Water Research Needs in Virginia

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Summary

In Virginia, there is a critical need for capacity building – providing scientific and advanced technological tools to decision makers in the local governments and state agencies – in order to facilitate environmentally sound and cost-effective solutions to a diverse set of water related problems. To better understand various water issues and research needs in Virginia, the Water Center conducted an enquiry of water research needs in Virginia in fall 2004. A single request was posed through electronic mail to a diverse group of approximately 120 stakeholders that included utilities, local and state governments, academia, and others. The enquiry was: *Describe water research needs in Virginia from your perspective.* About 25 responses were received; most responses included multiple suggestions.

This report provides a summary of the enquiry. From the enquiry, three major categories were established, and further defined by 11 subcategories that included identified research needs Three major research categories and associated subcategories are as follows:

1.   Water Resource Management
            Dynamic statewide knowledge-base for water resources
            Urban stormwater management
            Groundwater management
            Lake and reservoir management
            Science-based TMDLs (watershed-based approach)

2.   Water Source Development
            Waterworks infrastructure
            Alternative water sources
            Ecological impacts of hydrologic alterations

3.   Fate and Transport of Emerging Contaminants and Associated Health Risks
            Developing real-time sensors and decision support system
            Fate of emerging contaminants in natural systems
            Fate of emerging contaminants in engineered systems

The enquiry shows significant research is needed to develop essential decision-making tools. As a result of this enquiry, a total of 64 research topics were identified as potential water research needs in Virginia. Enquiry results, where appropriate, are applicable to all Virginia waters, including wetlands and estuaries. Also, where appropriate, socio-economic factors should be incorporated in to research development. The report includes a brief introductory section about general water resource issues in Virginia to familiarize the reader with the complex and challenging issues facing Virginia. This report will be used as a component of the Water Center's strategic planning to address water research needs in Virginia.

Introduction - Water Resource Issues of Virginia

The water resource issues of Virginia are rather complex because of Virginia's unique topography, with its mountainous western region, central Piedmont, and its tidal coastal plain in the east; its diverse geology, such as the existence of karst formations, fractured rock aquifers, and shallow and deep coastal aquifers; and accelerated urbanization and population growth. Below is a brief introduction to water resource issues in Virginia.

Based on 30 years of data, the mean annual precipitation in Virginia is about 43 inches. The precipitation distribution throughout the year is almost uniform with no distinct dry or wet periods. Virginia lies in the path of cyclonic storms that originate in the Gulf of Mexico and the Atlantic Ocean and is occasionally subject to extreme weather conditions, i.e., tropical storms and hurricanes. The state is also subject to cyclic droughts; for example, a severe drought occurred from 1999 to 2002. Virginia has an estimated 49,220 miles of rivers and streams within nine major basins. Virginia's other significant features include about 236,900 acres of tidal and coastal wetlands, 808,000 acres of freshwater wetlands, 120 miles of Atlantic coastline, and over 2,500 square-miles of estuaries. The total length of Virginia's shoreline, including the Chesapeake Bay and its sub-estuaries, is about 3,315 miles. There are 248 publicly owned reservoirs in Virginia with a combined total area of 162,230 acres. Virginia has only two natural lakes.

Virginia's land use consists of about 55% forests, 26% agriculture (7% cropland, 17% pasture and hay, 2% other), 15% urban, and 4% inland waters. Large metropolitan areas are mostly located in the southeastern area (Norfolk and Hampton Roads), Richmond, and northern Virginia near Washington, D.C. The 2000 census estimated Virginia's population to be 7,078,515. The state ranks 36th in size (40,741 square-miles) and 12th in population in the United States. About 72% of Virginians live in large metropolitan areas, 9% in smaller urban areas, and 19% in rural areas.

In general, water quantity problems in Virginia are manifested in terms of water supply/demand and groundwater decline (mostly in populated and developed areas of northern and eastern Virginia). There is a lack of adequate and safe drinking water in small rural and isolated communities across the state, specifically in the coalfie ld counties of southwest Virginia and in South-side Virginia along the North Carolina border.

In general, water quality problems in Virginia are manifested across the state. Nonpoint sources of pollution originating from animal production systems and urban runoff pose a major threat to the state's water quality. As of 2004, about 11,384 miles of Virginia's rivers and streams were monitored. From these, 6,948 miles have been designated as impaired, i.e., do not meet Virginia's established water quality standards. Also, an additional 19,000 miles had some monitoring conducted but not enough data are available to meet assessment criteria. These numbers do not include estuaries and lakes. The Virginia Department of Environmental Quality estimates about 650 Total Maximum Daily Load (TMDL) reports will be required by the year 2010 with an estimated cost of over $59 million.

In Virginia there is a critical need for capacity building – providing scientific and advanced technological tools to decision makers in the local governments and state agencies – in order to facilitate environmentally sound and cost effective solutions to a diverse set of problems. A single request was posed through electronic mail to a diverse group of about 120 stakeholders that included utilities, local and state governments, academia and others across the Commonwealth: *Describe water research needs in Virginia from your perspective*. About 25 responses were received; most responses included multiple suggestions. This report provides a summary of the enquiry. Research areas are not prioritized in this report.

<h1 style="text-align:center">Water Research Needs in Virginia</h1>

In this report, research needs in Virginia are categorized into three general topical areas:

I.   Water resource management
II. Water resource development
III. Fate and transport of contaminants and assocaited health risks

Enquiry results, where appropriate, are applicable to all Virginia waters, including wetlands and estuaries. Also, where appropriate, socio-economic factors should be incorporated in to research development. Research needs identified from the enquiry are listed below.

I. Water Resource Management

Water resource management includes issues of water quantity, quality, management and planning, as well as other related topics. Effective management of available water resources is the primary driver of all water research activities and should be a top priority. From the enquiry, five major water resource management issues were identified for Virginia.

 1) Dynamic statewide knowledge-base for water resources

The availability of comprehensive, science-based, statistically valid, and centralized databases are a prerequisite for scientific water research and decision-making. The most critical needs are as follows:

- a surface water quantity database (flow rates);
- a comprehensive surface water quality database;
- a groundwater (quantity and quantity) database;
- a dynamic link between water data and soil survey databases;
- a dynamic link between water data and climate databases.

2) Urban stormwater management

Urban stormwater runoff poses one of the greatest challenges in metropolitan and suburban Virginia. Critical identified research needs include the following:

- the statistical analysis of stormwater quality data being collected statewide through permitted municipal stormwater programs and various research projects;
- a comparison of the benefits of better land use planning to better technology in terms of costs and environmental impacts;
- the effectiveness and applicability of Low Impact Development (LID) scenarios under various conditions (such as in areas of high clay soils or a seasonally high water table);
- The effectiveness, both short and long-term, of best management practices (BMPs) for stormwater management and nonpoint source control.

3) Groundwater management

Local and regional entities need sound tools to determine water availability. There is a significant need to renew the state's water management plan. These needs apply to freshwaters, brackish and saline waters. Critical needs identified are:

- a better understanding of the mechanism of surface and groundwater interaction in each of Virginia's physiographic provinces, but particularly in coastal aquifers;
- a better understanding of the mechanism of the groundwater recharge in Virginia's physiographic provinces;
- the inter-aquifer transfer of water under natural and pumping conditions, particularly in coastal aquifers;
- the delineation of aquifer boundaries and developing potentiometric maps for aquifers across Virginia;
- the development of wellhead protection strategies for municipalities.

4) Lake and reservoir management

Most reservoirs in Virginia are man-made impoundments designed for multi-use, which complicates their management in terms of both water quantity and water quality. Critical needs identified are:

- the development of water sampling strategies that give representative coverage of an entire reservoir for establishing water quality criteria;
- a better understanding of sediment transport and delivery to lakes and reservoirs;
- an understanding of the mechanism of nutrient delivery to lakes and reservoirs, such as information on the magnitude and timing and magnitude of nutrient input and the response of the water body;
- investigations on spatial and temporal variations in sediment oxygen demand;
- investigations on dispersion of diffuser-induced plumes;
- a survey of Virginia reservoirs for the presence of toxic algae;
- the development of tools for multi-uses and management of urban reservoirs;
- research to clarify morphological and other differences between natural lakes and man-made reservoirs that affect water quality.

5) Science-Based TMDLs (watershed-based approach)

There is a critical need to develop scientifically and legally defensible TMDL reports and implementation plans in Virginia. Research needs relate to establishing appropriate water quality standards, integrating sound statistical and analytical procedures, and evaluating the effectiveness of nonpoint source control measures. Specific identified research needs include:

- the development of biologically based TMDLs - the assessment of how biotic metrics respond to groups of stressors and how these metrics can indicate recovery end-points;

- the development of reference conditions under different conditions (urban, agricultural, forested, etc.) - a concerted effort to identify reference streams, to have scientific consensus that selected streams are in fact appropriate reference sites (e.g., through a "panel" of experts) and to describe conditions of these streams and their watersheds (buffer zone conditions, land use, etc.) in a GIS environment;

- the development of "virtual reference streams" to provide model reference streams/conditions, using multivariate methods, sampling across the state, and focusing on macroinvertebrate, fish, and habitat (geomorphology, hydrology, and riparian zone conditions);

- the development of a statewide GIS database of reference streams

- the development of sound statistical procedures to determine violations of the established water quality standards;

- toxicological assessment of the validity of comparing toxic water quality standards to the passive integrative 30-day average produced using the single program multiple data (SPMD);

- the expansion of the existing libraries for bacteria source tracking;

- a differential risk assessment of pathogens associated with fecal bacteria from human, livestock, and wildlife sources;

- the development of pathogen-specific assays using emerging sensor technology

- a better understanding of the effects of urban forests on stormwater and nonpoint source (NPS) pollution control;

- the development of nutrient-loading rates to water bodies from various types of vegetative buffers and undisturbed sites;

- the potential use of green infrastructure concepts as a tool for TMDL implementation;

- an evaluation of the potential of alternative strategies such as performance-based incentives and/or standards, and trading for pollution-reduction responsibilities for agricultural NPS;

- the quantification of nutrient loadings from forested areas;

- a better understanding of atmospheric NPS loadings to water bodies.

II. Water Source Development

Water source development is essential to meet the domestic water demand and to facilitate economic activity. The water resource management issues described above under category I are a prerequisite for securing needed water sources. This category, on the other hand addresses research needs associated with enhancing existing waterworks infrastructure, developing other types of water sources, and the consequences of developing a new water source. Within a comprehensive water supply management plan, it is essential to consider the potential of developing alternative water sources that could complement existing water sources. The following research needs are identified:

1) Waterworks infrastructure

There is a significant need for infrastructure funding, including funds for water supply, wastewater, and stormwater infrastructure. Cost-effective water treatment technologies are needed to meet current and anticipated drinking water regulations and industrial water demand. Research needs include:

a. System operation

There is a research need to ensure efficient system operation. Potential research needs are:
- an evaluation of cost-effective options for balancing water supply and demand, such as alternative water-sharing arrangements, water-pricing strategies, water rationing, and waterworks construction;
- a coupling of the management of source water quality with water treatment plant operation.

b. Water quality control

Research is needed to address emerging water quality problems in water systems. Identified needs include:
- the control of arsenic;
- the control of disinfectant by-product formation;
- enhanced coagulation requirements;
- treatment options for toxic algae and their toxins that may be present in drinking water sources;
- corrosion and chemical leaching of water distribution pipes and home plumbing
- an understanding of the relation between disinfectant and bacterial growth in water distribution pipes;
- the effects of chloramines on lead release.

c. Water conservation

- the impact of plumbing codes, etc., on water consumption;
- methods of public education.

2) Alternative water sources

Alternative sources include water conservation, water reclamation and reuse, and desalination of brackish and saltwater. The following research needs were identified:

a. Feasibility of wastewater reclamation and reuse
- the development of science-based policy and regulation;
- the socio-economic implications of water reuse;
b. Feasibility of desalination (brackish and saltwater)
- ecosystem effects of desalination, such as water withdrawal and intake;
- ecosystem effects of brine disposal;
- cost-effectiveness of brine management technologies.

3) Ecological impacts of hydrologic alterations

Research is needed to expand understanding of the ecological impacts of water development. Research needs are as follows:

- a better understanding of the degree of hydrologic alterations of streams and rivers in Virginia;

- a better understanding of the impacts of identified hydrologic alteration on aquatic life and ecosystem services in Virginia;
- the impact of water withdrawals and water-intake structure design on fish and other aquatic organisms;
- the development of site-specific design criteria for water intake structures (freshwater, saline, and brackish waters) in Virginia.

III. Fate and Transport of Contaminants and Health Risks

There is a significant need for implementing various types of monitoring technologies to trace the contaminant path in soil, aquatic environments, and engineered systems. Real-time monitoring technologies are needed for early detection of undesired contaminants in both natural and engineered systems, and to assess the potential health risks of various contaminants. The need for research in this area exists for known contaminants, such as sediment and nutrients, emerging contaminants such as pharmaceutical wastes, and unexpected contaminants such as terrorist activities. Identified research needs are as follows:

1) Developing real-time sensors and decision-support systems

   - bio-sensors and pathogenic sensors;
   - sensor networks and decision-support systems based on sensor input.

2) Fate of emerging contaminants in natural systems

   - fate of micropollutants (pharmaceuticals, endocrine disruptors, personal care products) through natural systems;
   - fate of known and emerging pathogens in aquatic environments and potential health risks;
   - nutrient- and sediment- tracing techniques in natural systems;
   - link between environmental contaminants in the hydrosphere and human health.

3) Fate of emerging contaminants in engineered systems

   - fate of steroids, endocrine disruptors, and micropollutants through wastewater and water purification plants, and potential health risks.

Conclusions

The enquiry is organized around three major categories and 11 subcategories. A total of 64 research topics were identified as potential water research needs in Virginia. These research needs are based on the viewpoint of decision makers and researchers concerned with the Commonwealth's water resources issues on either a local or statewide level. However, most identified needs are applicable to regional and national situations as well.

The Virginia Water Resources Research Center will incorporate the results of this enquiry into its strategic planning to meet future water research needs in Virginia, to generate research funding, and to facilitate research by Virginia's colleges and universities.