EASTERN VIRGINIA GROUNDWATER MANAGEMENT ADVISORY COMMITTEE

Report to the Virginia Department of Environmental Quality and Virginia General Assembly

July 2017

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Transmittal Letter

August 4, 2017

The Honorable Thomas C. Wright, Jr, Chair
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Dear Director Paylor and Delegate Wright,

Pursuant to Code of Virginia Section 62.1-256.1, the General Assembly established the Eastern Virginia Groundwater Management Advisory Committee (the Committee). The Committee is an advisory committee charged with developing, revising, and implementing a management strategy for ground water in the Eastern Virginia Groundwater Management Area and then reporting the results of its examination and related recommendations to you.

A diverse committee of stakeholders was appointed as required by the statute. I had the privilege to facilitate the Committee on behalf of the Virginia Center for Consensus Building at VCU. As the facilitator, I am transmitting the attached report to you. The law requires that Director Paylor provide you with a response to this report no later than November 1, 2017.

The Committee utilized a consensus building process. A number of subcommittees worked throughout 2016 to create recommendations for the Committee. The subcommittees were comprised of members of the Committee and a number of nonmembers who had specific expertise in the subject area of the subcommittee. Each subcommittee held numerous meetings which required the devotion of a great deal of time and energy by these stakeholders. The Committee itself then met numerous times to make its own recommendations which are the recommendations in the report before you.

Appendix L contains a statement of support with some partial dissents and comments on specific recommendations from each of the Committee members. I believe it is fair to say that the report before you is a consensus document with no dissents to the entire report. The comments and partial dissents are instructive and included for your information.

As the facilitator, I want to recognize the extraordinary efforts of DEQ staff, particularly Jutta Schneider, Scott Kudlas and William Norris in not only supporting the work of the Committee but the level of expertise they brought to the process.

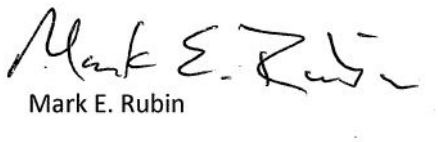
As you will read, the Potomac Aquifer is facing significant sustainability challenges. DEQ has taken steps to negotiate reduced permit levels for the largest users of groundwater in the region. This is an important step but does not create a long term strategy. It is important to look beyond the immediate time horizon for broader ideas of how to protect and sustain the aquifer for future human needs and

economic development. The General Assembly is to be commended for turning to the stakeholders in the region to utilize their expertise to arrive at consensus recommendations. The fact that they were able to reach complete consensus on the vast majority of the recommendations bodes well for the future support of these recommendations.

This also says a lot about the members of the Committee. In the Ground Rules that governed the process, the members all agreed, "They shall also keep the long term interests of the Commonwealth in mind as they participate in the process." I trust you will agree that they have fulfilled this promise.

I will be happy to provide you with any further information you may require about the process. I appreciate the opportunity to participate in this process.

Respectfully,



Mark E. Rubin

Cc: The Honorable Daniel W. Marshall III

The Honorable John M. O'Bannon

The Honorable David L. Bulova

The Honorable Richard H. Stuart

The Honorable Frank M. Ruff, Jr.

The Honorable Frank W. Wagner

Mr. Richard A. Street

Mr. Lamont "Bud" W. Curtis, P.E.

Mr. Scott Meacham

Mr. David Barry

Acknowledgments

The Virginia Department of Environmental Quality (DEQ) appreciates the significant commitment of time and effort committed by each member of the Eastern Virginia Groundwater Management Advisory Committee and the individuals that participated on the Committee's workgroups.

The Committee would like to thank the Virginia Coastal Policy Center (VCPC) at William & Mary Law School for its time and assistance with this report.

Executive Summary

Available groundwater supplies in the Eastern Virginia Groundwater Management Area (EVGMA) are insufficient to meet the long term demands of current and future groundwater users, and these groundwater resources are critical to the health, welfare, and economic prosperity of Eastern Virginia. Recognizing the current and future challenges in the EVGMA, the Virginia General Assembly created and tasked the Eastern Virginia Groundwater Management Advisory Committee (Committee) to assist the State Water Commission and Department of Environmental Quality (DEQ) in developing, revising, and implementing a management strategy for groundwater in the EVGMA. The Committee, comprised of stakeholders in the EVGMA, formed five workgroups to broaden participation and incorporate specialized and technical expertise into the process.

Since August of 2015, the Committee and five workgroups examined the six groundwater management subject areas assigned by legislation and provided recommendations regarding management, including:

(1) Alternative Water Sources and Solutions: The workgroups recommended a list of potential alternative water source projects to the Committee. The Committee adopted this list as a set of possible alternative sources and solutions, which included transitioning from groundwater to public and private surface water resources where applicable, piloting innovative aquifer recharge projects to create a greater water supply in the EVGMA (e.g., Hampton Roads Sanitation District's Sustainable Water Initiative for Tomorrow (HRSD SWIFT) regional project), and supporting water conservation and efficiency.

(2) Changes in Permitting Criteria: The Committee evaluated options for enhancing the current permitting program. Recommended options include addressing the need for greater certainty for permittees to make long-term infrastructure investment decisions by lengthening the permit term to 15 years. The Committee also recommends voluntary regional planning through Planning District Commissions working cooperatively with DEQ to enhance the Local and Regional Water Supply Planning Process. Since the efforts by permitted users to reduce consumption are not enough to restore the aquifer for the long term, the Committee also evaluated ways to address the concurrent impact that unpermitted users have on groundwater resources. Unpermitted sources are typically small individual uses and represent a growing portion of groundwater use. The Committee recommends encouraging and incentivizing the connection to and use of public water supply systems (particularly those served by surface water), unconfined aquifers, and irrigation ponds where applicable.

(3) Alternative Management Structures: The Committee concludes that the current groundwater management process is sufficient at the moment, but recommends DEQ, in cooperation with

other agencies, establish an annual "State of the Eastern Virginia Water Resources" forum. This forum would be open to the public and create a voluntary mechanism for communication among regulators and stakeholders on the overall status of Eastern Virginia's water resources.

(4) Groundwater Trading and Banking: Groundwater trading and banking programs can provide groundwater users various degrees of flexibility in how to conserve, manage, and/or allocate groundwater supplies. The Committee discussed and evaluated several banking and trading systems, and recommends the establishment of a groundwater banking framework as a mechanism for aquifer storage and recovery (ASR). This banking concept allows DEQ to grant a groundwater credit to any party that injects water into the coastal aquifer for water storage and recovery within the existing groundwater management areas. The Committee recognizes that a broader trading program could offer incentives to economize on water use and to develop alternative sources; however, due to the complexity of such a program the Committee does not recommend a particular trading system at this time. The Committee urges the General Assembly to continue to evaluate trading systems.

(5) Necessary Data Improvements: Collecting and maintaining credible data is essential for monitoring aquifer conditions and system responses to management actions. The groundwater management recommendations outlined in this report will keep this data current and establish the analytical capacity to assess ongoing management issues. DEQ proposed six areas for data improvements to the Committee that would allow DEQ to implement the groundwater program to its fullest extent. The Committee agrees that the list provided by DEQ with regard to data improvements identifies reasonable actions to be undertaken by DEQ. The Committee recommends that the General Assembly support such measures as listed by priority in the recommendations below. These data improvements will not only bolster current groundwater management efforts, but will also assist in measuring the success of future groundwater management projects.

(6) Funding Needs and Options: The Committee proposes two funding options to ensure that DEQ has the necessary operational funds to successfully manage groundwater resources in the Commonwealth. The Committee's preference is for funding this effort through General Fund Appropriations. As a second alternative, and only if absolutely necessary, the Committee recommends a two-tier (based on households and businesses), capped, reasonable flat fee that would be applicable to both permitted and unpermitted users within the EVGMA.

Overall, the Committee has reached consensus on the set of recommendations contained in this report in response to the future challenges and groundwater management concerns in the EVGMA. Because of the severe impact that depleted groundwater resources would have on communities, the economy, and the overall environment of the EVGMA, inaction is not an option for the Committee. The Committee's recommendations throughout this report, and listed

below in brief, reflect the next steps needed to successfully and sustainably manage the groundwater and promote the development of other alternative water sources in the EVGMA.

Recommendations

- ***Recommendation # 1:*** Committee recommends that SWIFT and similar projects, including storage, recovery, and recharge projects, be supported by the Commonwealth as a significant part of the set of solutions pursued to improve groundwater sustainability in the EVGMA, subject to appropriate public health and environmental conditions as determined by VDH and DEQ in coordination with HRSD and in light of federal requirements.

- ***Recommendation # 2:*** Committee recommends that the Commonwealth promote the development of the list of alternative water sources and solutions included in this report, including solutions for public/private partnerships and potential funding for further evaluation and study of short-term and long-term alternative water sources and solutions.

- ***Recommendation # 3:*** Committee recommends lengthening the maximum groundwater permit term to fifteen years by changing the statutory language in Virginia Code Section 62.1-266(C), while maintaining the ability for the State Water Control Board to reopen and amend current permits to take changing groundwater availability into account throughout the permit term under Virginia Code Section 62.1-266(E).

- ***Recommendation # 4:*** Committee recommends that the General Assembly establish additional incentives for voluntary regional planning efforts that will proceed through Planning District Commissions working with DEQ.

- ***Recommendation #* 5:** Committee recommends that the General Assembly create incentives for local governments and well owners to connect to the public surface water systems when reasonably available, with possible credits to localities to help lower connection fees or to provide low cost financing.

- ***Recommendation #* 6:** Committee recommends that the General Assembly require new non-agricultural irrigation wells only from unconfined aquifers in the EVGMA where available and adequate.

- ***Recommendation #* 7:** Committee encourages the General Assembly to develop a statement of regulatory intent to encourage the use of ponds and stormwater ponds and to work to remedy the regulatory barriers in the development of irrigation ponds for agricultural purposes.

- ***Recommendation # 8:*** Committee recommends that DEQ, in cooperation with other agencies, establish an annual "State of the Water Resources" forum, open to the public, where all stakeholders are invited to discuss and learn about the status of the EVGMA's water resources.

- ***Recommendation # 9:*** Committee recommends that the General Assembly authorize DEQ to develop and implement a groundwater banking system.

- ***Recommendation # 10:*** Committee recommends that the General Assembly direct DEQ with a timeline and resources to create a framework in consultation with stakeholders for an EVGMA groundwater trading program to be submitted to the General Assembly.

- ***Recommendation # 11:*** Committee recommends that the General Assembly provide funding to ensure a robust groundwater management program because of the importance of groundwater resources in Eastern Virginia and the unsustainable rate of demand on the resource. The Committee believes that the following DEQ activities, at a minimum, should be provided sufficient funding to be implemented. At this time, the activities, in priority order, are:
    1) Update unregulated use estimation methodology for use on an ongoing basis
    2) Ensure ongoing model maintenance consistent with best professional practice
    3) Address gaps in hydrologic framework and water level monitoring network
    4) Provide operation and maintenance for Suffolk and Franklin extensometers
    5) Ensure funding to perform ongoing existing well network repair and maintenance
    6) Implement saltwater intrusion network
    7) Install new extensometer near West Point

- ***Recommendation # 12:*** Committee recommends that the General Assembly fund the essential operation costs of DEQ to successfully manage the groundwater resources, first through General Fund Appropriations, and second, if absolutely necessary, through a reasonable flat fee applied only to households and businesses in the EVGMA. If a fee is applied, the funding provided by the fee shall not result in any reduction of the general funds appropriated.

I. Eastern Virginia Groundwater Management Advisory Committee: Background and Process

During the 2015 session of the Virginia General Assembly, Chapter 262 was enacted establishing the Eastern Virginia Groundwater Management Advisory Committee (Committee) to assist the State Water Commission and Department of Environmental Quality (DEQ) in developing, revising, and implementing a management strategy for groundwater in the Eastern Virginia Groundwater Management Area (EVGMA).[1] This legislation was sponsored by Delegate Hodges in the House (HB 1924) and Senator Norment in the Senate (SB 1341). The legislation directed DEQ to appoint the members to the Committee to be composed of non-legislative citizen members consisting of representatives of industrial and municipal water users; representatives of public and private water providers; developers and representatives from the economic development community; representatives of agricultural, conservation, and environmental organizations; state and federal agencies' officials; and university faculty and citizens with expertise in water resources-related issues. The DEQ Director appointed 24 members to the Committee in June 2015. The Committee included high-level decision makers in the respective areas designated by the General Assembly. To carry out the Committee's work, five workgroups were formed to broaden participation in the process and to incorporate specialized and technical expertise. The membership of the Committee and its workgroups may be found in Appendix A.

The Committee was charged with examining seven subject areas, including:

> (i) options for developing long-term alternative water sources, including water reclamation and reuse, ground water recharge, desalination, and surface water options, including creation of storage reservoirs; (ii) the interaction between the Department of Environmental Quality's ground water management programs and local and regional water supply plans within the Eastern Virginia Groundwater Management Area for purposes of determining water demand and possible solutions for meeting that demand; (iii) potential funding options both for study and for implementation of management options; (iv) alternative management structures, such as a water resource trading program, formation of a long-term ground water management committee, and formation of a commission; (v) additional data needed to more fully assess aquifer health and sustainable ground water management strategies; (vi) potential future ground water permitting criteria; and (vii) other policies and procedures that the Director of the Department of Environmental Quality determines may enhance the effectiveness of ground water management in the Eastern Virginia Groundwater Management Area.[2]

[1] VA. CODE ANN. § 62.1-256.1 (2015).
[2] *Id.*

The Committee was directed to develop specific statutory, budgetary, and regulatory recommendations, as necessary, to implement its recommendations. The Committee used a collaborative problem solving process facilitated by the VCU Center for Consensus Building to address the issues set out in the legislation and to identify long-term solutions for the Commonwealth.

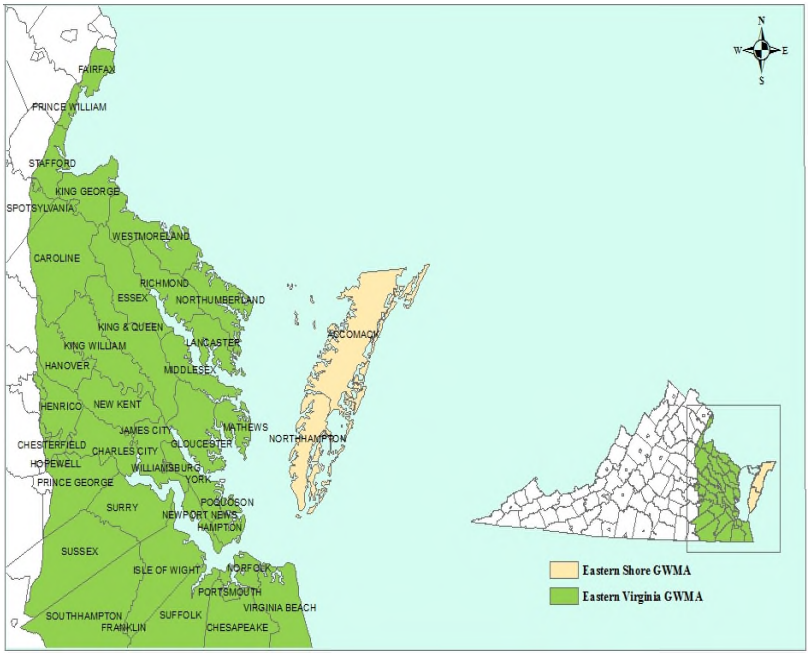
The Committee report must be provided to the DEQ Director by August 1, 2017. The DEQ Director must issue a report responding to the Committee's recommendations to the Governor, the State Water Commission, the Chairman of the House Committee on Agriculture, Chesapeake and Natural Resources, the Chairman of the Senate Committee on Agriculture, Conservation and Natural Resources, and the Joint Legislative Audit and Review Commission no later than November 1, 2017.

The Committee started meeting on August 18, 2015 and met 10 times through July 7, 2017. The Committee established five workgroups to examine subject matter identified in the legislation, including (1) Alternative Sources of Supply, (2) Alternative Management Structures, (3) Trading, (4) Options for Future Permit Criteria, and (5) Funding. These groups began working in the fall of 2015 and completed their investigations in December 2016. Combined, they met 36 times.

II. Introduction to Coastal Aquifer Water Level Declines

The Ground Water Management Act of 1992[3] authorized the State Water Control Board to designate Groundwater Management Areas (GWMAs) where groundwater levels in the area are declining; the wells of two or more groundwater users are interfering with one another; the available groundwater supply has been overdrawn; or the groundwater in the area is at risk of pollution.[4] Once a GWMA is designated, all withdrawals of 300,000 gallons per month or more must be permitted.[5] Currently, there are two GWMAs within the Coastal Plain province of Virginia: the Eastern Shore GWMA, which includes Accomack and Northampton Counties, and the Eastern Virginia GWMA (EVGMA), which is comprised of all areas east of I-95.[6] This report provides recommendations only for the EVGMA.

Evidence from DEQ, in conjunction with the U.S. Geological Survey (USGS),[7] concludes that the available groundwater supplies in the EVGMA are insufficient to meet the demands of current and future groundwater users. The Committee notes that the Joint Legislative Audit and Review Commission (JLARC) report confirms these findings that groundwater supplies are insufficient to meet the demands of current and future groundwater users in the EVGMA, but the Committee did not reach consensus on the recommendations outlined in the JLARC report.[8]



Groundwater Management Areas in Virginia as of August 2017

[3] VA. CODE ANN. §§62.1-254–270 (1992).
[4] VA. CODE ANN. § 62.1-257 (1992).
[5] VA. CODE ANN. § 62.1-258 (2015).
[6] By order of the State Water Control Board, Eastern Virginia is divided into two groundwater management areas: (1) the Eastern Virginia Groundwater Management Area (EVGMA), encompassing the counties of Charles City, Essex, Gloucester, Isle of Wight, James City, King George, King and Queen, King William, Lancaster, Mathews, Middlesex, New Kent, Northumberland, Prince George, Richmond, Southampton, Surry, Sussex, Westmoreland, and York; the areas of Caroline, Chesterfield, Fairfax, Hanover, Henrico, Prince William, Spotsylvania, and Stafford counties east of Interstate 95; and the cities of Chesapeake, Franklin, Hampton, Hopewell, Newport News, Norfolk, Poquoson, Portsmouth, Suffolk, Virginia Beach, and Williamsburg; and (2) the Eastern Shore Groundwater Management Area (ESGMA), encompassing the counties of Accomack and Northampton. 9 VA. ADMIN. CODE § 25-600-20 (2014).
[7] C.E. Heywood & J.P. Pope, *Simulation of Groundwater Flow in the Coastal Plain Aquifer System of Virginia*: *U.S. Geological Survey Scientific Investigations Report 2009–5039*115 (2009), http://pubs.usgs.gov/sir/2009/5039/.
[8] *See* JLARC, EFFECTIVENESS OF VIRGINIA'S WATER RESOURCE PLANNING AND MANAGEMENT (Oct. 2016),

Groundwater withdrawals will be more limited and costs may increase when demands exceed the supply of a given resource. These are expected natural consequences if no action is taken to improve current groundwater resources in the Coastal Plain. Since groundwater resources are of crucial importance to the health and welfare of the people in the EVGMA, and because the current situation is not sustainable, there is a great need for sufficient groundwater supplies to ensure public health, economic prosperity, and sustainable growth for business and industry in the region.

Groundwater in the Coastal Plain is of high quality and has generally low treatment costs. Coastal aquifers have significant lag time in natural recharge, resulting in low recharge rates that are currently thought to be much less than current withdrawals. This is believed to create the significant water level declines seen in these aquifers. Based on actual groundwater use reported in the 2016 Status of Virginia's Water Resources (using 2015 data); 62.4 MGD (82.5%) was used by permitted GWMA users, 13.2 MGD (17.5%) by reporting unpermitted GWMA users. Approximately 38.6 MGD (62%) of permitted withdrawals is for industrial uses. The remainder is mostly public water supplies.

DEQ reported that it had four overall management concerns:

(1) declining groundwater levels and loss of artesian characteristics,[9]
(2) increased potential for saltwater intrusion from gradient reversal and upconing,[10]
(3) accelerated rates of land subsidence, and
(4) irreversible loss of long-term aquifer storage.

As a result of these concerns, DEQ determined that reductions in permitted withdrawals were necessary. DEQ also sought legislation to help address unpermitted withdrawals, but that legislation was not enacted.[11]

Progress and Achievements of Stakeholder Efforts and DEQ Permitting

During the Committee's deliberations, DEQ continued to negotiate permit reductions with the remaining 12 of the 14 largest groundwater permittees. DEQ's goal was to reduce withdrawals to the point that rates of water level declines were held steady and that the identified "critical cells" were eliminated to the greatest extent possible by 2025. Critical cells are defined as grid

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http://jlarc.virginia.gov/pdfs/reports/Rpt486.pdf.

[9] This impact may lead to the possible increase in the number of "critical cells" in any of the coastal plain aquifers. "Critical cells" are model representations or observations of aquifer conditions where the water level has declined below the eighty percent of the "critical surface level." The "critical surface level" is the elevation of the potentiometric water level surface when eighty percent of the distance between the land surface and the top of the aquifer is removed.

[10] "Upconing" means the process by which saline water underlying freshwater in an aquifer rises upward into the freshwater zone as a result of pumping water from the freshwater zone.

[11] During the 2015 General Assembly session, Delegate Bulova introduced HB 1870, which would have evaluated groundwater withdrawals of subdivisions in a groundwater management area on a cumulative basis, thus subjecting subdivisions to permitting requirements.

cells in the DEQ VAHydro-GW groundwater flow model where water levels are predicted to fall below a level set as the regulatory standard. DEQ uses this model to evaluate the effect of existing permitted and estimated unpermitted withdrawals on water levels within the coastal plain aquifer system. DEQ modeling demonstrated that a collective evaluation resulted in less reduction than if results were analyzed on an individual basis. The necessary reduction from this collective evaluation was 57%.

The permittees and DEQ both came to the table committed to find ways to reduce groundwater withdrawals. The newly issued permits more closely reflect how these permittees actually operate and embody a number of new approaches. To the credit of all involved in these discussions, permittees looked seriously at how withdrawals could be reduced, ways to achieve greater efficiency, and considered how the water systems could be operated differently to reduce the overall impact to the aquifer system. Permittees invested significantly in additional alternative water source studies and system improvements. By working together toward a common purpose, significant progress was made toward achieving the goal of reducing groundwater withdrawals. With 12 permits issued and two drafted and in the public process, the collective permitted withdrawals have been significantly reduced. Maximum permitted use has been reduced from 146.54 MGD to 69.78 MGD, which is a 52.4% reduction. Modeling of these reductions indicates that rates of water level declines in the aquifer should be reduced system-wide and, in some cases, water levels should increase. The majority of critical cells in the Potomac and Piney Point aquifers will be eliminated. The Committee heard from DEQ that permit reductions alone would not solve the problem. But these results are expected to allow water levels to stabilize while alternative sources of supply are developed and aquifer replenishment projects implemented.

It is important to recognize that conditions of declining groundwater levels transpired under the current water withdrawal permitting and water supply planning statutory and regulatory framework,[12] and that additional challenges may arise in the future. Currently, the majority of unregulated users are individual landowners on an individual private well, who do not have access to a public water supply. Future challenges to sustainable use and management of groundwater within the EVGMA include:

- Increasing unregulated use (i.e., withdrawals of less than 300,000 gallons per month).
- Ensuring sufficient water is available to support economic growth without jeopardizing the achievement of groundwater management goals and the investments of existing users.
- Continuing inter-jurisdictional cooperation is essential to optimizing the use of the

[12] *See* Va. DEQ, *Groundwater Withdrawal Permitting and Fees*, http://www.deq.virginia.gov/Programs/Water/WaterSupplyWaterQuantity/WaterWithdrawalPermittingandCompliance/GroundwaterWithdrawalPermitsFees.aspx (last visited Mar. 24, 2017); Va. DEQ, *Water Supply Planning Program*, http://www.deq.virginia.gov/Programs/Water/WaterSupplyWaterQuantity/WaterSupplyPlanning.aspx (last visited Mar. 24, 2017).

resource. But there are institutional barriers to that cooperation, including the nature of water as a commodity and the competitive histories among localities. The ownership of existing reservoirs creates a market for surface water that does not optimize the use of surface water supplies over groundwater. Localities often cooperate on the development of new supplies. These relationships related to existing supplies are defined by contract negotiations between a buyer or seller.

- Developing alternatives to groundwater requires overcoming many financial and regulatory hurdles, along with the need to protect surface water resources.
- Increasing aquifer recharge in a safe, acceptable, and cost-effective manner creates another complex regulatory challenge with regard to project implementation and maintenance.
- Maintaining the effectiveness of the management program to meet the needs of communities requires finding resources to keep modeling tools current and transparent.
- Refining a management system that provides permitted users with stability to make cost effective long-term investment decisions, and allows the Commonwealth to adjust to new information about aquifer conditions.

In response to the groundwater management concerns and future challenges, the Committee developed a consensus set of recommendations for the management of groundwater and other alternative sources in the EVGMA. The set of recommendations includes specific statutory, budgetary, and regulatory changes. Traditionally in Virginia, groundwater has been treated as a free, public resource, where a well owner pays nominal costs to access the water and no cost to use the water. The Committee recognizes that contrary to the common assumption that there will always be groundwater for every person to freely use, groundwater is in fact limited. To ensure the public health, safety, and welfare, the authority for management and control of groundwater in the Commonwealth has been reserved to the state.[13] The Ground Water Management Act of 1992 declared "the right to reasonable control of all ground water resources within this Commonwealth belongs to the public . . . ."[14] The Ground Water Management Act also recognizes the need to preserve and protect existing groundwater uses.[15] With this statutory authority, the Committee acknowledged the need for the Commonwealth to create a stable regulatory process in which a level of certainty would allow for future economic investment balanced with the protection of water resources in Virginia. The overall intent is to sustainably

[13] *See,* VA. CODE ANN. § 62.1-44.4(1) (1970) ("[t]he right and control of the Commonwealth in and over all state waters is hereby expressly reserved and reaffirmed."); VA. CODE ANN. § 62.1-44.3 (2015) ("State waters" are defined as "all water, on the surface and under the ground, wholly or partially within or bordering the Commonwealth or within its jurisdiction, including wetlands."); VA. CODE ANN. § 62.1-44.36(1) (1972) (the responsibility of State Water Control Board in formulating policies shall "among other things, take into consideration but not be limited to the following principles and policies: (1) Existing water rights are to be protected and preserved subject to the principle that all of the state waters belong to the public for use by the people for beneficial purposes without waste . . . .").

[14] VA. CODE ANN. § 62.1-254 (1992).

[15] VA. CODE ANN. §§ 62.1-260, 261 (1992).

manage the resource so that it is productive and available to meet the human, industrial, agricultural, and environmental needs of the EVGMA. Because a significant amount of time is required to make measurable improvements to the aquifer, DEQ's early action on this matter gives the Commonwealth time to plan and implement meaningful, long-term solutions.

The Committee outlined the following goals to consider when evaluating solutions and providing recommendations for the current and future problems related to groundwater management in the Commonwealth:

- Minimize the potential for the return of, or increase in, the number of "critical cells."
- Halt or reduce the rate of land subsidence and restore elastic storage.[16]
- Minimize the potential for upconing or lateral saltwater intrusion resulting from groundwater pumping.
- Maintain groundwater availability to permitted and unpermitted users, while also allowing economic development to occur.
- Create regional-scale solutions, and encourage greater inter-jurisdictional cooperation to expand waters supplies through better distribution of available ground and surface waters.
- Provide a management system that supports cost-effective water infrastructure planning and investment.

[16] Elastic storage means groundwater storage ability or capacity that was lost to compaction that can be recovered (i.e., the storage area can be rehydrated and recovered).

III. Groundwater Management Subject Areas Examined and Recommendations

Short-Term and Long-Term Alternative Water Sources and Solutions

Alternative water sources and solutions include transitioning from groundwater to surface water resources where applicable, piloting innovative aquifer recharge projects to create a greater water supply in the EVGMA, and supporting water conservation and efficiency. The workgroups developed a list of potential alternative water source projects, identified the benefits, costs, actions needed to utilize such sources, described the feasibility of such projects, and provided examples of current projects. The workgroups recommended the list to the Committee, and the Committee adopts the list as a set of possible alternative sources. The workgroups developed a qualitative cost evaluation of the various water supply options that included a low-level, mid-level, and high-level rank associated with each option. The Committee also acknowledges that some of the ideas on the list are more viable than others, and some of the options may be more successful in certain areas of the aquifer than others.

Overall, in considering the options, the Committee stresses the need for public/private partnerships to facilitate the financing and development of short-term and long-term water supply projects. Financing alternative sources of supply can be daunting for individual localities and small water users due to limits in available financing, bonding capacity, and impacts to user rates. Even for larger private water well users, the costs can be overwhelming. The Committee further recommends, along with the following options, the need to identify options that foster innovation, including the use of new technologies.

Aquifer Recharge by Injection:

Purified Wastewater

Hampton Roads Sanitation District's Sustainable Water Initiative for Tomorrow (HRSD SWIFT) regional project is a purified wastewater aquifer injection project that is currently underway as a pilot project in Virginia (see a more detailed discussion below), and other potential local projects are being evaluated for New Kent and Hanover Counties. An aquifer recharge project is where tertiary treated wastewater is purified to drinking water standards through an advanced drinking water treatment plant and is injected into an aquifer. These systems utilize wells that pump water into the aquifer instead of withdrawing water. Projects of this kind are used successfully in many parts of the country and can create many benefits for the groundwater resources, including: (1) recharging the aquifer to increase water availability for consumptive use; (2) using a readily available source in most communities (i.e., wastewater); (3) potentially reducing pollutant loads currently being discharged into surface water; (4) potentially reducing land subsidence; and (5) utilizing the natural structure of the aquifer itself for distribution and storage. The cost associated with this type of project would be in the high-

level range. Using purified wastewater is based on a proven technology in other places (such as in Arizona, Texas, California, and Florida).

Actions that are typically taken to move forward with this type of project include: (1) pilot/demonstration study that could demonstrate the feasibility of operating this type of project in Virginia, along with determining the potential success to recharge the aquifer; (2) completion of an analysis of potential risks to the aquifer and human health; (3) coordination of government approvals, standards, and oversight, since the permitting for this type of project is currently done at the federal level (i.e., Underground Injection Control), and (4) public education.

HRSD's SWIFT project proposes to inject purified wastewater at seven of its existing treatment facilities across Hampton Roads. It is estimated that a total of 120 MGD of purified wastewater may be injected to recharge the aquifer.

The Committee believes that the SWIFT project meets the five goals it has set for any potential solution.

(1) The project injects approximately 20 MGD more water into the aquifer than is currently being withdrawn on a daily basis. This provides a solid basis for sustaining the aquifer into the future and, in conjunction with other measures, the project minimizes the potential for the aquifer to return to its current declining condition.

(2) The project reduces–and may possibly reverse–the rate of land subsidence, an important goal given that sinking land accounts for approximately half the sea-level rise recorded in Hampton Roads.

(3) The project provides protection to the groundwater from saltwater intrusion through re-pressurizing the aquifer along the coast, reversing the existing negative pressure gradient that has been created by the significant withdrawals for the past century.

(4) The project stabilizes the aquifer such that, in conjunction with other measures, groundwater availability is maintained for all users (i.e., residential, commercial, industrial, and agricultural) into the future.

(5) The project is inherently a regional-based water-quantity solution with additional water-quality and financial benefits across Hampton Roads. In addition to the injection sites being located across Hampton Roads, thereby broadly increasing the aquifer's volume, it will reduce HRSD's wastewater discharge by some 90% to the York and James Rivers. Elimination of such significant wastewater discharge will allow for no-cost nutrient-

reduction credits to nearly a dozen localities, thereby saving hundreds of millions, if not billions, of dollars in localities' Chesapeake Bay TMDL[17] compliance costs.

While the Committee recognizes SWIFT is still in the developmental stage with several hurdles to overcome, the technologies to purify wastewater to meet drinking water standards are well proven across the U.S. and around the world and recharging aquifers for locally available storage and groundwater augmentation has been successfully accomplished for decades, including in the Potomac aquifer by the City of Chesapeake. Based on SWIFT's proposed implementation of these proven technologies, the Committee recommends SWIFT be supported by the Commonwealth as a significant part of the set of solutions pursued to improve groundwater sustainability in the EVGMA, subject to appropriate public health and environmental conditions.

While highlighting SWIFT as a significant part of the long-term solution to improving groundwater sustainability, the Committee acknowledges that the SWIFT project will be subject to certain regulatory approvals. The Committee also recommends that in addition to regulatory approvals, the Commonwealth develop an oversight and monitoring program for any aquifer augmentation project (as was done with the Occoquan Watershed) to ensure long-term protection of the water quality within the EVGMA ensuring environmental and public health safety for future generations. The Virginia Department of Health (VDH) is currently working with DEQ to evaluate mechanisms for ongoing oversight of injected water quality. The focus of this effort is to provide public assurances that injected water meets the highest water quality required by law.

Recommendation # 1: Committee recommends that SWIFT and similar projects, including storage, recovery, and recharge projects, be supported by the Commonwealth as a significant part of the set of solutions pursued to improve groundwater sustainability in the EVGMA, subject to appropriate public health and environmental conditions as determined by VDH and DEQ in coordination with HRSD and in light of federal requirements.

Surface Water

Aquifer recharge projects inject treated surface water into the aquifer, rather than wastewater as in the previous example. The benefits of this type of project may include: (1) recharging the aquifer to increase water availability for consumptive use; (2) using an available source (surface water); (3) potentially reducing land subsidence; and (4) utilizing the natural structure (the aquifer itself) for distribution and storage. The potential cost, depending on whether new

[17] TMDL (Total Maximum Daily Load) is a term defined under the Clean Water Act as a starting point for restoring water quality; it establishes the maximum amount of a pollutant allowed in a particular waterbody.

construction is needed, is estimated between the low to mid-level ranges. Using purified surface water for injection is a proven technology in other places. A means to recover the costs would be needed.

In Virginia, the City of Chesapeake for years has used the Northwest River aquifer storage and recovery (ASR) well as a closed-loop aquifer recharge system, in which treated surface water is injected into the aquifer for long-term storage to meet peak demands.

Existing Impoundments and Quarries:

The use of existing impoundments or converting existing quarries to reservoirs may provide another viable option as an alternative supply of water. Some existing impoundments are not currently being used as water supplies and may be converted to water supply use. In other cases, existing reservoirs that are used for water supply may be able to be expanded to increase the available water supply. The Committee felt that these types of solutions are worthy of further exploration by localities and the private sector to help diversify the available water supply alternatives to groundwater. The benefits to this type of water source include: (1) utilizing the already-existing infrastructure, (2) minimizing environmental impacts, and (3) reducing the demand for groundwater. The potential cost, depending on whether new construction is needed, is estimated between the low to mid-level ranges. The feasibility of using existing impoundments and quarries to hold surface water depends on the proximity of such features to the area where the water is needed. In addition, most quarries are located near the Fall Line so they may not be a cost effective alternative to meet the water demands in the EVGMA. However, if a suitable location is found, then feasibility is high, based on proven technology.

Actions typically needed to move forward with such a project include: (1) applying for a surface water withdrawal permit; (2) obtaining easements or title to be able to use the quarries, impoundments, and reservoirs; (3) determining whether the impoundment/quarry is watertight; and (4) completing a thorough chemical analysis of the source water to ensure its treatability. In Virginia there are several examples of converting existing quarries into reservoirs for alternative water sources including projects in Loudoun County, Fairfax County, and the City of Richmond. There is also a project underway in Hanover County. Additionally, an innovative example of an existing privately-owned impoundment that has applied for a water withdrawal permit is Cranston’s Mill Pond in James City County. The water from the impoundment may result in much lower, long-term treatment costs compared to treating brackish water from other surface water sources.

New Surface Water Reservoir:

Constructing a new surface reservoir could be used in place of groundwater, but the cost is estimated between the mid to high-level range, because of the impacts to streams and wetlands that are caused by such projects and the mitigation costs associated with offsetting those impacts (depending on the location). The feasibility of developing a new surface water reservoir is dependent upon many factors, including: (1) impacts to streams, wetlands, and riparian lands; (2) proximity to the water source in relation to the demand for the water; (3) public acceptance of locating a facility in their community; (4) the ability to find cost-share partners to cover the costs for such a significant construction project; and (5) the flat topography of the eastern half of the management area provides few locations to create impoundments. These projects often exceed $250 million and there are few communities that are able to bear these costs alone.

Actions typically needed to move forward with this type of project include obtaining the appropriate environmental permits for the construction and maintenance of the project. Current projects underway include Cobb's Creek Reservoir in Henrico County and permitted projects for reservoirs in both Greene and Greensville Counties.

Surface Water Withdrawal:

Surface water could be used instead of groundwater to reduce the demand for groundwater. The cost ranges from low to high, depending on the quality, need for treatment, and the location of the water source. In some areas of the EVGMA, surface water is brackish and would require significantly greater treatment. Surface water sources may also not be as feasible to use as an alternative water source if the increased withdrawals will negatively affect aquatic life, and importantly, the reliability of the resource since it is more affected by short and long-term droughts compared to the previous options.

Actions needed to use surface water as a replacement for groundwater include: (1) obtaining the appropriate environmental permits; (2) construction of a water treatment plant and infrastructure for distributing the treated water; and (3) gaining local public acceptance of any impacts associated with the project construction and withdrawal**.** Current surface water withdrawal permitting actions are underway in James City County and New Kent County.

Groundwater from the Crystalline Bedrock Aquifer:

Although the workgroup did not consider it, the Committee received a presentation on use of groundwater in the crystalline bedrock aquifer as another potential groundwater resource.[18] The

[18] Kenneth E. Bannister & Bradley A. Fitzwater, *Groundwater Supply from the Crystalline Bedrock of the Virginia Coastal Plain*, DRAPER ADEN ASSOCIATES (June 8, 2017).

alternative of drilling deeper into the crystalline bedrock beneath the Coastal Plain sediments was introduced to the Committee very late in the process. The Committee recommends that this proposal be further investigated to determine its feasibility, including the costs and benefits. According to a preliminary consultant report, the cost for such a groundwater study could range from two million to six million dollars, but wells drilled for the study could be used as water supply wells if a viable water supply is located.[19] This study could involve DEQ and Department of Mines, Minerals and Energy (DMME).

Water Conservation and Efficiency:

The Committee and the various workgroups recognized the potential for reducing overall water demand by looking at opportunities for demand side reductions. These types of reductions typically take the form of eliminating leaks and improving water efficiency. The Committee heard about the overall reductions in municipal demand seen in most municipalities by the replacement of old plumbing fixtures and appliances with new more efficient toilets, shower heads, dishwashers, and clothes washers. Further, it was noted that new homes are much more water efficient than older housing stock which may have the effect of lower actual water use going forward than expected demand. On the industrial side, the Committee heard of the numerous efforts that industry is undertaking to reduce their water use footprint with at least one company leading their industry in water use per ton of product produced. The Committee was presented with other areas of water conservation efforts, as explained below.

Infrastructure (Potable Water) Enhancements

Evaluating greater regionalization of drinking water systems by enhancing and increasing the capacity of current municipal water systems is another option that may reduce the demand for groundwater, increase the reliability of the water supply by using available water, support economic development in local communities, and create opportunities to even out water rates. The costs for these types of projects are contingent on the type of project, ranging from low-level improvements to high-level improvements. Depending on the level of enhancement, a local scale project may be more feasible than a regional scale project. Funding may be challenging, as recovering the costs would typically require rate increases. Not only would capital costs be required, but also there would be a need for long-term maintenance.

Actions needed to move forward with this type of project include: (1) establishment of an alternative management structure; (2) acquiring the political support; and (3) incentivizing public/private partnerships. Projects underway in Virginia include projects in the City of Newport News and York County.

[19] See *id.*

Reducing Water Losses in Water Distribution Systems

Water loss from an aging infrastructure translates in Virginia to between 19 MGD to over 24 MGD of potable groundwater that is potentially lost per day.[20] According to the information submitted to DEQ in water supply plans, the reported metered water losses ranges from 3.95% - 22.66% of water produced. Other localities or community water systems not actively metering provided estimates within this range but they could be higher. Thus, improvements to water distribution systems, to reduce losses could reduce demand for groundwater, primarily for municipal withdrawals.[21] The costs for implementing such projects would be high-level improvements. EPA stated that Virginia needed $6.7 billion over the next 20 years just to maintain its drinking water infrastructure throughout the Commonwealth.[22] About 67% of that total, or about $4.5 billion, was needed for transmission and distribution mains across the Commonwealth.

Actions needed to move forward with these types of infrastructure projects include: (1) continuing to require entities to develop and implement a Water Conservation and Management Plan under Virginia's State Water Control Law and Groundwater Withdrawal Regulations; (2) continuing to require Permittees in the EVGMA to complete a water audit within the second year of a permit or for a reissued permit for an existing user; (3) creating more detailed specifications in the regulations regarding the implementation of a "leak detection and repair program" required by all permittees in the EVGMA; and (4) establishing a standard for an acceptable water loss rate in the Code of Virginia.

Recommendation # 2: Committee recommends that the Commonwealth promote the development of the list of alternative water sources and solutions included in this report, including solutions for public/private partnerships and potential funding for further evaluation and study of short-term and long-term alternative water sources and solutions.

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[20] *See* AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE), 2017 INFRASTRUCTURE REPORT CARD 36–41 (2017), https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/2017-Infrastructure-Report-Card.pdf. This report card only looked at the drinking water industry. It did not take into account industrial, commercial or other entities that are not regulated by the Safe Drinking Water Act. According to the report card, approximately 14% to 18% of the water produced is lost to leaky, aging pipes across the US (i.e., nearly six billion gallons of treated drinking water lost per day). Using 14% to 18% as a baseline and looking at the total permitted withdrawal for last year in the Annual Water Resources Report, from 2011-2015, the average groundwater withdrawal over the course of that five year period was about 135 MGD just from permitted users (14% of that number is about 19 MGD, while 18% would be over 24 MGD).

[21] The Committee heard from some Committee members that new technologies for infrastructure enhancements such as plastics vs. ductile iron might help improve water distribution systems. *See* PLASTICS PIPE INSTITUTES, INC., FREQUENTLY ASKED QUESTIONS: HDPE PIPE FOR WATER DISTRIBUTION AND TRANSMISSION APPLICATIONS (2009), http://plasticpipe.org/pdf/tn-27-faq-hdpe-water-transmission.pdf.

[22] *See* EPA, DRINKING WATER INFRASTRUCTURE NEEDS SURVEY AND ASSESSMENT (April 2013), https://www.epa.gov/sites/production/files/2015-07/documents/epa816r13006.pdf. When EPA starts looking at drinking water infrastructure maintenance and replacement issues to determine how much funding is needed, they do a "needs assessment."

Changes in Permitting Criteria

Permit Terms for Permitted Users

Although the Committee thoroughly discussed the current permitting system, no consensus was reached on a different approach, and no better alternative was proposed. Instead, the Committee evaluated options for enhancing the current permitting program. One issue is the need for greater certainty in making long-term infrastructure investment decisions. If permits can be changed dramatically every 10 years, then long-term capital assets (e.g., 20 to 30 year investments) could potentially be stranded and be ineffective in 10 years. The challenge for the Commonwealth is how to make management decisions based on new information and understanding of resource conditions, while minimizing the impact on capital investments made by permittees. Currently, the maximum groundwater permit term is 10 years as specified in Virginia Code Section 62.1-266(C). The Committee recommends lengthening the permit term to 15 years. This change would create additional certainty for permittees, including the certainty necessary when large capital investments are required for implementation of water conservation, recycling, or other beneficial projects. This change would also create consistency of permit terms for both surface and groundwater, since the term for surface water withdrawal permits is currently 15 years.[23] Groundwater withdrawal permit fees may need to be adjusted accordingly to cover the costs of a longer permit term. Revenue generated from groundwater permit fees fluctuates dramatically on an annual basis and longer permit terms would be expected to exacerbate this condition.

Additionally, the Committee recommends maintaining the ability of the State Water Control Board to amend and revoke permits as presently allowed in Virginia Code Section 62.1-266(E), and to review and modify such permits.[24] Virginia Code Section 62.1-263 outlines the criteria for such amendments, including in part, taking into account the supply of groundwater available and possible water supply alternatives, which the Committee explored in section III (A) of this report.

Recommendation # 3: Committee recommends lengthening the maximum groundwater permit term to fifteen years by changing the statutory language in Virginia Code Section 62.1-266(C), while maintaining the ability for the State Water Control Board to reopen and amend current permits to take changing groundwater availability into account throughout the permit term under Virginia Code Section 62.1-266(E).

[23] 9 VA. ADMIN. CODE § 25-210-185 (2001).
[24] 9 VA. ADMIN. CODE § 25-610-310 (1993).

Integration of Planning and Permitting

Both the Alternative Management Structures Workgroup and the Permitting Criteria Workgroup discussed incorporating regional consideration into the permitting process. Neither workgroup reached consensus on how to do so, and a particular concern was whether doing so would lengthen the permit application and DEQ review process. The current permitting process is completed on a "first come, first served" basis. The Committee discussed how a broader perspective of the region could be considered in the permitting process. A regional perspective would allow for a more holistic view of the resource and how it is allocated. There is a perceived benefit to having permits reviewed in a concurrent manner so that opportunities to optimize the use of available supply could potentially also translate to aquifer benefits. Theoretically, increases in allocation could be forgone if there could be cooperation to better distribute and share available supply to meet regional needs. This would benefit the aquifer by minimizing increases in aquifer stresses over time. The Committee did not make a consensus recommendation on this issue.

The Committee received information suggesting that incentivizing regional planning could enhance the Local and Regional Water Supply Planning process. Regional planning is allowed under existing regulations but is a local option and in most cases where a regional planning approach was pursued it was not conducted in a meaningful way. There was discussion that perhaps in areas where the resource could be optimized or used more efficiently, the Commonwealth might insist on a regional approach. The Committee recommends continuation of the voluntary regional planning effort with some enhancements. A regional planning effort could proceed through Planning District Commissions working with DEQ in order to make a regional determination as to where both surface and groundwater resources exist in relation to needs. An example of such regional planning can be seen in the ESVA Groundwater Committee. One member of the Committee also presented information to the Committee about incorporating a planning component into the current permitting statute, as included in Appendix F. Although no consensus was reached on amending the current permitting statute, the Committee supported ongoing consideration of ways to incorporate planning for more efficient groundwater use (see proposal discussed but not endorsed by the Committee in Appendix F).

Recommendation # 4: Committee recommends that the General Assembly establish additional incentives for voluntary regional planning efforts that will proceed through Planning District Commissions working with DEQ.

Unpermitted Users

Unpermitted users are those who are not required to obtain a groundwater permit if withdrawing less than 300,000 gallons per month.[25] VDH manages the permitting of individual private wells. They reported that approximately 275,000 to 300,000 homes are served by private wells in the EVGMA.[26] In addition it was reported that 2,115 new private wells were drilled in the GWMA in FY 16.

VENIS Data: GWMA Locality Total Well Permits (FY 16)				
Accomack – 2410 (108)	Caroline – 786 (31)	Charles City – 161 (15)	Chesapeake – 1970 (174)	Chesterfield – 782 (45)
Essex – 410 (13)	Gloucester – 1751 (98)	Hampton – 387 (18)	Hanover – 1690 (177)	Henrico – 806 (61)
Isle of Wight – 868 (16)	James City – 555 (54)	King & Queen – 265 (20)	King George – 710 (55)	King William – 528 (55)
Lancaster – 311 (13)	Mathews – 741 (4)	Middlesex – 637 (43)	New Kent – 315 (36)	Newport News – 137 (4)
Northampton – 1326 (93)	Northumberland – 701 (40)	Poquoson – 64 (1)	Prince George – 514 (31)	Prince William – 855 (69)
Richmond – 36 (7)	Southampton – 676 (24)	Spotsylvania – 1967 (117)	Stafford – 1534 (161)	Suffolk – 1514 (55)
Surry – 174 (20)	Sussex – 261 (7)	Virginia Beach – 7027 (416)	Westmoreland – 268 (17)	Williamsburg – 16 (0)
York – 427 (17)				

VDH also provided data to the Committee on the reported purpose for each of these private wells contained in the VENIS dataset for the EVGMA (the wells approved in 2016 are shown in

[25] VA. CODE ANN. § 62.1-259 (1992).

[26] This estimate came from a review of census data, VENIS data (the VDH database), and estimates for the existing digital data gap (1990 to 2003) that exists only in paper files in local health departments. These estimates do not include non-potable wells. VDH estimates that 27,500 wells were installed in EVGMA during this time (1990 to 2003). In addition, there are 33,580 well records in VENIS for EVGMA from 2003 to present.

parentheses). VDH requires that the purpose of the well be stated at the time of application. The information provided on the purpose of these wells is shown in the table below.

VENIS Data: GWMA Well Purpose (FY 16)

Purpose	# of Wells in VENIS Database	% of Total	# of New Wells in FY16
Abandonment	90	0%	0
Agricultural	140	0%	9
Drinking Water	23,632	67%	1,498
Geothermal	1,581	4%	153
Industrial	76	0%	6
Irrigation	9,570	27%	448
Other	154	0%	1
Total	35,243	100%	2,115

VDH's public water system program uses 100 gallons per day per person per household (or alternately 400 gallons per day per residential connection) for demand projections. DEQ reports actual reported groundwater use is holding consistently at about 180-200 gallons per day per household in the EVGMA. As much as twenty percent of the household groundwater usage is used for residential irrigation.

Based on a USGS study published in 2008, it was estimated that the cumulative amount of unpermitted groundwater use in the EVGMA was 29 MGD.[27] This value is used today as the estimated unpermitted use in DEQ's groundwater model. A preliminary investigation of private well permits issued in the GWMA since 2008 indicates an increase, on average, of approximately 1,500 new private wells permitted by VDH annually. Review of this data indicates that the use type assigned to these wells has remained generally proportional each year. Based on estimated usage by use type (irrigation, drinking water, etc.) this annual increase equates to additional demands of approximately 1 MGD per year, creating an estimated additional 10 MGD of use not included in the 2008 estimate of unpermitted withdrawals incorporated in DEQ's groundwater model. The total volume of unpermitted withdrawal is an estimated 39 MGD in 2016. If these trends continue, unpermitted use is projected to approach

[27] J.P. Pope, E.R. McFarland, & R.B. Banks, *Private domestic-well characteristics and the distribution of domestic withdrawals among aquifers in the Virginia Coastal Plain: U.S. Geological Survey Scientific Investigations Report 2007–5250* (2008), http://pubs.water.usgs.gov/sir2007-5250.

the actual reductions in permitted use recently accepted by permittees by the end of their current permit term (2027).

Even though unpermitted users impact the health of the aquifer, the withdrawals of these users are not managed under current law. Efforts by permitted users to reduce consumption are not enough to restore the aquifer for the long term in the absence of a way to address the concurrent impact that unpermitted users have on groundwater resources. The Committee generally supported the notion that these users bear a proportionate responsibility to maintain aquifer productivity and availability into the future.

The Committee discussed, but did not endorse, several options for addressing the challenge of unpermitted use of the groundwater supply, including:

(1) Requiring new construction, both residential and commercial, to connect to a reasonable surface water system (i.e., incentivizing public water supplies to be tied to public surface water supply) when available within 300 feet or less, setting a floor for local government ordinances. The Committee also discussed that requiring a connection fee should be reasonable in comparison to the cost of drilling a well.
(2) Creating incentives for existing agricultural and residential groundwater users to connect to public surface water supplies when available.
(3) Establishing an incentive for private well users who are dependent on the aquifer with no other alternatives available to replace plumbing fixtures to modern/efficient standards.
(4) Requiring that residential and commercial irrigation wells use only unconfined aquifers. Agricultural irrigation wells would be exempt from this requirement, but should still be encouraged to use unconfined aquifers where practical.
(5) Encouraging the use of reclaimed water and/or stormwater for irrigation purposes where practicable, while still meeting all safety standards and regulations. Accordingly, real or perceived regulatory barriers need to be assessed in the Section 404 and VWP permitting process in order to encourage the development of irrigation ponds for agricultural purposes as an alternative to groundwater.
(6) Creating a feedback mechanism on the status and health of the aquifer, as a means for public education and outreach about the importance of this resource. For example, the Eastern Shore Groundwater Committee of Virginia completes an annual state of the aquifer report to educate the community and draw awareness to the health of the aquifer.[28] More information on this subject can be found in section III (C).

[28] *See Publications and Resources*, ACCOMACK-NORTHAMPTON PLANNING DISTRICT COMMISSION, http://www.a-npdc.org/accomack-northampton-planning-district-commission/ground-water-management/publications-resources/. (last visited July 17, 2017).

Recommendation # 5: Committee recommends that the General Assembly create incentives for local governments and well owners to connect to the public surface water systems when reasonably available, with possible credits to localities to help lower connection fees or to provide low cost financing.

Recommendation # 6: Committee recommends that the General Assembly require new non-agricultural irrigation wells only from unconfined aquifers in the EVGMA where available and adequate.

Recommendation # 7: Committee encourages the General Assembly to develop a statement of regulatory intent to encourage the use of ponds and stormwater ponds and to work to remedy the regulatory barriers in the development of irrigation ponds for agricultural purposes.

Alternative Management Structures

The Alternative Management Structures Workgroup and the Committee evaluated the current groundwater management system and explored various examples of water management systems for other water bodies in Virginia and in other states to identify the components of an "ideal" water allocation framework. Among the components identified and presented to the Committee were:

- The need for one entity responsible for maintaining the data and determining what is needed to protect the resource.
- The need for a more robust planning process that is fully integrated with the permitting process.
- The need for predictability.
- The need for greater stakeholder involvement and consideration of groundwater as a shared regional resource.
- The need for a "One Water" concept. Groundwater, surface water, and stormwater all impact water availability, and developing a platform that considers all water sources would be helpful. One Water concept is typically defined as water from all sources should be managed cooperatively to meet economic, social, and environmental needs.
- The need for fairness/equity is important in the water allocation process, and it is important to understand how these concepts mean different things to different stakeholders.

The Committee discussed all the options listed below, but adopts only option number five. These options included:

(1) Formation of a Water Management District or other Regional Governing Body
(2) Regional Commission[29]
(3) Formation of a 501(c)(3)
(4) Extension of the Eastern Virginia Groundwater Management Advisory Committee

[29] One example in Virginia discussed by the Committee that may also provide a framework for a regional water management district is the Eastern Shore Groundwater Committee of Virginia. In 1990, that committee was formed by Accomack and Northampton Counties to study and plan for groundwater protection. The eleven-member committee meets monthly and includes elected officials, citizens, and local government staff. The Planning District Commission staffs that committee, and a consulting hydrologist advises the committee, prepares technical reports, and coordinates with the DEQ and USGS. That committee provides comments on groundwater permits during the development phase and provides input to DEQ. Along with comments, that committee maintains a Regional Groundwater Management Plan and engages the public through education and outreach. That committee's mandate is to "assist local governments and residents of the Eastern Shore in understanding, protecting and managing groundwater resources, to maintain a groundwater resources protection and management plan, to serve as an educational and informational resource to local governments and residents of the Eastern Shore, and to initiate special studies concerning the protection and management of the Eastern Shore groundwater resource." *See* ACCOMACK-NORTHAMPTON PLANNING DISTRICT COMMISSION, www.a-npdc.org/accomack-northampton-planning-district-commission. (last visited July 17, 2017).

(5) Annual "State of the Water Resources" Meeting

The Committee recommends implementation of an annual "State of the Eastern Virginia Water Resources" forum and report. This forum would be open to the public and create a voluntary mechanism for communication and dialogue among regulators and stakeholders, including transparency and a greater understanding of the DEQ groundwater model. The Committee recognizes that stakeholder involvement is critical. The hope is that this type of forum would not only inform those involved in the permitting process, but also create a collective view and provide a space for dialogue for stakeholders and citizens on the overall status of Eastern Virginia's water resources. A forum on the actual state of water resources, and the aquifer in particular, may also help stakeholders and the public understand the rationale behind setting particular goals and limits on groundwater usage. Such a forum could build upon DEQ's current annual reports (i.e., "Total Permitted Scenario" and the "Status of Water Resources in the Commonwealth").[30] The Committee concludes that the current management process is sufficient at the moment, but elevating awareness of the challenges, creating a forum for communication, and providing a space for dialogue among the stakeholders and regulators is a critical first step to making the necessary improvements and to encouraging buy-in for future management.

Recommendation # 8: Committee recommends that DEQ, in cooperation with other agencies, establish an annual "State of the Water Resources" forum, open to the public, where all stakeholders are invited to discuss and learn about the status of the EVGMA's water resources.

[30] *See* VA. DEQ, STATUS OF VIRGINIA'S WATER RESOURCES: A REPORT ON VIRGINIA'S WATER RESOURCES MANAGEMENT ACTIVITIES (OCT. 2016), http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterSupplyPlanning/Final_AWRR_2016.pdf; VA. DEQ, 2014-2015 ANNUAL SIMULATION OF POTENTIOMETRIC GROUNDWATER SURFACE ELEVATIONS OF REPORTED AND TOTAL PERMITTED USE (Sept. 2015), http://www.deq.virginia.gov/Portals/0/DEQ/Water/GroundwaterPermitting/DocumentsandForms/2014-2015AnnualSim-ReportedUseandTotalPermitted.pdf.

Groundwater Trading and Banking

The Committee discussed and evaluated several ways in which groundwater trading programs could be used to create incentives to conserve, manage, and/or allocate groundwater supplies in the Commonwealth. Groundwater trading and banking programs provide groundwater users various degrees of flexibility in how to share and manage scarce water supplies. The Committee reviewed a variety of ways groundwater trading and banking programs have been implemented in the United States and Australia.

In general, two different types of groundwater trading programs were discussed. The first type of trading program provides existing and additional users with some flexibility on how to share groundwater through the existing state permitting process. In this type of program, DEQ maintains responsibility for determining how much water each permitted user may withdraw during a 10 (or 15) year permit cycle and whether new users would be issued a permit to withdrawal groundwater in a fully allocated system. Once permitted withdrawals are established, permitted users could transfer portions of permitted withdrawals to existing or new users. The Committee also considered how the Commonwealth could grant groundwater users credit for injecting and temporarily storing groundwater underground for future use.

The second approach to groundwater trading is a more comprehensive market-like allocation system. Such a system would require the Commonwealth to determine the overall amount of groundwater available, but the groundwater users decide through a market exchange how groundwater would be allocated among users. New or expanding users could secure or increase groundwater withdrawals by purchasing allocations from other users. Such a system would replace a DEQ-based permitting system.

In the short-term, the Committee recommends the establishment of a groundwater banking framework (outlined below) as a mechanism for aquifer storage and recovery (ASR). A "strawman" framework for such a program is included in Appendix H. This banking concept allows DEQ to grant a groundwater credit to any party that injects water into the coastal aquifer for water storage and recovery within the existing groundwater management areas. This credit would be considered as an addition to a groundwater allocation granted under the normal permitting process. Other states, including Arizona, Nevada, New Jersey, Delaware, Florida, Kansas, and North Carolina, have adopted and implemented various ASR programs (see Appendix G for a summary). These programs were explored by the workgroups as examples of how to create such a program in Virginia and led to the proposal included in this report.

While the Committee recognizes that a broader trading program could offer incentives to economize on water use and to develop alternative sources, it would require significant statutory and regulatory changes. Although the Committee discussed the possibility of Virginia implementing a market-based allocation system (based on the comprehensive water

management system in Australia), due to the complexity of such a program the Committee does not recommend a particular trading system at this time. The Committee urges the General Assembly to continue to evaluate trading systems, since the Committee recognizes that a trading system is an important concept that will take time to develop.

Groundwater[31] Banking for Aquifer Storage and Recovery

The Committee recommends draft language for a groundwater banking system that could be implemented within the existing groundwater management area permitting system, and DEQ would be expected to complete the following actions. Under this recommendation, within existing groundwater management areas, DEQ would grant a *groundwater storage credit* to any party that injects treated water into the coastal aquifer for purposes of using the aquifer for water storage and recovery. Currently, such a banking system could apply in existing or planned projects, including the City of Chesapeake, and potentially the HRSD SWIFT Project. A groundwater storage credit is the total quantity of injected water authorized to be recovered from the aquifer. Credit available for use in a given year would be equal to the remaining injected water at the end of the previous year multiplied by the recovery factor,[32] examples of recovery factors adopted in other states can be found in Appendix G. Credit would be deposited into the permittee's groundwater storage account that would be maintained and published annually by DEQ for any permittee holding groundwater storage credit and retired when authorized water is recovered.

A groundwater credit would be considered additional to a groundwater allocation granted under a groundwater withdrawal permit. Groundwater allocations should not be reduced based on injection activity of the permittee. Overall, the credit would be based on the scale and location of the injection. A well injection permit would be required before any water is injected into the Virginia aquifers.

For the first year, the recovery factor would be 1 (i.e., 1:1 injected to recovery rate). But for injected water that may be withdrawn across multiple years, the recovery factors will be based on estimated *annual aquifer losses*[33] using the groundwater model. Guidelines for estimating aquifer losses would be published and updated by DEQ. To provide for some certainty in planning, DEQ would establish predetermined limits for the recovery factor.

A recovery factor schedule covering 15 years will be established by DEQ. To promote predictability once established, the 15-year schedule will not be modified. At the end of the 15-

[31] For the purposes of this report, injected groundwater is defined as treated water that is injected into an aquifer in the Eastern Virginia and Eastern Shore Groundwater Management Areas.
[32] "Recovery factor" here refers to the annual fraction of the remaining injected water that is available for recovery by a permittee and is calculated as one minus the annual water loss rate.
[33] The water loss rate is the rate at which the injected water is lost for recovery.

year period the schedule will be re-evaluated and the recovery factor may be revised based on new information. Generally, annual recovery factors contained in the recovery factor schedule may vary across time. For instance, the recovery factor may increase over time if annual loss rates are not constant over time. DEQ may establish maximum annual limits on the rate of withdrawal from recovery wells. Groundwater monitoring is critical in developing the recovery factor and the recommendations outlined in section III (E) of this report must be considered for the success of a banking/trading system. Additionally, the General Assembly could authorize that a portion of the injection volume be set aside for aquifer recovery.

Recovery can occur either on-site or off-site of the injection location. The spatial recovery zone[34] will be delineated during the permitting process. DEQ will develop guidelines for defining the spatial recovery zone since the size and location of the injection is relevant in the permitting process and must be implemented into the modeling process. The spatial recovery zone will be defined to the maximum practical extent and subject to reasonable expectations that no adverse impacts will be imposed on the groundwater resource. The "spatial recovery zone" will be re-evaluated every 15 years. Groundwater storage credits may be transferred to another party within the spatial recovery zone.

Recommendation # 9: Committee recommends that the General Assembly authorize DEQ to develop and implement a groundwater banking system.

Groundwater Trading as Part of a Water Management System

The Committee recognizes that although a comprehensive groundwater trading process may not need to be implemented currently, it could have value to foster innovation, private investment and alternative supplies, particularly if groundwater supplies in the groundwater management areas remain scarce in the future. As such, a more comprehensive market-like groundwater allocation system should be considered further. Therefore, the Committee recommends that the General Assembly establish a timeline and resources to create a body that would evaluate comprehensive groundwater trading designs for Virginia, along with giving DEQ the appropriate authority and resources to develop the modeling necessary to support such a trading program. Since Virginia has a nutrient-trading program, the Committee suggests that lessons might be learned from this previous process regarding trading.[35] Also, the Committee agrees that the possibility of conservation and efficiency credits and credits for switching to non-groundwater sources be considered by DEQ in the permitting process.

[34] The recovery zone refers to the area within the spatial boundary (i.e., the size and location of the injection) from which injected water recovery is authorized.

[35] The Commonwealth has a decade of experience with nutrient trading in the Chesapeake Bay Watershed that may be informative to the groundwater trading process. *See* VA. CODE ANN. § 62.1-44.19:12 (2005).

The Commonwealth can benefit from the successful design and implementation of water allocation systems implemented in other states and countries. For example, the workgroup analyzed the Australian model, in which trading plays a part in a comprehensive water management system. The Australian model is a government-led planning process that identifies the total amount of water available for withdrawal for consumptive use after determining what needs to be available for environmental purposes. The government then issues "shares" (i.e., "water access entitlements") of the total available volume of water. This share is expressed as a percentage of the total available water. The percentage cannot be reduced but the government can change the amount of total available water based on changing conditions and science. The share cannot be modified without the consent of the shareholder. The share is recognized as a secure asset owned by the holder of the share. It can be subdivided, amalgamated, traded or used as collateral. The total amount of water permitted to be withdrawn by the shareholder in a specific period of time is a "water allocation," which is determined by the total available water for withdrawal and the share owned by the withdrawal shareholder. This allocation can be traded, banked or carried forward. The government establishes the rules for all trading processes. The Committee discussed how the Australian model could be implemented in Virginia, explained more thoroughly in Appendix I. The advantage with regards to allocation is certainty, since this process gives stability to the marketplace, while still preserving the Commonwealth's ability to manage the resource to meet the groundwater objectives. The system ensures that overall water use remains consistent with overall Commonwealth water management goals.

Recommendation # 10: Committee recommends that the General Assembly direct DEQ with a timeline and resources to create a framework in consultation with stakeholders for an EVGMA groundwater trading program to be submitted to the General Assembly.

Necessary Data Improvements

The Committee was informed by DEQ that the recent groundwater permit reductions and the associated complexities of those permits, the modeling of the SWIFT project, and increasing questions by policy makers about local scale impacts from water level changes, land subsidence, saltwater intrusion, and well interference are challenging the existing 10-year old model. The Committee also heard that over time, models tend to diverge from monitored results as new withdrawals are permitted over time. This is due to a number of factors including: (1) in some cases new data is required on an ongoing basis to maintain the capacity to answer the question; (2) new withdrawals were installed in locations, which do not have field data that existed prior to the withdrawal to calibrate the model; and (3) the questions being asked exceed the resolution of the current tool or the tool was not designed to answer that question. DEQ outlined six major areas for data improvements that would allow DEQ to implement the groundwater program to its fullest extent, including:

- Updating the unregulated use estimation methodology, including private well irrigation and geothermal gaps
- Addressing gaps in the hydrologic framework, including model maintenance
- Installing a new extensometer
- Addressing gaps in the water monitoring network, including water levels
- Repairing and maintaining the existing monitoring well network
- Implementing a saltwater intrusion network

The Committee agrees that the list provided by DEQ with regard to data improvements identifies reasonable actions to be undertaken by DEQ. Credible data is essential for moving forward with the groundwater management recommendations outlined in this report. Also, since the management program was designed to inform regional level decisions, the need for additional data and upgrades of management tools are necessary for DEQ to address groundwater availability concerns on a sub-regional and local level. The Committee recommends that the General Assembly support such measures, as listed by priority in the recommendation box below. These data improvements will not only bolster current groundwater management efforts, but will also assist in measuring the success of future groundwater management projects. Since model estimates tend to be conservative estimates, actual data is very beneficial to understanding how much groundwater is actually in the system. More uniform coverage of data and more precise data will allow for an adaptive and active decision-making process by DEQ in managing these resources that will also be able to reflect sub-regional and local scale concerns. Not funding these efforts will ensure greater uncertainty over time regarding the impact of water withdrawals on the aquifer and other users, and increase the likelihood of unanticipated impacts or problems.

Recommendation # 11: Committee recommends that the General Assembly provide funding to ensure a robust groundwater management program because of the importance of groundwater resources in Eastern Virginia and the unsustainable rate of demand on the resource. The Committee believes that the following DEQ activities, at a minimum, should be provided sufficient funding to be implemented. At this time, the activities, in priority order, are:

1) Update unregulated use estimation methodology for use on an ongoing basis
2) Ensure ongoing model maintenance consistent with best professional practice
3) Address gaps in hydrologic framework and water level monitoring network
4) Provide operation and maintenance for Suffolk and Franklin extensometers
5) Ensure funding to perform ongoing existing well network repair and maintenance
6) Implement saltwater intrusion network
7) Install new extensometer near West Point

*The cost for each recommendation is listed below and outlined in Appendix K.

Since current state-funded research and groundwater resource model development is conducted with regional and national expert peer review but with limited stakeholder coordination, DEQ should increase coordination with stakeholder groups, such as the Eastern Shore of Virginia Groundwater Committee. The process of including stakeholders in the development of the subject and scope of research objectives, and in the model development for resources management, can result in: (1) more robust research programs and resource models, (2) a potential reduction in cost by focusing on critical areas or issues that local stakeholders identify, and (3) an increase in participation and motivation by stakeholders in the maintenance of a sustainable resource. The Committee suggests that DEQ look for ways to increase the inclusion of appropriate stakeholders.

Update Unregulated Use Estimation Methodology

DEQ uses an estimate of 29 MGD for "unregulated use" based on a methodology developed by USGS. This estimate was published in 2008[36]. It is estimated that unregulated use increased to approximately 39 MGD in 2016. Thus, a new method is needed using both VDH and DEQ private well data in order to get a more accurate estimate of unregulated use estimate.

Priority #1: Update Unregulated Use Estimation Methodology (~$200,000 per project)

This would be conducted as a USGS Cooperative Agreement as a joint project with DEQ and VDH. USGS estimates 1 man-year of effort to complete this work. One-man-year equals approximately $200,000. On a cooperative project USGS typically is able to contribute 30% of the project cost. The project would blend collection and review of on-site well records and use of newly registered private wells to develop an updated snapshot of unregulated water withdrawals (including private wells, irrigation, and geothermal) as well as a methodology for updating this estimate over time using the new well registration program data. Further detail would be negotiated as part of a project proposal. This water withdrawal estimate would be used in the model as part of the 2019-2020 rebuild/update.

Ensure Ongoing Model Maintenance

DEQ has reviewed and analyzed existing available data from other state and federal agencies, from other DEQ programs, and from private sector sources, but gaps remain. There are areas of uncertainty with regard to the stratigraphy of the layered aquifer system because the data is based on estimates rather than core samples taken in the field. These areas include the Norfolk Arch area south of the James River, the expanded groundwater management area north of the Mattaponi River, and the north and western edge of the Chesapeake Bay Impact Crater (CBIC). The challenge to expand the collection of well core or geophysical data in these areas of greater uncertainty by DEQ initiative or by requiring the permittee to pay for the work is based on several factors: the location of a new permit, whether or not extra DEQ funds become available for such a project, and whether or not suitable bids are submitted that are consistent with the budget available.

[36] J.P. Pope, E.R. McFarland, & R.B. Banks, *Private domestic-well characteristics and the distribution of domestic withdrawals among aquifers in the Virginia Coastal Plain: U.S. Geological Survey Scientific Investigations Report 2007–5250* (2008), http://pubs.water.usgs.gov/sir2007-5250.

Priority #2: Model Maintenance (Cost TBD)

The main VAHydro-GW model was put into use in 2010 and in accordance with best practice standards. It will be due to be rebuilt or be updated in 2020. This work would include updating the hydrogeologic framework in the model to reflect aquifer picks made on site from geophysical data and cuttings collected during permit review and the information from any new cores. Ideally, core data could be collected for use in this review in the Middle Peninsula and Northern Virginia area and in the primary area of critical cells in the Norfolk Arch west of Franklin. This work will be conducted through contractual services with a DEQ modeling contractor and may also include a cooperative agreement with USGS to supply data analysis of recent cores.

Task 1 – Evaluate impact of HUF (Hydrogeologic-Unit Flow) package
Task 2 – Recalibrate heads to include new water level monitoring through 2016
Task 3 – Interpolate to create "new" hydrogeologic framework surfaces based on new data from permit process
Task 4 – Update MD/NC pumping
Task 5 – Review boundary conditions
Task 6 – Evaluate performance and determine need for larger rebuild

Address Gaps in Hydrologic Framework and Water Level Monitoring Network

The lack of an operation and maintenance budget for DEQ staff to monitor groundwater levels creates challenges. DEQ staff faces challenges taking groundwater measurements, calibrating the monitoring equipment, and repairing and replacing the equipment when needed. Overall, the primary areas of uncertainty with regard to field-measured groundwater levels include the Norfolk Arch area south of the James River and the expanded groundwater management area north of the Mattaponi River. Since DEQ is currently at its staffing limit to maintain the system, options to resolve these challenges are to either add staff to DEQ or to increase funds to contract with USGS to perform these monitoring tasks. FY18 fees for this work are $1,400 per well for quarterly water level readings and $2,800 or $5,000 per well for continuous monitoring wells.

Priority #3: Address Gaps in Hydrologic Framework and Water Level Monitoring Network ($993,000 per year)

Currently this work is bid on the open market in an ad-hoc manner by both DEQ, when funds allow, and by permittees as permit requirements.

- Task 1 ($500,000) - New SOW (State Observation Well) installation (Coastal Plain), one per year at $500,000 each equals $500,000 per year
- Personnel ($234,000) - 1 FTE to service new SOW wells in Coastal Plain at $78,000 per year plus 2 FTEs for new SOW installation, at $156,000 per year (salary and fringe)
- Other costs ($259,000) - Initial real-time equipment costs for 15 wells per year at $10,000 per well ($150,000 per year) and annual operational costs, (fuel, vehicles, field supplies, etc.) of $100,000 per year. Also, USGS cost to host real time water level data on their website, add 10 new data points per year at $900.00 each ($9,000 per year).

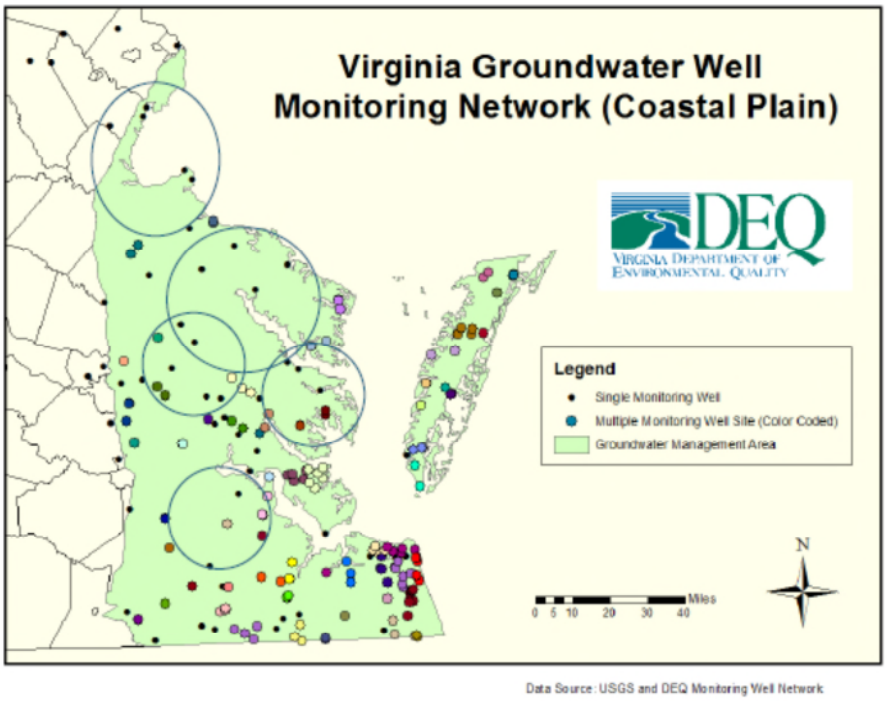

Image 1: Gaps in Hydrogeologic Framework (Coastal Plain)

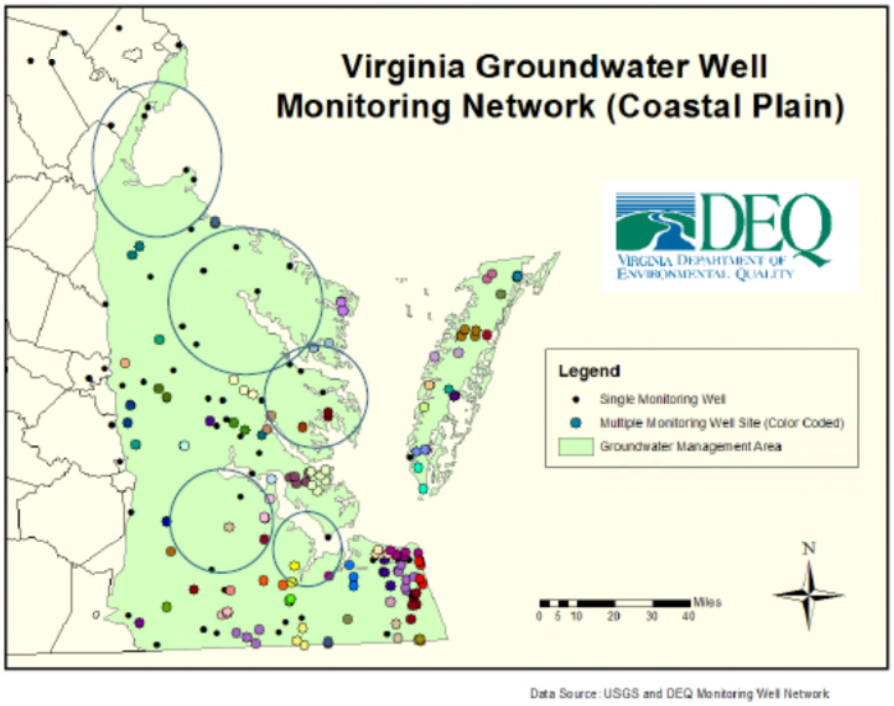

Image 2: Gaps in Water Level Monitoring Network (Coastal Plain)

Provide Operation and Maintenance for Suffolk and Franklin Extensometers, and Install New Extensometer Near West Point

A study conducted by USGS in 2013 found that land subsidence in the coastal plain had occurred and that an estimated 25% of the land subsidence could be attributed to subsidence associated with the over pumping of groundwater.[37] DEQ's groundwater model estimates nearly a foot of subsidence has occurred near West Point, since 1910. Also, HRSD and USGS installed an extensometer at Nansemond for $1.3 million. The estimated costs for the operation and maintenance for the extensometer at Nansemond is $40,000 per year, along with $30,000 per year for the existing Suffolk and Franklin extensometers.

Ensure Funding to Perform Ongoing Existing Well Network Repair and Maintenance

Priority #4: Suffolk and Franklin Extensometers Operation and Maintenance ($40,000 per year)
The cost of contractual services with the USGS for operation and maintenance of these facilities is $40,000 per year. The priority should include operation and maintenance expenses for all three extensometer sites (Nansemond, Suffolk, and Franklin at $70,000 per year).

Priority #7: Install New Extensometer near West Point ($1.3 million first year then $30,000 per year thereafter)

The installation of an extensometer near West Point in this area is critical to monitoring land subsidence in an area of known land subsidence. The extensometer will be installed through a cooperative agreement with the USGS as was done this year at Nansemond. The costs associated with the project are $1.3 million with an on-going O & M cost of $30,000 per year.

In order to ensure scientifically reliable and valid data, monitoring wells need continual maintenance. Most of the existing monitoring wells were installed at least thirty years ago (over fifty percent of the 243 wells). In 2015 as part of maintaining the current well network, DEQ started assessing the condition of between twenty and twenty-five wells per year. Currently, sixteen of twenty-nine wells exhibit problems that need to be addressed. These problems include aging casings, silted screens, and obstructions. The estimated cost of maintenance of these wells varies by situation and bid offering. DEQ no longer has the equipment for these tasks, so the maintenance services must be procured when funds are available. For example, a recent bid to remove sediment for one well was $38,275, and because there is no existing budget for the operation and maintenance of these wells, maintenance is dependent on having excess funds. Further, DEQ only has two staff members to address the needs of all 243 monitoring wells across the Commonwealth. Industry best practices call for one staff member per 50-60 wells.

[37] Jack Eggleston, & Jason Pope, *Land subsidence and relative sea-level rise in the southern Chesapeake Bay region: U.S. Geological Survey Circular 1392* (2013), https://dx.doi.org/10.3133/cir1392.

Priority #5: Existing Well Network Repair and Maintenance ($306,000 per year)

DEQ is currently assessing the scope of this activity. Estimated costs represent the costs of contracting these services on the open market. Assessment of network wells to date indicates that it is prudent to assume the following:

Task 1 - SOW well replacement, 1 per year at $100,000

Task 2 - SOW well abandonment, 5 per year at $10,000 (total $50,000 per year)

Personnel - 2 FTE's to coordinate well maintenance, replacement, and abandonment at $156,000 per year (including fringe benefits)

Implement Saltwater Intrusion Network

DEQ contracted with USGS to develop a monitoring strategy for lateral and upconing movement of saltwater.[38] This process assessed 612 monitoring wells for proximity to 250 milligrams per liter (mg/L) of chloride surfaces. The results concluded that (1) eighty-one "priority" wells were within 50 feet, (2) forty-two wells were at risk of intrusion that needed further monitoring, and (3) fifty-four additional monitoring wells were needed to track the movement of these surfaces due to pumping at the wells. Unfortunately, no existing wells are suitable to monitor the movement of saltwater in groundwater. Thus, the total cost of implementation for new monitoring wells would be $12.5 million over 10 years, averaging about $1.35 million in annual costs.

Priority #6: Implement Saltwater Intrusion Network
($2.5745 mil. per year for 10 years then $1.35 million per year thereafter)

Chloride Network installation estimates are based on current well installation costs using commercial drillers; the number of wells necessary was determined by assessing the USGS chloride monitoring strategy. Three geologists would be needed over ten years to oversee chloride monitoring and well installation and maintain the installed equipment. The Chloride Network sampling costs are estimates based on current analytical costs. The sampling program will shift from a more comprehensive analyte suite and frequent sampling up front to a less comprehensive suite less frequently with time.

The estimate is based on 200 samples a year (higher frequency) at $1,250 per sample (reduced analyte suite). It is estimated that 75 to 100 samples per year can be collected by a dedicated sampling team consisting of two employees. The proposal includes four employees (two teams) and sufficient equipment to acquire the target number of samples. The sampling costs also include budget for overnight travel and per diem while conducting the sampling. The chloride monitoring support and assistance is based on the current cost of contracting one joint study per year between DEQ and USGS. One full-time support staff is included to manage and analyze the data. Maintenance costs are estimated based on an average repair/replacement cost of $5,000 for 20 incidents per year.

[38] E.R. McFarland, *A conceptual framework and monitoring strategy for movement of saltwater in the Coastal Plain aquifer system of Virginia: U.S. Geological Survey Scientific Investigations Report 2015–5117* (2015), http://dx.doi.org/10.3133/sir20155117.

Funding Needs and Options

The Committee recognizes the severe impact that depleted groundwater resources would have on the communities, economy, and overall environment of the EVGMA. Inaction is not an option for the Committee, and the Committee's recommendations throughout this report reflect actions needed to manage the groundwater resources in the EVGMA. Current funding for the groundwater program derives from general funds and permit fees. The Committee proposes two funding options to ensure that DEQ has the needed funds to successfully manage groundwater resources in the Commonwealth, including funding for the necessary data needs as prioritized in section III (E) of this report. The Committee also recognizes there may be an increase of federal funding for infrastructure and encourages the Commonwealth to pursue these federal funds if available.

There are two main categories of costs discussed in this report, including (1) operational support for DEQ, and (2) larger capital costs for alternative water solutions and diversifying water sources. The Committee reached consensus to recommend funding for specific DEQ operational funds that are essential to the management of the groundwater resources, as outlined in section III (E). The Committee recommends the General Assembly fund this effort through General Fund Appropriations as the first funding option.

If general appropriations are not available, the Committee recommends a minimal fee covering a broad base of regional users to keep the costs both reasonable and equitable. The Committee suggests that this type of flat fee needs to be applicable to both permitted and unpermitted users within the EVGMA. The Committee discussed that such a fee must be practicable and efficient to collect, and would be two-tiered based on households and businesses. Also, the Committee agrees that a fee must be capped at a level that generates revenue needed for operational costs of the groundwater management program. The idea to implement a flat fee was not unanimous within the Committee based on concerns over the impact a flat fee may have on individual homeowners, and the ability for such a fee to be increased over the years.

Recommendation # 12: Committee recommends that the General Assembly fund the essential operational costs of DEQ to successfully manage the groundwater resources, first through General Fund Appropriations, and second, if absolutely necessary, through a reasonable flat fee applied only to households and businesses in the EVGMA. If a fee is applied, the funding provided by the fee shall not result in any reduction of the general funds appropriated.

HRSD SWIFT Funding

The HRSD enabling legislation empowers the HRSD Commission to set rates and fees. In practice, the Commission reviews rates, fees and charges annually with the budget process and revises these rates as required to support the budget and future investment needs. The future investment needs are based on capital improvement projections over the forecast period. The capital needs include investments to meet known regulatory requirements; appropriate reinvestment in existing infrastructure renewal and any anticipated new capacity. This is done with a 20-year financial forecast that is constrained by HRSD financial policies to ensure adequate revenues are available throughout the forecast period to meet all obligations including maintaining debt service coverage ratios and unrestricted reserves within policy limits and as required by current bond holders (in accordance with trust agreements). The 20-year forecast includes the required revenue requirements (rate increases) over the forecast period and is published annually with the HRSD budget.

HRSD is capable of supporting the SWIFT program through the USEPA's Integrated Planning framework (i.e., the ability to prioritize obligations and invest in projects with the greatest local environmental benefits). Beyond SWIFT implementation, however, there is a recognized need for third party oversight of SWIFT and potentially other managed aquifer recharge projects within the Potomac Aquifer. The Occoquan Watershed Monitoring Laboratory (OWML) provides a successful model that may help guide the development of a Potomac Aquifer Monitoring Program to provide this oversight. HRSD is committed to working with VDH, DEQ, and other key stakeholders to develop a third party oversight program. Though the general structure of the OWML may provide a useful framework, the funding mechanism for the OWML in which the costs are split equally between water supply and sewage uses does not have direct applicability to a Potomac Aquifer program. Innovative funding approaches will be needed to support a third party oversight program.

Appendix A: List of the Committee and Workgroup Members

EASTERN VIRGINIA GROUNDWATER MANAGEMENT ADVISORY COMMITTEE MEMBERS	
John J. Aulbach – Aqua Virginia, Inc.	David Paylor – DEQ
James Baker – City of Chesapeake	Chris Pomeroy – Western Tidewater Water Authority
Nina Butler – WestRock	Travis Quesenberry – King George County
Tom Frederick – VA Water and Wastewater Authorities Association	Paul Rogers, Jr. – Farmer – Production Agriculture
George Harlow – USGS	Nikki Rovner – The Nature Conservancy
Rhu Harris – Hanover County	Curtis W. Smith – Accomack-Northampton PDC/ Eastern Shore Groundwater Committee
Bryan Hill – James City County	Kurt Stephenson – Virginia Tech
Chip Jones – Northern Neck Soil & Water Conservation District	Mike Toalson – VA Home Builders Association
Marissa Levine – VDH	Dennis Treacy – Smithfield Foods
Keith Martin – Chamber of Commerce	Brett Vassey – Virginia Manufacturers Association
Sandi McNinch – VA Economic Development Partnership	Ellis Walton – Farm Bureau
John O'Dell – VA Well Drillers Association	Bob Wayland - Citizen

EVGMAC – WORKGROUP #1 – ALTERNATIVE SOURCES OF SUPPLY	
Richard Costello – VA Home Builders	Whitney Katchmark – Hampton Roads PDC
Larry Dame – New Kent County	Mike Kearns – Sussex Service Authority
Kyle Duffy – International Paper	Kristen Lentz – City of Norfolk
Judy Dunscomb – The Nature Conservancy	Britt McMillan - ARCADIS
Jason Early – CARDNO	Jamie Mitchell – Hampton Roads Sanitation District
Katie Frazier – VA Agribusiness Council	Don Rice – Newport News Waterworks
Bill Gill – Smithfield Foods	Paul Rogers, Jr. – Farmer – Production Agriculture
Jeff Gregson – VA Well Drillers Association	Erik Rosenfeldt – Hazen and Sawyer
Carole Hamner – WestRock	Thomas Swartzwelder – King and Queen County
Steve Herzog – Hanover County	Chris Thomas – King George County SA
Brent Hutchinson – Aqua Virginia	Brett Vassey – VA Manufacturers Association
David Jurgens – City of Chesapeake	Michael Vergakis – James City Service Authority

EVGMAC – WORKGROUP #1 – ALTERNATIVE SOURCES OF SUPPLY - STATE AGENCIES	
Drew Hammond – VDH - ODW	Scott Kudlas - DEQ
Skip Harper – VA Department of Housing and Community Development – State Building Codes Office	John Loftus – VA Economic Development Partnership
Allen Knapp – VDH - OEHS	

EVGMAC – WORKGROUP #2A – ALTERNATIVE MANAGEMENT STRUCTURES	
Elizabeth Andrews – William & Mary	Nikki Rovner – The Nature Conservancy
Rhea Hale - WestRock	Rebecca Rubin – Marstel-Day
Brent Hutchinson – Aqua Virginia, Inc.	Kurt Stephenson – Virginia Tech
Whitney Katchmark – Hampton Roads PDC	Wilmer Stoneman – VA Farm Bureau
James Maupin – Maupin's Well Drilling - VWWA	Eric Tucker – City of Norfolk
Britt McMillan – ARCADIS – Eastern Shore Groundwater Committee	Andrea Wortzel – Troutman Sanders/Mission H2O
Jamie Mitchell – Hampton Roads Sanitation District	

EVGMAC – WORKGROUP #2A – ALTERNATIVE MANAGEMENT STRUCTURES - STATE AGENCIES	
Susan Douglas – VDH - ODW	Sandi McNinch – VA Economic Development Partnership
Scott Kudlas - DEQ	Dwayne Roadcap – VDH - OEHS

EVGMAC – WORKGROUP #2B - TRADING	
Terry Blankenship – Aqua Virginia	Jamie Mitchell – Hampton Roads Sanitation District
Eric Gregory – King George County	Chris Pomeroy – Western Tidewater Water Authority
Jeff Gregson – VA Well Drillers Association	Don Rice – Newport News Waterworks
Rhea Hale - WestRock	Kurt Stephenson – Virginia Tech
Lewie Lawrence – Middle Peninsula PDC	Wilmer Stoneman – VA Farm Bureau
Britt McMillan – ARCADIS – Eastern Shore Groundwater Committee	Shannon Varner – Troutman Sanders/Mission H2O

EVGMAC – WORKGROUP #2B – TRADING - STATE AGENCIES	
Susan Douglas – VDH - ODW	Sandi McNinch – VA Economic Development Partnership
Scott Kudlas – DEQ – Central Office	Dwayne Roadcap – VDH - OEHS

EVGMAC – WORKGROUP #3 – ALTERNATIVE PERMITTING CRITERIA	
Nina Butler - WestRock	David Jurgens – City of Chesapeake
Curtis Consolvo – GeoResources, Inc.	Whitney Katchmark – Hampton Roads Planning District Commission
Jeff Corbin – Restoration Systems	Mike Kearns – Sussex Service Authority
Larry Dame – New Kent County	Mike Lawless – Draper Aden Associates
David DePippo – Hunton & Williams	Britt McMillan - ARCADIS
Kyle Duffy – International Paper	Jamie Mitchell – Hampton Roads Sanitation District
Judy Dunscomb – The Nature Conservancy	Doug Powell – James City County Service Authority
Katie Frazier – Virginia Agribusiness Council	Wilmer Stoneman – Virginia Farm Bureau
Bill Gill – Smithfield Foods, Inc.	Mike Toalson – Home Builders Association of Virginia
Chris Harbin – City of Norfolk – Department of Utilities	Brett Vassey - VMA

EVGMAC – WORKGROUP #3 – FUTURE PERMITTING CRITERIA - STATE AGENCIES	
Lance Gregory – VDH - OEHS	Rob McClintock – Virginia Economic Development Partnership
Scott Kudlas - DEQ	

EVGMAC – WORKGROUP #4 - FUNDING	
Jay Bernas – Hampton Roads Sanitation District	Doug Powell – James City Service Authority
Robert Carteris – City of Norfolk – Department of Utilities	Jeff Scarano – Brown and Caldwell
Richard Costello – AES Consulting Engineers	Kurt Stephenson – Virginia Tech
Eric Gregory – King George County	Chris Tabor – Hazen and Sawyer
Barrett Hardiman – Luck Stone	Brett Vassey - VMA
Whitney Katchmark – Hampton Roads Planning District Commission	Michael Vergakis – James City County
Mike Lang – New Kent County	Matt Wells - WestRock
Britt McMillan - ARCADIS	Andrea Wortzel – Troutman Sanders/Mission H2O

EVGMAC – WORKGROUP #4 – FUNDING - STATE AGENCIES	
Howard Eckstein – VDH - ODW	Scott Kudlas - DEQ
Lance Gregory – VDH - OEHS	Sandi McNinch – Virginia Economic Development Partnership

SUPPORT STAFF	
Brandon Bull - DEQ	Amber Leasure-Earnhardt – VCU/VA Center for Consensus Building
Drew Hammond - DEQ	Bill Norris - DEQ
Angie Jenkins - DEQ	Mark Rubin – VA Center for Consensus Building
Scott Kudlas - DEQ	Jutta Schneider - DEQ

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Appendix B: Enabling Legislation Establishing the Committee

§ 62.1-256.1. (Expires January 1, 2018) Eastern Virginia Groundwater Management Advisory Committee established.

A. The Eastern Virginia Groundwater Management Advisory Committee (the Committee) is hereby established as an advisory committee to assist the State Water Commission and the Department of Environmental Quality in developing, revising, and implementing a management strategy for ground water in the Eastern Virginia Groundwater Management Area. The Committee shall be appointed by the Director of the Department of Environmental Quality and shall be composed of nonlegislative citizen members consisting of representatives of industrial and municipal water users; representatives of public and private water providers; developers and representatives from the economic development community; representatives of agricultural, conservation, and environmental organizations; state and federal agencies' officials; and faculty of baccalaureate institutions of higher education and citizens with expertise in water resources-related issues. The Committee shall meet at least four times each calendar year.

Members of the Committee shall receive no compensation for their service and shall not be entitled to reimbursement for expenses incurred in the performance of their duties.

B. The Committee shall examine (i) options for developing long-term alternative water sources, including water reclamation and reuse, ground water recharge, desalination, and surface water options, including creation of storage reservoirs; (ii) the interaction between the Department of Environmental Quality's ground water management programs and local and regional water supply plans within the Eastern Virginia Groundwater Management Area for purposes of determining water demand and possible solutions for meeting that demand; (iii) potential funding options both for study and for implementation of management options; (iv) alternative management structures, such as a water resource trading program, formation of a long-term ground water management committee, and formation of a commission; (v) additional data needed to more fully assess aquifer health and sustainable ground water management strategies; (vi) potential future ground water permitting criteria; and (vii) other policies and procedures that the Director of the Department of Environmental Quality determines may enhance the effectiveness of ground water management in the Eastern Virginia Groundwater Management Area. The Committee shall develop specific statutory, budgetary, and regulatory recommendations, as necessary, to implement its recommendations.

C. The Committee shall report the results of its examination and related recommendations to the State Water Commission and the Director of the Department of Environmental Quality no later than August 1, 2017. The Director of the Department of Environmental Quality shall issue a report responding to the Committee's recommendations to the Governor, the State Water Commission, the Chairman of the House Committee on Agriculture, Chesapeake and Natural Resources, the Chairman of the Senate Committee on Agriculture, Conservation and Natural Resources, and the Joint Legislative Audit and Review Commission no later than November 1, 2017.

2015, cc. 262, 613.

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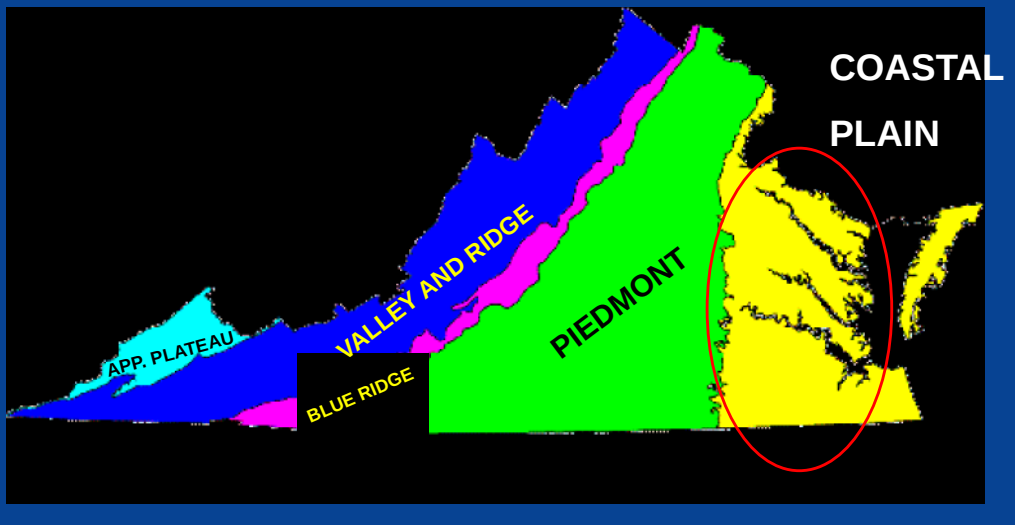
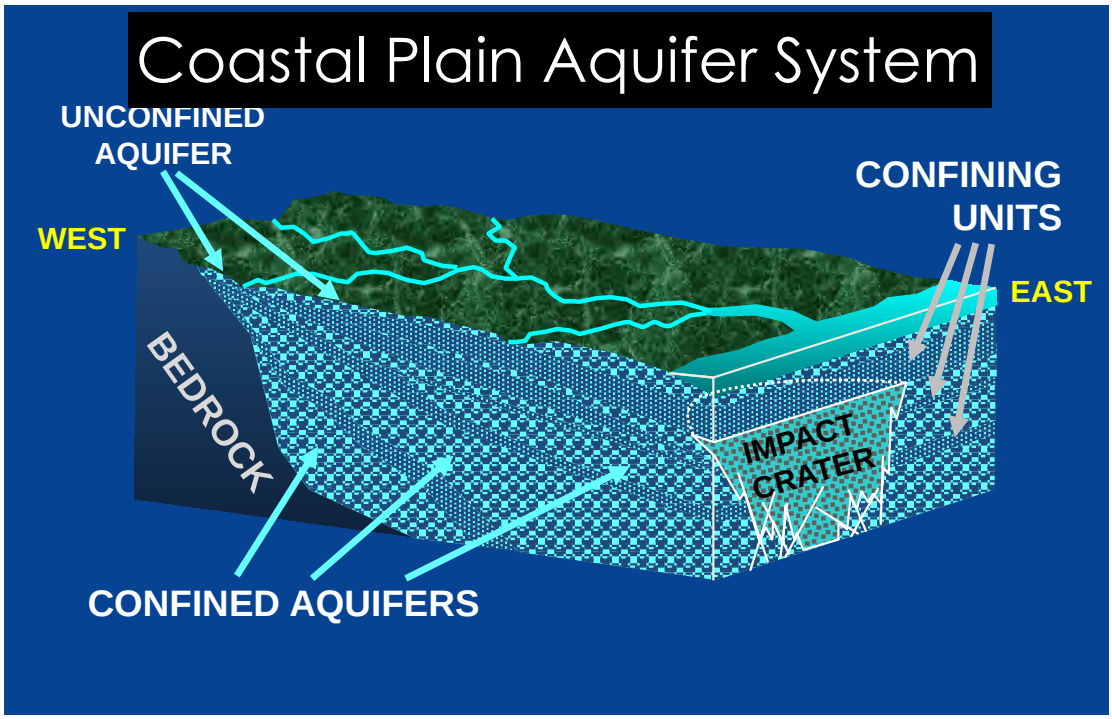
Appendix C: DEQ Virginia Coastal Plain Groundwater Issues Presentation I and II

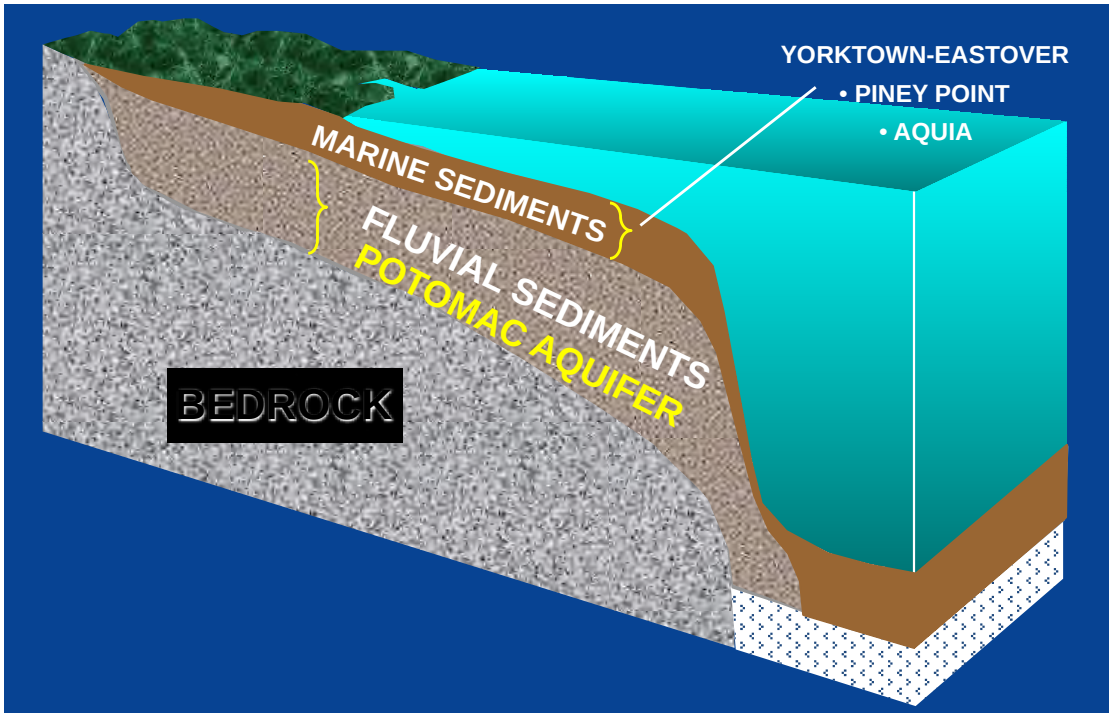
Virginia Coastal Plain Groundwater Issues
EVGMA Advisory Committee
August 18, 2015

Geology 101

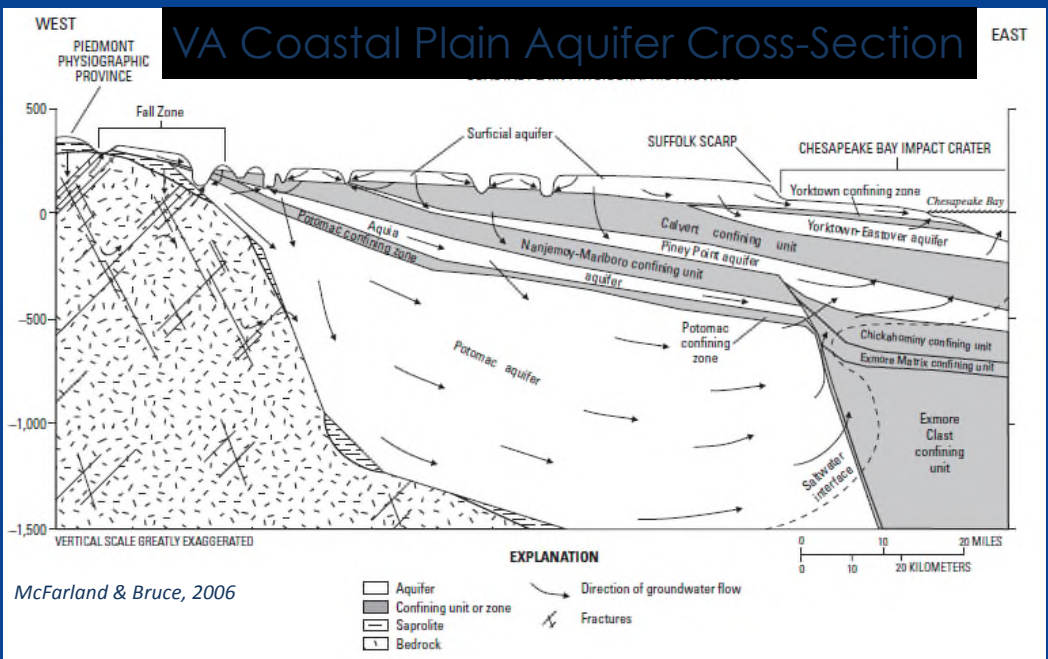
Virginia Physiographic Provinces




Coastal Plain Aquifer System
UNCONFINED AQUIFER
WEST
CONFINING UNITS
EAST
BEDROCK
IMPACT CRATER
CONFINED AQUIFERS

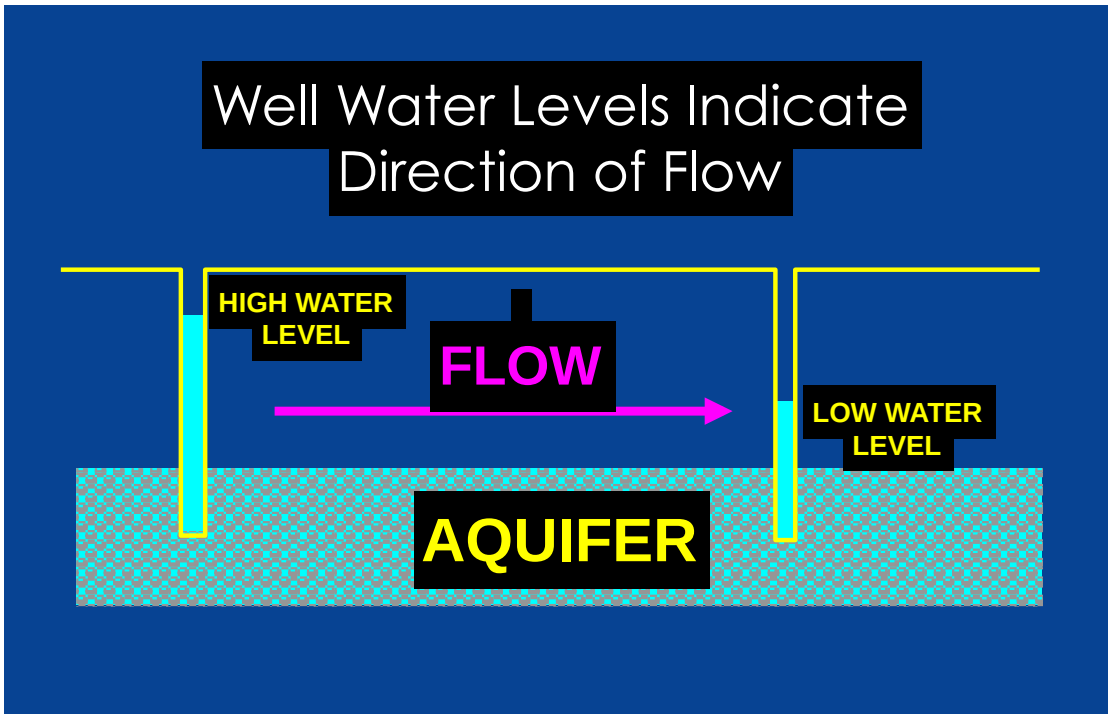

YORKTOWN-EASTOVER
• PINEY POINT
• AQUIA
MARINE SEDIMENTS
FLUVIAL SEDIMENTS
POTOMAC AQUIFER
BEDROCK

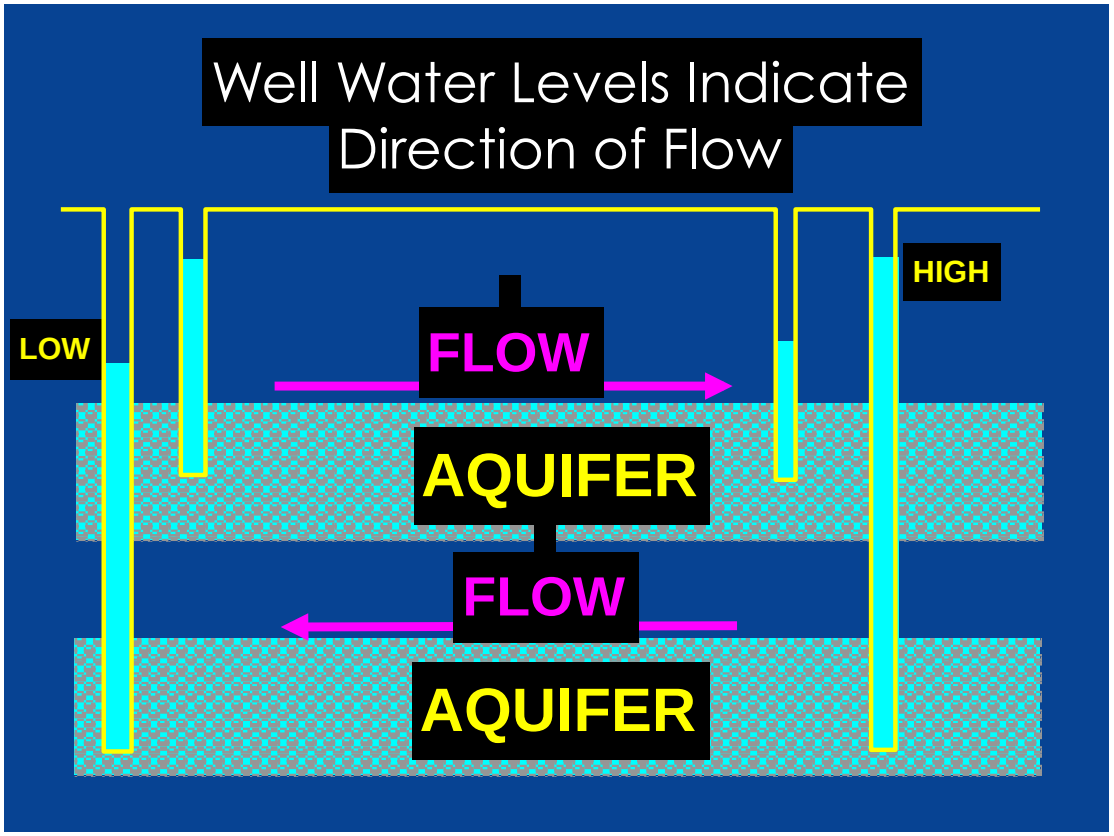
VA Coastal Plain Aquifer Cross-Section

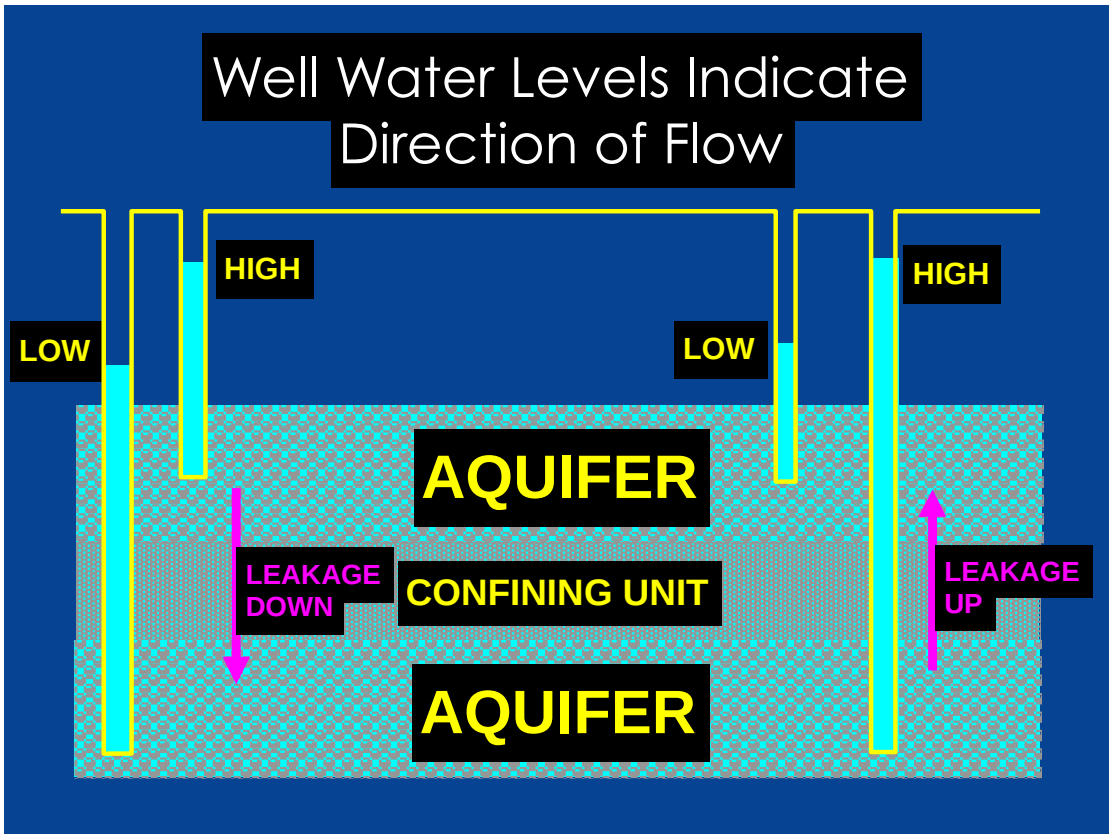


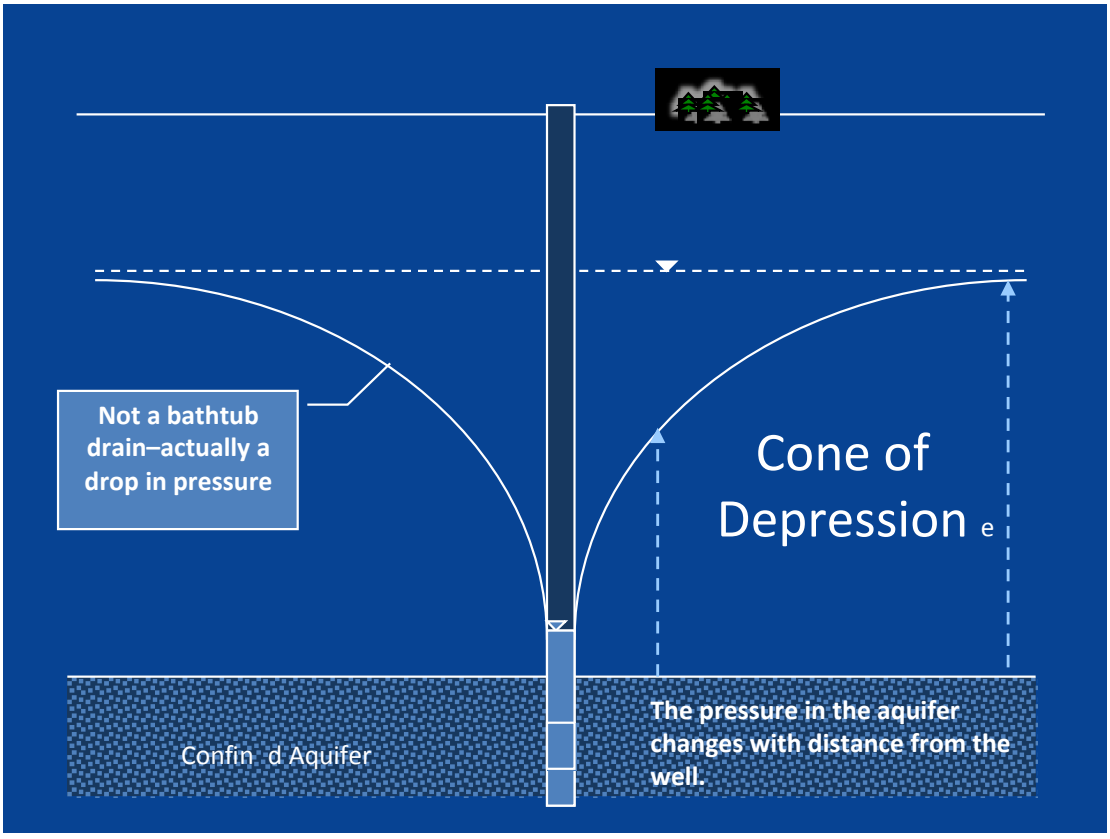
McFarland & Bruce, 2006

Groundwater Terms and Concepts

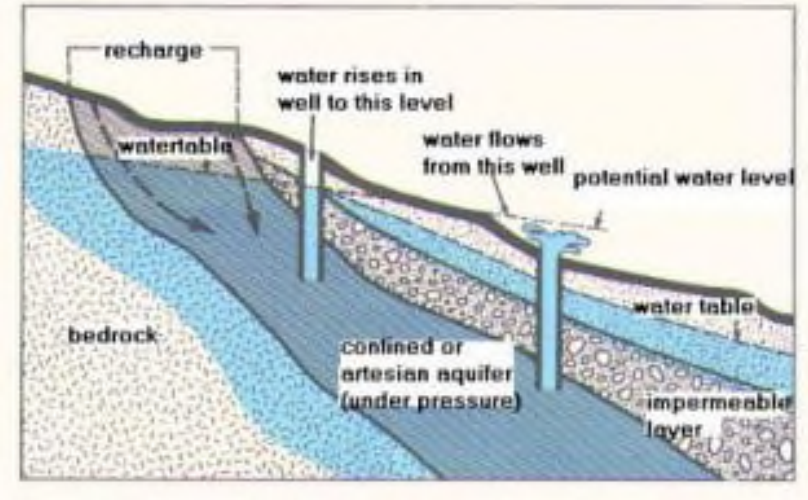

Well Water Levels Indicate
Direction of Flow
HIGH WATER
LEVEL
FLOW
LOW WATER
LEVEL
AQUIFER


Well Water Levels Indicate
Direction of Flow
LOW
FLOW
HIGH
AQUIFER
FLOW
AQUIFER


Well Water Levels Indicate Direction of Flow
HIGH
LOW
LOW
HIGH
AQUIFER
LEAKAGE DOWN
CONFINING UNIT
LEAKAGE UP
AQUIFER


Not a bathtub drain–actually a drop in pressure
Cone of Depression e
Confin d Aquifer
The pressure in the aquifer changes with distance from the well.

Potentiometric Surface

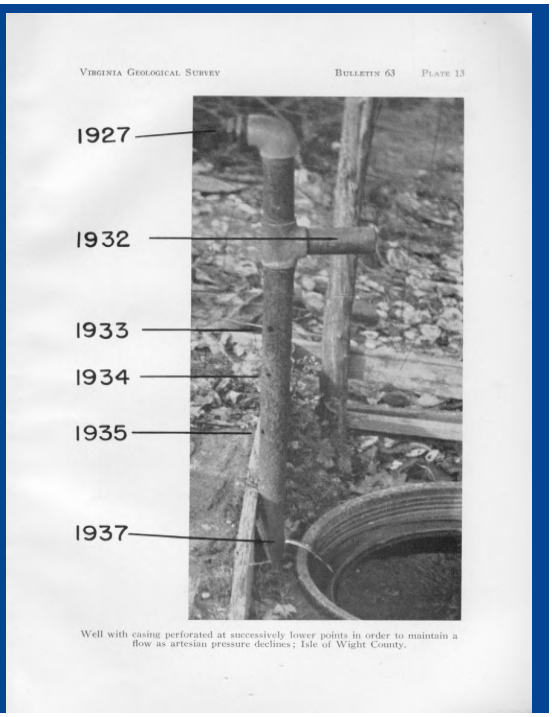


Management Issues

- Declining water levels
- Reversal of the hydraulic gradient (groundwater flow) leads to salt water intrusion
- Subsidence and loss of storage

Groundwater Level Declines

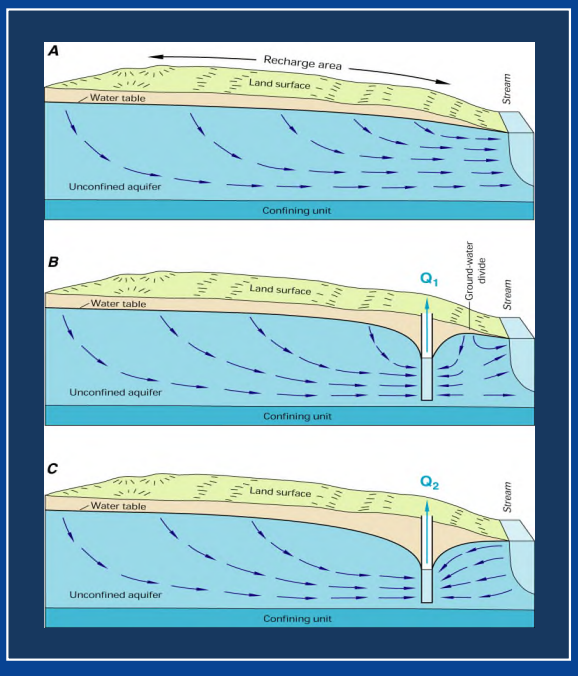
Artesian Characteristics Lost Over Time



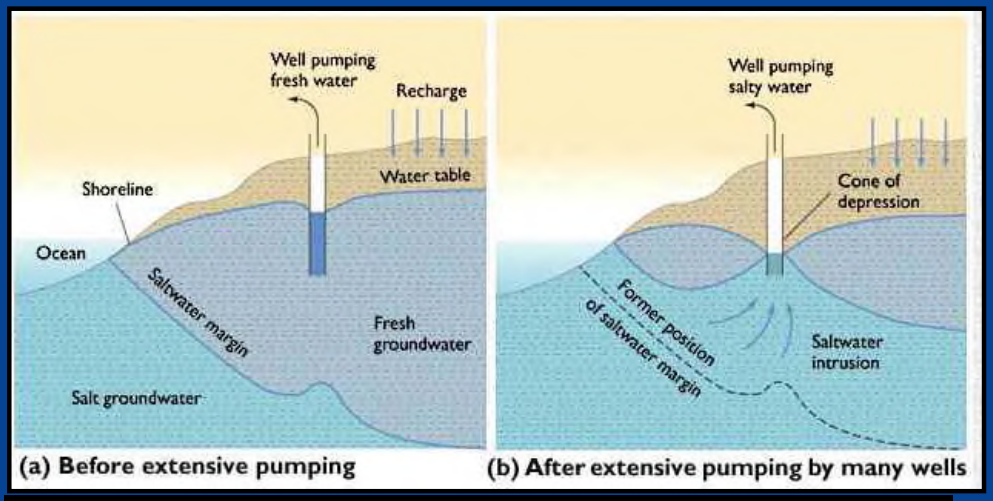
Long Term Water Level Decline

Reversal of Hydraulic Gradient and Saltwater Intrusion

Groundwater Pumping and Reversal of Hydraulic Gradient



Salt Water Intrusion - Upconing



Pumping draws the salt water upwards into the well.

Salinity Within the Aquifer System

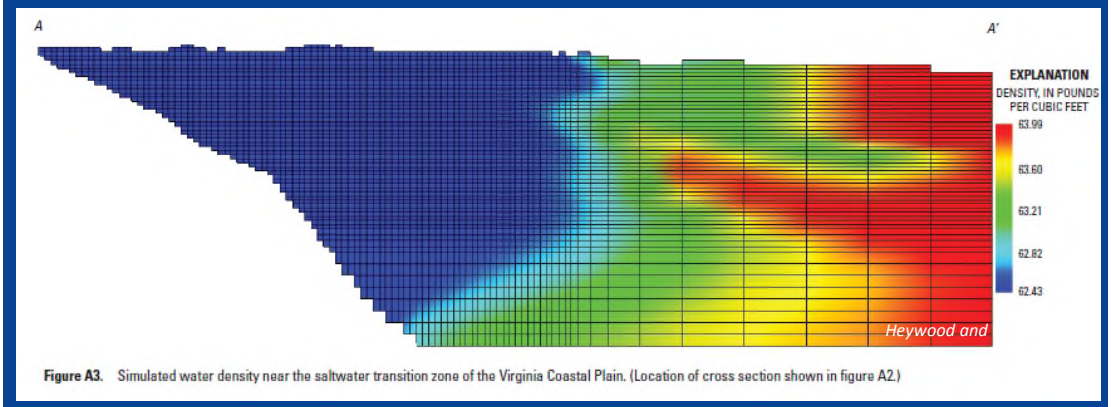
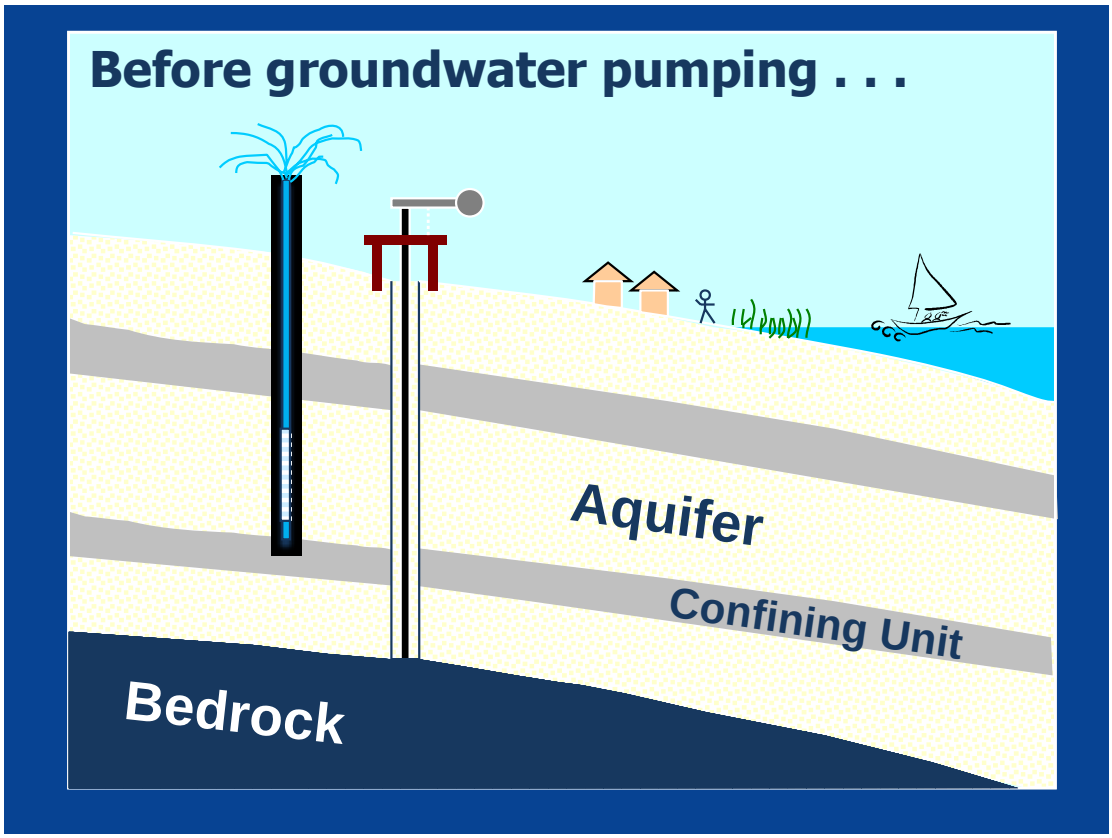
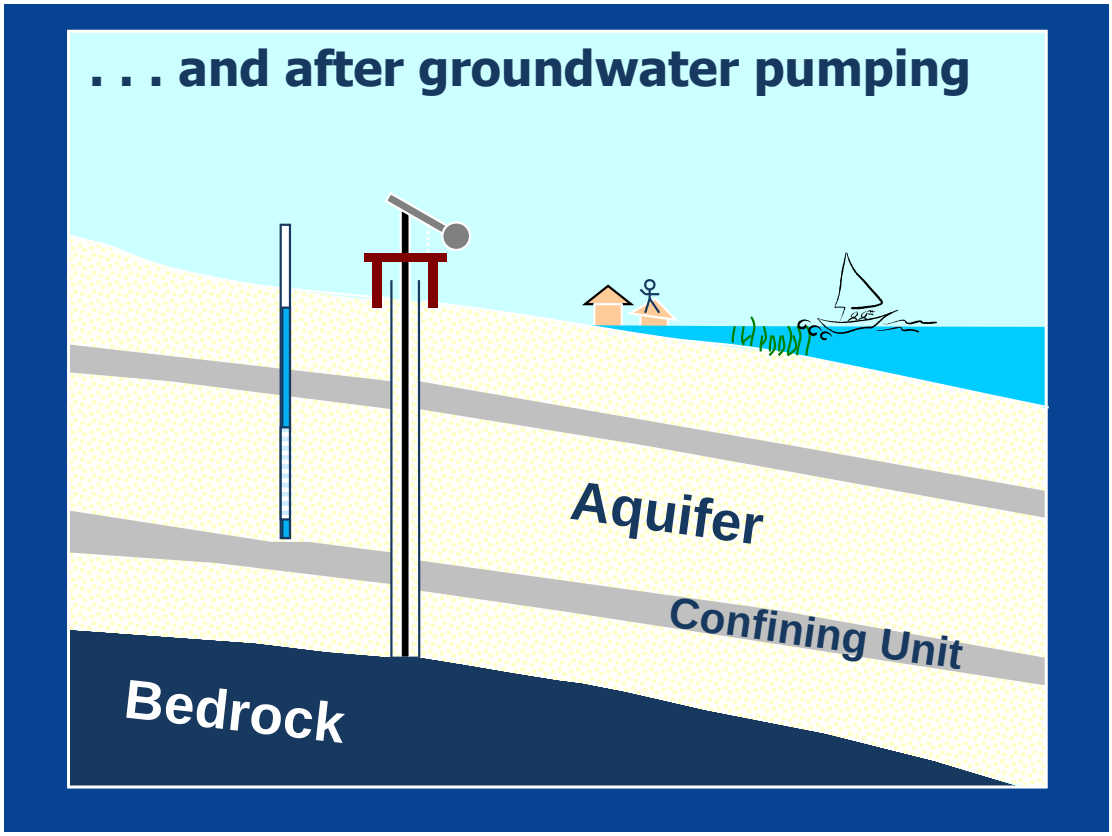
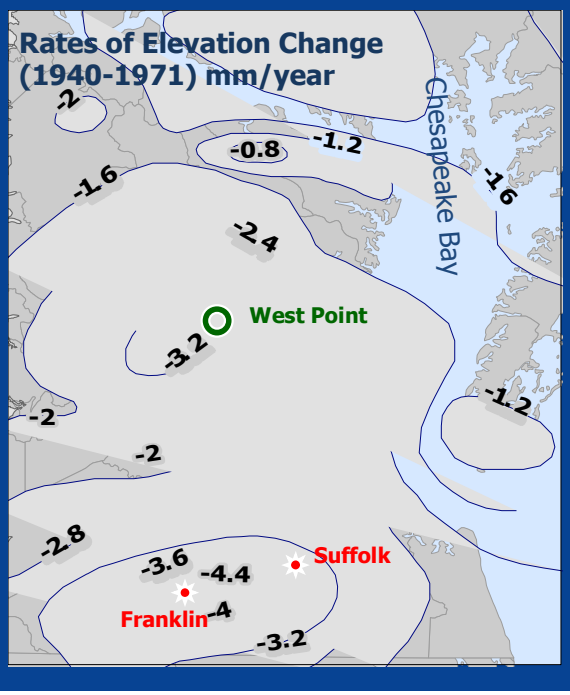


Figure A3. Simulated water density near the saltwater transition zone of the Virginia Coastal Plain. (Location of cross section shown in figure A2.)

Land Subsidence and Loss of Storage


Before groundwater pumping . . .
Aquifer
Confining Unit
Bedrock


. . . and after groundwater pumping
Aquifer
Confining Unit
Bedrock



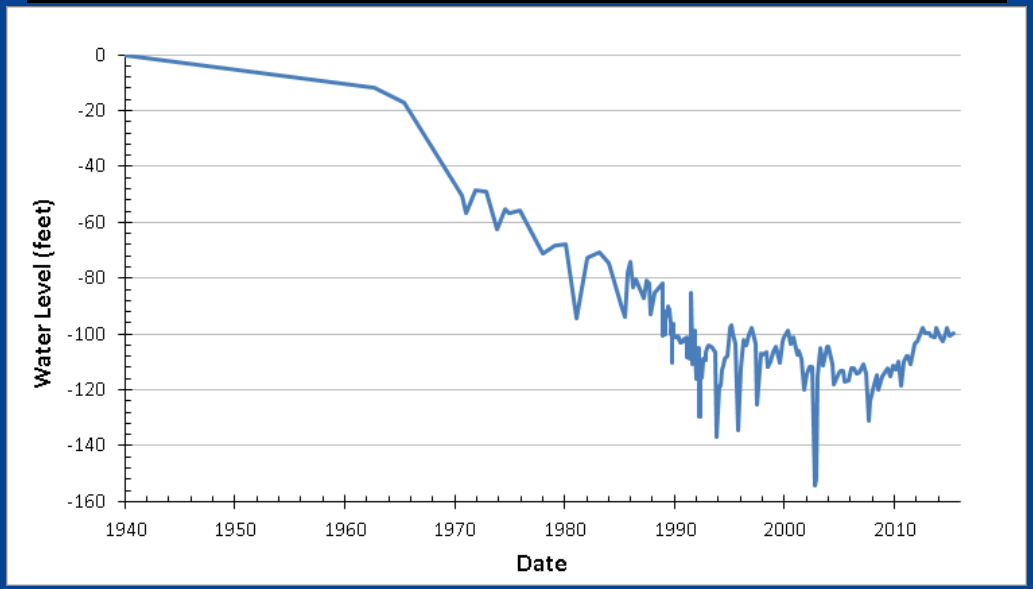
Measurement of Compaction and Subsidence

Franklin Extensometer
Oct. 1979 – Dec. 1995
Depth = 255.1 m

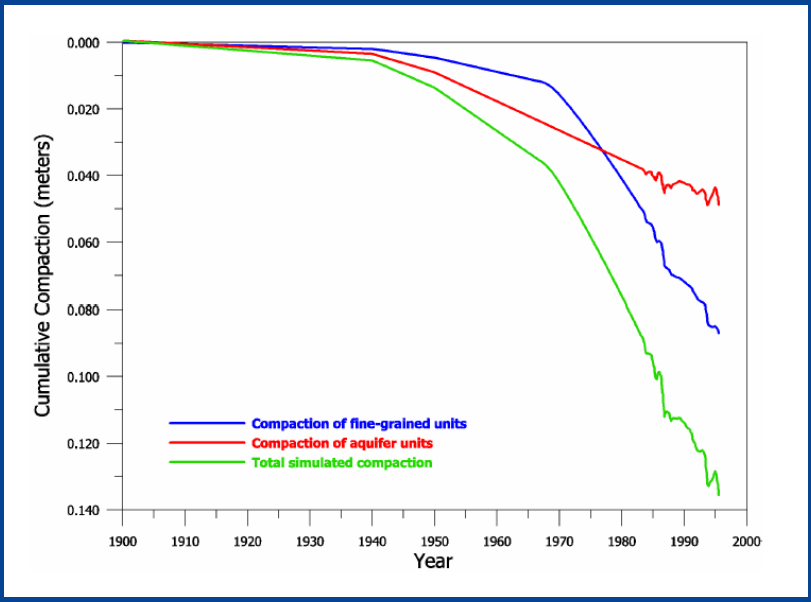
Suffolk Extensometer
June 1982 – Dec. 1995
Depth = 484.0 m

Miles
0 25

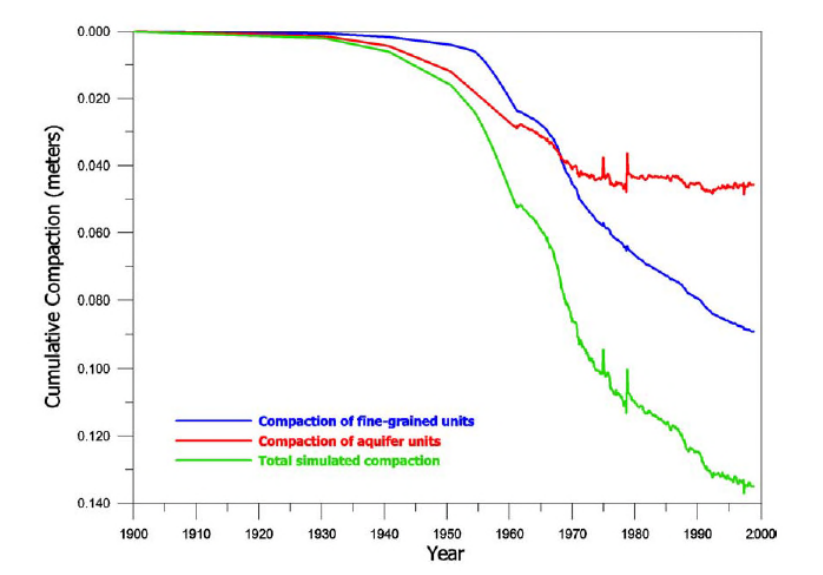
Potomac Aquifer Declines at Suffolk



Simulated Compaction at Suffolk



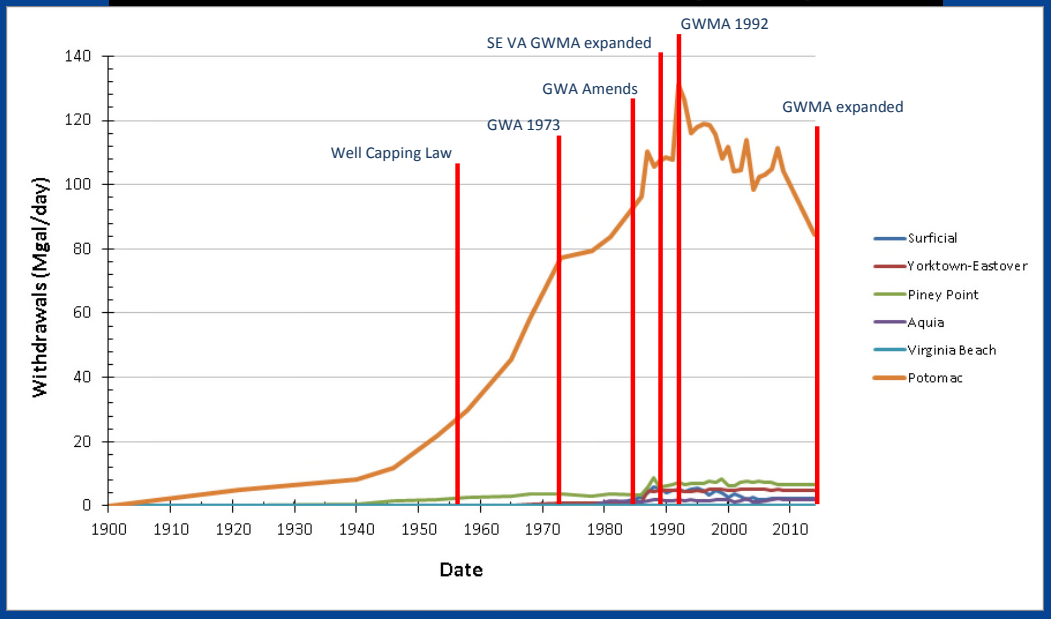
Simulated Compaction at Franklin

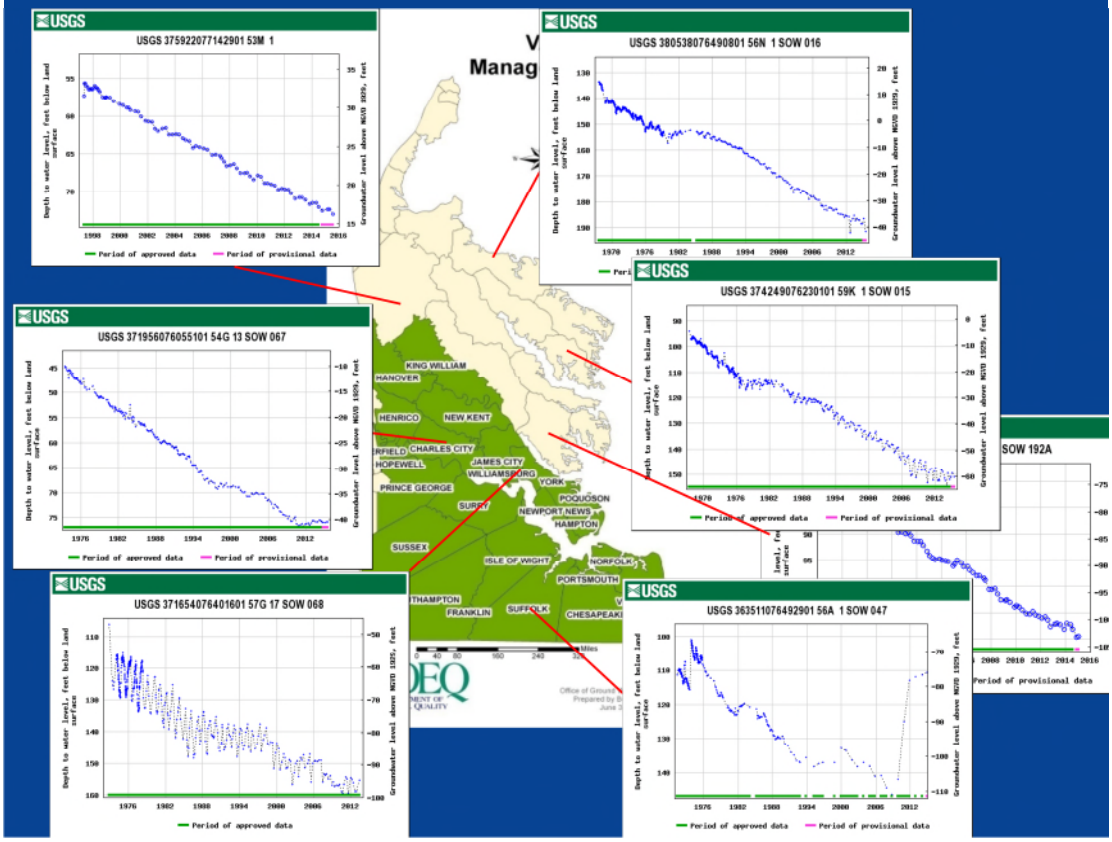


Groundwater Management in Virginia

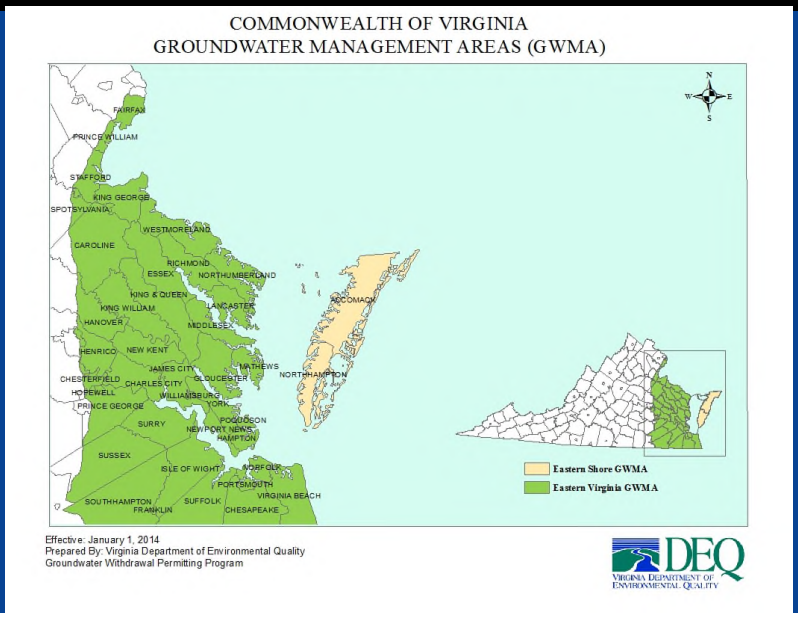
- Regional studies (late 1970s –early 1980s)
- Hydrologic Framework I (1988)
- Coastal Plain Groundwater Flow Model I (1990)
- Coastal Plain Groundwater Flow Model II (1998)
- Chesapeake Bay Impact Crater (1999)
- Land Subsidence Study I (2002)
- Hydrologic Framework II (2006)
- Coastal Plain Groundwater Flow Model III (2009)
- Eastern Shore Model I (2009)
- Groundwater Quality Trend Study (2010)
- Program Peer Review (2011)
- Potomac Aquifer Study (2013)
- Land Subsidence Study II (2013)
- Piney Point Aquifer Study (2014, publication pending)
- Saltwater Monitoring Network Study (2015, publication pending)

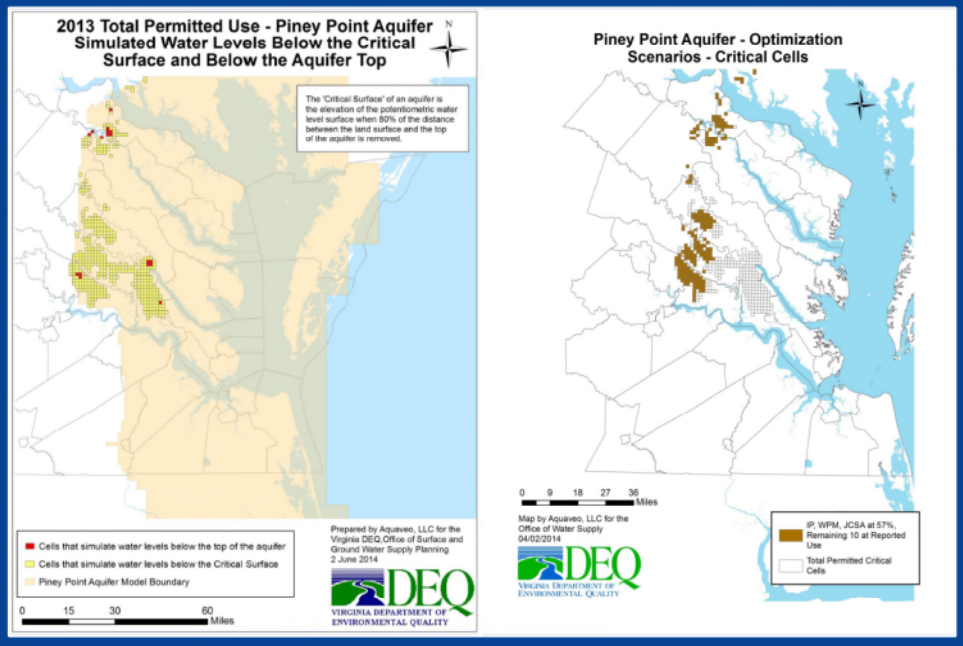
Actual Withdrawals by Aquifer

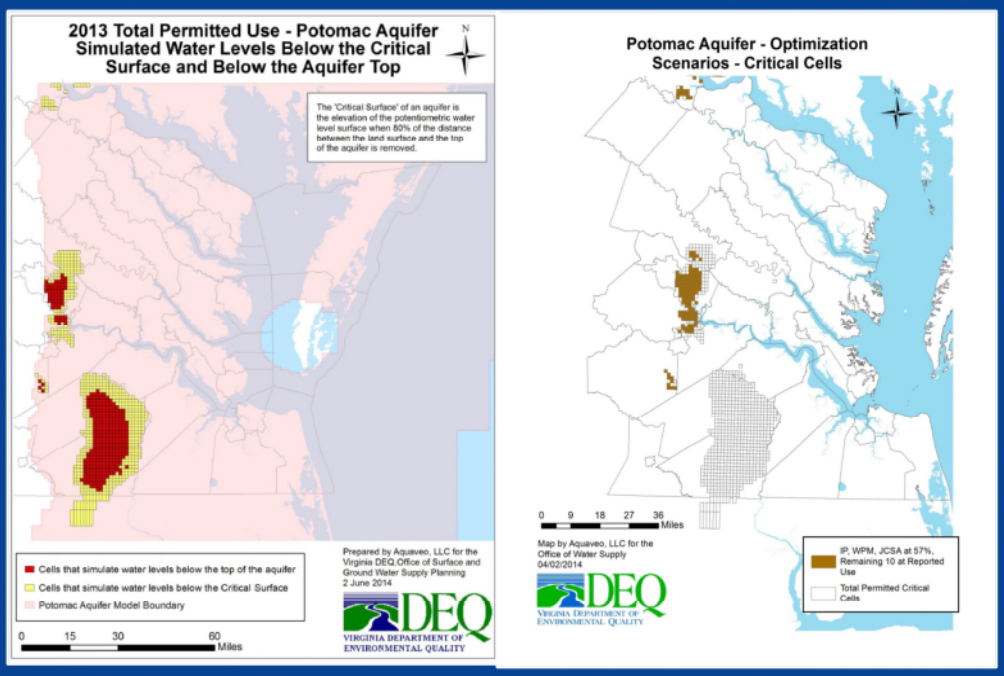




GW Management Areas






2013 Total Permitted Use - Potomac Aquifer
Simulated Water Levels Below the Critical
Surface and Below the Aquifer Top
The 'Critical Surface' of an aquifer is the elevation of the potentiometric water level surface when 80% of the distance between the land surface and the top of the aquifer is removed.
Cells that simulate water levels below the top of the aquifer
Cells that simulate water levels below the Critical Surface
Potomac Aquifer Model Boundary
0 15 30 60 Miles
Prepared by Aquaveo, LLC for the Virginia DEQ Office of Surface and Ground Water Supply Planning
2 June 2014
DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY
Potomac Aquifer - Optimization
Scenarios - Critical Cells
0 9 18 27 36 Miles
Map by Aquaveo, LLC for the Office of Water Supply
04/02/2014
DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY
IP, WPM, JCSA at 57%, Remaining 10 at Reported Use
Total Permitted Critical Cells

Questions?

Groundwater Issues II
EVGMA Advisory Committee
November 19, 2015

Permit Process

Virginia Ground Water Management Act of 1992, Code of Virginia 62.1-254

The General Assembly hereby determines and finds that, pursuant to the Groundwater Act of 1973, the continued, unrestricted usage of ground water is contributing and will contribute to pollution and shortage of ground water, thereby jeopardizing the public welfare, safety and health. It is the purpose of this Act to recognize and declare that the right to reasonable control of all ground water resources within this Commonwealth belongs to the public and that in order to conserve, protect and beneficially utilize the ground water of this Commonwealth and to ensure the public welfare, safety and health, provision for management and control of ground water resources is essential.

Who Needs a Permit?

- **ANY** user in a **GROUND WATER MANAGEMENT AREA** whose ground water withdrawals exceed **300,000** gallons in a month
- 300,000 gallons equates to approximately 1" of irrigation applied over 11 acres

OR

Operation of a well with a 125-gpm yield for 40 hours

Permit – max 10 year term

- Specifies limits on withdrawals
  - annual
  - monthly
  - source aquifer
  - location
- Includes the Water Conservation & Management Plan
- Contains Reporting Requirements
  - metered withdrawals
  - other special conditions (ex water levels, water quality, etc)
- Includes the Mitigation Plan – applies to Area Of Impact
  - Permittee has rebuttal assumption of responsibility for negative impacts to existing users within the area

Technical Evaluation Requirements

- Compare hydrogeologic framework
- Compare water levels
- Analyze aquifer pump tests
- Run appropriate regional model
- Determine Area of Impact (AOI)
- Evaluate 80% drawdown criteria
- Assess adverse water quality changes

Technical Evaluation - Office of Ground Water Withdrawal Permitting

Applicant: Virginia Department of Conservation and Recreation.

Facility: Kiptopeke State Park

Application #: GW0054000

Facility Type: Public water supply

Location: Northampton County

Requested withdrawal amount: 3,590,200 gallons per year (9,836 average gpd) not to exceed 750,000 gallons in any month (25,000 average gpd)

Requested Apportionment of Withdrawal:
Kiptopeke State Park is requesting the withdrawal be apportioned to wells within the well field as follows (based on Table 2 of the permit application).

DEQ Well #	Owner Well #	Aquifer	% of Withdrawal
165-00463	Cabin Well	Middle Yorktown-Eastover	23.7%
165-00378	New Park Supply Well	Middle Yorktown-Eastover	69.5%
165-00380	Dump Station Well	Middle Yorktown-Eastover	0.3%
165-00560	Environ. Center Well	Middle Yorktown-Eastover	6.5%

Summary of Requested Withdrawal:
The application is for a renewal of permit GW0031600 with modification under the 1992 Ground Water Management Act. The new application represents a slight increase from the previously permitted 3.24 million gallons per year (mgy) to 3.59 mgy. The withdrawal is a public water supply to support the campground, the beach area, a picnic area, offices and shops, and a proposed Visitor Environmental Center. Water for the park is withdrawn from the Middle Yorktown-Eastover aquifer. A proposed well is to be installed to provide water supply to the Visitor Environmental Center that is not yet scheduled for construction.

This report presents the results of the technical evaluation of the requested withdrawal. Section 14 and Section 16 of the Application for a Ground Water Withdrawal Permit[1] define the two components of the technical evaluation:

Section 14. Area of Impact of the Proposed Withdrawal:
Pursuant to 9 VAC 25-610-110(D)(2) of the Ground Water Withdrawal Regulations[2], DEQ staff will perform a technical evaluation to determine the areas of any aquifers that will experience at least one foot of water level decline due to the proposed withdrawal. Hydrogeologic information such as, but not limited to, aquifer properties (transmissivity and storage coefficient) obtained from aquifer testing may be required.

[1] Refer to http://www.deq.virginia.gov/groundwater/pdf/R_APPLICATION.pdf

[2] Refer to http://www.deq.virginia.gov/groundwater/pdf/gwwithdrawal_regs.pdf

Evaluation Criteria (9VAC25-610-110)

- No more groundwater than will be applied to the proposed beneficial use
- Determine the areas of any aquifers that will experience at least one foot of water level declines and the potential for the proposed withdrawal to cause salt water intrusion...
- Demonstrate that the maximum safe supply of groundwater will be preserved and protected for all other beneficial uses
- Demonstrate no significant unmitigated impact on existing groundwater users or the groundwater resource

Evaluation Criteria (9VAC25-610-110)

- Demonstrates that **no other sources of water supply, including reclaimed water, are practicable**
- Demonstrates that the groundwater withdrawal will originate from the aquifer that contains **the lowest quality water that will support the proposed beneficial use**
- Demonstrates that the amount of groundwater withdrawal requested is the **smallest amount of withdrawal necessary** to support the proposed beneficial use and that the amount is representative of the amount necessary to support similar beneficial uses when adequate conservation measures are employed
- **Implements the water conservation and management plan** as an enforceable condition of the withdrawal permit

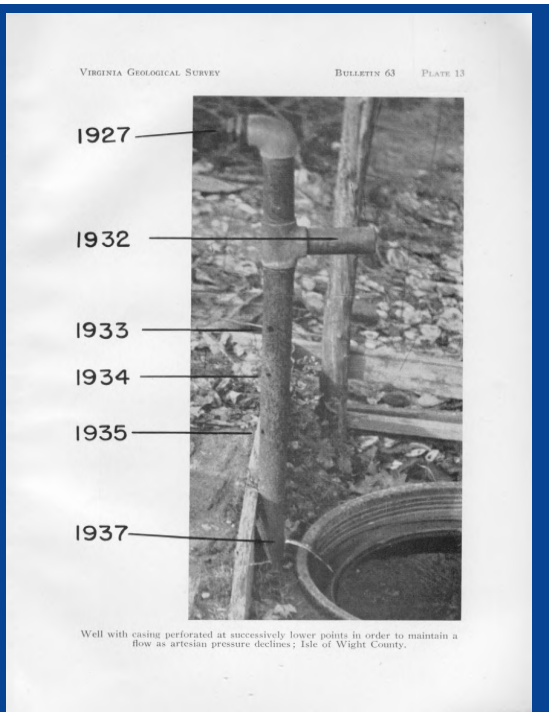
Evaluation Criteria (9VAC25-610-110)

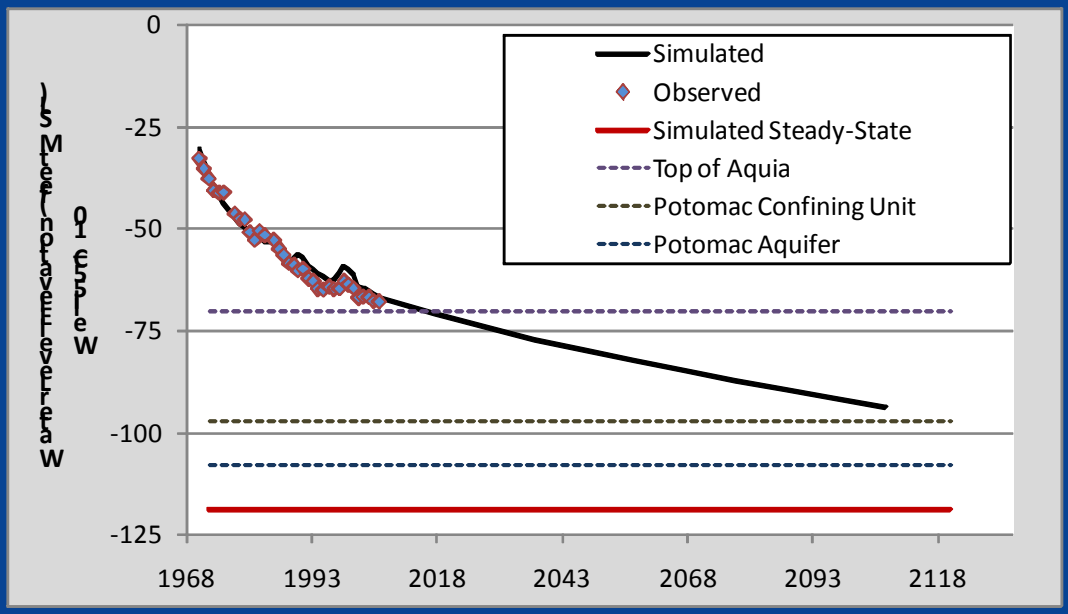
- Demonstrates that the area of impact of the proposed withdrawal will remain on property owned by the applicant or that there are no existing groundwater withdrawers within the area of impact of the proposed withdrawal
- Shall provide and implement a plan to mitigate all adverse impacts on existing groundwater users
- Withdrawals will not lower water levels, in any confined aquifer that the withdrawal impacts, below a point that represents 80% of the distance between the land surface and the top of the aquifer
- Demonstrate that the proposed groundwater withdrawal will not result in salt water intrusion

Critical Groundwater Level Concepts Raised in the Workgroups

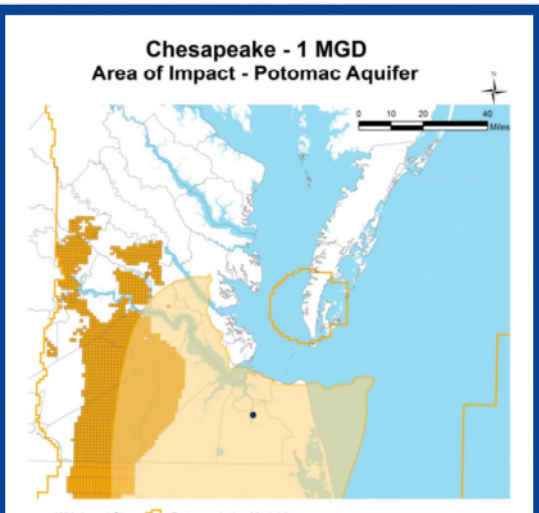
Can't use GW without declines in water levels

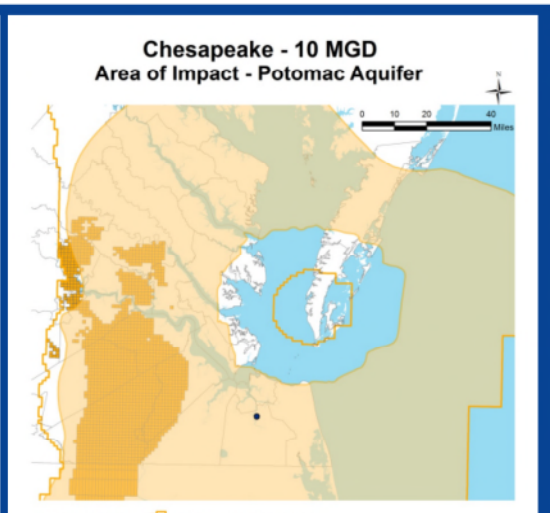
(Watch Scott Draw)

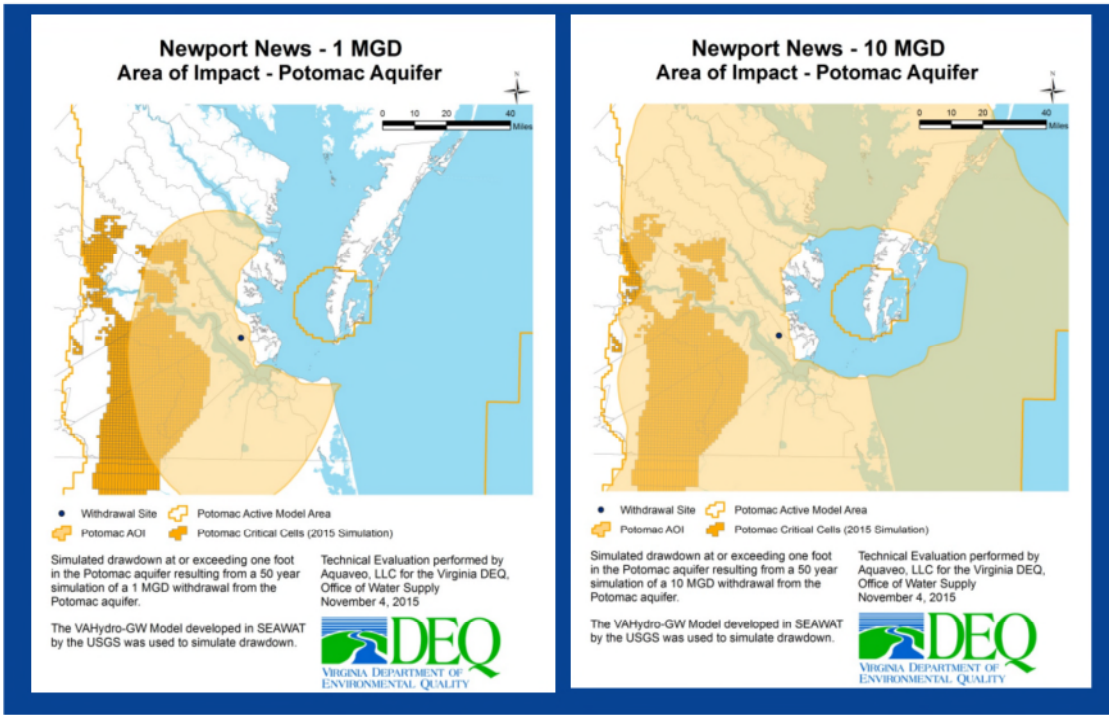


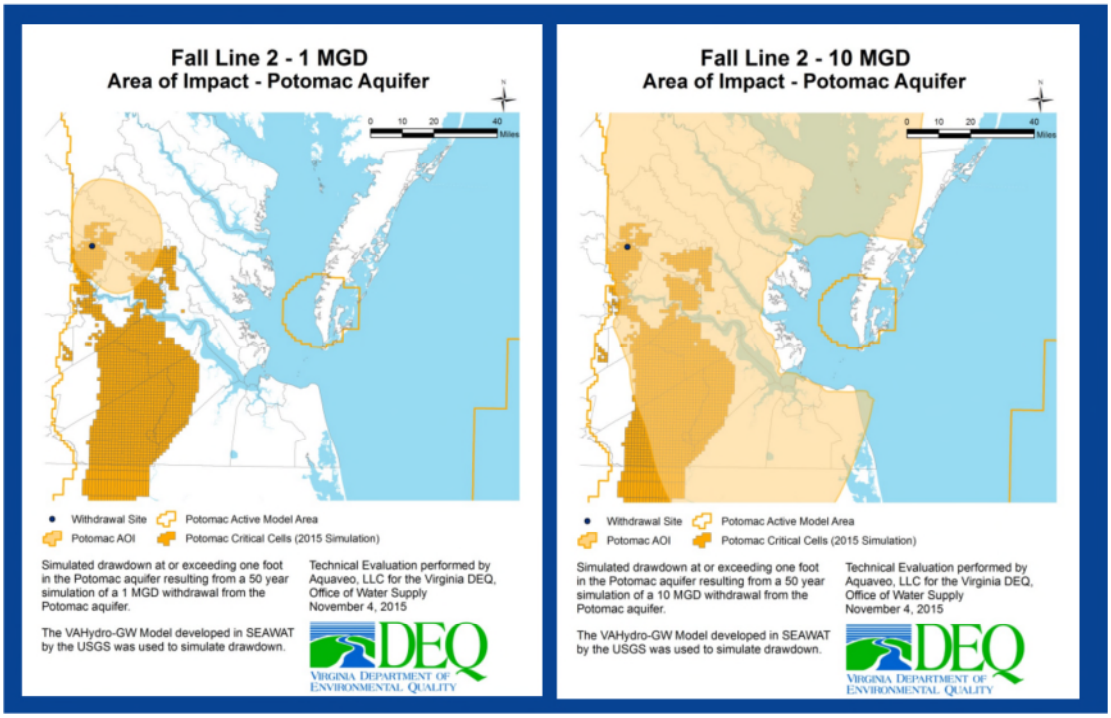


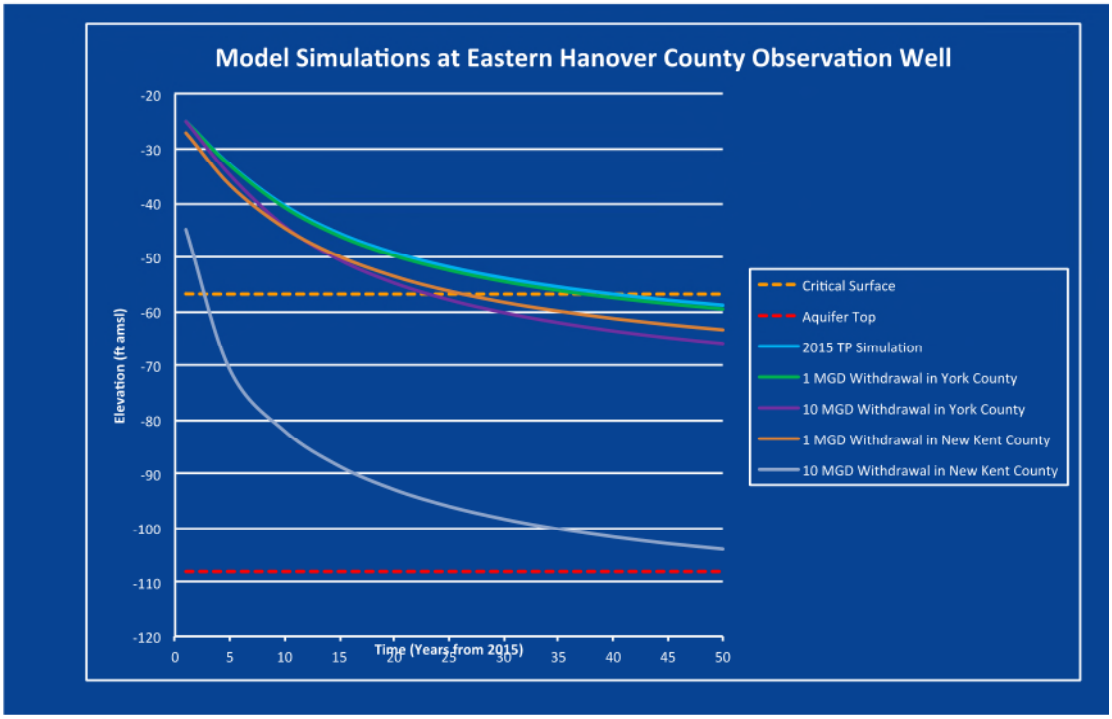
Withdrawals of the same size have different impacts based on location

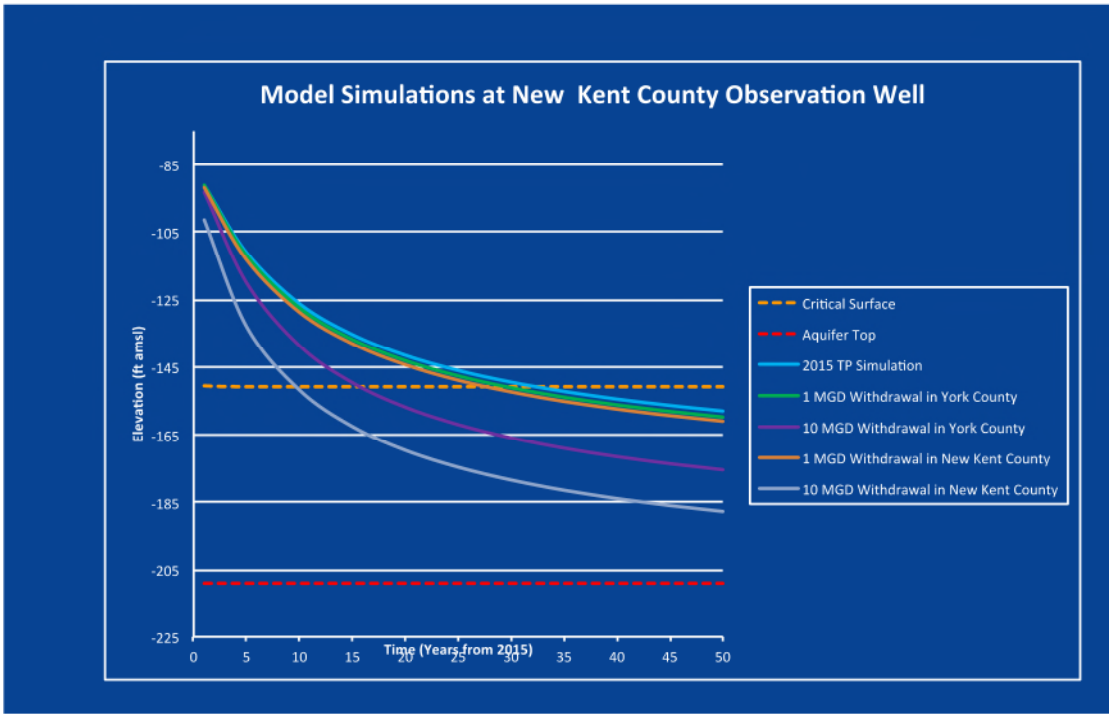


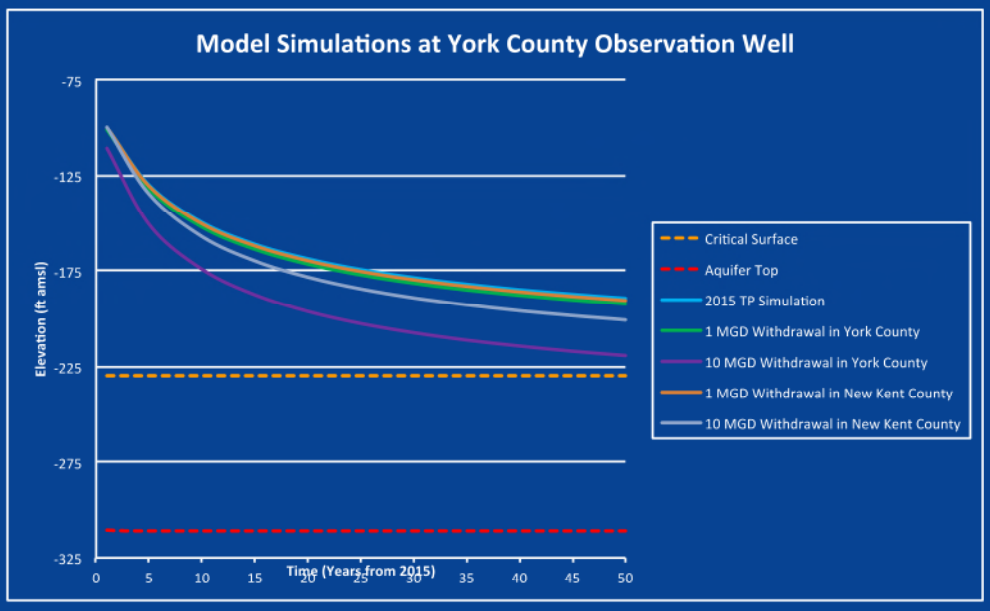



Newport News - 1 MGD
Area of Impact - Potomac Aquifer
0 10 20 40 Miles
Withdrawal Site
Potomac Active Model Area
Potomac AOI
Potomac Critical Cells (2015 Simulation)
Simulated drawdown at or exceeding one foot in the Potomac aquifer resulting from a 50 year simulation of a 1 MGD withdrawal from the Potomac aquifer.
Technical Evaluation performed by Aquaveo, LLC for the Virginia DEQ, Office of Water Supply
November 4, 2015
The VAHydro-GW Model developed in SEAWAT by the USGS was used to simulate drawdown.
DEQ
Virginia Department of Environmental Quality
Newport News - 10 MGD
Area of Impact - Potomac Aquifer
0 10 20 40 Miles
Withdrawal Site
Potomac Active Model Area
Potomac AOI
Potomac Critical Cells (2015 Simulation)
Simulated drawdown at or exceeding one foot in the Potomac aquifer resulting from a 50 year simulation of a 10 MGD withdrawal from the Potomac aquifer.
Technical Evaluation performed by Aquaveo, LLC for the Virginia DEQ, Office of Water Supply
November 4, 2015
The VAHydro-GW Model developed in SEAWAT by the USGS was used to simulate drawdown.
DEQ
Virginia Department of Environmental Quality


Fall Line 2 - 1 MGD
Area of Impact - Potomac Aquifer
0 10 20 40 Miles
Withdrawal Site
Potomac Active Model Area
Potomac AOI
Potomac Critical Cells (2015 Simulation)
Simulated drawdown at or exceeding one foot in the Potomac aquifer resulting from a 50 year simulation of a 1 MGD withdrawal from the Potomac aquifer.
Technical Evaluation performed by Aquaveo, LLC for the Virginia DEQ, Office of Water Supply
November 4, 2015
The VAHydro-GW Model developed in SEAWAT by the USGS was used to simulate drawdown.
DEQ
Virginia Department of Environmental Quality
Fall Line 2 - 10 MGD
Area of Impact - Potomac Aquifer
0 10 20 40 Miles
Withdrawal Site
Potomac Active Model Area
Potomac AOI
Potomac Critical Cells (2015 Simulation)
Simulated drawdown at or exceeding one foot in the Potomac aquifer resulting from a 50 year simulation of a 10 MGD withdrawal from the Potomac aquifer.
Technical Evaluation performed by Aquaveo, LLC for the Virginia DEQ, Office of Water Supply
November 4, 2015
The VAHydro-GW Model developed in SEAWAT by the USGS was used to simulate drawdown.
DEQ
Virginia Department of Environmental Quality


Model Simulations at Eastern Hanover County Observation Well
Elevation (ft amsl)
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0
5
10
15
20
25
30
35
40
45
50
Time (Years from 2015)
Critical Surface
Aquifer Top
2015 TP Simulation
1 MGD Withdrawal in York County
10 MGD Withdrawal in York County
1 MGD Withdrawal in New Kent County
10 MGD Withdrawal in New Kent County


Model Simulations at New Kent County Observation Well
Elevation (ft amsl)
-85
-105
-125
-145
-165
-185
-205
-225
0
5
10
15
20
25
30
35
40
45
50
Time (Years from 2015)
Critical Surface
Aquifer Top
2015 TP Simulation
1 MGD Withdrawal in York County
10 MGD Withdrawal in York County
1 MGD Withdrawal in New Kent County
10 MGD Withdrawal in New Kent County


Model Simulations at York County Observation Well
-75
-125
-175
-225
-275
-325
Elevation (ft amsl)
0
5
10
15
20
25
30
35
40
45
50
Time (Years from 2015)
Critical Surface
Aquifer Top
2015 TP Simulation
1 MGD Withdrawal in York County
10 MGD Withdrawal in York County
1 MGD Withdrawal in New Kent County
10 MGD Withdrawal in New Kent County

Questions?

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Appendix D: HRSD SWIFT Presentation

Who/What is HRSD?

- Provide wastewater treatment for 18 localities (250 mgd treatment capacity)
- Serve 1.7 million people (20% of all Virginians)
- Independent political subdivision with Governor appointed Commission

Water Issues Challenging Virginia and Hampton Roads

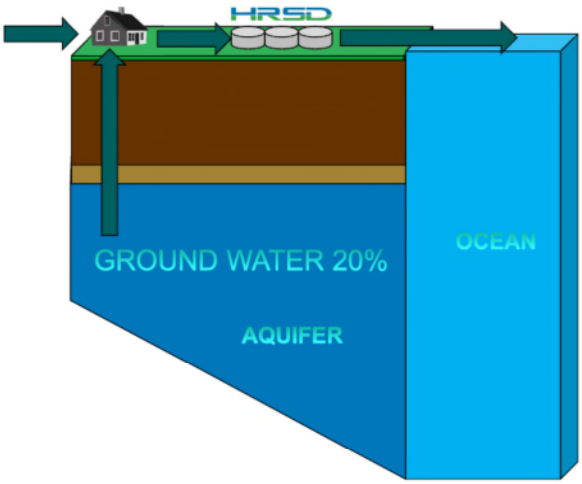
- Depletion of groundwater resources
  - Including protection from saltwater contamination
- Water quality concerns
  - Chesapeake Bay restoration
  - Local water quality issues
- Sea level rise
  - Compounded by land subsidence
- Wet weather sanitary sewer overflows (SSO)
  - Compliance with Federal enforcement action

Current state of wastewater in Hampton Roads

SURFACE WATER 80%

HRSD costs are rising to treat water to higher standards.

Treated water currently discharged to area waterways – no beneficial use.

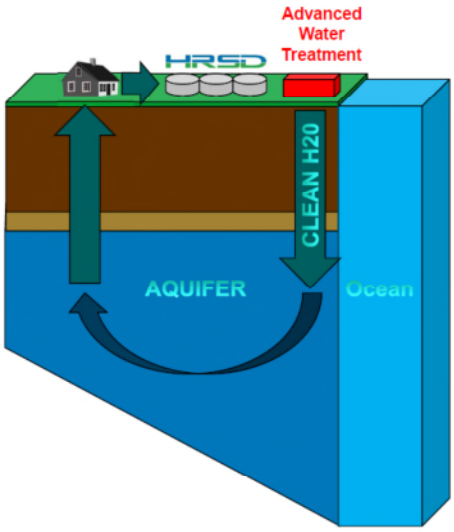


Regulatory uncertainty

- Wastewater permits have 5 year terms
- New regulations can require extensive investment in new treatment processes
- Always concerned about the next issue on the horizon
  - Viruses
  - Pharmaceutical products
  - Further nutrient reductions (e.g. TMDL Backstops)
- Challenging to manage appropriate risk factors

SWIFT – Sustainable Water Initiative for Tomorrow

- Treat water to meet drinking water standards and replenish the aquifer with clean water to:
  - Provide regulatory stability for wastewater treatment
  - Reduce nutrient discharges to the Bay
  - Reduce the rate of land subsidence
  - Provide a sustainable supply of groundwater
  - Protect the groundwater from saltwater contamination



Advanced water treatment – to drinking water standards

- Further advanced treatment of treated wastewater for the purposes of drinking water supply augmentation occurs throughout world, many locations in USA and even in Virginia, producing water that exceeds drinking water standards
  - Upper Occoquan Service Authority/Fairfax Water, VA 1978
  - Loudoun Water
  - Montebello Forebay, CA 1962
  - El Paso, TX 1985
  - Scottsdale, AZ 1999
  - Orange County, CA 2008
  - Arapahoe, CO 2009
  - ***San Diego, CA 2020***

Membrane Pilot Train

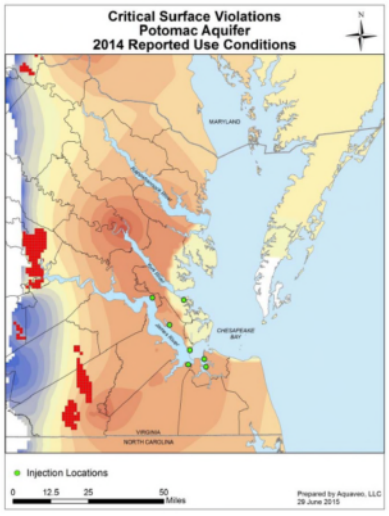
Carbon Pilot Train

Water Issues Challenging Virginia and Hampton Roads

- **Depletion of groundwater resources**
  - **Including protection from saltwater contamination**
- Water quality concerns
  - Chesapeake Bay restoration
  - Local water quality issues
- Sea level rise
  - Compounded by land subsidence
- Wet weather sanitary sewer overflows (SSO)
  - Compliance with Federal enforcement action

Unsustainable Aquifer Withdrawals

- Over-allocated permitted withdrawal
  - Water levels falling several feet/yr
- 177 permits = 147.3 MGD
  - Currently withdrawing approximately 115 mgd
- 200,000 unpermitted "domestic" wells
  - Estimated to be withdrawing approx. 40 mgd growing at 1 mgd per year



Hydrogeologic Section: Coastal Plain of Virginia

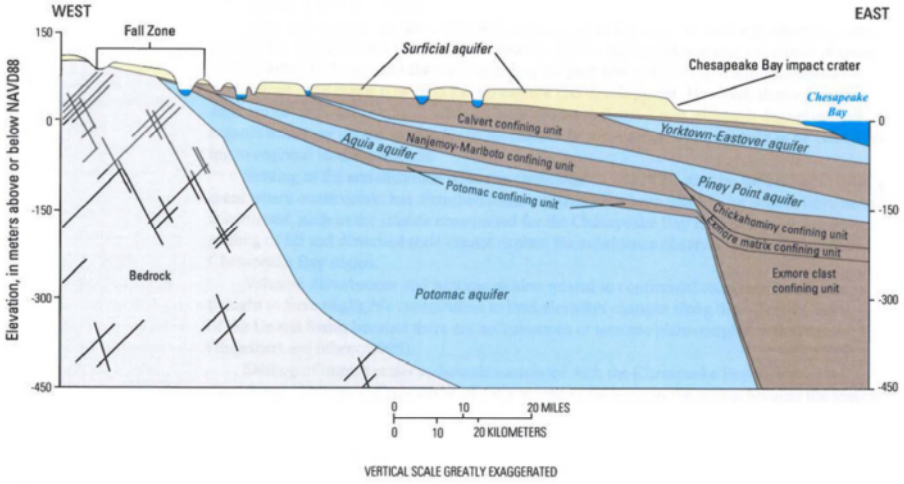
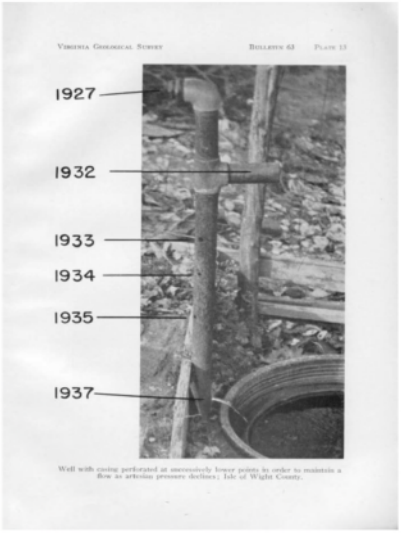


Figure 11. Section illustrating layering in the Virginia Coastal Plain aquifer system from west to east. Elevation relative to North American Vertical Datum of 1988 (NAVD88). Modified from McFarland and Bruce (2006).

Groundwater depletion has been rapid

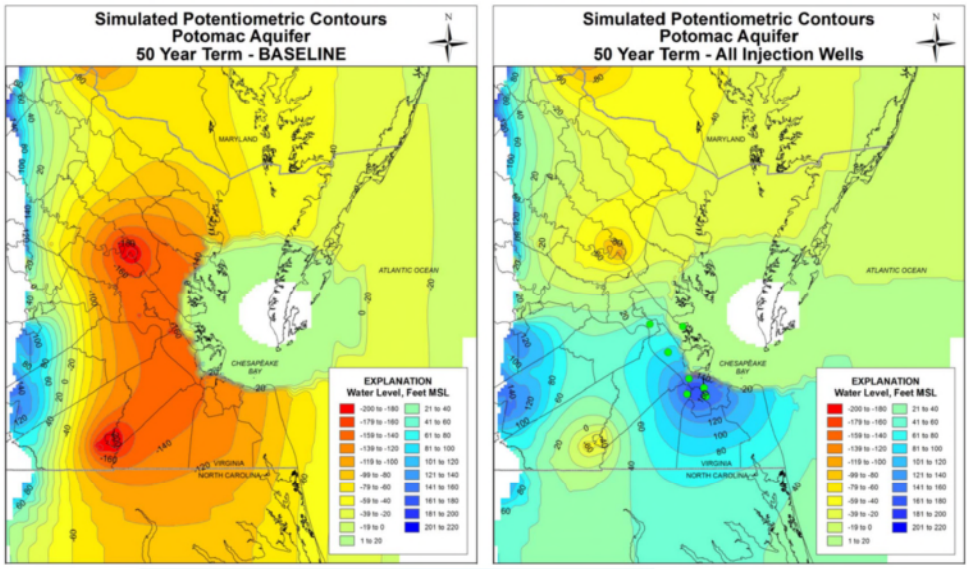
A, Overflow from artesian well in Isle of Wight County is wasted.



Well with casing perforated at successively lower points in order to maintain a flow as artesian pressure declines; Isle of Wight County.

- Artesian wells in early 1900s – groundwater wells required valves not pumps!
- In about 100 years have gone from water levels at 31 feet above sea level to 200± feet below.

Modeled Potomac Aquifer water levels with and without SWIFT

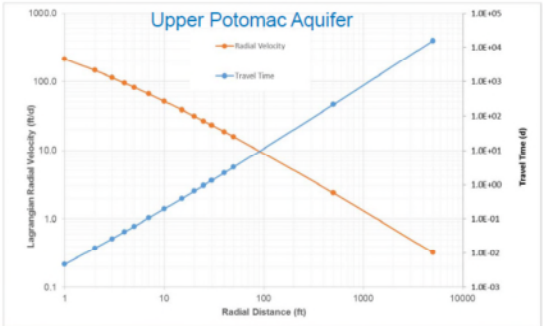


What is the travel time of the injected water?

Approximately 180 years to travel one mile

- Recharge water velocity isn't constant and decelerates relatively rapidly as it moves from the injection site
- Regional model predictions reflect the steady state velocities that would be experienced at distances of a mile and greater. Model predictions range from 3 to 29 feet/year
- Data from the SWIFT Research Center will allow refinement of recharge velocities and travel times

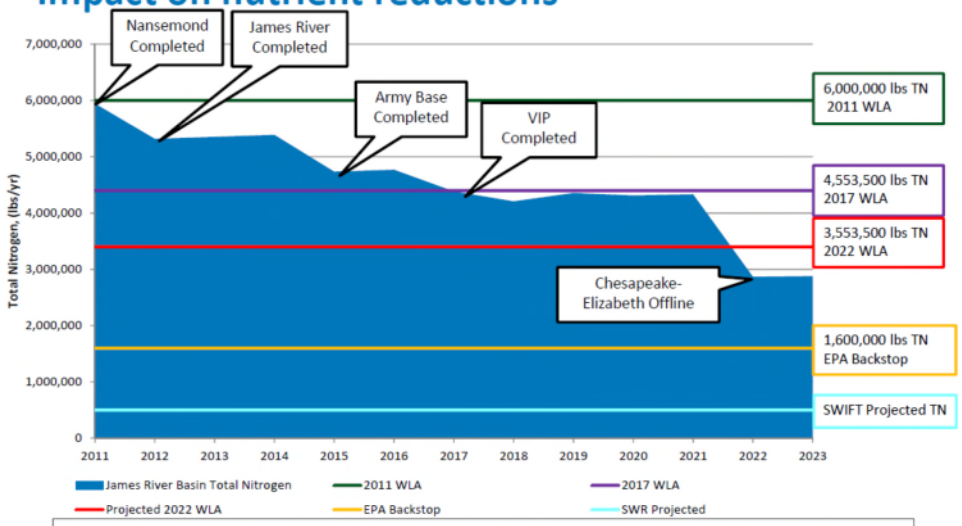
As shown in the figure, as distance from the recharge well increases, recharge flow velocity decreases while travel time increases



Water Issues Challenging Virginia and Hampton Roads

- Depletion of groundwater resources
  - Including protection from saltwater contamination
- **Water quality concerns**
  - **Chesapeake Bay restoration**
  - **Local water quality issues**
- Sea level rise
  - Compounded by land subsidence
- Wet weather sanitary sewer overflows (SSO)
  - Compliance with Federal enforcement action

Impact on nutrient reductions



James River Basin – TN Similar results with TP and TSS and in other river basins.

WLA – Nutrient Waste Load Allocation in lbs/yr

SWIFT Benefits: Chesapeake Bay Restoration Goals

	HRSD Bay TMDL Allocations	HRSD Post SWIFT Loads (2030)	Available for other needs	Stormwater Reduction Needs*
Nitrogen				
James	3,555,500	500,000	3,055,500	63,039
York	288,315	39,000	249,315	19,114
Phosphorus				
James	318,436	50,000	268,436	13,088
York	19,315	6,000	13,315	3,887
Sediment				
James	14,000,000	700,000	13,300,000	5,269,142
York	1,400,000	66,000	1,334,000	1,413,762

* DEQ Regulated Stormwater w/o federal lands

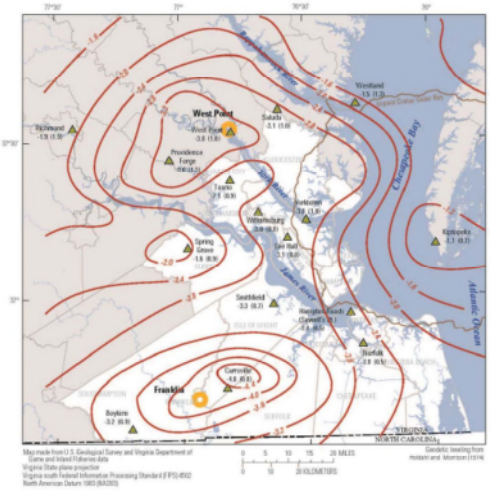
Water Issues Challenging Virginia and Hampton Roads

- Depletion of groundwater resources
  - Including protection from saltwater contamination
- Water quality concerns
  - Chesapeake Bay restoration
  - Local water quality issues
- **Sea level rise**
  - **Compounded by land subsidence**
- Wet weather sanitary sewer overflows (SSO)
  - Compliance with Federal enforcement action

Land subsidence – *we are sinking*

- According to USGS
  - Up to 50% of relative sea-level rise may be due to land subsidence
  - **Up to 50% of land subsidence may be due to aquifer compaction**

HAMPTON ROADS IS THE #2 LARGEST POPULATION CENTER AT RISK

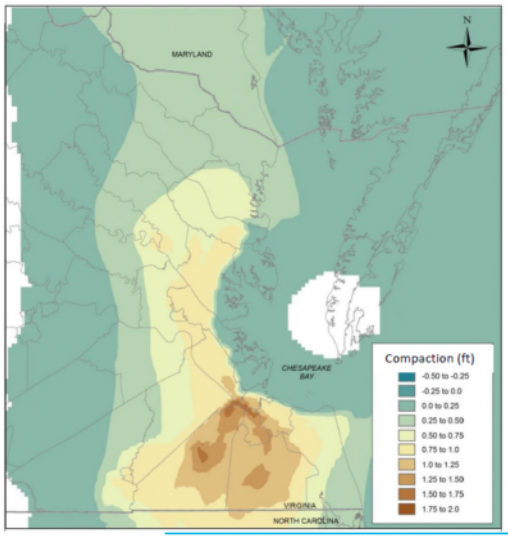


Extensometer – HRSD Nansemond Plant, Suffolk

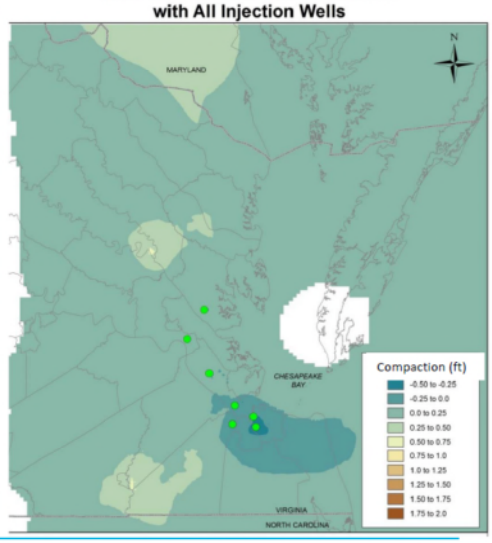
- Extensometer used to measure land subsidence
- New instrument installed at HRSD's Nansemond Plant in 2017
- Funding approved in 2017 General Assembly session

Aquifer compaction without and with SWIFT

Simulated Total Aquifer System Compaction from 1890 to 2064 - Total Permitted



Simulated Total Aquifer System Compaction from 1890 to 2064 - Total Permitted with All Injection Wells



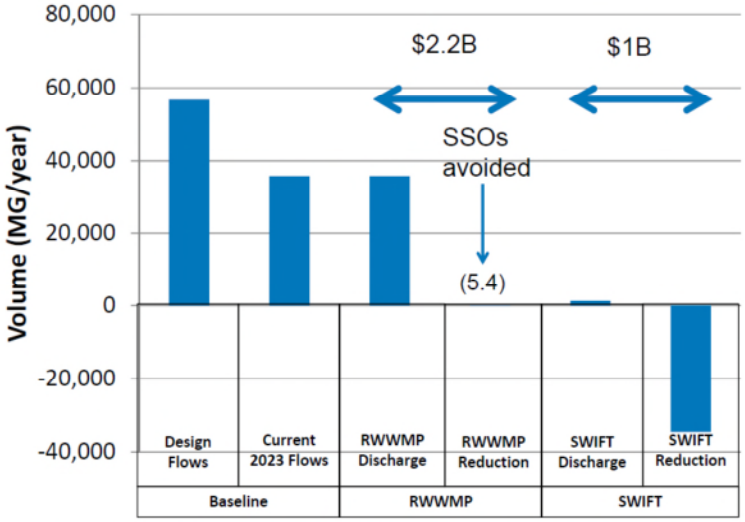
Water Issues Challenging Virginia and Hampton Roads

- Depletion of groundwater resources
  - Including protection from saltwater contamination
- Water quality concerns
  - Chesapeake Bay restoration
  - Local water quality issues
- Sea level rise
  - Compounded by land subsidence
- **Wet weather sanitary sewer overflows (SSO)**
  - **Compliance with Federal enforcement action**

Sewer Overflows

- No chronic locations
- No data to support episodic SSOs contribute to local water bacteria impairment
- Recent success with more focused efforts
  - Wet weather and dry weather monitoring
  - Source tracking "hot spots"
  - Coordinating field work with locality
- Overflows not eliminated with Regional Wet Weather Plan when weather event generates flows above designed service level

SSO Work Versus SWIFT – Volume Discharged



RWWMP values: based on avoidance of 271 MG loss over 50 years associated with capacity-related overflows (5 yr Level of Service).

SWIFT Approach

- Initial feasibility study – desktop and modeling
- Work with regulators, policy makers and public to identify challenges and build support
- Define water quality targets
- Drill test wells at injection sites
- Pilot treatment at HRSD facility
- 1 MGD Research Center – treatment and aquifer recharge

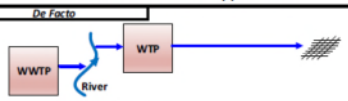
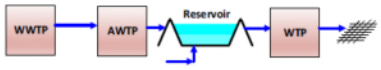
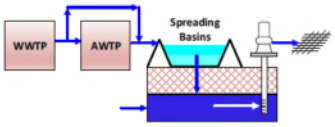
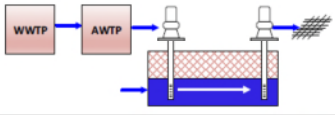
SWIFT Regulatory Process

- Permits obtained through EPA Underground Injection Control (UIC) Program
  - Program designed to protect the underground sources of drinking water
- Permits will include regulatory limits for recharge water as defined through collaboration with VDH and DEQ
- HRSD will work with VDH, DEQ and other key stakeholders to establish a third-party oversight body, likely similar in structure to the Occoquan Watershed Monitoring Laboratory

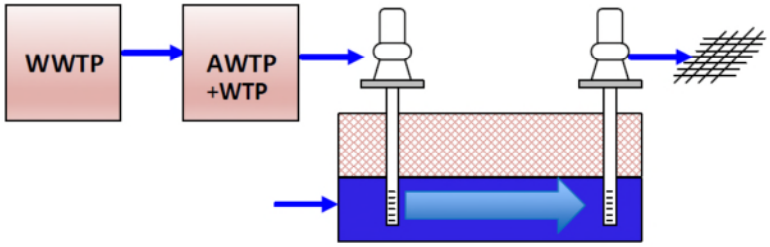
SWIFT Independent Panel Review

- HRSD reached out to the National Water Research Institute (NWRI) to convene a panel of experts to review the SWIFT program
  - The panel consisted of national experts in the fields of potable reuse, public health protection, water treatment process engineering, and emerging contaminant research
- Panel supported the SWIFT program as a water supply augmentation project and identified several opportunities to further enhance the program
- NWRI will continue to review the program

Water Supply Augmentation Approaches

Indirect Potable Reuse Approaches	Examples
De Facto 	Common throughout the world (e.g., Mississippi River, Colorado River, etc...)
Surface Water Augmentation 	Upper Occoquan Service Authority (Northern Virginia); Gwinnett County (Georgia); Singapore NEWater
GW Recharge via Spreading Basins 	Montebello Forebay (Los Angeles, CA); El Paso (Texas); Chino Basin (Chico, CA)
GW Recharge via Direct Injection 	GWRS (Orange County, CA); West Basin (CA); Los Alamitos (Long Beach, CA); Scottsdale Water Campus (AZ)

Managed Aquifer Recharge



- Travel time – >100 years?
- Soil aquifer treatment, blending with existing groundwater
- Human health criteria still apply due to drinking water designation of aquifer
- Geochemical compatibility is required!

Typical Approach to Developing Finished Water Goals for Groundwater Recharge

- Meet all primary Maximum Contaminant Levels (MCLs) regulated by the USEPA in the SDWA
- Provide multiple barriers to pathogens and organics (including chemicals)
- Aquifer compatibility
- Hazard Analysis and Critical Control Point System
  - System for identifying, evaluating, and controlling hazards which are significant for human health protection
  - Controls or actions in place to prevent or detect deviations in treatment processes at earliest possible opportunity
  - Action level exceedance will prevent water from entering the recharge well

Example Water Quality Goals

Parameter	Pertinent Regulatory Requirements					
	UOSA (VA); Surface Water Augmentation	El Paso (TX) – Direct Injection	FL – Direct Injection	EPA Guidelines – Direct Injection	CA – Direct Injection	TX – Direct Potable Reuse (min reqmts)
MCLs		Comply with all primary drinking water MCLs				
Nitrogen	TKN < 1 mg/L	NOx – N < 10 mg/L	TN < 10 mg/L	None	TN < 10 mg/L	NO3-N < 10 mg/L; NO2-N < 1 mg/L
Solids	TSS < 1 mg/L; Turb < 0.5 NTU	Turb < 1 NTU	Turb < 2 to 2.5 NTU	Turb < 2 NTU	Turb < 2 NTU	-
Organics (TOC/COD)	COD = 10 mg/L (~ 3.8 mg/L TOC)	None	3 mg/L; TOX < 0.2 mg/L	2 mg/L (of WW origin)	0.5 mg/L	-
Enteric Viruses	Multiple barriers required (total coliform < 2 / 100 mL)	None, but multiple barriers required	Multiple barriers required (Total Coliform < 4 / 100 mL)	Multiple barriers required (Total Coliform BDL)	12-log LRV	8-log LRV
Crypto					10-log LRV	5.5-log LRV
Giardia					10-log LRV	6-log LRV
Misc	TP < 0.1 mg/L					

Not all parameters are listed (e.g., other requirements such as travel time, disinfection residual, etc… are required in some states and locations)
NOTE: LRV= Log Removal Value

Finished Water Quality Preliminary Targets

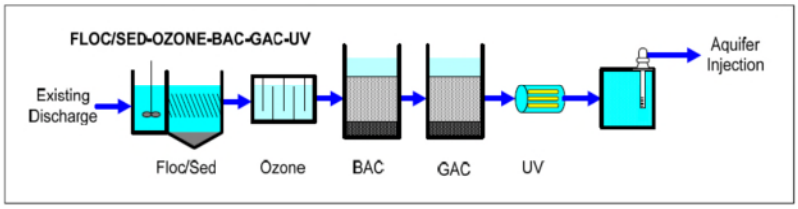
Parameter	Proposed Regulatory Limit	Water Quality Goal (non-regulatory)
MCLs	Meet all primary MCLs	N/A
Nitrate (NO3-N)	5 mg/L monthly average; 8 mg/L max daily	Secondary Effluent CCP Action Limit for TIN = 6 mg/L
Turbidity	IFE <0.15 NTU 95% of time & never > 0.3 NTU in two consecutive measurements	CCP Action Limit at 0.10 NTU to initiate backwash or place filter in standby
TOC	4 mg/L monthly average	COP Action Limit at 4 mg/L, laboratory 10 day average
Total coliform	< 2 CFU / 100 mL; 95% of time	CCPs to achieve 12 LRV for viruses and 10 LRV for Crypto & Giardia
E. Coli	Non-detect 95% of time	
Unregulated Chemicals	None	Monitor suite of chemicals and address as necessary
Total Dissolved Solids	None	Monitor PAS compatibility

Aquifer Compatibility

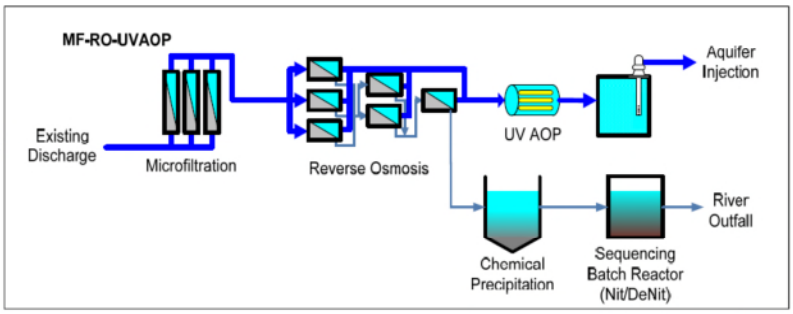
- Important to inject similar water quality to that present in the aquifer
  - Ionic strength should be within ½-order of magnitude of aquifer (TDS ~ 1,400 – 4,800 mg/L) to prevent swelling, repulsion, and migration of clay mineral fragments
  - Proportion of major ions should match to prevent damaging ion exchange
    - Calcium (~30 mg/L) and sodium (~1,000 mg/L)
- EPA secondary MCL for TDS = 500 mg/L
- Pilot values for Carbon-based Train:
  - 50th Percentile: 541 mg/L
  - 99th Percentile : 635 mg/L
- Recommendation:
  - Given high ionic strength of aquifer, aquifer compatibility should take precedence over finished water TDS limit
  - No specific TDS limit; targets will be created for compatibility

Advanced water treatment alternatives

Carbon Based



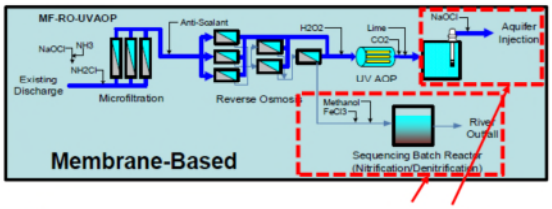
Membrane Based



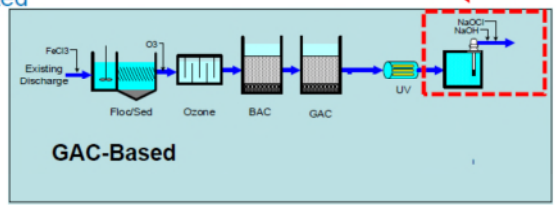
The SWIFT Pilot

Pilot Plants

- Membrane-Based Train
  - Ultrafiltration
  - Reverse Osmosis
  - UV Advanced Oxidation
- Carbon-Based Train
  - Coagulation/Flocculation/Sedimentation
  - Ozone oxidation
  - Biologically Active Granular Activated Carbon (BAC)
  - Granular Activated Carbon (GAC)
  - UV Disinfection



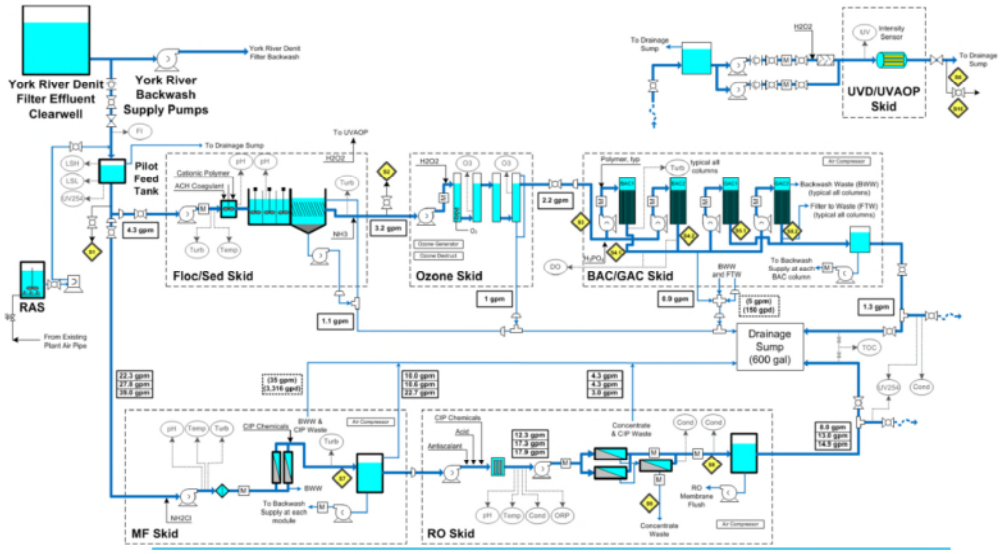
Not tested during piloting



Membrane-Based Pilot

Carbon-Based Pilot

SWIFT Pilot Process Flow Diagram



Pilot Testing Results

- Both trains meet drinking water quality standards
- All primary MCLs (regulated) are being met
  - Bromate has been the only challenge (expected)
- All secondary MCLs (aesthetics) are being met, except in the Carbon-based AWT system:
  - TDS (salt) is slightly above 500 mg/L (50%/99% = 541/635 mg/L)
  - Sulfate and chloride are consistently less than 250 mg/L

Pilot Evaluation: Carbon vs Membrane Aquifer Compatibility

- Potomac Aquifer System (PAS) compatibility analysis showed that due to the high total dissolved solids (TDS) in the receiving aquifer, the carbon-based effluent is more suitable for recharge
  - Membrane-based effluent would require significant salt addition to the finished water to achieve PAS compatibility targets

Pilot Evaluation: Carbon vs Membrane Contaminants of Emerging Concern

- A suite of 96 CECs analyzed in both treatment processes
- Treatment case study for 8/31/16
  - Only constituents detected by analysis through the train are displayed in chart
- Multi-barrier approach is shown by decrease in concentration through the treatment process
- All values shown in ng/L (parts per trillion)

Final sample point for each train:
Carbon train = GAC Low
Membrane train = UVAOP Eff

		Carbon Train			Membrane Train	
Contaminant	Pilot Feed	O3 Eff	BAC Low	GAC Low	RO Eff	UVAOP Eff
4-nonylphenol	1100	320	<100	<100	100	<100
Acesulfame-K	1100	360	290	<20	<20	<20
Iohexal	7500	4000	1400	<10	31	<10
Sucralose	43000	28000	12000	<100	140	130
Primidone	130	46	21	<5	<5	<5
TCEP	140	130	45	<10	<10	<10

Pilot Evaluation: Carbon vs Membrane Organic Carbon

- Removal of total organic carbon (TOC) differed between the two pilot processes
  - Given similar performance of both pilot trains with respect to emerging contaminant removal, higher TOC concentration present in the finished water from the carbon train does not equate to a higher human health risk
- Bioassay analyses designed to detect the potential endocrine disruption or cell toxicity were conducted
  - Neither train was shown to have the potential to cause endocrine disruption or cell toxicity

Pilot Evaluation: Carbon vs Membrane Pathogens

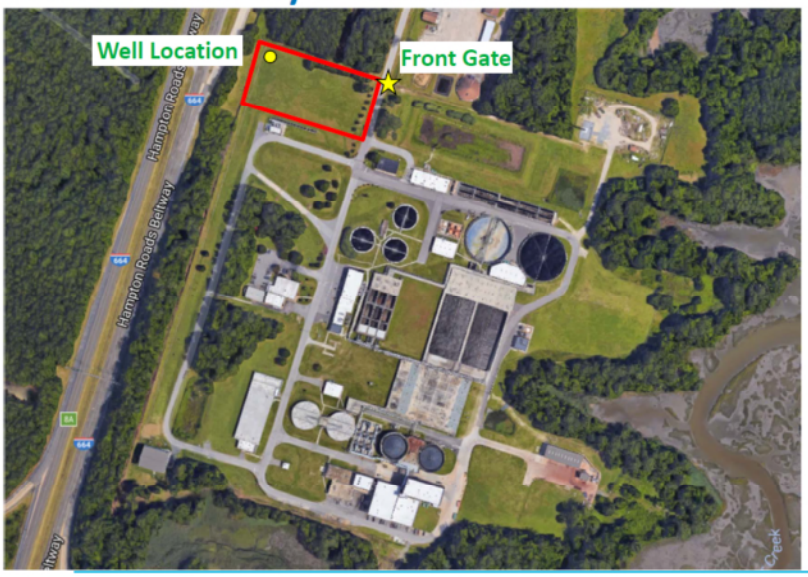
- Both trains provide similar quantifiable log removal credit for viruses, *Cryptosporidium*, and *Giardia*, and demonstrated complete removal of Male specific coliphage (virus) (>8 log removal) in challenge testing

Pathogen Indicators	Carbon Train Finished Water	Membrane Train Finished Water
Total coliform, 99th percentile	<1 MPN/100mL	1
E coli, 99th percentile	<1 MPN/100mL	<1 MPN/100mL
MS2 Challenge Test	> 8-log removal	> 8-log removal
Pepper Mild Mottle Virus	>5.9 log removal	>5.9 log removal

The SWIFT Research Center

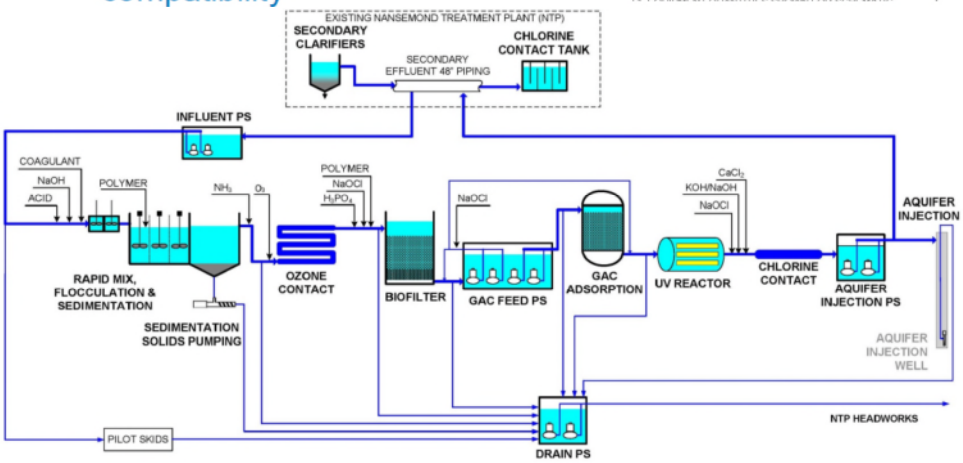
SWIFT Demonstration Facility – 1 MGD with Injection Well

Location of facility within Nansemond TP site



Process Flow Diagram for SWIFT Research Center

- Carbon treatment process selected to ensure aquifer compatibility



Timeline

- Now
  - Pilot AWT system operating since June 2016
  - Soil column tests to evaluate soil aquifer treatment
  - Working with VDH to identify existing private wells around recharge sites
  - Preparing for full-scale implementation
  - MS4 trade agreements with Hampton Roads localities
- 2018
  - SWIFT Research Center with 1 MGD recharge well
- 2020
  - Permits issued for full scale facilities
- 2020 to 2030
  - Construction through phased implementation
- 2030 Fully operational
  - 120 MGD of clean water recharging the aquifer

Why now?

- Consent Decree requires plan submittal with schedule to EPA October 2017
  - Lose financial ability to pursue water recycling project until 2037 at earliest
- Bay TMDL deadline is 2025
  - Will require more significant investments in nutrient and sediment removal without SWIFT
  - HRSD is backstop if Agriculture and Stormwater come up short
- Groundwater scarcity will continue to get worse
  - Will force development of additional water supplies by local governments
  - Chills development in eastern Virginia
  - Potential loss of water dependent industries
- Next regulation (viruses, emerging contaminants, ???) will require plant upgrades


swift
Daily Press
GROUNDWATER DRAIN: A BIG-DOLLAR DILEMMA
PENINSULA CITIES IN ECONOMIC DOLDRUMS
Pilot
Can your sinks and toilets fight sea-level rise?
HRSD doesn't want to waste wastewater
NO WASTING WATER
Following the lead of other regions, local plant tries treating wastewater
Sip shape
Hampton Roads Sanitation District's treated sewage water tastes great, say officials, and could shore up the area's sea level rise and bay cleanup issues
Sustainable Water Initiative for Tomorrow
50


swift
Hopes that wastewater can conserve land in coastal Va.
BY DARRYL FEARS
SEAFORD, VA. — It looks like a mad scientist's lab, something straight out of a sci-fi novel. Valves turn in every direction. Tubes are stacked halfway to the ceiling. Tiny bubbles dance in large vats of water.
But what's happening in a hangar of the York River Treatment Plant is real, part of a grand experiment that could help keep this coastal region from continuing to subside and eventually being claimed by the rising sea. Over the next 15 months, tests will determine whether millions of gallons of wastewater can be purified to drinking water quality and injected into the ground.
If successful, the project of the Hampton Roads Sanitation District could start to replenish a giant aquifer that thousands of industries and half a million households in the area are sucking dry. Over the past five decades, they have collectively pumped out so much water that land here is falling 4 millimeters a year — or more than 1⅝ inches by 2026.
Ted Henifin's jaw-dropping, eyebrow-raising idea was proposed in 2015, and last month the sanitation district general manager kicked off the pilot phase to stop what some scientists have called a nightmare in super slow motion.
Aquifers big and small exist under Hampton Roads in muddy
AQUIFER CONTINUED ON A16
The Washington Post
Trump's refusal to honor outcome swells GOP angst
These Sukkot guests live a mile and a world apart
Sustainable Water Initiative for Tomorrow
51

SWIFT Research Center

For more information on SWIFT, visit SWIFTVA.com

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Appendix E: Alternative Sources Chart

The Alternative Source Work Group reviewed and discussed the following alternative sources:

- Fresh Surface Water – Direct Use
- Fresh Surface Water – Reservoirs
- Storm water ponds to replace irrigation wells
- Storm water treatment from pump stations
- Transfer storm water to reservoirs
- Supplemental flows to reservoir
- Reclaimed water – direct potable reuse
- Reclaimed water – indirect potable reuse
- Reclaimed water – industrial / agricultural reuse
- Desalination – brackish surface water
- Desalination – brackish groundwater
- Decentralized small scale systems supplied by quarries or other impoundments
- Inter-basin transfers
- Aquifer storage and recovery
- Aquifer recharge – treated surface water
- Aquifer recharge – purified wastewater
- Interconnections/Redistribution

In addition to the alternative sources discussed by the Work Group, the following alternative sources were supplied by Planning Regions and Localities in their Water Supply Plans:

ALTERNATIVES FROM WATER SUPPLY PLANS FOR GROUNDWATER MANAGEMENT AREA LOCALITIES					
	New or expanding GW	New or expanding River Intake	New or expanding Reservoirs or Quarries	Purchase agreements/ Inter-connections	Other (Reuse, optimization, management, conservation)
Appomattox River Water Authority Regional Water Supply Plan	Y	Y - Appomattox	Y – Lake Chesdin	Y	Y – reuse, demand mgmt, conservation
Charles City County 2013 Water Supply Management Plan	Y	N	N	Y	N
Caroline County and the Town of Bowling Green Regional Water Supply Plan	Y	Y – Rappahannock	N	Y	N
Cumberland, Goochland, Henrico, and Powhatan Regional Water Supply Plan	Y	Y - James	Y – Cobbs Creek Reservoir, Sandy River Reservoir	Y	Y – conservation, groundwater mgmt policy
Greensville-Sussex-Emporia Regional Water Supply Plan	Y	Y – Nottoway	Y – Emporia	N	N

		River	Reservoir		
Hampton Roads Regional Water Supply Plan	Y incl. ASR	Y – no specific location, desalination	Y – no specified location	Y	Y – system optimization, reuse
Hanover County and Town of Ashland Long Range Water Resources Plan	N	Y – North Anna, Little River	Y – Verdon Quarry	N	N
King George County Water Supply Plan	N	Y – Rappahannock	Y - Upper Machodoc Creek, Pepper Mill, Pine Hill Creek	Y	Y reuse
Middle Peninsula Regional Water Supply Plan	Y	Y - Pamunkey	N	Y	Y – system upgrades, desalination
New Kent County Water Supply Plan	Y	Y – Pamunkey (reverse osmosis)		Y	Conservation
Northern Neck Regional Water Supply Plan	N/A – water demand met through 2050				
Northern Virginia Regional Water Supply Plan	N	Y – Potomac, Occoquan (reverse osmosis)	Y – Fairfax and Loudoun quarries	N	Y – "smart" irrigation systems, outdoor water use allocation calculations, informative billing
Spotsylvania County - City of Fredericksburg Regional Water Supply Plan	N/A – water demand met through 2050				
Stafford County Regional Water Supply Plan	Y	Y – Potomac (desalination) and Rappahannock tributaries	Y – Rocky Pen Run Reservoir, Abel Lake, Vulcan Quarry, others	N	N

Statements of Need and Alternative Water Sources – York River, Rappahannock River, Albemarle-Chowan River, Chesapeake Bay – Small Coastal, James River, Potomac-Shenandoah River

Appomattox River Water Authority Regional Water Supply Plan

GWMA includes parts of Chesterfield and Prince George Counties east of I-95 and City of Hopewell; Prince George indicates a deficit by 2020, 2030, and 2040 Chesterfield County indicates a peak day deficit by 2040. Several alternatives are recommended for meeting this additional demand in the future: increases in current water supply allocations, new sales/purchase agreements, development of water reuse capacity, increases in water demand management and conservation efforts, and development of additional supply through new groundwater sources, raising the water level of Lake Chesdin, building a river intake on the Appomattox River, and development of a new surface water reservoir.

Charles City County 2013 Water Supply Management Plan

Water supply plan indicates a deficit by 2040. Additional groundwater sources are expected to meet demands in neighborhood service areas. Deficits in planned industrial areas (with no current source) may be met with interconnection with Henrico or Richmond.

Caroline County and the Town of Bowling Green Regional Water Supply Plan

GWMA includes portion of the county east of I-95; Indicates a deficit by 2030 and 2040. Alternative water supply sources listed in the plan include groundwater development, interconnection with other localities, and an intake on the Rappahannock River and construction of a WTF.

City of Richmond Water Supply Plan

The City of Richmond has sufficient water treatment and supply capacity to meet the city and its wholesale customers' water demand in the planning period, through 2060.

Cumberland, Goochland, Henrico, and Powhatan Regional Water Supply Plan

GWMA includes part of Henrico County east of I-95; no deficit for Henrico County indicated until 2045. Henrico County: (including demands of Goochland County that are met by Henrico County) Cobbs Creek Reservoir is the preferred alternative. For all four localities, including those not in the GWMA, several alternatives are recommended for meeting this additional demand in the future: the regional Cobbs Creek Reservoir project; continuing the existing water conservation policies or developing new ones; initiating discussions with Prince Edward County concerning the availability of water from the Sandy River Reservoir; regional coordination between the Department of Corrections and Goochland and Powhatan Counties to increase the withdrawal of water from an existing James River water withdrawal; developing and implementing groundwater management policies to manage the groundwater resources; and expanding existing water purchase contracts or developing new ones.

Greensville-Sussex-Emporia Regional Water Supply Plan

GWMA includes Sussex County only; alternatives listed for GCWSA. The GCWSA also plans to deepen/refurbish groundwater wells and dredge/refurbish the Emporia Reservoir if the storage capacity is reduced to 500 acre feet.

Hampton Roads Regional Water Supply Plan

Projected supply is anticipated to meet projected demand for the region through 2050. There is potential for demand to exceed supply by 2040 in the York-James Peninsula sub-region. Alternatives considered to meet the potential need in the Peninsula sub-region include additional surface water storage, additional groundwater withdrawals, desalination, aquifer storage and recovery, interconnection, reuse, and system optimization.

Hanover County and Town of Ashland Long Range Water Resources Plan

GWMA includes only the portion east of I-95; deficit anticipated by 2030. A single alternative is mentioned in the plan, the Verdon Quarry side storage reservoir project which includes: river intakes and raw water pumping stations on North Anna and Little Rivers, and a reservoir intake and raw water pumping station on Verdon Quarry.

King George County Water Supply Plan

Alternative water sources identified include wastewater reuse, interconnection with a neighboring locality, reservoir development, and an intake on the Rappahannock River.

Middle Peninsula Regional Water Supply Plan
King and Queen County existing sources appear adequate to meet current and projected demands through the planning period. Alternative sources listed for the Town of West Point include system upgrades and groundwater permit modifications that allow for greater use of existing wells. New well development and an intake on the Pamunkey River are King William County's preferred alternatives for source water.

New Kent County Water Supply Plan
In the short term, a waterline extension is being designed to connect two county-operated CWS to alleviate the anticipated 2017 deficit. The two top ranked alternatives for future water supply listed in the plan are an intake on the Pamunkey River (reverse osmosis water treatment) and the purchase of water from the City of Richmond.

Northern Neck Regional Water Supply Plan
Regional water supply appears to be adequate to meet demand through the planning period. Alternatives listed: water conservation, increased permitted withdrawal capability, new or refurbished groundwater wells, reclaimed water, desalination, rainwater harvesting, water marketing and transfer, development of a surface water reservoir

Northern Virginia Regional Water Supply Plan
GWMA includes only the portion of Fairfax and Prince William Counties east of I-95. The region's plan to address the projected shortfall of municipal supply includes constructing a stream intake/pumping station on the Potomac estuary below Little Falls (recently permitted by DEQ); utilizing a reverse osmosis membrane treatment plant on the Occoquan estuary, using quarries located in Fairfax County to augment Fairfax Water storage, and using Loudoun County quarries to augment system storage (recently
permitted by DEQ).

Spotsylvania County - City of Fredericksburg Regional Water Supply Plan
Existing water sources are adequate to meet current and projected demand. Only portion of Spotsylvania County east of I-95; no deficit indicated, but alternatives provided off-stream reservoirs, on-stream reservoirs, run-of-the-river intake, augmentation or modification of existing sources, quarry storage, groundwater, purchase water/interconnections, conservation measures, ASR, reuse, desalination.

Stafford County Regional Water Supply Plan
GWMA includes only portion of the county east of I-95. The region plans to address a projected shortfall of municipal supply by completing the construction of the Rocky Pen Run Reservoir project and pursuing other surface water and groundwater alternatives as needed. Additional alternatives listed in the plan include expansion of existing Abel Lake; increase dam height at Rocky Pen Run facility, development of Potomac River and Rappahannock River tributaries for surface water reservoirs (Austin Run, Aquia Creek, Potomac Run, Long Branch Creek, Alcotti Run), development of offstream pumped storage reservoirs adjacent to the Rappahannock River (Alcotti Run, Horsepen Run, Richland Run, increase to Rocky Pen Run facility), development of Vulcan Quarry offline storage reservoir adjacent to Aquia Creek, desalination of Potomac River water, and groundwater development.

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Appendix F: Option for Incorporating Groundwater Planning into the Code of Virginia

§ 62.1-257.1. Ground Water Management Area Planning Process

A. To address ground water shortage and water quality issues in a ground water management area, the Board, with the advice and guidance from the Commissioner of Health, local governments, public service authorities, representatives from industry and agriculture, and other interested parties, shall establish a ground water management planning process for the development of plans and coordination of efforts to achieve ground water goals consistent with the provisions of this chapter. This process shall be designed to ensure and maintain long term beneficial uses of the Commonwealth's ground water resources.

B. A groundwater management area plan shall be established for each ground water management area and revised every 10 years and status reports issued annually. The ground water management area plan shall be used to inform the local and state water supply planning process (62.1-44.38:1) about the current and future availability of ground water in a management area. The annual state of the aquifer report shall provide updates on the status of ground water resource and progress made toward meeting the objectives of the plan.

C. A groundwater management area plan shall, at a minimum, include (i) an inventory of total ground water withdrawals from all sources and status of ground water levels within the groundwater management area, (ii) identification of ground water management goals for the ground water management area consistent with the provisions of this chapter, (iii) identification of alternatives to achieve groundwater management goals, and (iv) summary of planned actions for permitted and nonpermitted users necessary to achieve ground water management goals.

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Appendix G: Workgroup Analysis of Aquifer Storage and Recovery (ASR) Programs Nationally

Program/Project	Crediting Rate (limits on recovery of stored water)	Credit Time Conditions (Duration)	Spatial Recovery Limits	Water Credit Transfer	Aquifer condition
Arizona Water Banking: Long Term Storage Credits	Deduct 5% "cut to the aquifer" Deduct 3-5% for delivery losses (evaporation, overflow, outflow, etc.).	No credit time limit, but rate of withdrawal is regulated by ADWR (ADWR formula for determining each year how much water is available for recovery)	Zonal (predefined area): Recovery must be within the storage area (Active Management Areas, or AMAs)	Yes (within GW Management Areas)	Unconfined Aquifer
Southern Nevada Groundwater Bank	Deduct small percentage at the time of initial injection	No time limit. Max rate of withdrawal of 20,000 AFY	Las Vegas Valley groundwater basin	Yes (within GW basin)	Confined
Other long term Nevada groundwater banks	GW recharge credited in GW storage account: X% of credits deducted annually for storage losses (the amount depends on modelled loss estimates). Loss rate may change (decrease) over time based on new info (model results)	All stored credits lost after 10 years.	Within same GW basin, subject to permit conditions	Yes (within GW basin)	Varied
Other short term Nevada Groundwater banking	1:1 (or nearly so)	1 season	Generally same location	None	Varied
New Jersey ASR	1:1 banking on three year rolling average	3 Water years	None. The category does not typically apply to conventional ASR	Permit specific	Confined

			facilities employing dual purpose well		
Delaware ASR	1:1	1 season unless, a utility petitions for water banking	None. The category does not typically apply to conventional ASR facilities employing dual purpose well	None	Confined
Florida ASR	1:1*	Multiple seasons, but, permit specific (used for seasonal water supply management)	None. The category does not typically apply to conventional ASR facilities employing dual purpose well	None	Confined
Kansas	1:1	1 season unless, a utility petitions for water banking	None. The category does not typically apply to conventional ASR facilities employing dual purpose well	None	Confined
North Carolina (planned/experimental ASR projects Cape Fear, Greenville)	1:1	No official policy, but proposals are for seasonal storage	Same location	N/A	Confined

***** In Florida, permittees do not typically withdrawal 1:1. Florida ASR project are injecting into brackish aquifer systems, but permittees only wish to recover the injected freshwater. Recovery rates range from 20-40% following the initial years of ASR operation and increase to 70 to 90% as ASR systems mature and freshwater is built up in the aquifer.

Sources:

Arizona:

http://www.azwater.gov/azdwr/WaterManagement/Recharge/RechargeCreditsandAccounting.htm
http://www.azleg.state.az.us/ars/45/00852-01.htm
http://www.azwaterbank.gov/Water_Storage/Recharge_and_Facilities.htm#Facilities
http://www.azwaterbank.gov/Plans_and_Reports_Documents/documents/Joint_RecoveryPlan04-14-14withsignedpreface.pdf

Nevada

https://www.snwa.com/ws/future_banking.html
http://water.nv.gov/hearings/past/spring/browseable%5Cexhibits%5CSNWA/511.pdf
https://www.snwa.com/assets/pdf/wr_plan_chapter3.pdf
Personal communication (K. Stephenson) with Adam Sullivan, Nevada Division of Water Resources, April 19th, 2016

New Jersey, Delaware, Florida, Kansas

Personal communication, Daniel Holloway, CH2M, April 2016.

Personal communication (B. Bull) with Joe Haberfeld, Florida Department of Environmental Protection (DEP) and Bob Verrastro, South Florida Water Management District, April 2016.

North Carolina

Personal communication (K. Stephenson), Nat Wilson, North Carolina DEQ May 25, 2016.

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Appendix H: Groundwater Banking (ASR) "Strawman"

Definitions

Injected water: water that is injected into an aquifer in the eastern Virginia and Eastern Shore Groundwater Management Areas.

Groundwater storage credit: the total quantity of injected water that is authorized to be recovered from the aquifer. Credit available for use in a given year is equal to the remaining injected water at the end of the previous year multiplied by the recovery factor. Credit is deposited into the permittee's groundwater storage account at DEQ and retired when authorized water is recovered.

Recovery factor: the annual fraction of the remaining injected water that is available for recovery by a permittee. The recovery factor is calculated as one minus the annual water loss rate.

GW storage account: DEQ will maintain and publish annually a groundwater storage account for any permittee holding groundwater storage credits.

Recovery zone: the area within the spatial boundary from which injected water is authorized to be recovered.

Seasonal storage: injected water that may be recovered within 12 months of the date of injection.

Long term storage: injected water that may be withdrawn across multiple years.

Water loss rate: the rate at which injected water is lost for recovery.

Groundwater Credit

Within existing groundwater management areas, DEQ will grant a *groundwater credit* to any party that injects water into the coastal aquifer for purposes of using the aquifer for water storage and recovery.

A groundwater credit is considered additional to a groundwater allocation granted under a groundwater withdrawal permit. Groundwater allocations shall not be reduced based on injection activity of the permittee.

A well injection permit would be required before any water is injected into the Virginia aquifers.

Seasonal Storage

Recovery factor for seasonal storage shall be 1. (1:1 inject to recovery rate)

Credit duration: 1 year. Credits not used within the year of being injected will be retired.

Spatial Recovery: Recovery occurs at the same facility as injection.

Credit transfer between permittees: None

Long Term Storage

Recovery factor: Recovery factors will be based on estimated *annual aquifer losses* using the groundwater model. Guidelines for estimating aquifer losses will be published and updated by DEQ. For projects injecting into the Potomac coastal plain aquifer, the recovery factor shall not be less than "to be determined".

A recovery factor schedule covering 10 years will be established by DEQ. Once established, the 10-year schedule shall not be modified. At the end of the 10-year period the schedule will be re-evaluated and the recovery factor may be revised based on new information.

Annual recovery factors contained in the recovery factor schedule may vary across time. For instance, the recovery factor may increase over time if annual loss rates are not constant over time.

DEQ may establish maximum annual limits on the rate of withdrawal from recovery wells.

Spatial Recovery: Recovery can occur off-site of the injection location. The spatial recovery zone will be delineated during the permitting process. DEQ will develop guidelines for defining the spatial recovery zone. The spatial recovery zone will defined to the maximum practical extent and subject to reasonable expectations that no adverse impacts will be imposed on the groundwater resource. The "spatial recovery zone" will be re-evaluated every 10 years.

Credit transfer between permittees: Groundwater storage credits may be transferred to another party within the spatial recovery zone.

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Appendix I: Australia Water Sharing Policy Model: Illustrative Application for Virginia

Kurt Stephenson[39] and Gwendolen DeBoe[40]

Australia has developed a national water sharing policy framework that has applicability for Virginia. This policy brief summarizes in conceptual terms the Australian approach to managing scare water resources. We illustrate how the key conceptual elements of the Australian model could be used within the existing Virginia law and could incorporate ideas being explored by the Eastern Virginia Groundwater Advisory Committee (EVGWAC).

The Australian Approach: A Brief Synopsis

Australia's water allocation system is a comprehensive system that specifies broad goals and well-defined implementation rules that govern both surface and groundwater. Like Virginia, Australia considers a public resource:

> "In Australia water is vested in governments that allow other parties to access and use water for a variety of purposes – whether irrigation, industrial use, mining, servicing rural and urban communities, or for amenity values. Decisions about water management involve balancing sets of economic, environmental and other interests. The framework within which water is allocated attaches both rights and responsibilities to water users – a right to a share of the water made available for extraction at any particular time, and a responsibility to use this water in accordance with usage conditions set by government. Likewise, governments have a responsibility to ensure that water is allocated and used to achieve socially and economically beneficial outcomes in a manner that is environmentally sustainable." [41]

To implement these overall goals, the national water plan includes explicit objectives such as:

- Clear and secure access to water
- Transparent planning process
- Provision for the achievement of environmental objectives
- Clear assignment of risk from changes in future water access and use
- Support for expanding the use of water markets
- Policy settings to facilitate water use efficiency
- Comprehensive water accounting system.

Implementation centers on both a planning process and market-based allocation system. While the details of both are quite complex and specific to the legal and environmental setting in Australia, the overall system can be summarized conceptually. A government-

[39] Professor, Department of Agricultural and Applied Economics, Virginia Tech
[40] Acting Director of Water Markets at the Australian Competition and Consumer Commission (ACCC). DeBoe is acting in a personal capacity and the views expressed here do not reflect those of the ACCC.
[41] An overview of Australia's "National Water Initiative" can be found in *Intergovernmental Agreement on a National Water Initiative*, available at http://www.agriculture.gov.au/water/policy/nwi.

led planning process identifies the water sources being managed, water for environmental objectives, and rules governing access and use of water supplies for consumptive use.[42] A key element of the water sharing plan is the identification of the total amount of water available for withdrawal (consumptive use). Setting the overall water available for consumptive uses requires a balancing with non-consumptive (environmental) uses. Government agencies are responsible for devising the overall water plan with consultation from major stakeholder organizations and the public. The government issues "shares" to the total available water, called "water access entitlements".[43] Users must possess water access entitlements in order to use water. The entitlement is an open-ended (perpetual) share of the total allowable water for withdrawal.[44] A share could be expressed as a percentage of the total available water.[45] To manage overall groundwater levels, the government can change the total available water for withdrawal, but does not change the users' total shares. Thus water access entitlements (shares) are not altered without consent of the holder. Water access entitlements are recognized as a secure asset that can be subdivided, amalgamated, traded, or used as collateral.

The total available water allowed to be withdrawn by the user in a specific time period, called a water allocation, is determined by the available water for withdrawal and the water access entitlement.[46] Water allocations are defined as the authorization to use a specific quantity of water and can also be traded. This share based system allocates the risk of future reductions in overall withdrawal levels across all users and provides certainty in how future withdrawal limits would be distributed but provides the government flexibility to adjust total water withdrawals.

Water access entitlements and water allocations can be transferred voluntarily between users. While specifics vary depending on the type of water system, users can also bank or carry forward unused allocation. The government establishes rules for all trading processes that protect the environment and third-parties from adverse impacts that could arise from trading across time and geographical area.

Illustration of Applying the Australian Conceptual Model to Virginia

One illustration of how the Australian framework could be adopted in Virginia is shown in Figure 1. Responsibility for implementing state groundwater management goals in designated

[42] The New South Wales is a good example of the Australian water sharing planning process applied to groundwater. In general see: Department of Primary Industries, New South Wales Government, "Macro Water Sharing Plans – the Approach for Groundwater" November 2015 at: http://www.water.nsw.gov.au/__data/assets/pdf_file/0019/547300/macro-water-sharing-plans-the-approach-for-groundwater.pdf

[43] Water access entitlements are sometimes called water access "licenses" or "shares".

[44] An analogy to a water access entitlement or water share might be stock share in a corporation. The stock represents an ownership share in a company. A water access entitlement represents a share of the total available water (Mike Young, The University of Adelaide, May 2016 talk to the Interstate Commission on the Potomac River Basin).

[45] Shares add to 100% but the government may elect not to allocate a small percentage of shares. These shares may be held in reserve to address critical future water needs.

[46] Continuing the company stock analogy, if a water share is similar to a stock, then the water allocation is analogous to a dividend paid to the stock owner. The dividend represents the share of the available profits going to the company owners. While a holder's stock may not change, dividends may vary with the level of profits earned by the company.

groundwater management areas is assigned to the Department of Environmental Quality (DEQ). Virginia, however, could establish a Groundwater Management Area Advisory Committee to advise DEQ on establishing overall goals and implementation strategies for the aquifers within the state's groundwater management areas (GWMA). The Groundwater Management Act (GWA), which authorized the creation of groundwater management areas, [47] establishes a permitting system to manage withdrawals, but does not include a process or requirement to establish explicit long-term management goals for total groundwater withdrawals. Amendments to the GWA could establish such aquifer goal setting and the advisory committee would provide input into the setting overall withdrawal levels and long range planning objectives for the GWMA.[48] With committee input, the DEQ would establish groundwater withdrawal zones and the total amount of water available for withdrawal in each zone. The DEQ would decide and announce the total water available for withdrawal ("total allowable withdrawal") within groundwater management zones for specific durations (example: an average annual 10,000 million gallon withdrawal in the SE zone of the Eastern Groundwater Management Area over 10 years).

Groundwater access shares would be issued to users.[49] Groundwater access shares could be expressed as a percent (%) of the total available water for withdrawal. Guidance or determination of the initial allocation of shares would be authorized by statute and assigned either through statute or a regulatory process (See Figure 1).[50] Groundwater access shares would be an ongoing authorization, extending across groundwater withdrawal periods. Groundwater access shares would be transferable between users, subject to predefined trading rules.

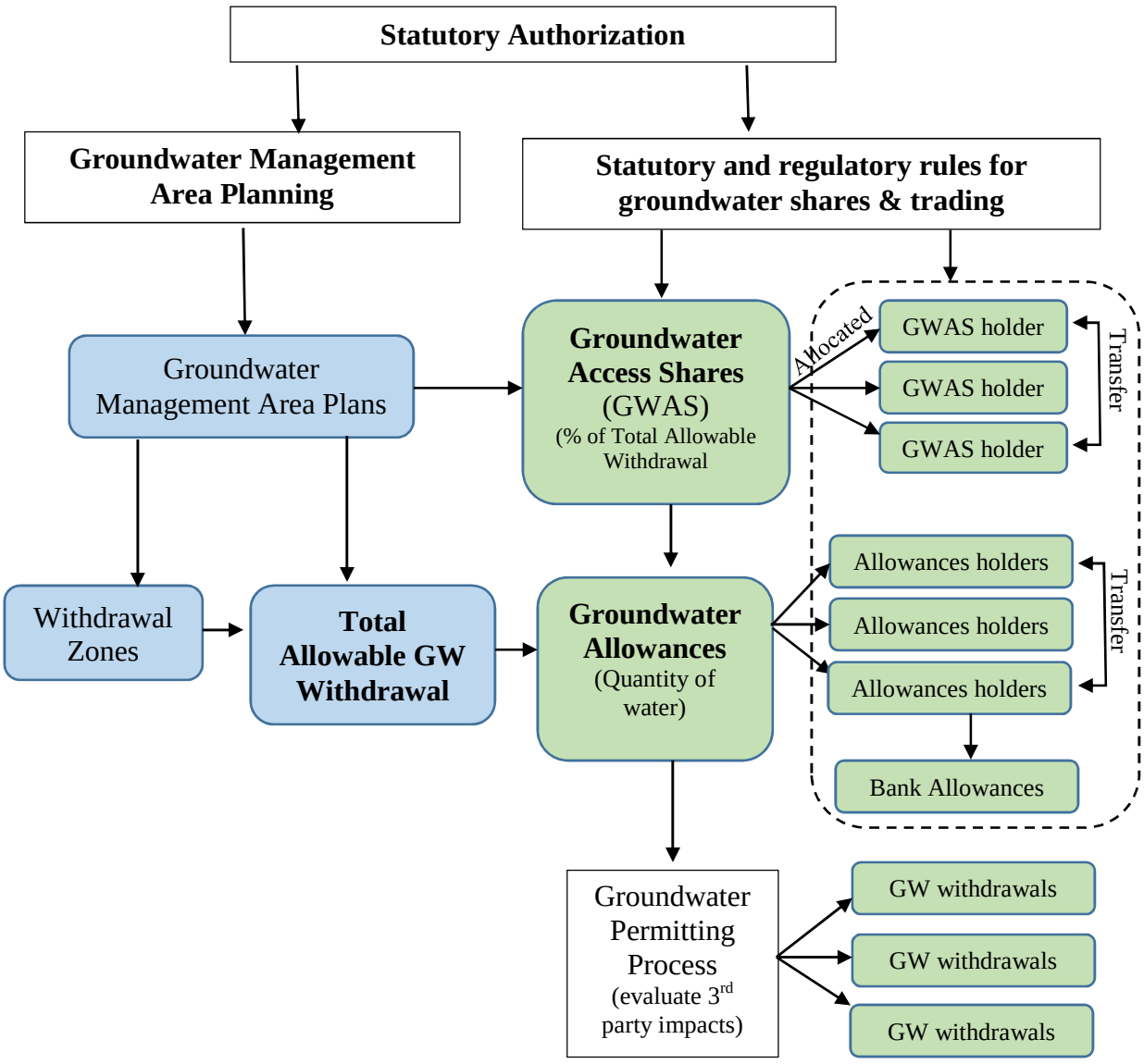
Upon announcement of the total allowable withdrawals, groundwater allowances would be issued to all holders of groundwater access shares. Groundwater allowances are expressed as the authorization to use a specific quantity of water.[51] For instance, suppose an allowance is defined as 1 million gallons. If total allowable groundwater withdrawals for a particular area is established by the Committee to be 10,000 million gallons per year and a municipality has a 10% share, then the municipality would be allocated 1,000 allowances each year (over the given allocation period). Allowances are retired as groundwater is withdrawn. Groundwater allowances may be banked (saved) for future years. Groundwater allowances may also be created by users themselves if new water is injected and stored in the aquifer (similar to the draft rules already discussed). Allowances are also transferable between users (see Figure 1).

Holders of groundwater allowances would still be required to obtain a permit from DEQ as a condition to withdrawal water. During the permitting process, DEQ would evaluate the effect of groundwater use granted by allowance holdings on third party users within and across

[47] §62.1-254 through 270.
[48] Statutory authorization would likely be needed to establish a share based system.
[49] "Users" could be existing users or existing and potential users. For instance groundwater access shares could be allocated to local governments that have not yet accessed groundwater supplies. The aquifer would be closed to any permitted user without an access share or groundwater allowance.
[50] This is similar process for how nitrogen and phosphorus wasteload allocation is assigned to municipal and industrial point sources in the Chesapeake Bay watershed under the Nutrient Credit Exchange Act.
[51] In Australia called water allocations.

management zones. For instance, the groundwater permit may establish maximum limits on the *rate* at which water may be withdrawn from individual wells (example gallons per month) to protect against well interference. DEQ would also approve all groundwater allowance transfers.

Figure 1: A Hypothetical Illustration of a Virginia Share-based Groundwater Allocation System



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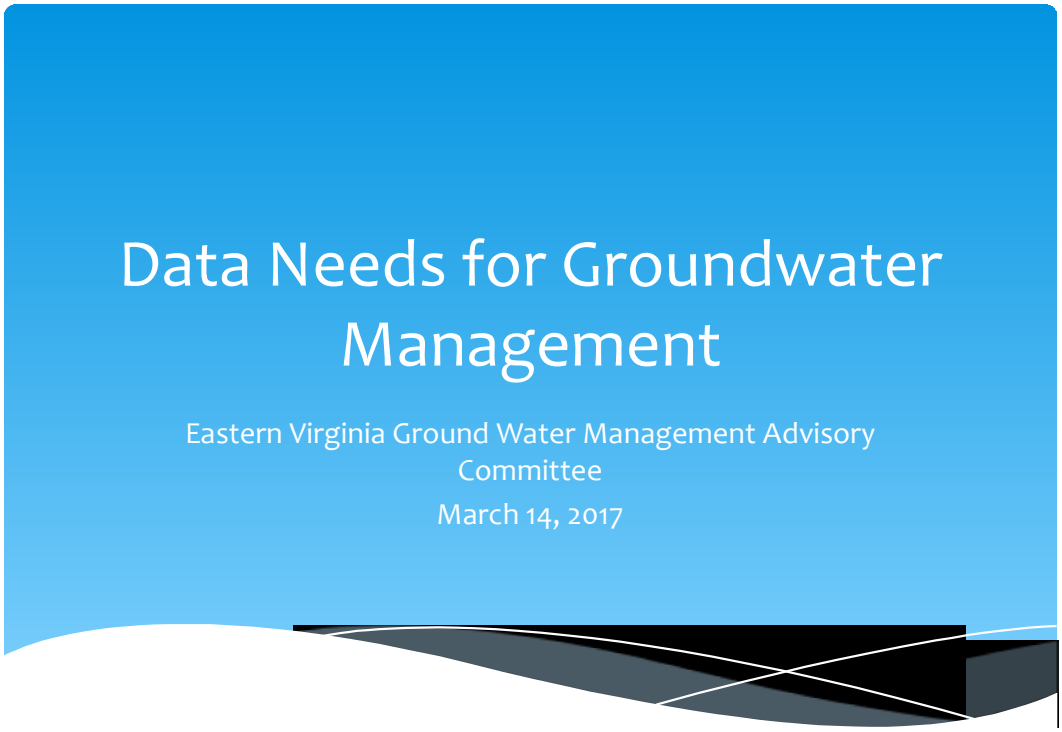
Appendix J: DEQ Data Needs for Groundwater Management Presentation



Discussion of Data Needs

* Existing Well Network Repair and Maintenance
* Address Gaps in Hydrologic Framework
  * Model maintenance
* Address Gaps in Water Monitoring Network
  * Water levels
* Update Unregulated Use Estimation Methodology
  * Private well irrigation and geothermal gaps
* Implement Saltwater Intrusion Network
* Install New Extensometer

Well Maintenance and Repair

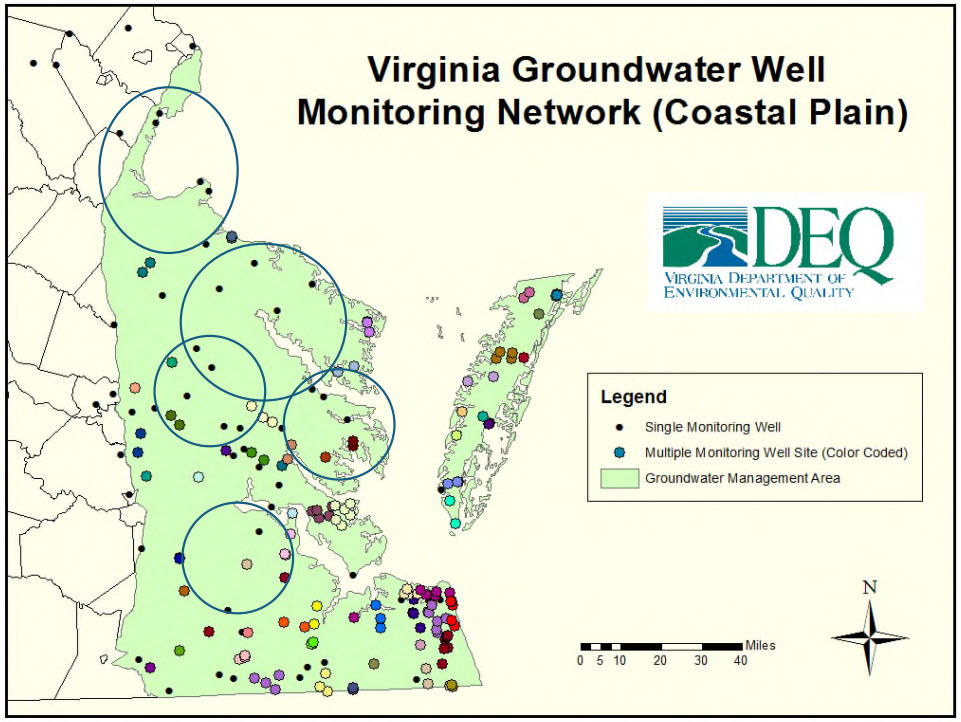
* Need to ensure scientifically reliable and valid data
* Most of the current well network was installed at least 30 years ago (50% of 243 wells)
* As part of maintaining the network, we have started assessing the condition of 20-25 wells per year
* 16 of 29 have shown problems that need to be addressed
* Problems include aging casings, silted screens, and obstructions

Well Maintenance and Repair

* Estimated costs of maintenance…
  * Varies by situation and bid offering
  * Last time we bid for 1 well received a proposal for $38,275 to remove sediment.

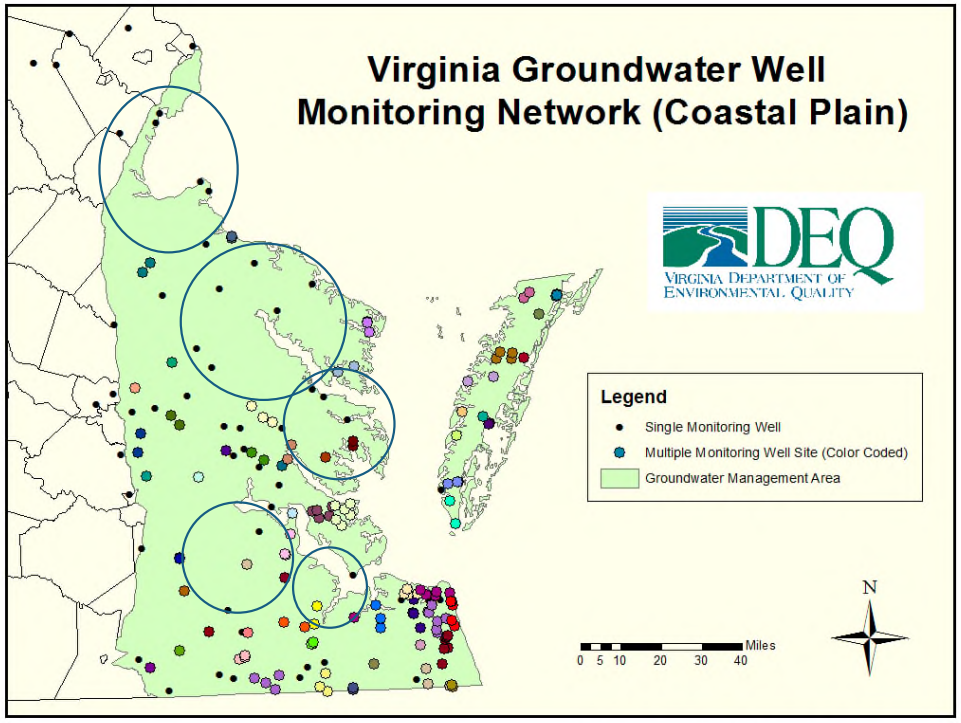
Hydrologic Framework

* Areas of uncertainty in the Norfolk Arch area south of the James River, expanded GWMA north of the Mattaponi River including "panhandle area", north and western edge of CBIC
* Capacity to add data is by happenstance based on permittee location/uncertainty, if extra DEQ funds to develop become available, if suitable bids come in that are consistent with the budget available



Water Level Monitoring

* Areas of uncertainty in the Norfolk Arch area south of the James River, expanded GWMA north of the Mattaponi River including "panhandle area"
* No operation and maintenance budget fortstaff o take measurements, calibrate monitoring equipment, repair and replace equipment
* Currently at the staffing limit to maintain the system: optionsare to add staff r add funds to contract with USGS


Virginia Groundwater Well Monitoring Network (Coastal Plain)
DEQ
Virginia Department of Environmental Quality
Legend
Single Monitoring Well
Multiple Monitoring Well Site (Color Coded)
Groundwater Management Area
N
0 5 10 20 30 40
Miles
Data Source: USGS and DEQ Monitoring Well Network

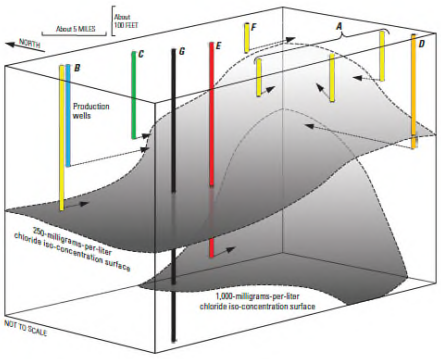
Unregulated Use Estimation

* DEQ uses an estimate of unregulated use based on a methodology USGS developed under contract
* Published in 2008 using 2006 data (US census data)
* 29 mgd based on 2006 data
* Growth to 2016 estimated at 1 mg per day per year or new total of ~39 mgd
* New method needed using VDH and DEQ private well data

Saltwater Intrusion Network

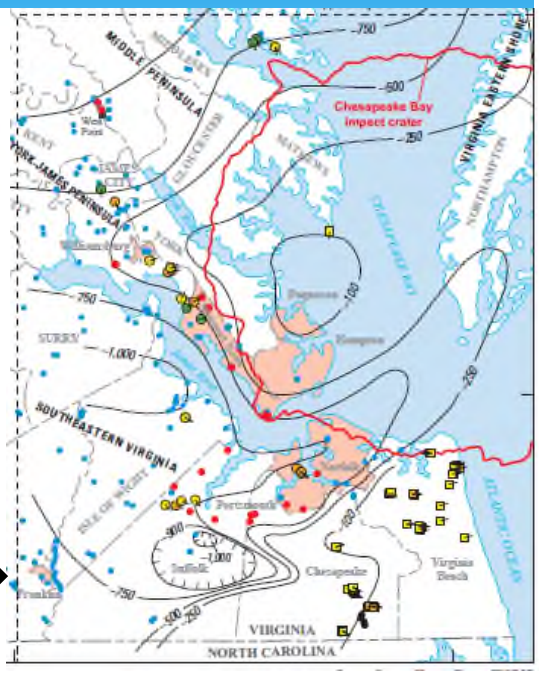
* DEQ contracted USGS to develop a monitoring strategy for lateral and upconing movement of saltwater
* 612 wells assessed for proximity to 250 mg/l chloride surface
* 81 priority wells within 50 feet; 42 wells at risk of intrusion needing monitoring-- 54 monitoring wells needed
* No existing wells (~200) suitable to monitor this movement
* Total cost of implementation $12.5 mil over 10 years + $1.35 in annual costs

Chloride Monitoring



Generalized spatial relations of groundwater production wells to chloride iso-concentration surfaces.

Conceptual Framework and Monitoring Strategy



Extensometer

- Field investigation by Dr. Reay of the Virginia Institute of Marine Science has documented sea level rise/land subsidence impacts to the Pamunkey Marshes near West Point
- New subsidence package built for DEQ groundwater model estimates nearly a foot of subsidence has occurred near West Point
- HRSD-USGS installed an extensometer at Nansemond for $1.3 million + $30,000 estimated O & M
- Estimated $40,000 per year O & M for existing Suffolk and Franklin extensometers

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Appendix K: DEQ Cost Estimates for Data Needs

Item	Number	Unit Cost	Total Cost	
Upconing MW	42	$ 150,000	$ 6,300,000	
Lateral MW	12	$ 150,000	$ 1,800,000	
Geologist (MW install)	30	$ 125,000	$ 3,750,000	3 annually for 10 years
Instrumentation	54	$ 5,000	$ 270,000	
Land/Access	1	$ 125,000	$ 125,000	Lump sum estimate
TOTAL WELLS			**$ 12,245,000**	

Item	Number	Unit Cost	Total Cost	
Geologist (Sampling)	4	$ 100,000	$ 400,000	Annually
Sampling Equipment	1	$ 100,000	$ 100,000	Annually
Sampling Budget	1	$ 250,000	$ 250,000	Annually (200 @$1,250)
Per Diems	1	$ 50,000	$ 50,000	Annually
SAMPLING			**$ 800,000**	**Annual**

Item	Number	Unit Cost	Total Cost	
Hydrogeology Studies/ Consultation	1	$ 100,000	$ 100,000	Annually
Data Management/ Statistics Staff	1	$ 100,000	$ 100,000	Annually
Geologist (Equip Maint.)	1	$ 125,000	$ 125,000	Annually
Geologist (Manager)	1	$ 125,000	$ 125,000	Annually
Equipment Maintenance	1	$ 100,000	$ 100,000	Annually (20 @$5,000)
SUPPORT			**$ 550,000**	**Annual**

Appendix L: Final Comments from EVGMAC Members

Name and Affiliation	Final Comments on EVGMAC Report
John J. Aulbach – Aqua Virginia, Inc.	I don't have any major concerns and generally am in consensus with the overall findings.
James Baker – City of Chesapeake	After careful review of the "Final" Report of the GWAC, I am writing to confirm my support for the report and it's recommendations. My support should not be construed as unequivocal. In general, I believe the report understates the risks presented by current levels of withdrawals from aquifers in the groundwater management area. Further, I believe it materially oversells the value of recent reductions in the maximum levels of permitted withdrawals; as the reductions, for the most part, simply reflect the difference between previously permitted levels and actual use. In other words, virtually no real reductions in actual use were achieved. Finally, I believe the report language was softened and watered down in many instances to achieve broader consensus on the Committee. Having said this, my criticisms are typical of similar Committee processes and while I undoubtedly would have written a different report on my own accord, I recognize practical need to compromise and adjust the report language to accommodate the views of all Committee members. Though I have reservations about some areas of the report and some recommendations, there are none that I oppose and I can certainly live with the entire content. Consequently, I support the Final Report.
Nina Butler – WestRock	I have appreciated the opportunity to serve on the Eastern Virginia Groundwater Management Advisory Committee over the past two years. By bringing a diverse group of stakeholders together, the Commonwealth has made great strides toward preserving Eastern Virginia's groundwater resource for future generations. You and the entire DEQ team are to be commended for your hard work in supporting this effort and in preparing the summary report on the Committee's activities. WestRock generally agrees with the recommendations set forth in the draft report. I hope the work of the committee will foster further efforts to preserve and protect the groundwater resources in Eastern Virginia. As a company that counts sustainability as one of our core values, WestRock is prepared to continue working collaboratively with the Commonwealth and other stakeholders to achieve this goal.
Tom Frederick – VA Water and Wastewater Authorities Association	I support this report and its recommendations, but also offer a small number of comments to strengthen the text without amending its recommendations. My support applies whether the changes are incorporated or not and are simply for your use. Comments: Page 5, Line 20: I'd be cautious in using the phrase "to the fullest extent" and maybe suggest we state the six areas for data improvements will "close presently known gaps in the current groundwater program." This reflects my

	experience that modeling can improve in predicting reality when calibrated to more complete and accurate data, but they are never perfect. Page 15, Line 15: I would delete the 's' in "waters" amending the phrase to "expand water supplies". Page 22. Just a comment. Not all of the difference between water metered as produced and water metered for consumption constitutes water loss that can be recovered by leak detection programs. Some non-revenue water is actual and unauthorized unmetered water use, such a fire hydrant testing or fire fighting. Further, water meters have error. Mechanically-operated meters on consumption taps are more likely to under-register than over-register, giving the appearance of water loss. Today's electronic (digital) meters are more balanced in this respect, but their use will depend on the extent to which the water utility aggressively replaces or tests its meters. Page 43, Line 11: Suggest the word "required" in front of "revenue requirements" is redundant and can be deleted. I appreciate the hard work that went into writing the report and hope this is helpful. I also appreciate the opportunity to participate on this Committee with many strong professional colleagues.
Rhu Harris – Hanover County	I support this report and its recommendations; While the report does not go into detail about how the possible fee would be administrated I do want to go on record as not supporting it be added to any of our local tax billings.
Bryan Hill – James City County	James City County Supports the report. Thank you for your time and work put forth on this action item.
Chip Jones – Northern Neck Soil & Water Conservation District	
Marissa Levine – VDH	This is in reply to your request for comment regarding the final draft of the Eastern Virginia Groundwater Management Advisory Committee (EVGMAC) report. Thank you for giving me an opportunity to offer a final agency position on the report. I approve of the report and most of its recommendations but wanted to add a clarification to recommendation #6. In addition, I offer several suggested clarifications to the report for your consideration. • Clarification for Recommendation #6: Committee recommends that the General Assembly require new non-agricultural irrigation wells only from unconfined aquifers in the EVGMA where available and adequate. The report states that the Committee discussed, but did not endorse, the option to require residential and commercial irrigation wells to use only unconfined aquifers. However, the report offers this idea as a specific recommendation, which suggests a typographical error. I believe the intent of this recommendation is to limit withdrawals for non-agricultural irrigation to

unconfined aquifers. I recommend making the following revision to clarify the intent:
"Committee recommends that the General Assembly require new non-agricultural irrigation wells to withdraw only from unconfined aquifers in the EVMA where available and adequate."

There is no clear meaning of "available and adequate" or clarification of how such terms would be determined or by whom. DEQ has jurisdiction over groundwater use, and VDH has jurisdiction over the construction and location of private wells, including irrigation wells. Many wells already installed into the unconfined aquifer serve as potable water for private residential homes and small businesses. I support an assessment of the unconfined aquifer to determine whether the resource is capable of supporting demand for non-agricultural irrigation withdrawal.

Suggested Clarifications to the report for your consideration:

- The draft report uses the term "purified wastewater" in the discussion of aquifer recharge. Using the term "purified" may confuse some stakeholders because it suggests that that treated effluent would be "pure" or free from any potential constituents or contaminants, when it is not. The report should use a different term, such as "treated wastewater," to describe the reference aquifer recharge concept.
- On page 18, consider clarifying that the groundwater augmentation project in the City of Chesapeake injects treated surface water in the Potomac aquifer, not highly treated wastewater. The comment regarding the City of Chesapeake's groundwater augmentation project follows discussion on existing projects across the U.S. to treat wastewater to meeting drinking water standards. Some stakeholders may confuse the report to indicate that the City of Chesapeake has for decades discharged treated wastewater in the Potomac aquifer.
- On page 21, the study recommended to evaluate well drilling into the crystalline bedrock aquifer should also include VDH in addition to DEQ and DMME.
- On page 26 of the report, it states "VDH and most public water utilities use a 325-gallons per day per household number for demand projections." VDH should be removed from this statement because VDH does not use 325-gallons per day per household to implement its regulatory programs.
- There is conflicting information in the estimated withdrawal volumes from unpermitted users.
    - On page 26, the report states DEQ estimates an annual increase of 1 million gallons per day (MGD) from private wells based on an average of 1,500 new wells installed each year. This estimate means each well is using approximately 666 gallons per day (GPD). However, another paragraph states 325 GPD is the standard, and DEQ found actual use Is between 180 and 200 GPD. Based on data observed by DEQ, consider revising the estimated annual increase to between 270,000 GPD and 487,500 GPD or providing additional information to support the estimated 1 MGD annual increase.
    - The estimated 10 year increase, given as 10 MGD, should be revised to 2.7 to 4.8 MGD. The report states the total estimated withdrawal from private wells is 39 MGD. Given the estimates provided in the report, this would mean 25.6% of all private wells in the EVGMA were installed in just the

	last 10 years. Please consider revising the estimated increase over the last 10 years to between 2.7 and 4.8 MGD, or providing additional information to support the estimated 10 MGD increase. This revised estimate would mean that private wells installed in the last 10 years account for 8.5% to 14.2% of all private wells in the EVGMA. o Finally, the report states that "[i]f these trends continue, unpermitted use is projected to nearly equal the actual reductions in permitted uses recently accepted by permittees by the end of their current permit term (2027)." The actual reduction in permitted uses recently accepted by permittees was 76.76 MGD. Using DEQ's estimate that private wells currently account for 39 MGD of withdrawal would mean the EVGMA would see an increase of 37.76 MGD from private wells over the next 10 years. However, the trend provided in the report for the last 10 years is only 10 MGD. Thank you again for the opportunity to offer a final agency position on the report. Our ongoing partnership with DEQ and the EVGMAC is critical to protecting the health and promoting the well-being of all Virginians.
Keith Martin – Chamber of Commerce	We support the report's recommendations.
Sandi McNinch – VA Economic Development Partnership	I support this report and its recommendations.
John O'Dell – VA Well Drillers Association	The Virginia Water Well Association approves of the report and most of its recommendations but dissent from the following recommendation for the following reason: Recommendation # 5 - The VWWA believes that the decision on where individuals get their water supply is a personal choice and that government at any level should not be in the business of promoting or creating incentives to individuals in making that choice.
Chris Pomeroy – Western Tidewater Water Authority	I have skimmed the final draft of the Report and it appears to me to be consistent with the Committee discussion at the final meeting in July. In accordance with the instructions and definitions below, please register my response as "support." Thank you for your efforts on behalf of the Eastern Virginia Groundwater Management Advisory Committee. It was a pleasure working in this capacity with you, the other Committee Members, and your colleagues at DEQ.
Travis Quesenberry – King George County	I support this support and its recommendations.
Paul Rogers, Jr. – Farmer – Production Agriculture	I support this report and its recommendations.
Nikki Rovner – The Nature Conservancy	I support this report and its recommendations.
Curtis W. Smith – Accomack-Northampton PDC/ Eastern Shore	I have reviewed the final document and am in agreement with the report and its recommendations.

Groundwater Committee	
Kurt Stephenson – Virginia Tech	Support
Mike Toalson – VA Home Builders Association	HBAV will support the statement with only the reservation that more onerous conditions would be imposed on landowners (homeowners) with no other choice for drinking water.
Dennis Treacy – Smithfield Foods	I have reviewed the document and shared it with my colleagues at Smithfield. I support the document as written and without additional comment.
Brett Vassey – Virginia Manufacturers Association	The VMA is pleased to submit comments on the Eastern Virginia Groundwater Management Advisory Committee (EVGMAC) final "Report to the Virginia Department of Environmental Quality and Virginia General Assembly." I approve of the report and most of its recommendations but dissent from the following recommendations for the following reasons: 1. Recommendation #6 - Committee recommends that the General Assembly require new non-agricultural irrigation wells only from unconfined aquifers in the EVGMA where available and adequate. It is my recollection that the consensus was regarding residential irrigation wells only. The use of "non-agricultural irrigation wells" is inaccurate and would limit commercial and industrial irrigation wells, which was not discussed. 2. JLARC (page 11) – I agree with the statement that the Committee did not reach consensus on the JLARC recommendations. However, the JLARC report and its summary did not properly account for the impacts of non-regulated withdrawals – estimated at 50MGD by 2026 – which this report has now corrected. The JLARC report and its summary also clearly established human consumption, without a clear definition, as the state's statutory priority and went as far as suggesting that new business growth may be a higher priority than existing business retention with statements such as "Substantial industrial use of low cost, high quality water has the effect of 'crowding out' higher priority use for human consumption…Without substantial changes to the state's groundwater permitting process, this crowding out and higher costs to residential customers and businesses will continue." The JLARC report was missing any relevant economic and limit of technology analysis on its recommendation to continue to reduce existing permittees' withdrawals by 50%. The report also appeared to attempt to prematurely inoculate the state from any responsibility in infrastructure solutions to meet these challenges by stating that "The state role in the financing and construction of water supply projects is also minimal, but Virginia's sustainability challenges are not significant enough to justify materially changing this role." It was my observation that the Committee recognized these facts and, perhaps, it should be stated as such in this report so that the JLARC report does not undercut the EVGMAC final report recommendations. 3. Beneficial Use - The report is missing reference to the Committee's discussion that the Code of Virginia should have a uniform definition of "beneficial use" as it pertains to groundwater use. The current Section 62.1-44.36 of the Code of Virginia allows one to presuppose that "human consumption" is defined as water actually being ingested by human beings. Based upon other sections of the Code, this may be an inadequate interpretation and, thus, requires standardization. In closing, the VMA commends David Paylor, Scott Kudlas, Mark Rubin and

	you for conducting a thoroughly transparent and collaborative process. Conducting 36 meetings is quite an undertaking with such a broad group of stakeholders. Reaching consensus on so many issues while taking great efforts to balance the environmental and economic realities of this work was nothing short of astonishing. Thank you for the opportunity to contribute to this work on behalf of Virginia industry.
Ellis Walton – Farm Bureau	The programs or requirements arising from the recommendations contained in this report should be implemented throughout the geographic reach of the aquifer. This report represents the consensus and thorough discussion of the issues. Virginia Farm Bureau supports the report to the extent of its positive impact on agriculture and rural communities, while issues of disagreement will require further discussion and debate.
Bob Wayland - Citizen	I support this report and its recommendations.