuxent and Occoquan Reservoirs remain available for use during the summer low flow season and reduces the probability of system failure.

The WMA water suppliers institutionalized cooperative management through the 1982 Water Supply Coordination Agreement, which also designated ICPRB's Section for Co-operative Water Supply Operations on the Potomac (CO-OP) as the agency to coordinate operations. In addition, CO-OP performs an array of other water resources-related work such as drought exercises, seasonal forecasts of water supply conditions, operational and administrative support during droughts, and research (Sheer and Eastman, 1980; Sheer, 1983;Steiner, 1984; Smith, 1988, 1989; Sheer *et al.,* 1989; Steiner *et al.,* 1997, 2000).

REEMERGENCE OF WATER SUPPLY ISSUES

The issue of water resources adequacy has recently reemerged as a major concern in the WMA. After the early exploration of regional resource management at Johns Hopkins University, the construction of the Jennings Randolph and Little Seneca Reservoirs in the early 1980s, and the enactment of the Water Supply Coordination Agreement, concerns about adequacy of regional water supplies faded from prominence among policy makers and the public. The water resources available in the Jennings Randolph and Little Seneca Reservoirs were judged adequate to meet water supply demands in the eventuality of a drought in the Potomac River basin (National Research Council, 1984). Through the 1980s and almost all of the 1990s, flows in the Potomac River never dropped low enough to require releases of water from the upstream Jennings Randolph and Little Seneca Reservoirs. However, over the past six years there were two periods during which upstream reservoirs were tapped to augment Potomac River flows, including an extensive period in 2002. The droughts of 1999 and 2002, which occurred during hot, dry summers, caused a significant rise in interest in water supply management. These events, combined with the continued growth in water supply demands and potential for future resource shortfalls, prompted increased participation by stakeholders in water planning as well as greater scrutiny of resource alternatives, study methods and assumptions, and upstream water uses.

The authors of the Water Supply Coordination Agreement solved the WMA's immediate water supply need with the coordinated management solution but also had the foresight to provide a framework for studying future needs. The agreement requires water supply demands and resources to be evaluated in 1990 and every fifth year thereafter, with a forecast horizon of 20 years into the future.

METHOD FOR FORECASTING WATER SUPPLY DEMAND

A unit use coefficient approach was chosen for the WMA water supply studies in 1990 (Holmes and Steiner, 1990), 1995 (Mullusky *et al.,* 1996), 2000 (Hagen and Steiner, 2000), and 2005 (Kame´enui *et al.,* 2005) as it is a transparent and easily understandable method that can be applied to multiple jurisdictions and was judged to provide the right balance between data needs and accuracy. This is especially true in an era when the WMA's available supply of water was in excess of water supply demands.

This method is limited in that it does not account for the impact that variables such as price might have on water demand and does not allow for explicit estimation of uncertainty in the water demand estimate. Because past studies show that resources may be strained in the future due to demand growth, it is appropriate to include more comprehensive forecast methods for future studies that more explicitly incorporate uncertainty and other factors that can influence water demand. An annotated bibliography of forecasting techniques is provided by Dziegielewski *et al.* (1981). While by no means an exhaustive list, discussions of municipal water supply management including water demand forecasting techniques are provided by Baumann *et al.* (1997), Prasifka (1988), Wurbs (1994), and Mays (2003). In 2000, Planning and Management Consultants Ltd. conducted a demand forecast for the City of San Diego, California, that quantified forecast risk and uncertainty.

The unit use coefficient approach used for the WMA forecast disaggregates demand among three main categories of water uses: single family household use, multifamily water use, and employee water use. The employee water use category includes all commercial, office, governmental, and industrial water use, although industrial water use in the WMA is negligible. The main components of WMA water demand are due to single-family and multifamily residences, with significant contribution from government and office workers.

Estimates of future annual average water demands are made by applying unit use factors for each type of water use to regional demographic projections of the number of future households and employees from the Metropolitan Washington Council of Governments (MWCOG, 1988, 1994, 1999, 2004). Unit use coefficients are calculated and demographic projections are collected for 17 different geographic regions and service areas in the WMA. The 2000 study (Hagen and Steiner, 2000) and 2005 study (Kame´enui *et al.,* 2005) modified future unit use rates to account for the increasing use of more efficient plumbing fixtures.

This method of demand forecasting requires a high degree of interaction with regional water supply and other planning agencies. The most recent forecast covered the WMA water suppliers and their seven wholesale customers. Agreements by the utilities to wholesale water outside their direct service areas make it necessary to include these additional utilities in the estimation. The service areas shown in Figure 1 include the wholesale customers of each of the WMA water suppliers.

A summary of the most recent study's forecast of households, population, and employees for the WMA water suppliers' service area is shown in Table 1 (Kame´enui *et al.,* 2005), for the intermediate or "most likely" growth scenario. The forecast, based on MWCOG demographic projections from 2004 shows that households, employees, and population were projected to increase between 22 to 32 percent from 2005 to 2025 (MWCOG, 2004).

TABLE 1. Forecast of Households, Population, and Employees for the Water Supplier Service Area for the Intermediate or "Most Likely" Growth Scenario.

	2005 Estimates	Forecast For Year 2025	Percent Increase 2005 to 2025
Households	1,556,000	1,899,000	22.0
Single Family	974,000	1,160,000	19.0
Multifamily	581,000	737,000	26.9
Employees	2,612,000	3,444,000	31.9
Population	4,070,000	4,863,000	24.2

Data from Kame´enui *et al.* (2005).

The population forecasts were combined with the unit use factors to obtain a comprehensive demand forecast for the metropolitan area. WMA water supplier unit use factors for single-family households, multifamily households, and employees are shown in

TABLE 2. Unit Use Factors for 1988. 1998, and 2004.

	Aqueduct Division – Washington, D.C., Service Area	Fairfax Water – Retail Service Area	WSSC Service Area	System Average Unit Use[1]
Single-Family (gallons per day)				
1988	325	240	241	262
1998	279	227	179	214
2004	170	212	179	185
Multifamily (gallons per day)				
1988	315	177	223	236
1998	279	165	184	201
2004	160	163	175	168
Employment (gallons per day)				
1988	50	44	58	53
1998	43	44	45	44
2004	57	46	47	51

Notes: Data from Kame´enui *et al.* (2005).

[1]Weighted by relative numbers of houses or employees in DC WASA, Fairfax Water, and WSSC service areas as estimated in 1990, 2000, or 2005.

Table 2. In the 2000 demand study (Hagen and Steiner, 2000) and the 2005 study (Kame´enui *et al.,* 2005), unit use factors were projected to decrease to account for the growing use of low water using fixtures as a result of the Energy Policy Act of 1992. Unit use in the WMA is forecast to decline based on assumptions about residential water use rates (Mayer *et al.,* 1999), the number of existing households with remodeled bathrooms, bathroom fixture replacement rates, and the number of new houses with associated low flush toilets and low flow showerheads (Hagen and Steiner, 2000) (Table 3). These assumptions reduce the system average unit use by about 7 percent in year 2020 as compared to the calculated 2000 unit use rate for single-family households.

Forecasts of annual average water supply demand published in the 1990 (Holmes and Steiner, 1990), 1995 (Mullusky *et al.,* 1996), 2000 (Hagen and Steiner, 2000), and 2005 (Kame´enui *et al.,* 2005) water resource adequacy studies, as well as older forecasts from other agencies, have declined over time (Figure 3). The 2005 CO-OP forecast predicts an annual average WMA demand of 572 mgd (2.16 million m^3/d) in 2025, representing a 17 percent increase over 2005 demand levels but still less than the older forecasts. Of the CO-OP forecasts, the 1990 forecast predicts

TABLE 3. Estimated Effects of the Energy Policy Act of 1992 on WMA Toilet and Shower Household Water Use.

	1990	2000	2010	2020
Household Toilet Use, gallons per day	45	40	33	28
Household Shower Use, gallons per day	33	31	29	28
Total Household Toilet and Shower Use, gallons per day	78	71	62	56

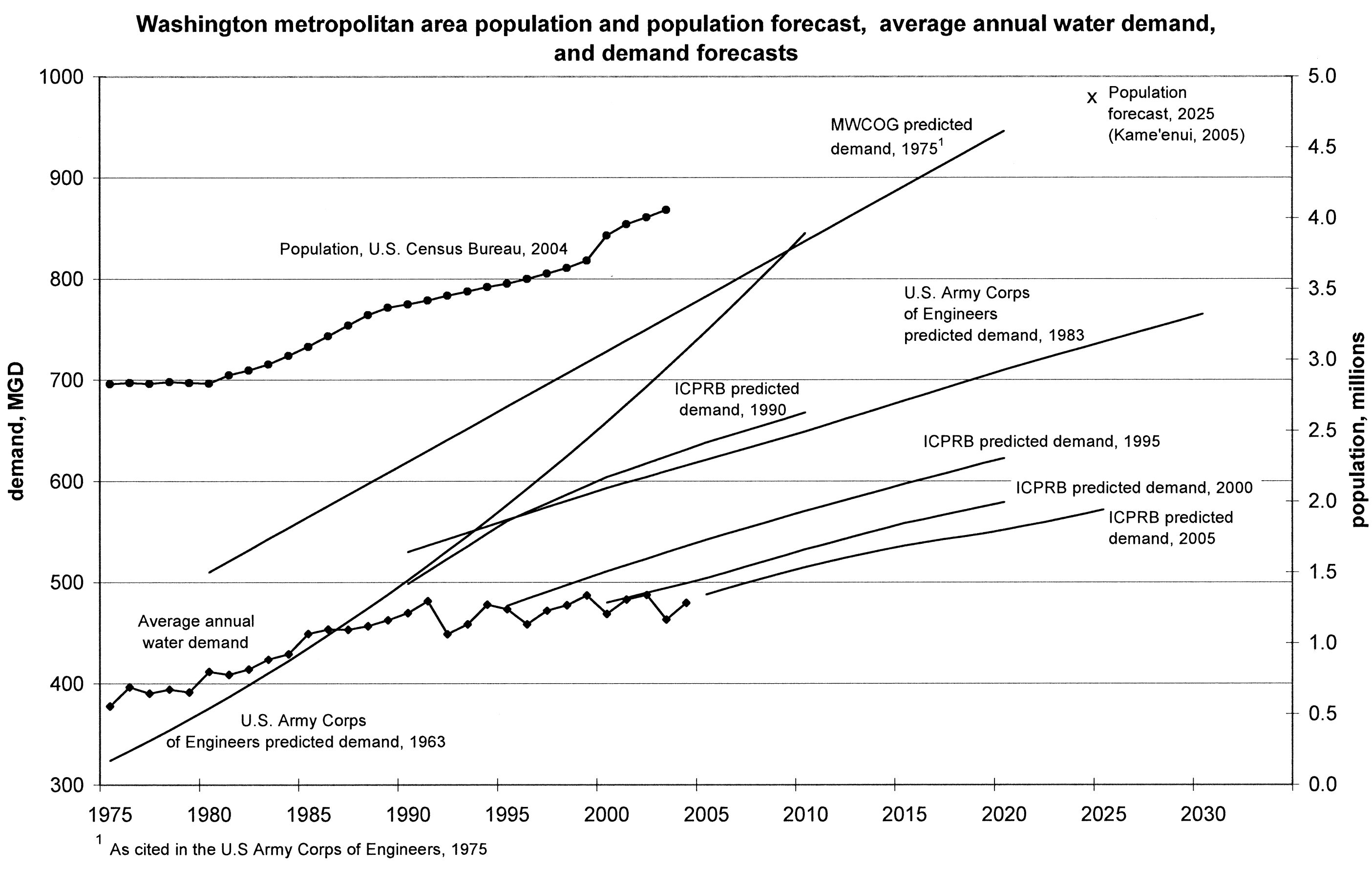

Figure 3. Washington Metropolitan Area Population, Average Annual Water Demand, and Demand Forecasts.

higher demands than both later forecasts and is higher than the demands that were actually realized.

Changes in the unit use factors and in demographics help explain the differences in the forecasts. The actual unit use factors calculated in the 1990 (Holmes and Steiner, 1990), 2000 (Hagen and Steiner, 2000), and 2005 (Kame´enui *et al.,* 2005) demand studies (based on the years 1988, 1998, and 2004) are compared in Table 2. These factors show that on average, unit use from 1988 to 2004 dropped by 29 percent for single-family housing, by almost 29 percent for multifamily housing, and by about 4 percent for employees. Changes in demographic information account for a portion of the remaining difference in forecasts. The household and employee forecasts for the 1990 (Holmes and Steiner, 1990) and 2000 (Hagen and Steiner, 2000) water demand studies are compared in Table 4. The numbers of households and employees were forecast in 1990 to be higher than those actually realized, with the number of system households in 2000 about 6.4 percent less than predicted in the 1990 study (Holmes and Steiner, 1990) and the numbers of employees about 11.3 percent less.

The slopes of the first three ICPRB forecasts are nearly identical in Figure 3, and while the forecasts were shifted down at each reevaluation, it appears that the results contradict the historical data, which show a clear concave downward trend and clearly indicate that growth in demand has leveled off in recent years. This trend is contrary to the relatively constant rate of population growth. In addition, all water demand forecasts for the WMA from the 1970s through the 1990s overpredict demand (Figure 3).

Water managers in the WMA have voiced a preference for conservative estimates of variables that become factors in the water demand forecast, especially in the face of the rapid growth experienced in the WMA (Figure 3). For example, water utility technical staff in the WMA discouraged CO-OP from adjusting unit use rates to account for the effects of the federal Energy Policy Act for the 2005 study. The staff preferred to plan for the higher estimate of future demands and viewed their preference as reflective of their responsibility to provide a safe and reliable source of water supply. Additionally, staff cited climate variability and the possibility of droughts that are worse than those recorded as reasons to estimate demands conservatively. While these factors are conservative, water managers must balance the risk of inadequate water service with the possibility of excess capacity and associated unnecessarily higher costs.

TABLE 4. Household and Employee Forecasts.

	Number of Households by Forecast Year			Number of Employees by Forecast Year		
	1990	**2000**	**2010**	**1990**	**2000**	**2010**
Washington Aqueduct Division						
1990 Study	390,395	410,014	421,405	1,033,627	1,173,505	1,267,627
2000 Study	379,155	368,702	395,599	1,043,799	1,006,502	1,119,352
Difference (percent)	-2.9	-10.1	-6.1	1.0	-14.2	-11.7
Fairfax Water						
1990 Study	370,240	482,971	539,508	416,362	626,406	785,989
2000 Study	361,276	455,882	551,776	460,011	614,250	774,132
Difference (percent)	-2.4	-5.6	2.3	10.5	-1.9	-1.5
Washington Suburban Sanitary Commission						
1990 Study	509,320	594,772	662,749	700,586	874,181	1,043,860
2000 Study	503,120	568,455	638,880	696,250	751,561	894,460
Difference (percent)	-1.2	-4.4	-3.6	-0.6	-14.0	-14.3
System Total						
1990 Study	1,269,955	1,487,757	1,623,662	2,150,575	2,674,092	3,097,476
2000 Study	1,243,551	1,393,039	1,586,255	2,200,060	2,372,313	2,787,944
Difference (percent)	-2.1	-6.4	-2.3	2.3	-11.3	-10.0

Note: Data from the 1990 Study (Holmes and Steiner, 1990) and the 2000 Study (Hagen and Steiner, 2000).

Conducting these studies on a regular five-year interval provides a mechanism for updating the unit use factors and demographic forecasts. While earlier forecasts may have been too high, the forecast interval of five years allows an opportunity to modify projections as demographic forecasts and water use rates change.

METHOD FOR ASSESSING RESOURCE ADEQUACY

The resource analysis is used to determine how well the regional resources can meet the forecasts of future demands. The method used for this analysis evolved from simple comparisons of cumulative deficits versus total system resources (Holmes and Steiner, 1990) to the use of the Potomac Reservoir and River Simulation Model (PRRISM) in later years. PRRISM simulates coordinated management of the reservoirs and incorporates associated conjunctive gains in system resources (Prelewicz, 2004). Assessing conjunctive gains is an important improvement in the resource analysis because it allows the efficiency gains from cooperative management to be incorporated into the analysis (Hirsch *et al.,* 1977; Palmer *et al.,* 1979). It also provides a more realistic representation of how the system would operate during drought conditions.

PRRISM is a deterministic simulation model that incorporates the daily operating rules of the system of reservoirs for the WMA. The original version of PRRISM, called the Potomac River Interactive Simulation Model, was developed at Johns Hopkins University by Richard Palmer and colleagues (Palmer *et al.,* 1979). This model was instrumental in obtaining consensus for the cooperative arrangement agreed to in the Water Supply Coordination Agreement. The most recent version of PRRISM was developed for the demand and resource studies using the object-oriented programming language Extend™ (Imagine That!, 2005) and is conceptually similar to the original model developed in the late 1970s; both models use a water balance at the reservoirs and simulate flows over the period of record.

PRRISM models Jennings Randolph Reservoir in the headwaters of the Potomac River basin, Little Seneca Reservoir in the WMA, and Potomac flow upstream and downstream of the WMA. PRRISM also models the Occoquan and Patuxent reservoirs, which provide about 25 percent of the total water supplied in the WMA. An outline of PRRISM's modeling components, inputs, and outputs is presented in Table 5. The model can be used to determine how the current or modified system of reservoirs and the Potomac River would respond to current or future demands given the current reservoir operating procedures and the historical record of streamflow.

TABLE 5. Inputs and Outputs for the Potomac River and Reservoir System Model (PRRISM).

Modeled System Components	Inputs	Outputs
Reservoirs		
• Jennings Randolph • Savage • Little Seneca • Patuxent • Occoquan	• Historic Streamflow (1929-2002) • Historic Reservoir Inflow • Forecast Year (annual demand as determined by demand study)	• Daily Reservoir Volumes • Reservoir Release Rates • Overall Efficiency of the Jennings Randolph and Seneca Releases • Number of Days of Releases • Potomac River Flow Upstream and Downstream of the Water Supply Intakes
Water Withdrawals For		
• Washington Aqueduct Division • Fairfax County Water Authority • Washington Suburban Sanitary Commission	• Seasonal Demand Pattern (choice of simulating different years' patterns of daily demand) • Choice of water supply alternatives • Restriction Percentages and Trigger Level	• Potomac "Natural" Flow (that flow unaffected by upstream human activities) • Magnitude and Frequency of Low Flows

PRRISM is run in a continuous mode through 72 years of historical reservoir inflow and Potomac River flow records on a daily time step. Continuous modeling allows for an examination of the effects of multiyear droughts on reservoir storage. The drought of 1930 to 1931 is the longest drought included in the historical record, lasting from the summer through the fall and winter of 1930 to 1931 and causing the largest depletion of modeled storage. The 1966 drought was not as lengthy but resulted in the lowest adjusted Potomac River flow of 388 mgd (1.47 million m^3/d) as calculated by the United States Geological Survey (USGS) for the Little Falls gage (USGS, 2001). The 388 mgd (1.47 million m^3/d) flow is equal to a gage flow of 98 mgd (0.37 million m^3/d) plus upstream diversions of 290 mgd (1.10 million m^3/d) for municipal use.

Seasonal demands in the WMA are also highly variable; the extremes include summer demands during the 1990s rising to as much as 741 mgd (2.80 million m^3/d) in June 1999, a drought year, and in winter periods dropping down to as low as 348 mgd (1.32 million m^3/d) in January 1993. Given this range of demands, assessing the adequacy of WMA resources is dependent on modeling the daily and seasonal demand pattern in PRRISM.

Forecasts of annual average demands are converted to forecasts of daily patterns of demand by using a model that relates historical weather and other variables to daily demand.

Daily variability in demands affects the efficiency of upstream reservoir releases. Reservoir releases from Jennings Randolph can take up to nine days to reach the intakes, and in a nine-day time frame, historical system demand has dropped by as much as 242 mgd (0.916 million m^3/d) (August 15 through 24, 1997). In both model runs and actual operations, if water is released from Jennings Randolph Reservoir and demand is lower than predicted, then flow exceeds the minimum flow recommendation. (From the water supplier perspective, this is an inefficient operation, but it should be noted that the variation in flow echoes natural variability and can be viewed as a net benefit to the environment.) Alternatively, if water is released from Jennings Randolph Reservoir and demand is higher than predicted, then the extra demand must be met with releases from Little Seneca Reservoir, requiring a day of travel time to the most downstream water supply intake. In operations and model algorithms, the storage remaining in Jennings Randolph and Little Seneca reservoirs is managed by conjunctive use algorithms.

RESULTS OF RESOURCE ADEQUACY ANALYSIS

Results from the most recent resource analysis conducted in 2005, indicate that the existing system can meet forecasted 2025 through 2045 water supply demand during a repeat of the drought of record (1930) without depleting all reservoir storage (Table 6). Various scenarios were examined to explore the sensitivity of the system, including development of a stochastic streamflow record to explore how the system would respond to a drought more severe than that in the historical record (Table 6). The system meets forecasted 2020 demand throughout a simulation of 500 years of stochastic streamflow, although mandatory restrictions are required in 1.1 percent of years and emergency restrictions are implemented in 0.6 percent of years.

TABLE 6. Results of Year 2000 Demand Forecast Study.

Scenario	Minimum Combined Water Supply Storage in All Reservoirs, Billion Gallons, Plus or Minus One Standard Deviation (percent full)
"Most likely" estimate of 2025 demands, simulation of historical streamflow record	12.0 ± 0.2 (23 percent)
"High" estimate of 2025 demands, simulation of historical streamflow record	10.3 ± 0.4 (20 percent)
"Most likely" estimate of 2045 demands, simulation of historical streamflow record	6.7 ± 0.3 (13 percent)
"Most likely" estimate of 2020 demands, simulation of 500 years of synthetic (stochastic) streamflow	2.0 ± 0.2 (6 percent)

Note: Data from Kame´enui *et al.* (2005).

BENEFITS OF FIVE-YEAR CYCLE

The five-year interval provides benefits obviously realized for the demand forecast, as the interval is appropriate for capturing changes in demographic trends and projections and updating the unit use numbers using observed quantities. The interval is just as important for the resource adequacy analysis as discussed in more detail below.

Improvements to Modeling Tools and Understanding of Physical System

The five-year interval is influential for the resource adequacy analysis, allowing significant improvements in the methodology and improved understanding of the physical system to be incorporated into subsequent analyses. As each study is conducted, questions about the physical system are raised that can be investigated and then incorporated into the next round of analysis.

In 1999, actual drought operations showed that the travel time from Jennings Randolph Reservoir to the downstream water supply intakes is approximately nine days, much longer than the four to five days originally assumed (Trombley, 1982). As the lead time for release decisions is longer, so is the uncertainty of demand and weather forecasts. As the Jennings Randolph release travels to the water supply intakes, a chance thunderstorm somewhere downstream in the basin can cause Potomac flow to increase, erasing the need for the water supply release. Since releases must be made based on both weather and demand forecasts, the accuracy of release decisions is diminished, causing reservoir storage to be depleted more quickly than it would otherwise. This decreased efficiency of reservoir operations was incorporated into the 2000 study (Hagen and Steiner, 2000).

Another critical question is the level of upstream consumptive water use. Given that the Potomac River basin upstream of the WMA is not heavily populated, resource adequacy analyses done in 1990 (Holmes and Steiner, 1990) and 1995 (Mullusky *et al.,* 1996) assumed that upstream consumptive use was insignificant. This assumption was examined in a study sponsored by the Maryland Department of the Environment that estimated current and future consumptive use in the basin due to industrial, commercial, municipal, thermoelectric, mining, livestock, and irrigation demand (Steiner *et al.,* 2000). The study found that consumptive use in 2000 upstream of the WMA was significant, estimated at 129 mgd (0.49 million m^3/d) for a hot and dry summer day and expected to grow to 149 mgd (0.56 million m^3/d in 2020. This understanding of the significance of consumptive water use was incorporated into the resource analysis study conducted in 2000 (Hagen and Steiner, 2000). Historical river flows were adjusted to account for current and projected levels of upstream consumptive use. This reduction in historical flows during the critical drought period of 1930 affected decreased the projected time when resources may be stressed.

After the 2000 study (Hagen and Steiner, 2000), the decision was made to more explicitly model the water quality operations of the Jennings Randolph Reservoir and Savage Reservoir in the North Branch Potomac basin. These reservoirs are operated by the USACE for water quality improvements by increasing summertime low flows with releases typically in the 150 mgd to 300 mgd (0.5 million to 1 million m^3/d) range. When water supply releases are called for by CO-OP, the USACE typically reduces its water quality release to 77 mgd (0.29 million m^3/d). The version of PRRISM used in the 2000 study (Hagen and Steiner, 2000) conservatively assumed the minimum release from water quality storage at all times. Since that time, substantial effort went into the calibration of a model of the USACE's North Branch water quality operations that was incorporated into the current version of PRRISM. North Branch water quality operations usually result in higher releases from the North Branch than the minimum 77 mgd (0.29 million m^3/d) release, which offsets the timing and magnitude of reservoir releases needed from water supply storage. Including the effects of North Branch water quality operations increases historical yield by approximately 29 mgd (0.11 million m^3/d).

When regulatory, environmental, or other water quantity questions are raised, the tools, expertise, and results are immediately accessible and information is available to answer questions about water supply and river flow. Without this ongoing commitment to assessment of system resources, such analyses would be difficult to conduct in a timely manner.

Improvements in Policy and Management

Policy and management questions were raised and addressed in successive demand and resource studies. Each study improved through the dialogue facilitated through interaction with the stakeholder community.

A key policy/management question examined by utility managers was whether to plan to meet unrestricted demand. The 1990 (Holmes and Steiner, 1990) and 1995 (Mullusky *et al.,* 1996) planning studies assumed unrestricted demands when assessing the ability of resources to meet projected demands. During quarterly meetings of the water suppliers at

ICPRB prior to the 2000 demand study (Hagen and Steiner, 2000), water managers began discussing trade offs between periodic restrictions during drought years and gains in long term water supply reliability. Before this discussion could be resolved, actual drought events intervened. During the drought of 1999, the governor of Maryland established statewide mandatory restrictions. These restrictions were implemented uniformly across the state. These restrictions were in conflict with an assessment by water managers in the WMA that the available supply was more than adequate to meet current levels of unrestricted demands. Elected officials in Virginia and Washington, D.C., chose not to implement restrictions in the WMA, citing the water managers' assessment of resource reliability. Residents on the Washington, D.C., side of Eastern Avenue could water lawns, but those on the Maryland side could not, which was confusing to the public since all jurisdictions used the same source of water. While restrictions would not increase Potomac River flow (the river is controlled to meet a minimum flow recommendation), restrictions would increase the amount of storage left in Little Seneca Reservoir in Montgomery County, Maryland.

Little Seneca Reservoir had not been used as a water supply reservoir since its construction in 1981. The area surrounding the reservoir had been developed with townhouses and single-family homes, and the lake itself had become a valuable local recreational resource. Montgomery County politicians preferred not to use the water supply reservoir until water users in Maryland, Washington, D.C., and Virginia (all of whose residents had paid for the construction of the reservoir) restricted their water use. While issues of equity and fairness were debated, the controversy was eventually ironed out in closed door meetings of the WMA politicians, who agreed to implement restrictions per a compromise that was codified in a regional drought plan (MWCOG, 2000). While water resource managers would prefer that the compromise be motivated by more idealistic concern over long-term water supply reliability, the accommodation of recreational interests and homeowner property values at Little Seneca Reservoir through the regional compromise has a corollary benefit: it increases the long-term water supply reliability with a relatively minor reduction in level of service. The resource assessment of the 2000 demand study (Hagen and Steiner, 2000) was modified to mirror this regional policy, modeling voluntary reduction in demand when the reservoirs reached 60 percent full. Future water resources modeling and analysis could be done to more explicitly examine the tradeoffs among various demand reduction triggers and gains in water supply reliability and implemented through an educational campaign.

The relatively short interval between studies allows sufficient time to begin the planning process for meeting future water supply needs in the event a shortfall is forecast. The conclusions of the 2000 study (Hagen and Steiner, 2000) state that under the most likely growth scenario, current resources met 2020 levels of demand with about 18 percent remaining storage in the Potomac reservoirs and met 2030 demands with about 9 percent remaining. That modeled reservoir storage dropped to relatively low levels was enough to trigger evaluation of water supply alternatives. Water managers did not wish to fully deplete reservoir storage, even in a planning context, and as a result began exploring various water supply alternatives in feasibility studies. FCWA led a study funded by the USEPA of the viability of several new water supply alternatives such as the use of an abandoned quarry for water supply storage. Concurrently, and at the request of the WMA water suppliers, CO-OP investigated the feasibility of improvements to operational efficiency, regional benefits associated with various structural alternatives, and demand management alternatives. The subsequent 2005 study (Kame´enui *et al.,* 2005) showed that the existing system remains adequate to meet future demand through 2025.

Interaction With Stakeholder Community

The iterative and cooperative nature of this work enhances regional understanding of the WMA water supply issues and provides a comprehensive body of knowledge about regional water supply reliability. The five-year cycle provides a rationale for CO-OP interaction with utilities, planning agencies, and interested stakeholders for substantial information input, further integrating them into the process.

CO-OP's involvement with the League of Women Voters' study of water supply is an example of this interaction with stakeholder groups outside the water utilities. The League of Women Voters used the results of the 1995 resource adequacy study (Mullusky *et al.,* 1996) as a motivation and basis for its report on water supply prospects and options in the WMA for the 21st Century (League of Women Voters of the National Capital Area Water Supply Task Force, 1999). The report, developed with input and participation from CO-OP staff, included several recommendations for improvements to future resource adequacy studies by CO-OP. Suggestions included: (1) incorporating changes in predicted per capita water use over time due to the effects of conservation, especially with regard to water conserving technologies mandated by the Federal Energy Policy Act of 1992; (2) modeling the effects of reduced demand due to the effects of voluntary and mandatory water use restrictions; (3) addressing reservoir siltation as a factor in reducing the volume of storage available in future years; and (4) providing a more sophisticated treatment of the level of detail of modeled upstream reservoir operations in the resource analysis. While these improvements were already planned by CO-OP for the 2000 study that was then under way, the interaction between CO-OP and the League of Women Voters enabled a collaborative understanding of the issues at hand and enhanced regional support of the overall study process.

CONCLUSIONS AND FUTURE WORK

The five-year interval has proven to be rewarding. Taken together, the studies present an evolving understanding of regional water supply reliability and are the basis of a comprehensive body of knowledge. The iterative nature of the work allows for a forum for cooperation and interaction among the WMA water suppliers and provides regular updates and incorporation of recent demographic forecasts.

For the time between studies, the tools and expertise that are developed for the demand studies are immediately accessible (they are maintained and improved for use in the next study) and can be used or modified to answer regulatory, environmental, or other water quantity questions as they arise. The interval provides an opportunity to reevaluate previous assumptions, both technical and policy, triggered by multiple passes at the resource adequacy analysis. Research and refinement of the technical tools is pursued with input from various experts, allowing significant improvements in the methodology and improved understanding of the physical system to be incorporated into subsequent analyses.

Policy and management questions are raised and addressed in successive demand and resource studies. Each study is improved through the dialogue between policy and engineering that is facilitated through interaction with the stakeholder community. The iterative and cooperative nature of this work enhances regional understanding of the WMA water supply issues by the stakeholder community, keeping the public and local governments involved and informed on regional water supply issues.

In the event that future resources are found wanting, the interval provides an adequate lead time for the water utilities, ICPRB, and other stakeholders to begin planning for new water supply alternatives. The same tools used in the studies for the resource assessment can be used to evaluate the system benefits of water supply alternatives.

Future demand and resource studies will continue to consider a stochastic analysis to quantify the risks of experiencing a drought that is more extreme than the historical observed droughts, to better quantify the versatility of the existing system. While such an analysis will not directly address or quantify possible changes due to climate variability or climate change, this analysis will begin to address the additional uncertainty introduced by potential changes in climate on the management of water resources and will allow for testing alternative designs and policies against a larger range of flow sequences that are likely to occur in the future beyond that of just the historical flow sequence (Loucks *et al.,* 1981). Additional study is warranted to examine the effects of variability of climate on WMA water resources.

Prior studies used unit use methods for demand forecasts. Because past studies show that resources may be strained in the future due to demand growth, it is appropriate to consider more comprehensive forecast methods. More comprehensive studies can be useful for evaluating demand-side management strategies such as pricing or conservation alternatives and can provide a more quantitative evaluation of risk and uncertainty.

Future work could be done to more explicitly examine the tradeoffs between various demand reduction triggers and gains in water supply reliability and implemented in an educational campaign. Such is the opportunity afforded in the intervals between demand studies.

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