Prepared by:

Kurt Stephenson
Dept. of Agricultural & Applied Economics
Virginia Tech
Blacksburg, Virginia 24061

Abt Associates Inc.
4550 Montgomery Avenue
Suite 800 North
Bethesda, MD 20814

An Investigation of the Economic Impacts of Coastal Plain Aquifer Depletion and Actions That May Be Needed To Maintain Long-Term Availability and Productivity

Submitted to
Virginia Department of Environmental Quality

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Executive Summary

Groundwater in Virginia's Coastal Plain provides a low cost, high quality water resource for community water systems, businesses and individual homeowners. The Coastal Plain aquifers are a critical water source for water systems that together serve hundreds of thousands of people and several manufacturers that directly employ hundreds of workers. The Department of Environmental Quality (DEQ) is increasingly concerned about the consequences of groundwater depletion in the Coastal Plain and DEQ is evaluating a number of options to limit groundwater withdrawals in the Eastern Virginia Ground Water Management Area (EVGWMA).

At the time this report was drafted, DEQ had not yet made any decision regarding overall groundwater withdrawal targets. Preliminary groundwater modeling work, suggested that an overall groundwater withdrawal target between 90 and 100 MGD (for all coastal aquifers among all groundwater users) might be required to meet existing state groundwater regulatory criteria. That target was preliminary and DEQ had not finalized any groundwater withdrawal targets. For purposes of this report, and working from the preliminary target of 90 to 100 MGD for total withdrawals, the tentative target for the permitted sector was assumed to range between 55 to 65 MGD. Withdrawals among small, unregulated groundwater users (those that use less than 300,000 gallons per month and, thus, are not required to obtain a permit from DEQ) was estimated to be about 29 MGD. This report describes possible costs and other economic consequences of limiting overall groundwater withdrawals for the permitted and unpermitted groups of users in the EVGWMA to these targets.

Historically groundwater withdrawals among permitted users exceeded 80 MGD and these levels of withdrawals caused substantial declines in groundwater levels. Recent declines in water use among several municipal and industrial groundwater users have reduced total estimated permitted withdrawals within the EVGWMA to approximately 60 MGD, resulting in some recovery in groundwater levels. Current average withdrawals fall within the tentative groundwater targets for permitted users, but many groundwater users have been withdrawing less than their current permitted limit. The total permitted capacity is approximately 114 MGD.

With current permitted withdrawals well below permitted capacity, this report identifies opportunities to develop and phase in new water supply plans to meet a 90-100 MGD groundwater withdrawal target in ways that might minimize costs to residents and businesses. Nonetheless, actions that limit increases in groundwater use are likely to raise concerns among users about whether future water supplies will be adequate to serve future growth in use, and may impose some costs on both municipal and industrial permitted water users who may need to manage use or gain access to alternative water sources. The report also recognizes that total costs for meeting any groundwater withdrawal target will depend not only on the magnitude of the final reduction target but also on how the reductions are allocated among permitted users and between the permitted and unpermitted sectors. However, time and budget limitations meant that this report does not evaluate the costs of specific allocations of permitted groundwater withdrawals among users.

Municipal water utilities have formulated water use and infrastructure plans with the expectation of having access to more than twice the amount of groundwater than what is currently being withdrawn: current groundwater withdrawals among the largest utility permit holders (permitted withdrawals exceeding 1 MGD) is about 19 MGD, while permitted capacity is about 49 MGD. Further, population in the region is expected to grow and water use among utilities is projected to increase. Therefore, the primary economic impact of restricting groundwater use among utilities will be largely future costs for securing replacement water supplies or pursuing more aggressive water use reduction measures. Emerging national and regional trends suggest that per capita water use is growing slowly if at all and regional water conservation efforts will likely mitigate some of the costs associated with replacing significant reductions in permitted capacity. The report recognizes that the consequences of large reductions in permitted groundwater withdrawal capacity impacts will differ among the utilities depending on growth, available water sources, and state permitting decisions. Several utilities rely solely on groundwater and some could face high costs to replace groundwater, requiring purchases from neighboring utilities, new or expanded treatment facilities or other measures. Larger utilities in the region generally use a mix of surface water and groundwater and may face lower near term costs to adapt to reduced groundwater withdrawal limits.

The analysis in this report suggests that the cost of alternative water supply development could be postponed with increased regional coordination and water sharing among utilities. Taken as a whole, the region's utilities appear to have sufficient water supplies to meet water use for the next 20 to 30 years (or longer) even with more restrictive groundwater permits. Regional coordination, however, would require additional administrative and coordination costs, as well as costs for new distribution infrastructure. With or without regional coordination municipal water users might consider several alternatives to compensate for future reduced access to groundwater. Per capita water use among regional utilities generally falls within the lower range of a sample of utilities from across the U.S., but there may be cost-effective opportunities for additional per capita water use reductions. Alternatives to increase water supply include desalination, wastewater reuse, and new surface water development. These tend to be more costly (in many instances, much more costly) than relying on ground water and their implementation could face substantial regulatory hurdles. The state could develop a mix of strategies to lower alternative source water development costs through some combination of regulatory support, facilitation of regional coordination, and targeted direct investments.

Turning attention to industrial groundwater uses, the six largest industrial water users currently withdraw about 39 MGD and in aggregate hold permits to withdraw as much as 57 MGD. Two paper mills withdrew about 33 MGD in 2012. The least costly means to make incremental reductions in groundwater use among industrial facilities appears to be additional investments in enhanced water use efficiency, including but not limited to, water recycling. The cost to achieve reductions in water use through water efficiency measures, however, is uncertain as is the amount of water that can be saved. Large scale switching to alternative sources such as surface water and/or wastewater reuse would appear to impose high costs for infrastructure development. In addition, there may be regulatory or consumer resistance and barriers to wastewater reuse for the kind of products currently being produced by the paper mills and other industrial groundwater users.

Small (less than 300,000 gallons per month) unpermitted groundwater users comprise a significant share (approximately 30%) of total groundwater withdrawals in the EVGWMA. Projections of population and land settlement patterns suggest that this use will increase in the future. For those small users not located near existing distribution lines, there may be no cost-effective alternative water source. For small users that are near existing distribution systems, current connection and water costs exceed costs for drilling and maintaining wells, creating an incentive for residents and businesses to continue reliance on individual wells. This incentive may increase if municipal water rates increase (perhaps due to adjustment costs to less groundwater access). State programs or actions that provide water use reduction incentives to local government or individual households might prove to be a cost-effective way to reduce total withdrawals from this sector.

DEQ's groundwater permitting system as currently structured is the primary tool for the state to manage groundwater withdrawals in the EVGWMA. New policy tools that modify and/or complement the current permitting approach could help reduce costs of meeting state groundwater management goals. This report provides a conceptual level description of such options. The possibilities include coordinating and extending the length of permits, allowing users to readily exchange the water use rights created by the permits, enhanced state technical and financial support for future needs and supply assessment, innovative approaches to water use reduction and regional water sharing and supply expansion.

1. Introduction

The Virginia Department of Environmental Quality (DEQ) is concerned about declining aquifer levels in the Coastal Plain and the possibility that current and likely future withdrawals from the aquifers cannot be sustained. Because of this concern, DEQ is exploring possible new actions that would reduce groundwater use in the region. While lower overall groundwater withdrawals are desired, DEQ has not yet proposed specific actions to address depletion in the coastal aquifers. Before proceeding with new actions, DEQ is interested in understanding the potential economic impacts of reduced groundwater availability and the potential economic impacts of a range of management alternatives. This report summarizes an investigation into these potential economic impacts.

The introductory section provides context for the rest of the report. Section 1.1 describes existing state policies and regulations, as well as DEQ's groundwater management goal and regulatory criteria. Section 1.2 provides an overview of the problem while Section 1.3 describes the aquifer conditions and groundwater use trends that provide the motivation and context for this study. Finally, section 1.4 provides an overview of the remainder of the report.

1.1 Existing Groundwater Management

Groundwater management and regulations in Virginia were established by the Groundwater Act of 1973 and are currently implemented through the Ground Water Management Act of 1992. These laws empower DEQ to establish groundwater management areas and to require permits for withdrawals exceeding 300,000 gallons in any month within the groundwater management areas. DEQ issues permits pursuant to the Act based on demonstrated need and, overall, the groundwater withdrawal permitting program is meant to protect all beneficial uses of groundwater throughout each groundwater management area. If groundwater supplies conflict and are insufficient to satisfy all beneficial uses, DEQ must grant preference to human consumption over other beneficial uses (§ 62.1-263). Permits are granted for 10 years and typically stipulate an annual or 10-year total quantity of pumping that is allowed. DEQ has started writing more complex permits that vary allowable withdrawal amounts based on drought conditions.

In 1992, DEQ designated the Eastern Virginia Ground Water Management Area (EVGWMA) as the counties and cities east of Interstate 95 and south of King William and Hanover Counties. Due to increasing concerns throughout the Coastal Plain, DEQ expanded the EVGWMA on January 1, 2014 to include all local jurisdictions east of Interstate 95 (see Exhibit 1-1 for the original and new EVGWMA maps). As of 2013, over 130 permitted groundwater users withdraw groundwater in the original EVGWMA. Complete withdrawal data in the expanded areas are not yet available. In the original EVGWMA, individual permitted withdrawals have ranged from 0.003 million gallons per day (MGD) to 35 MGD. In addition to permitted withdrawals, thousands of unregulated individual groundwater users withdraw water from the Coastal Plain aquifers. These unpermitted self-supplied users (SSU) withdraw groundwater below the permitting threshold of 300,000 gallons a month and less than 10,000 gallons per day, but local water supply plans suggest that unpermitted self-supplied users that have a direct impact on Virginia's Coastal Plain aquifers withdraw about 29 MGD. Pope et al. (2008) estimate that approximately 78% of these groundwater withdrawals come from deep, confined aquifers within EVGWMA.

Pursuant to the Ground Water Management Act of 1992, the Groundwater Withdrawal Regulations (9VAC25-610-110) stipulate that the state shall issue permits if "the applicant's proposed withdrawal will have no significant unmitigated impact on existing groundwater users or the groundwater resource." The manner in which DEQ implements this objective is somewhat complex (see Exhibit 1-2). The regulations apply primarily to confined aquifers (but include the surficial aquifers); confined aquifers have an impermeable layer (compact clay and rock) above and below the groundwater and the groundwater between them is under pressure. When a well is drilled into one of the aquifers, water naturally rises up into the well because of this pressure. Pumping water out of the aquifer reduces the pressure in the areas around any particular well and, therefore, reduces how high water will rise within a well. This reduction in pressure is known as the cone of depression, and can extend for many miles around points of withdrawal. DEQ's goal in regulating withdrawals from the Coastal Plain is to keep groundwater levels throughout the region above the top of the aquifer with some margin of safety. If water levels drop below the top of the aquifer, there is a risk of permanent loss of storage and other problems. Specifically, DEQ aims to prevent groundwater levels from dropping more than 80% of the distance between the top of the aquifer and the land surface. This will be referred to as the "80% criterion" throughout the rest of this report. DEQ believes that a 20% margin of safety above the top of the aquifer is an adequate safety margin to protect overall beneficial uses of the aquifer.

Exhibit 1-1: The Original and Expanded EVGWMA

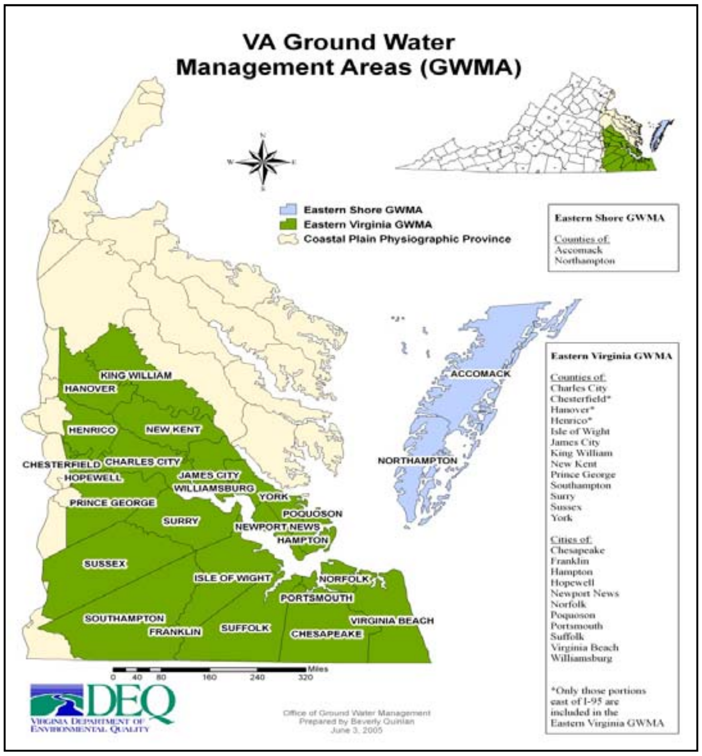
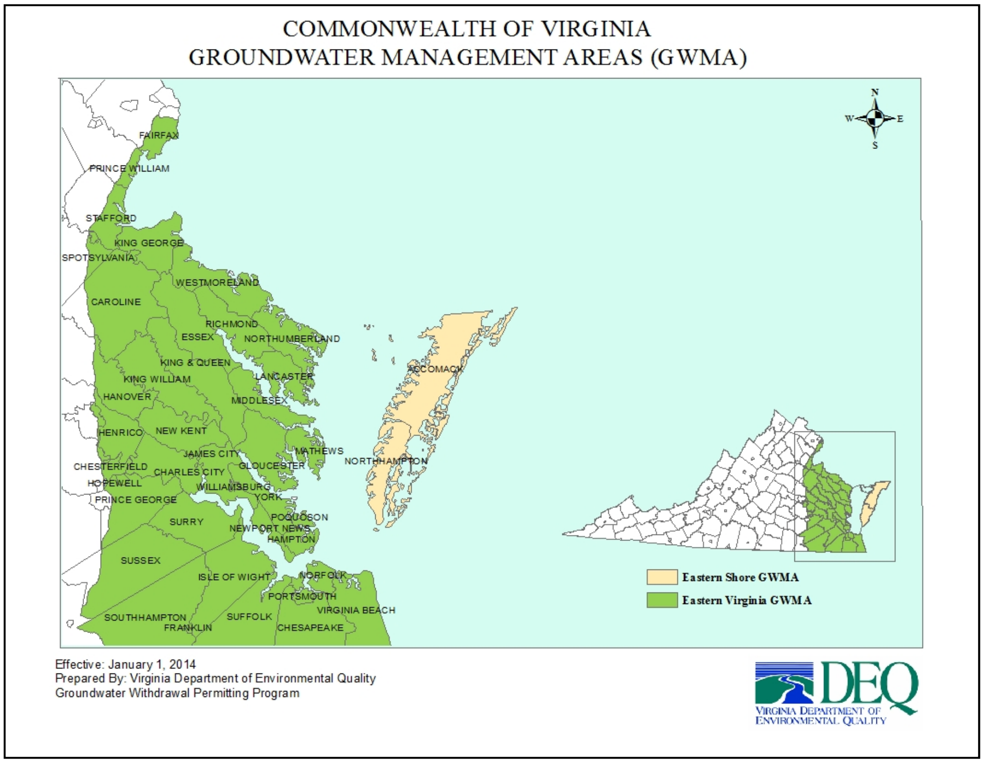


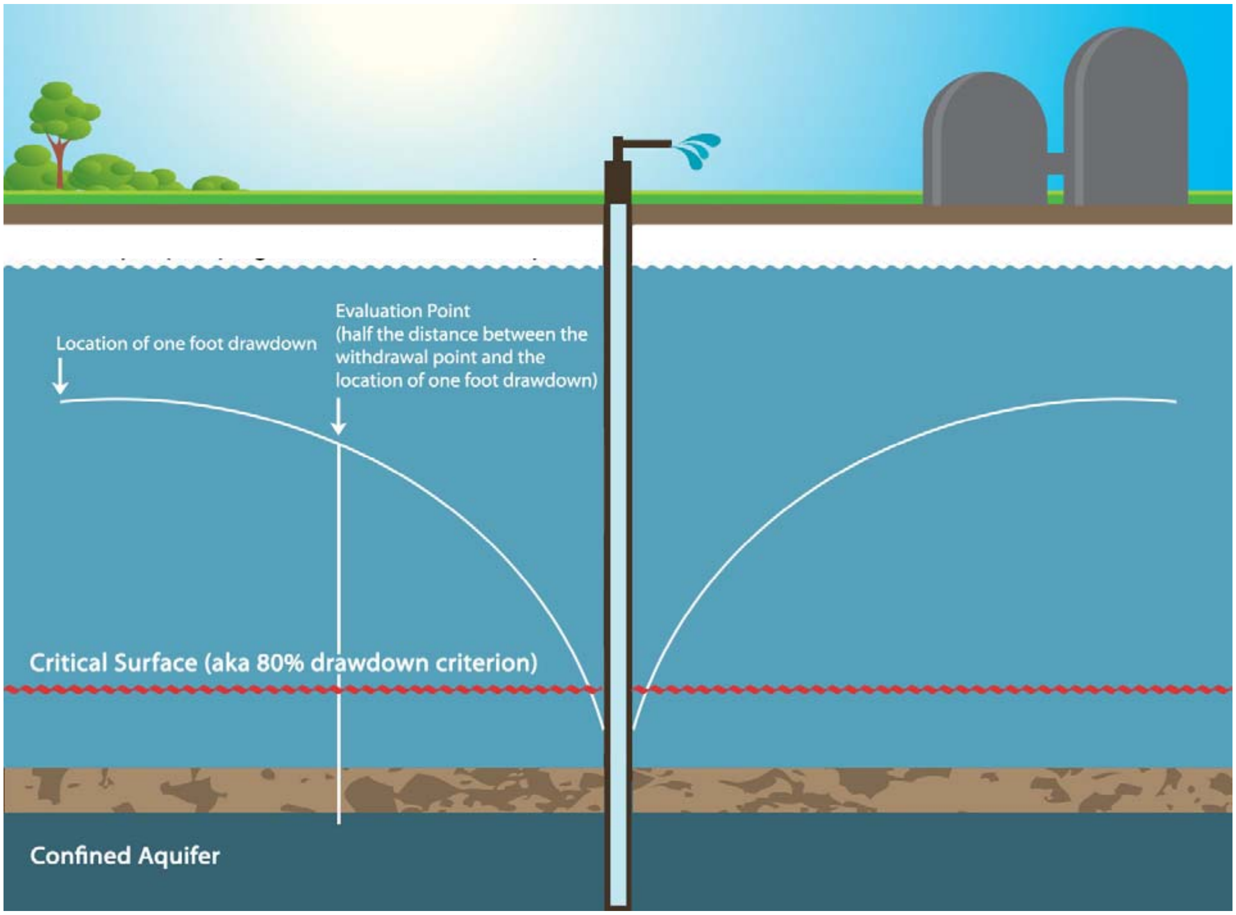
Exhibit 1-1: The Original and Expanded EVGWMA


COMMONWEALTH OF VIRGINIA
GROUNDWATER MANAGEMENT AREAS (GWMA)

Effective: January 1, 2014
Prepared By: Virginia Department of Environmental Quality
Groundwater Withdrawal Permitting Program

This investigation focuses on the original EVGWMA, primarily because complete data are not available to investigate groundwater use in the new expanded areas of the EVGWMA and because DEQ estimates that the majority of the largest groundwater withdrawals occur in the original EVGWMA.

Exhibit 1-2: The 80% Drawdown Criterion



Notes: Graphic is for illustrative purposes and is not to scale.
The "80% criterion" means that DEQ aims to prevent groundwater levels from dropping more than 80% of the distance between the top of the aquifer and the land surface.

1.2 Consequences of Declining Groundwater Levels

Several aquifers underlie the Virginia Coastal Plain. Virginia's coastal aquifers typically start near the fall-line (a geologic boundary separating the Coastal Plain from the Piedmont Physiographic Province) and generally deepen toward the Chesapeake Bay and the ocean (Pope et al., 2008; McFarland & Bruce, 2006; see Exhibit 1-3). Groundwater withdrawals come primarily from the Potomac, Aquia, Yorktown-Eastover, Piney Point, and the surficial aquifers, with the Potomac aquifer supplying the majority of all groundwater. The Potomac, Aquia, Yorktown-Eastover, and Piney Point are confined aquifers, with relatively low recharge from rainfall, and they are the focus of this report.

The Coastal Plain aquifers make up a primary source of water for many municipal water systems, industrial and other commercial facilities, and individual homeowners in eastern Virginia. Withdrawals from these aquifers increased rapidly after World War II and resulted in declines of groundwater levels of up to 200 feet (USGS, 2009). Those declines have generally continued, though there have been some recent increases in groundwater levels due to recent decreases in withdrawals (see Exhibit 1-4). Total reported pumping among permitted groundwater users is shown in Exhibit 1-5. As explained below, a number of permitted groundwater users reduced groundwater withdrawals since 2008, but the largest single reduction in withdrawals occurred due to the temporary closure of the paper mill in Franklin. As shown in Exhibit 1-4, upturns in groundwater monitoring well levels in the southern EVGWMA are associated directly with the large reduction in withdrawals from the Franklin Mill. The other observed recovery shown in Exhibit 1-4 (Henrico) occurred when municipal and industrial users in the area switched from groundwater to surface water.

Declining groundwater levels can cause a number of problems for individuals and local communities. Water availability can become a problem. Any given groundwater well is drilled and screened at a certain depth. If groundwater levels drop below the well depth, that well will no longer be able to extract water. This would require a groundwater user to go without groundwater, deepen the well, or secure an alternative source, all of which would impose costs. Further, if groundwater is pumped to the point that the water level drops below the top of the aquifer, such that soils within the aquifer itself are dewatered, the aquifer can permanently lose storage capacity as those soils settle. This permanent loss in groundwater storage capacity can create future costs for Virginia citizens because other water supply sources may be needed to compensate for the reduction in stored groundwater. Even less severe declines in groundwater levels can increase pumping costs to all groundwater users because of the increased energy needed to bring water up to the surface from lower points in the aquifer.

In addition, dewatering aquifers can cause land subsidence as the soils in the aquifer settle in the absence of water. Pope (2002) and Pope and Burbey (2004) noted that between 1979 and 1995, the land in the southeastern Coastal Plain of Virginia was subsiding, with a drop of 24.2 millimeters at Franklin between 1979 and 1995 (an average of 1.5 millimeters per year) and 50.2 millimeters at Suffolk between 1982 and 1995 (an average of 3.7 millimeters per year). Land subsidence can impact the hydrology and ecology of wetlands and it can increase flood risk to citizens living in the Coastal Plain. Eggleston (2013) concluded that more than half of the rate of sea level rise in southeastern Virginia is attributable to subsidence of all forms, with half of the total subsidence from groundwater pumping. Virginia has the highest rates of relative sea level rise on the Atlantic seaboard.

Finally, aquifer declines due to groundwater pumping can change the dynamics between fresh groundwater and saltwater along the coasts. As water levels decline in the aquifers, the saltwater gradient tends to move inland, degrading the quality of water in the aquifer. This saltwater intrusion can make groundwater unusable for some purposes without new or additional treatment. Treatment to remove salts typically requires advanced technologies, such as reverse osmosis, which is costly.

Exhibit 1-3: Generalized hydrogeologic section for aquifers in Virginia's Coastal Plain

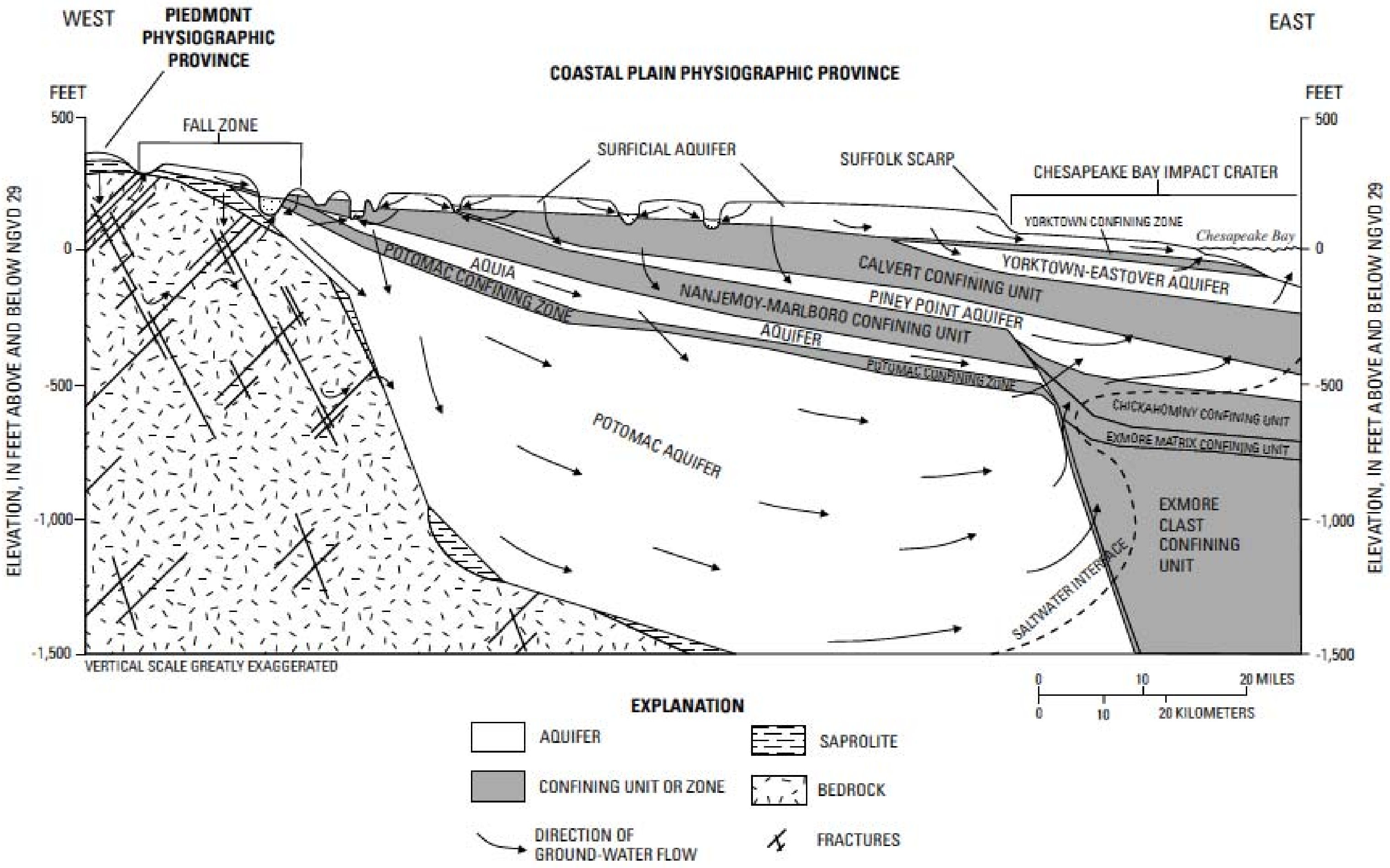
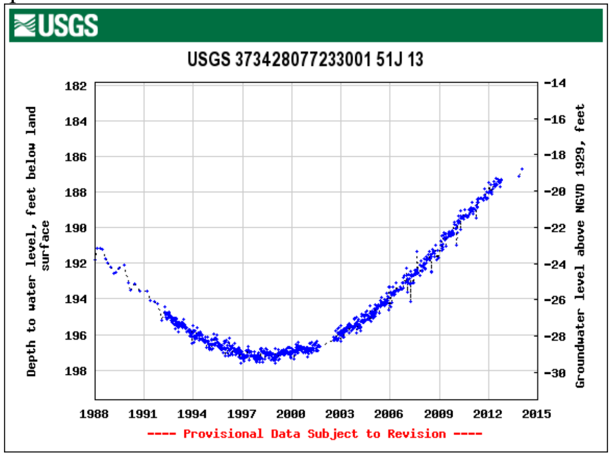


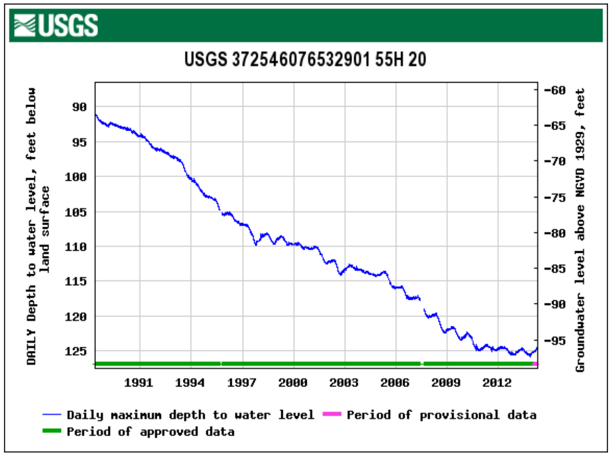
Figure taken from Pope et al, 2008

Exhibit 1-4: Groundwater levels in the Virginia Coastal Plain

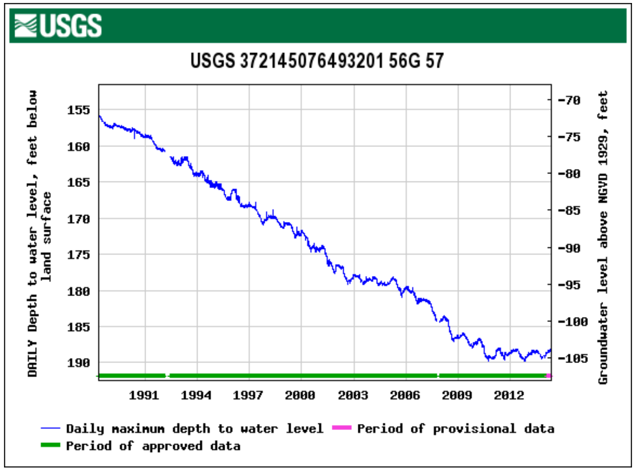
Henrico County, Virginia
Well depth = 275 feet below land surface



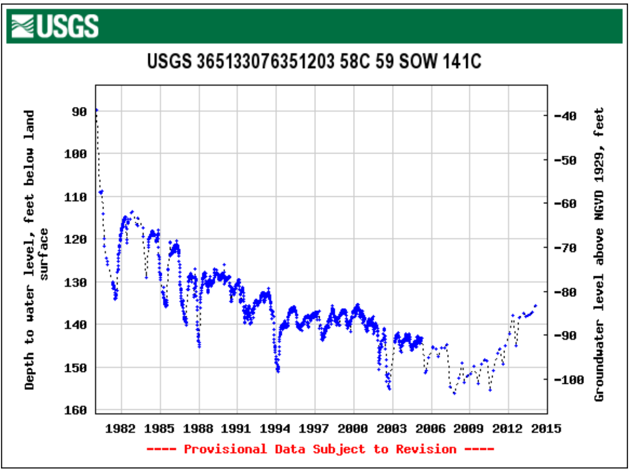
James City, Virginia
Well depth: 735.00 feet



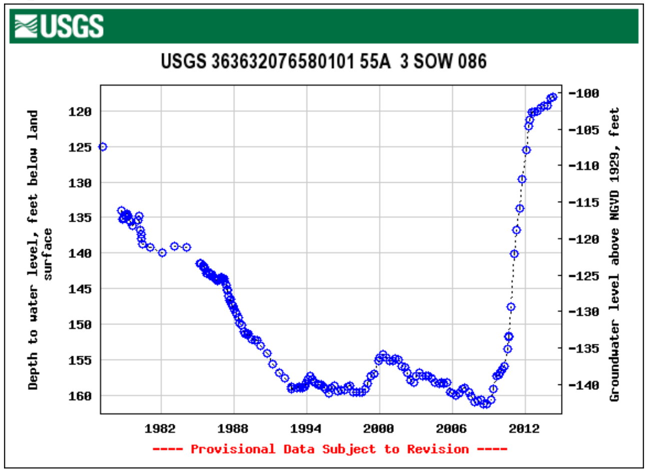
James City, Virginia
Well depth: 695.00 feet



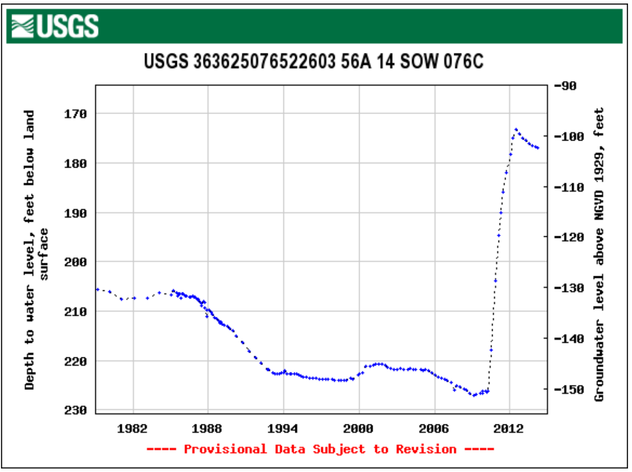
Suffolk City, Virginia
Well depth: 447 feet



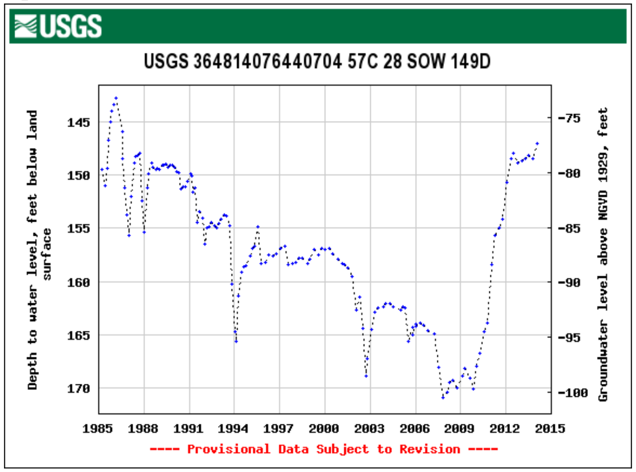
Southampton County, Virginia
Well depth: 745 feet



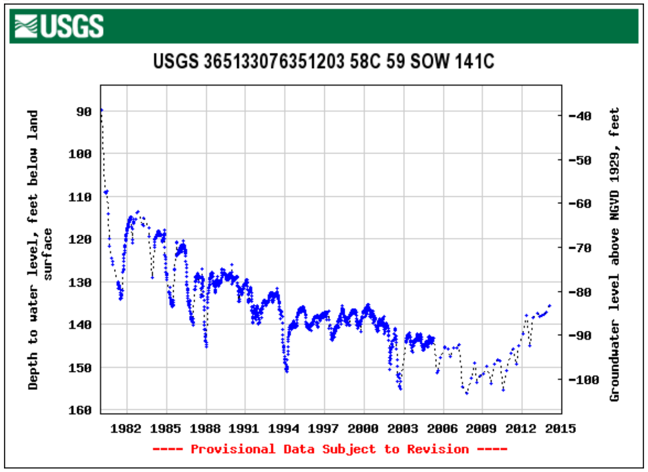
Suffolk City, Virginia
Well depth: 735 feet



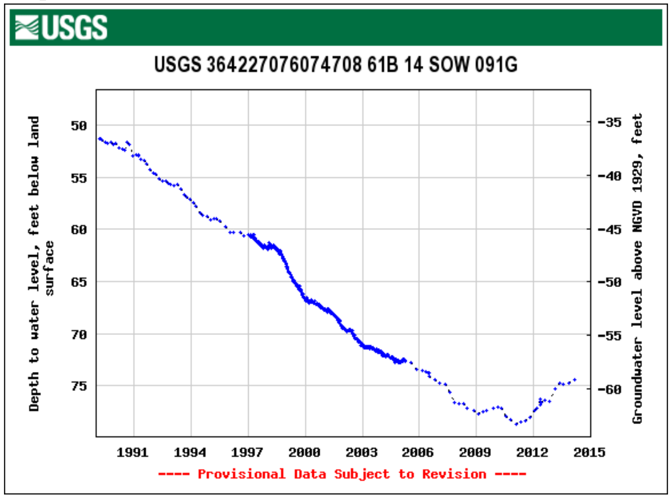
Isle Of Wight County, Virginia
Well depth: 807 feet



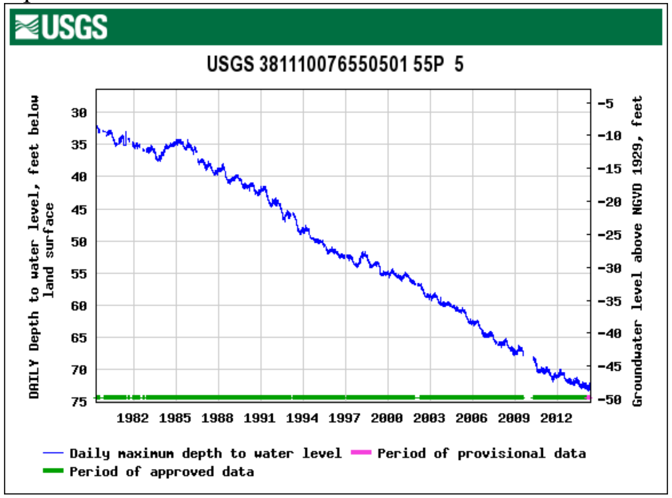
Suffolk City, Virginia
Well depth: 447 feet



Chesapeake City, Virginia
Well depth: 1,113 feet



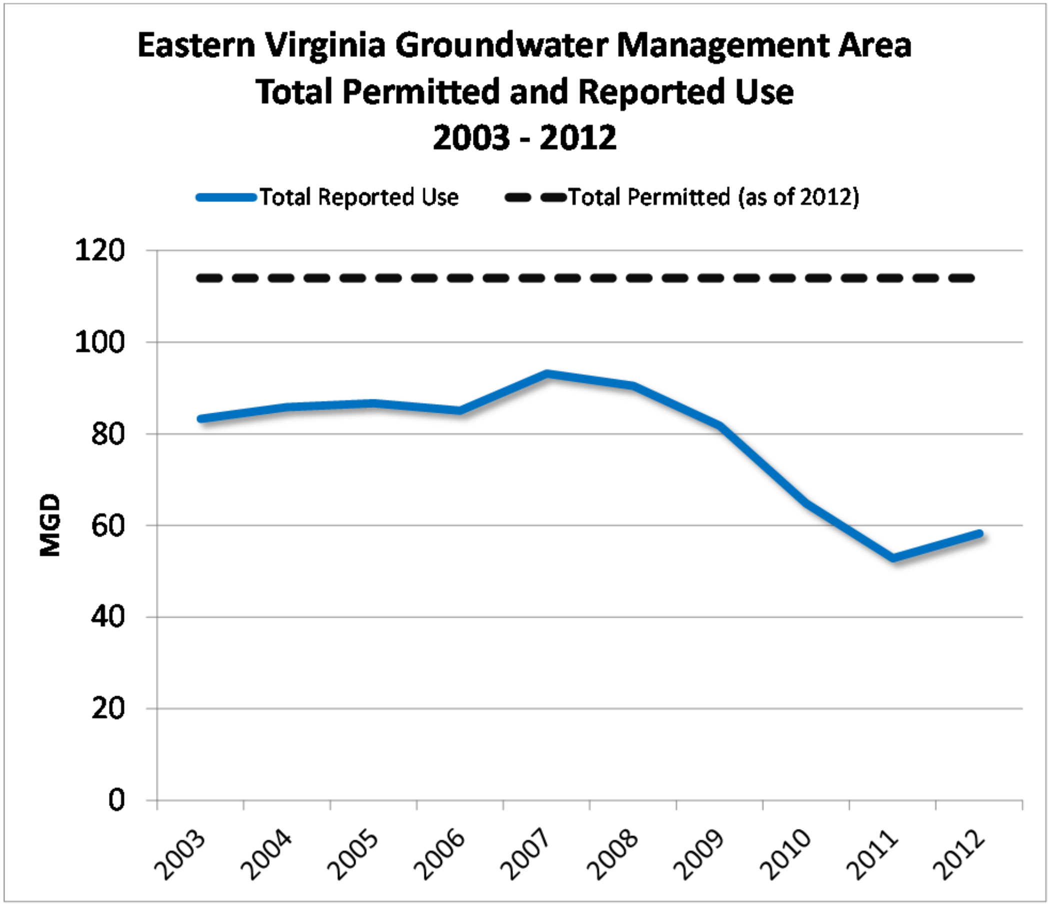
Westmoreland County, Virginia
Well depth: 471 feet



1.3 Understanding Current and Future Groundwater Conditions

Groundwater levels in the Coastal Plain over the last 20-30 years reflect two general trends. First, groundwater levels in most areas across the Coastal Plain show a general downward trend until about 2008 (see Exhibit 1-4). Second, starting around 2008, some monitoring wells began to show increases in groundwater levels. Those increases tend to be in the southern portions of the region and there is evidence that the increases may be leveling off over the last 1-2 years. The single largest reduction in groundwater use occurred when International Paper shut down its paper mill in Franklin. Before closing, the mill was steadily withdrawing 30-35 MGD from the aquifer system. The mill's withdrawals dropped below 5 MGD during the closure and have slowly climbed back to about 13 MGD today (details are given in Section 2.4.4). The largest rebounds in aquifer levels have occurred in the region around the paper mill.

Exhibit 1-5: Total Reported Use, 2003 – 2012



Total reported use includes permitted users and Portsmouth Utilities, which operates under a Certificate of Prior Use. Portsmouth withdrawals are included for 2003 to 2012; no data are available for Portsmouth for 2013; Average withdrawals by Portsmouth are approximately 3.5 MGD.

Despite recent reductions in withdrawals and associated recovery in groundwater levels, concerns about the sustainability of groundwater pumping remain for several reasons. First, the recovery in groundwater levels was generally localized to the southern areas of the Coastal Plain and the recovery in groundwater levels has been associated with the temporary downturn in the economy (2008 recession). Second, current permits do not prevent substantial future increases in groundwater use. As shown in Exhibit 1-5 and Exhibit 1-6, the total amount currently permitted is about 114 MGD, which is more than twice the amount of current withdrawals. In the early 2000s groundwater pumping among permitted users totaled about 80 MGD and groundwater levels were generally declining at this rate of pumping. Finally, thousands of unregulated individual groundwater users exist throughout the Virginia Coastal Plain,[1] with the estimated total withdrawal from confined aquifers among this unregulated sector equaling about 29 MGD within the EVGWMA (Heywood and Pope, 2009). Less is known about the characteristics and trends in this sector, but information from water supply plans (e.g., Hampton Roads Planning District Commission (HRPDC), 2011; Middle Peninsula Planning District Commission, 2011) suggests that groundwater use in this sector is growing as more people move to the region.

A model of the Coastal Plain aquifers was developed by the U.S. Geological Survey in 2009 (Heywood & Pope, 2009). DEQ modified this model to incorporate regulatory criteria to support permitting and DEQ's model is known as VAHydro-GW. VAHydro-GW estimates the future groundwater levels in the Coastal Plain aquifers given the location and amount of current and future groundwater withdrawals across the EVGWMA. DEQ has adopted the VAHydro-GW model as a primary decision-support tool for evaluating permit applications and for studying the physical impacts of different groundwater withdrawal scenarios.

Results from the VAHydro-GW suggest the consequences of high groundwater withdrawals.
shows modeled results for a scenario in which the total permitted amount (about 114 MGD) is pumped from the aquifers year after year for 50 years (with other withdrawals held constant). Red shaded cells on the map indicate areas in which aquifer levels would drop below the top of the aquifer; this could result in permanent loss of storage and increases in well interference as described above. Yellow shaded cells indicate areas where aquifer levels would drop below the 80% criterion. This map shows results for the Potomac aquifer only, for illustration purposes, but the model yields similar results for the Aquia and other aquifers. The results suggest that if groundwater users withdraw groundwater at full current permitted capacity, many areas would be susceptible to increased pumping costs, well failures, permanent loss of storage, and land subsidence.

DEQ has performed several additional model runs to investigate the amount of total withdrawals that the aquifers can sustain and meet DEQ's 80% criterion. Exhibit 1-8 shows model results for a scenario in which the 2012 *reported use* among all large groundwater users is pumped from the aquifer for 50 years (about 61.8 MGD, including those with permits in the original EVGWMA and those in expanded areas of the EVGWMA that do not yet have permits). Other groundwater uses were held constant at current withdrawal rates. In this scenario, some isolated areas along the western edge of the Coastal Plain drop below the 80% criterion (yellow shading) and the area that drop below the top of the aquifer (red shading) is substantially less than in the "total permitted" scenario described above. In this "reported use" scenario, the water levels that fall below the regulatory standard would be clustered along the fall line, mostly just north of Richmond. In this area, the aquifers tend to be rather shallow (Heywood & Pope, 2009).The VAHydro-GW results and data from monitoring wells lead to several conclusions. Limiting

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[1] Virginia groundwater regulations require permits for withdrawals that exceed 300,000 gallons a month but not for withdrawals that are less than this amount. A typical individual homeowner would use much less than this amount.

the future growth in groundwater withdrawals can substantially slow the rate of groundwater declines across the Coastal Plain aquifers (though declines in some areas could continue). Thus, new actions to reduce the total permitted amount of pumping may be warranted to achieve state aquifer management goals and reduce the adverse impacts associated with continued declines in aquifer levels. DEQ has been evaluating different amounts of total withdrawals to identify the maximum amount that would minimize areas that violate the 80% criterion. Total withdrawal targets have not been yet finalized at the time of this report. This investigation assumes a target range for total withdrawals across all groundwater users within the entire EVGWMA to be between 90 to 100 MGD.[2] This range of total withdrawals can be broken down to different sectors (see Exhibit 1-6). In general, DEQ's preliminary targets would limit total future withdrawals from different groups of users to an amount roughly equal to current use. Total withdrawals among the unregulated, small self-supplied users are about 29 MGD. Total current withdrawals among permitted users in the *original EVGWMA* are 59 MGD. Users with withdrawals greater than 300,000 gallons per month in the new areas of the expanded EVGWMA are not yet permitted. DEQ estimates that total withdrawals among large users in the new portions of the EVGWMA are between 5 to 10 MGD. Therefore, tentative target withdrawals for the permitted sector in the original EVGWMA range between 55 and 65 MGD and target withdrawals for the small self-supplied users are approximately 29 MGD. These limits are subject to change, but these targets will be the focus of this report.

Exhibit 1-6: Permitted capacity, estimates of use, and preliminary groundwater targets

Category of Use	Current Total Permitted Capacity (MGD)	2003-2012 Avg. Use (MGD)	2012 Reported Use	Preliminary Target (MGD)
Permitted users in the Original EVGWMA*	114**	78.3*	59.2*	55-65*
Largest 14 Users	100.4	73.3	53.9*	n/a
Largest 8 CWSs	*43.1*	*20.7**	*18.7**	*n/a*
Largest 6 Industrial Users	*57.3****	*52.5*	*35.1*	*n/a*
All other permitted users	13.6	5.0	5.3	n/a
Large[‡] users in the expanded EVGWMA	n/a	n/a	n/a	5-10
Unpermitted Self-Supplied Users	n/a	29	n/a	30

*Includes Portsmouth Utilities
**DEQ Modeling assumes 114 MGD for total permitted capacity
***Assumes Franklin Paper Mill permit will be renewed at 20.6 MGD
[‡]Users that withdraw more than 300,000 gallons per month and will require permits

It should be stressed that **these are preliminary groundwater withdrawal targets**. Different targets may eventually be pursued by DEQ based on new VAHydro-GW results, the results of the investigation reported here, and future evaluations by DEQ, groundwater users, and the State Water Control Board. The targets are used here as a starting point to describe the costs and other economic impacts that may be experienced due to possible future limits on groundwater withdrawals.

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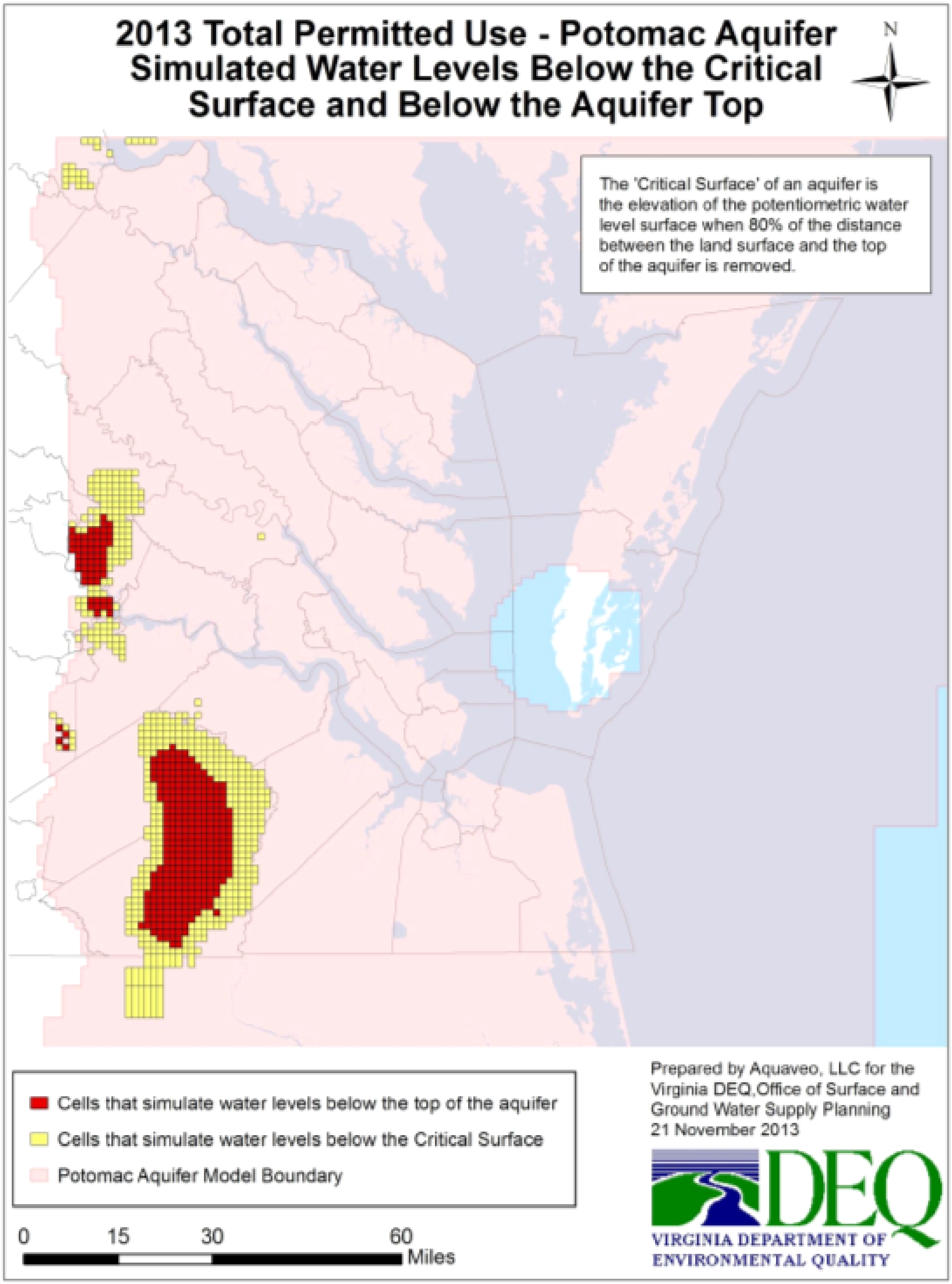
[2] These are preliminary targets based on current model results at the time of this analysis. DEQ continues to refine the model and input data and so these targets may change as new model results are produced. They are used as a tentative target to structure this investigation.

Exhibit 1-7: VAHydro-GW Results with Total Permitted Groundwater Use

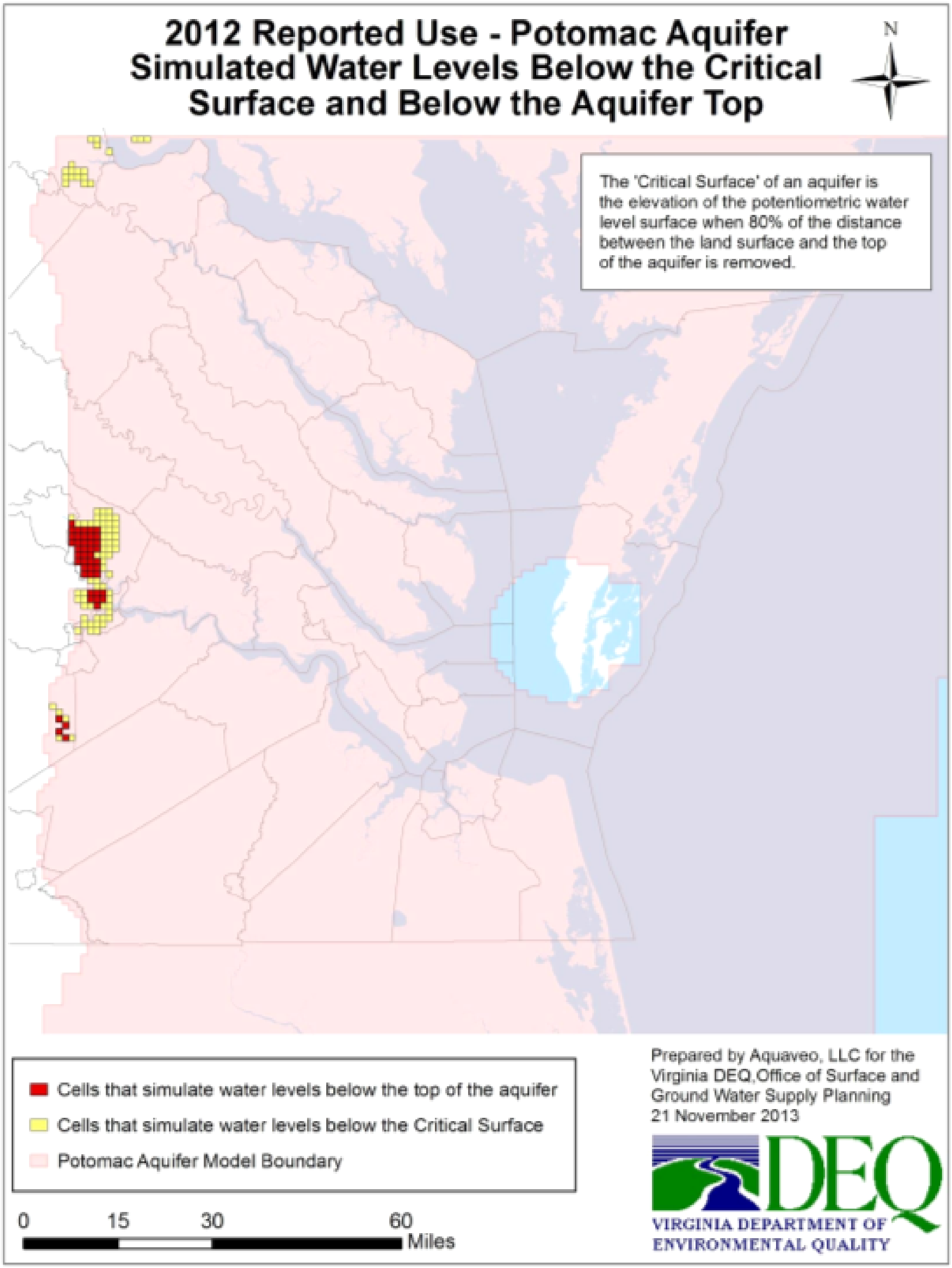


2013 Total Permitted Use - Potomac Aquifer Simulated Water Levels Below the Critical Surface and Below the Aquifer Top

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.

Prepared by Aquaveo, LLC for the Virginia DEQ,Office of Surface and Ground Water Supply Planning
21 November 2013

Exhibit 1-8: VAHydro-GW Results with 2012 Reported Use



2012 Reported 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.

Prepared by Aquaveo, LLC for the
Virginia DEQ,Office of Surface and
Ground Water Supply Planning
21 November 2013

VIRGINIA DEPARTMENT OF
ENVIRONMENTAL QUALITY

1.4 Overview of this Report

While the target for the original EVGWMA is roughly equivalent to the level of recent reported use, these targets would represent a 55 to 65 MGD reduction in permitted capacity across the EVGWMA. The concern is that such cutbacks in total permitted withdrawals will impose costs on groundwater users and the regional economy, but that these costs are not known and need to be considered in any water management decisions. It is already clear that groundwater use at the Franklin Paper Mill is increasing and it is expected to continue increasing (but not up to historical pumping levels). This trend alone may increase total use beyond the preliminary target levels for permitted withdrawals. Other industrial groundwater users anticipate potential expansion of production, potentially increasing groundwater use more. Further, based on local water supply plans submitted to DEQ, most localities in the EVGWMA expect population and economic activity to continue to grow in the future. Many community water systems (CWSs) in the region rely on groundwater for an important share of their total water supply and many of these same systems have constructed water supply plans around the expectation of increased groundwater use in the future. With industries and municipal CWSs expecting to use more groundwater in the future, the targets being evaluated by DEQ may impose constraints on these growth plans and require new investments in water use efficiency or alternative sources of water.

This report describes the potential economic impacts of reducing the amount of groundwater that industries, CWSs, and individual homeowners can use. This report groups groundwater users into several categories based on the type of use and the amount of use. Those categories are defined as follows:

- **Large municipal groundwater users** – municipal water supply utilities (i.e., CWSs) that rely on groundwater for all or part of their source water; large groundwater users are defined here as permitted withdrawals of 1 MGD or more; there are eight large municipal groundwater users in the original EVGWMA.
- **Large industrial groundwater users** – industrial facilities that rely on groundwater for all or part of their source water and have permitted withdrawals of 1 MGD or more; there are six large industrial groundwater users in the EVGWMA.
- **Small permitted groundwater users –** smaller permitted groundwater users of any type (industrial, municipal etc.); withdrawals are less than 1 MGD, but exceed 300,000 gallons in any month and require a groundwater withdrawal permit from the Virginia DEQ; there are 113 small permitted groundwater users in the original EVGWMA.
- **Unpermitted self-supplied users** – small unregulated groundwater users generally for domestic purposes; withdrawals do not exceed 300,000 gallons a month and do not require a groundwater withdrawal permit from the Virginia DEQ; estimates from the 2000 U.S. Census suggest there are 200,000 wells of this type (Pope et al, 2008).[3]

Future permitting and management actions to limit the adverse impact of declining aquifer levels on multiple beneficial uses will require new limitations on groundwater withdrawals. Limitations on access and use of groundwater will impose costs and other economic impacts on citizens and businesses in the Commonwealth. Conceptually, the costs of future actions to limit groundwater use are the incremental costs above and beyond those costs that would have been incurred without a change in groundwater

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[3] The 2010 U.S. Census did not ask whether a home was supplied by a well. Therefore, this number, which is based on older 2000 Census data, is likely an underestimate.

management approach. Thus, any examination of the possible costs of future statutory or regulatory actions to limit groundwater use also requires consideration of both future water demand and supply conditions and the likely response by users to those future conditions.

The report describes several types of potential impacts and costs as follows:

- The impact of reduced groundwater availability on the regional balance between future water supply and future water use among large municipal groundwater users (see Box 1-1 for an explanation of how the terms *water supply* and *future water use* are used in this report);
- The alternatives available to groundwater users within the original EVGWMA to meet water supply needs given new limitations on future groundwater use;
- Potential unit costs of general alternative strategies for developing alternative water supplies and/or reducing water use through conservation investments, reuse, and water recycling;
- The impact of reduced groundwater availability on the supply of each of several large groundwater users within the EVGWMA;
- Likely consequences and costs for each of those large groundwater users to replace groundwater or reduce water use if their groundwater allocations were decreased; and
- Potential costs if new groundwater management options limited the amount of wells or withdrawals within the currently unpermitted self-supplied sector.

The purpose of this study is to provide DEQ a high-level description of these potential direct costs and consequences of new groundwater management actions in sufficient detail (as the data allow) for the state to make groundwater management decisions. Given the complexity of the issue and the limited timeframe, many of the costs cannot be directly quantified with any degree of confidence. The report focuses on the largest permitted users in the EVGWMA since these users withdraw more than half of all water from Virginia Coastal Plain aquifers (see Exhibit 1-6). Furthermore, this report focuses on first order economic costs and impacts. Future water use restrictions could conceivably alter the regional economic growth and development, but detailed examination of these impacts is beyond the scope of this report.

The report draws from several sources of information. A series of informal interviews was conducted with representatives of the largest 14 groundwater users in the region. These interviews provided information on how groundwater is used, future plans and expectations, and available data on costs and feasibility of alternative sources of water. DEQ requested that this investigation be completed in three months. With this short time-frame, it was not possible to gather original data, conduct new modeling of economic conditions, or prepare detailed cost estimates of specific outcomes, such as specific alternative water sources. One exception is that new future water use projections were prepared for this study. Describing the impacts of reduced groundwater availability requires a baseline projection of how much water will be used in the region in the future. The new water use projections incorporate new data on recent water use and population trends.

Section 2 of the report describes current and projected future water use in the region, including a detailed account of the methods and data used to project future water use. Since current use is roughly equal to DEQ's target groundwater withdrawals, future water use is a critical element in identifying the cost of achieving overall groundwater targets in the long term. Section 3 summarizes general water supply alternatives that could be implemented to replace groundwater, including increased regional water sharing, new surface water storage, wastewater reuse and others. Possible costs of these alternatives are described using available data from grey and peer-reviewed literature. Drawing from the interviews with groundwater users and published sources of information, Section 4 describes the potential cost implications of groundwater cutbacks on the largest individual groundwater users, as well as impacts across the rest of the permitted and unregulated sectors. Section 5 provides summary economic evaluations of a range of changes that DEQ could implement to achieve state groundwater management goals. Several appendices offer supporting data for the findings throughout the report.

Box 1-1: Water Supply Terminology for this Report

It is necessary to define how certain terms and concepts are used in this report to make sure the analysis and conclusions are clear.

Water Use

The terms water use, water demand and water need are often used interchangeably. In this report we employ the term “water use” and avoid the terms demand and need. For municipal systems, ***water use*** means the total deliveries of water to customers, including residential, commercial and industrial customers. It does not include treatment or production losses, which are accounted for in estimated supply (see below), but it does include unaccounted for water which consists of distribution system leaks and other post-treatment losses (e.g. water use is all water that leaves the water treatment facilities). For industrial water users, water use means the total amount withdrawn from aquifer sources. For both industrial and municipal water users, current water use means recent total deliveries or withdrawals. The exact period used for recent deliveries/withdrawals differs from user to user based on data availability and other factors.

Future water use for municipal systems is a projection of total future deliveries to customers based on recent patterns of per capita water use and available projections of future population (details on the methodology used are presented in Section 2.2). The report includes a range of future water use projections based on different assumptions about per capita water use and future population growth. Future water use does not include treatment or production losses, but does include unaccounted-for water. For industrial users, future water use is the total amount of water that each user is expected to withdraw from aquifers in future years based on production trends and other information. A single number is assumed for industrial users and in most cases it is the amount in their current groundwater withdrawal permit.

Water use varies from day to day and year to year. For purposes of this report, for both municipal and industrial entities, water use is expressed as an overall daily average in millions of gallons per day, or MGD.

Water Supply

The term water supply refers to the provision of water to customers or self-supplied by industrial users for production purposes. Water supply can come from various sources and the report distinguishes between groundwater sources and surface water sources, but does not distinguish between the various aquifers.

In addition, the term *water supply* or just *supply* is used in technical discussions throughout this report to refer to a specific quantity of water that can be supplied. Often the term *yield* or *safe yield* is used for this concept, but yield has specific meaning in Virginia regulations, so it is generally avoided in this report. Water supply as a quantity generally refers to the amount of water that can be reliably supplied from a given system of sources, treatment plants and other infrastructure under specific climatic conditions. For this report, it includes total withdrawals from sources minus treatment losses. This report relies on the Hampton Roads Regional Water Supply Plan (HRPDC, 2011) for data on the available water supply of municipal water systems covered in this report. For that plan, safe yield is defined as the minimum reliable water that can be provided by a given system through the worst drought on record since 1930. We adopt the same definition for water supply. Droughts worse than those from the last 85 years are entirely possible, but safe yield as defined above is a standard way for water utilities to plan for the risk of potential shortages of water.

2. Current and Future Water Supply and Use

Limitations on groundwater use will impose costs on how groundwater users provide for future water supply. The magnitude and timing of impacts and costs depend on both the availability of alternative water supplies and the growth in water use. This section profiles the current and likely future water use of the largest 14 users of groundwater in the EVGWMA. In addition, the section describes current and likely future water use for Virginia Beach, which is not a major groundwater user, but has major connections with other water users and has the potential to play a major role in overall water supply and demand balance in the region. This section also provides a brief overview of current and likely future water use among the remaining permitted users (current groundwater withdrawal of 5.3 MGD in the original EVGWMA in 2012), and among the unpermitted self-supplied sector. Groundwater use among the unregulated self-supplied sector was estimated to be about 29 MGD based on data provided in the local water supply plans for areas that impact Virginia coastal aquifers. In general, less is known about these users' spatial distribution and usage patterns. This section concludes with a discussion of current and future withdrawals among the unregulated self-supplied sector.

2.1 Projecting Water Use for Large Municipal Systems

There are eight municipal utilities that are among the largest groundwater users in the EVGWMA. These municipalities are concentrated in the southeastern area of the EVGWMA. Data on recent water use patterns (from all water sources) was taken from the HRPDC's 2011 Hampton Roads Regional Water Supply Plan (HRRWSP), including attachments to the plan. In addition, information about how each municipality meets its water needs, including sources, treatment and other factors, were taken from the HRRWSP, public websites and direct interviews with representatives of the eight municipal utilities.

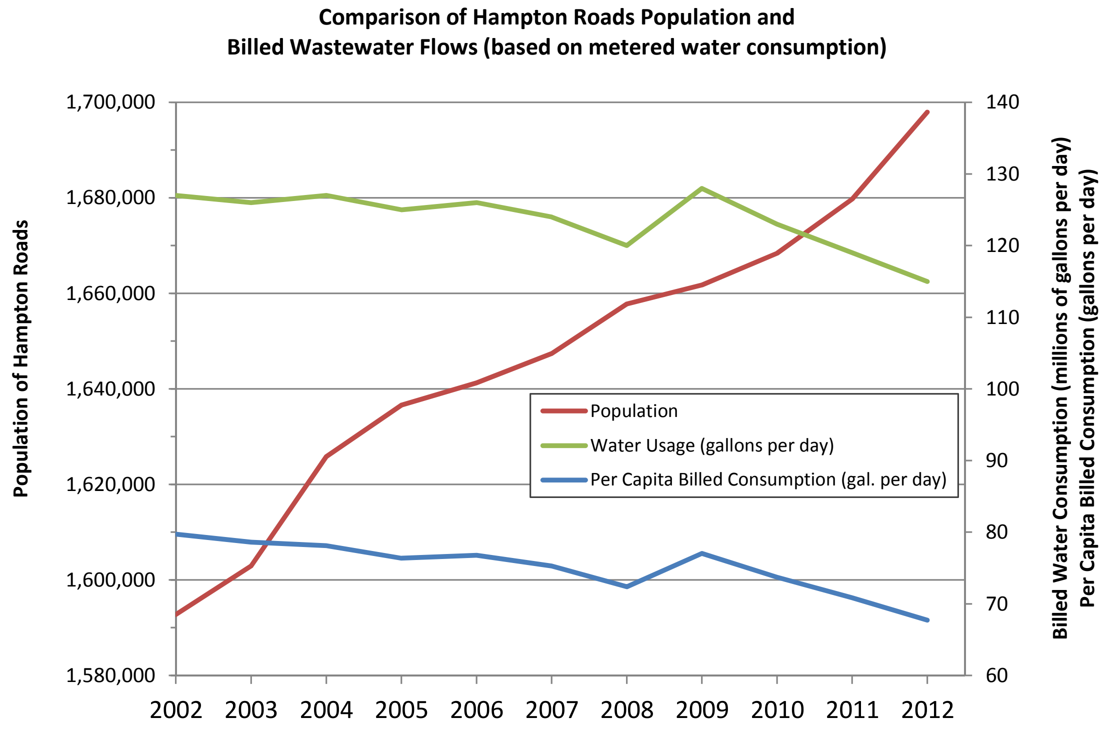
This analysis presents several future water use projections for each large municipal water system within the original EVGWMA. The HRRWSP provides one potential water use projection for this study. Future water use, however, will likely fall short of the original HRRWSP projections for two reasons. First, the HRRWSP relied on population growth projections prior to the 2010 U.S. Census. The 2010 Census showed that population was generally lower for cities in this region than what was projected for 2010 in the water supply plan. Some of this difference was likely due to the 2008-2010 recession. The water use projections employed here take advantage of updated population estimates from the 2010 Census (see Appendix 1 for charts of historical and projected future population growth). Second, recent water use data from the Hampton Roads Sanitation District (HRSD; see HRPDC, 2013 for an example) shows that water use (total and per capita) in the region has been declining. The decline in total water use has occurred while the population has increased (see Exhibit 2-1). Declining per capita water use is a national trend and is likely driven by water and energy efficiency standards for household appliances, water use efficiency among non-residential water users, water use plumbing codes, public education programs to promote water conservation, economic conditions and other factors (Rockaway et al, 2011).

Projecting future use in commercial, industrial, and institutional sectors can be even more difficult than for the residential sector. Adding one large industrial water user to a city can add several MGD of water use. Growth in these sectors can make a municipal system's water use increase substantially faster than population growth alone would imply. In the projections developed for this report, different water use sectors (residential, industrial, etc.) were not accounted for separately and no attempt was made to project how growth in non-residential sectors would affect water use.

Water utilities have a responsibility to plan for future growth and ensure that future populations and businesses have reliable access to sufficient clean water. Future water use is very difficult to predict because of the uncertainty in future population growth, residential water use patterns, economic development, and other factors. Each individual utility will make operational and capacity decisions in the face of these uncertainties about future water use. Municipal water utilities will make these decisions based on their own unique circumstances and the priorities of their customers and political leaders. Utilities may understandably base their plans and investment decisions on different water use projections than those developed for this report. For example, some municipalities may want to plan to provide water above anticipated population growth in order to accommodate future economic development opportunities.

The projections prepared for this report are based on the most recent information about the determinants of total water use and, therefore, provide a reasonable baseline for describing the possible impacts of new groundwater management actions. The methods used to produce new demand projections are summarized below.

Exhibit 2-1: Declining water use in the Hampton Roads Region



Source: 2002-2011 population data from HRPDC 2012 Data Book; 2012 population estimate from the University of Virginia, Weldon Cooper Center for Public Service, July 1, 2012 Estimates for Virginia and its Counties and Cities; billed consumption data from HRSD FY2012 Comprehensive Annual Financial Report.

Data and chart provided by the Hampton Roads Planning District Commission

2.2 Municipal Water Use Projection Methods

Water use is projected for the years 2020, 2030, and 2040 for each of the following municipal utilities:

- City of Chesapeake Public Utilities;
- James City Service Authority;

- Western Tidewater Water Authority;
- Newport News Waterworks;
- Norfolk Department of Utilities;
- City of Franklin;
- Town of Smithfield;
- City of Portsmouth; and
- City of Virginia Beach.

Water use is projected as an annual average daily demand in MGD for each utility as follows:

Water Use in Future Year = Current Per Capita Use Rate × Reduction in Use Rate × Projected Locality Population Served by the Utility

New projections are calculated in two steps. In the first step, the population served by public water in each locality was calculated, using several scenarios of population projections:

Projected Locality Population Served by Public Water = Total Locality Population Projections × Shares of Locality Population Served by Public Water

The next step was to calculate each locality's population served by each individual utility, and then to sum across localities. This step accounts for service areas that cross locality boundaries (e.g., about 8,000 people in James City County are served directly by Newport News Waterworks).

Projected Locality Population Served by the Utility = Projected Locality Populations Served by Public Water × Utility's Share of Locality Population Served by Public Water

The sections below describe the data sources and calculations used to derive the values in these equations.

2.2.1 Per Capita Water Use

Attachment 1 of the HRRWSP provides spreadsheet calculations of the average per-capita water usage (gallons per capita per day, GPCPD) for several utilities. Attachment 1 of the HRRWSP gives a detailed breakdown of water use rates, rates with unaccounted-for water (UAW), and rates with both UAW and production losses. Where available, per capita water use rates include UAW but exclude production losses. Note that the data for Isle of Wight County and the City of Franklin do not specify whether water use rates include UAW. This analysis assumes that these localities' water use rates include UAW.

Since Attachment 1 did not include all types of water uses for Norfolk and Virginia Beach, total water use in 2007 was obtained from the HRRWSP (Figure 2-11 for Norfolk and page 2-15 for Virginia Beach) and divided by the respective total populations (from Attachment 1 for Norfolk and from the Weldon Cooper Center for Public Service for Virginia Beach). In addition, since Smithfield's per capita water use was unusually high in 2007, data from 2010 were used to calculate per capita water use.

Exhibit 2-2: Per Capita Water Use (average from 2004-2008)	
Utility	**Per Capita Water Use (gpcd)**
City of Chesapeake Public Utilities	97
Franklin Water System [a]	133
James City Service Authority	106
Newport News Waterworks	112
Norfolk Department of Utilities	122
City of Portsmouth	112
Town of Smithfield [c]	89
Western Tidewater Water Authority [a,b]	106
City of Virginia Beach	83

Source: Figure 2-11, page 2-15, and Attachment 1 of the HRRWSP (HRPDC 2011).

a. The data for Isle of Wight County and the City of Franklin do not specify whether water use rates include UAW. This analysis assumes that these localities' water use rates include UAW. The data for all other water use rates in this table do specify that they include UAW.

b. Per capita water use for the Western Tidewater Water Authority was calculated as the population-weighted average of water use from Suffolk (103 MGD) and Isle of Wight County (281 MGD).

c. Per capita water use for the Town of Smithfield was calculated using 2010 data on groundwater withdrawals, production losses, and population.

Future water use scenarios are based on two different assumptions about future per capita use rates. First, two water use scenarios assume that per capita use in the future will equal per capita use from 2004-2008, as presented in Exhibit 2-2. Second, two other water use scenarios are estimated using lower per capita water use rates. Recent HRSD data for 2013 suggests that per capita use in the region has fallen by about 14% since 2004-2008 (see HRPDC, 2013; more recent data were provided by HRPDC staff). Therefore, two future water use scenarios assume per capita use will be 14% below 2004-2008 levels. It is entirely possible that per capita use will drop further, but such a scenario is not included in this investigation. In addition, it is possible that per capita use will, in fact, increase above 2004-2008 levels, although the general view throughout the industry suggests that increases in per capita use rates are unlikely. Water efficient fixtures and appliances will continue to penetrate the market through new construction and consumer investments to update or renovate. Increases in per capita water use could be driven by more outdoor irrigation in the future, but with prices increasing (Walton, 2013), this also seems unlikely among more than a small minority of consumers.

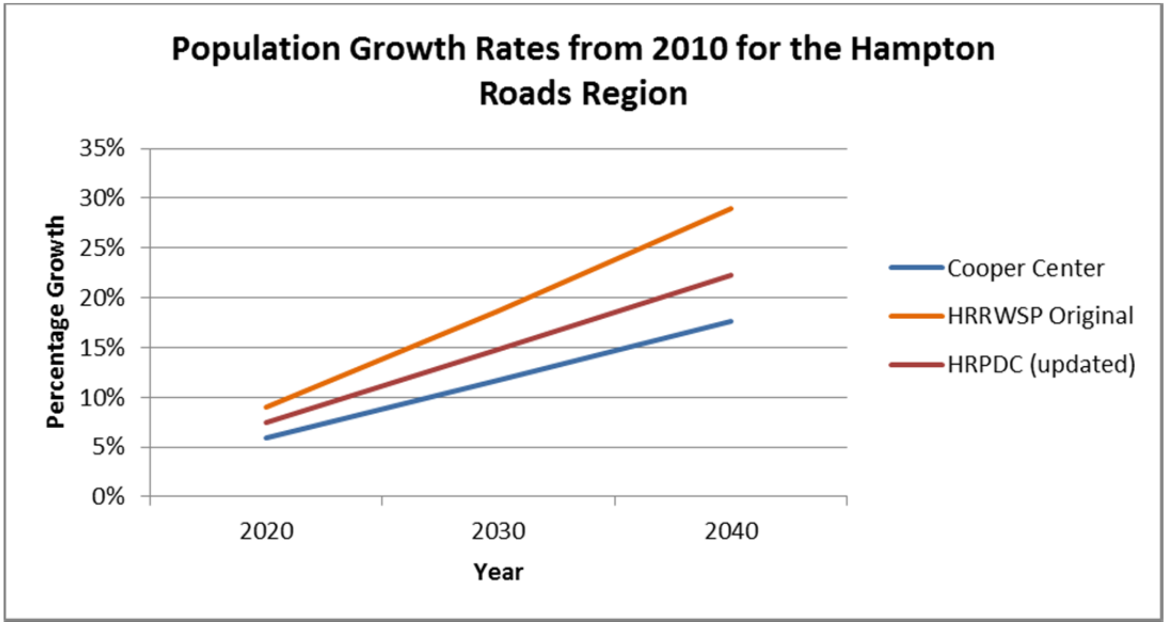
2.2.2 Locality Population Projections

While developing locality population projections, two population growth scenarios were considered. For each scenario, future populations were projected by multiplying each locality's population count from the 2010 U.S. Census by percentage growth rates from 2010 to three future years (2020, 2030, and 2040).

This analysis uses population growth scenarios from two regional datasets: updated HRPDC projections (Hampton Roads Transportation Planning Organization (TPO) 2013) and the Weldon Cooper Center for Public Service (2012). Hampton Roads TPO (2013) provides estimates of the total population in each locality in 2040.[4] The Cooper Center provides population projections for each locality in 2020, 2030, and 2040.

Exhibit 2-3 shows the comparison of population growth rates from each population projection scenario for the Hampton Roads region in total. Overall, the 2011 HRRWSP projects more growth than the updated HRPDC projections or the Cooper Center. However, the scenario with the highest growth rate varies by locality (see discussion below).

Exhibit 2-3: Comparison of Population Projection Scenarios



2.2.3 Shares of Locality Population Served by Public Water

Attachment 1 of the HRRWSP (HRPDC, 2011) provides estimates of the percentage of the population in each locality that is served by public water by decade through 2050 (see Exhibit 2-4). These percentages were multiplied by the locality population projections from each scenario for 2020, 2030, and 2040; this calculation results in projections of the total locality population served by public water.

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[4] Note that the HRPDC calculated population projections for the 2011 HRRWSP using the Hampton Roads TPO's projections for 2035. Since projections for 2020 and 2030 were not published, the HRPDC used a straight line projection to obtain a projection for each year in between. Therefore, the updated HRPDC projections in this report used the same approach: a straight-line projection was used to extrapolate the 2020 and 2030 populations.

Exhibit 2-4: Shares of Locality Populations Served by Public Water

Locality	Proportion Served by Public Water 2020	2030	2040
Chesapeake	89%	89%	89%
Franklin	100%	100%	100%
Hampton	100%	100%	100%
Isle of Wight County	39%	48%	56%
James City County	79%	81%	83%
Newport News	100%	100%	100%
Norfolk	100%	100%	100%
Poquoson	100%	100%	100%
Portsmouth	100%	100%	100%
Smithfield	98%	98%	98%
Suffolk	83%	86%	98%
Virginia Beach	97%	97%	97%
York	96%	97%	98%

Source: Attachment 1 of the HRRWSP (HRPDC, 2011).

2.2.4 Utilities' Shares of Locality Populations Served by Public Water

The water use equations above require that estimates of the local population served by public water be apportioned to the different municipal water utilities. Specifically, based on information from the 2011 HRRWSP, the following localities are served entirely by one utility:

- All of Norfolk is served by the Norfolk Department of Utilities (page 1-27).
- The entire cities of Newport News, Hampton, and Poquoson are served by Newport News Waterworks (page 2-6).
- All of Suffolk is served by the Western Tidewater Water Authority (Tables 1-6 and 5-1).
- The Town of Smithfield's water system serves its entire town (page 2-26).
- All of Virginia Beach is served by the city's water system (page 2-17).
- The City of Portsmouth's water system serves the entire city (page 1-32).

The remaining localities in the region are served by more than one of the major utilities (Exhibit 2-5).

Most of Chesapeake is served by the City of Chesapeake Public Utilities (174,586 people in 2007, according to Table 1-6 of the HRRWSP). In addition, 474 Chesapeake residents are served by Portsmouth (page 2-16). Therefore, the total population served by both utilities was calculated, estimating that 99.7% of Chesapeake's population is served by the City of Chesapeake Public Utilities. Communication with HRPDC indicates that the number of Chesapeake residents served by Portsmouth is unlikely to grow. Therefore, instead of using a proportion, this population (484 people) is kept constant in the projections.

In Isle of Wight County, the population served by public water was 4,625 in 2007 (Figure 2-19 of the HRRWSP). The county's Newport Development Service District (DSD) is served by the Western Tidewater Water Authority and has a population served of 1,284 (Table 1-19 of the HRRWSP). The county's Gatling Pointe Subdivision is served by Smithfield and has a population served of 480 (Table 1-19 of the HRRWSP). Therefore, 28% of the county's residents are served by Western Tidewater, and 10% are served by Smithfield. The remainder is served by smaller utilities.

In James City County, the James City Service Authority (JCSA) serves most county residents, with the remainder served by Newport News Waterworks. HRRWSP provides the following information: the county population served by public water in 2007 was 53,836 (Figure 2-2); and the county population served by Newport News Waterworks is 8,222 (Attachment 1). Therefore, an estimated 15% (8,222 / 53,836) of James City County is served by Newport News Waterworks, and the remaining 45,614 residents (85%) are served by JCSA. However, communication with HRPDC indicates that the number of James City County residents served by Newport News Waterworks is unlikely to grow. Therefore, instead of using the 15% share, this population (8,222 people) is kept constant in the projections.

In York County, Newport News Waterworks serves most county residents, and small portions are served by JCSA and Williamsburg. According to Figure 2-2 of the HRRWSP, the population served by public water in York County was 60,803 in 2007. The number of county residents served by each utility was determined as follows:

- **JCSA:** Table 5-1 of HRRWSP states the population served by JCSA in 2007 was 45,836. Above, it was estimated that 45,614 residents of James City County are served by JCSA.[5] Therefore, the number of York County residents served by JCSA is: 45,836 – 45,614 = 222.
- **Williamsburg:** Williamsburg's water system serves approximately 13,800 people (page 1-14 of the HRRWSP), include 13,273 residents of Williamsburg in 2007 (Figure 2-2 of the HRRWSP). Thus, the number of York County residents served by Williamsburg is: 13,800 – 13,273 = 527.
- **Newport News Waterworks:** The remaining York County residents are served by Newport News: 60,803 – 222 – 527 = 60,054.

Therefore, the following percentages of York County's population served by public water were allocated to the three utilities: 98.8% for Newport News Waterworks, 0.4% for JCSA, and 0.9% for Williamsburg.

The Franklin Water System serves 9,000 people, including Franklin's total population, two neighborhoods in Southampton County, and Isle of Wight County's Camptown Development Service District (DSD) (page 1-47 of the HRRWSP). The plan also provides estimates of the population served by public water in Franklin (8,357) and the Camptown DSD's population served (900) in 2007.[6] However, the sum of these estimates is greater than 9,000, even without accounting for the two neighborhoods in Southampton County. It is likely that the estimate of 9,000 for the entire system is rounded. Thus, to calculate projected locality population served by for the Franklin Water System in future years, it was assumed that the population served by Franklin Water System in 2010 is 9,000, and project this number to future years using population growth rates for the city of Franklin.

Exhibit 2-5: Summary of Utility Shares of Locality Populations

Utility	Proportions of Localities' Populations Served by Public Water
City of Chesapeake Public Utilities	99.7% of Chesapeake
James City Service Authority	85% of James City County 0.4% of York County

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[5] Note that the list of "large" water users includes the JCSA Central System, not the entire JCSA. JCSA has several small systems that served a total of 899 residents in 2007 (see page 1-11 of the HRRWSP). However, the available data did not allow the calculation of projections that excluded these small systems. Thus, this estimate for the JCSA Central System may overestimate future water use.

[6] See Table 1-19 and Attachment 1 of the HRRWSP.

Exhibit 2-5: Summary of Utility Shares of Locality Populations

Utility	Proportions of Localities' Populations Served by Public Water
Western Tidewater Water Authority	100% of Suffolk 28% of Isle of Wight County
Newport News Public Utilities	100% of Newport News, Hampton, and Poquoson 8,222 residents of James City County 98.8% of York County
Norfolk Department of Utilities	100% of Norfolk
City of Franklin*	N/A
Town of Smithfield	100% of Smithfield 10% of Isle of Wight County
City of Portsmouth	100% of Portsmouth 484 residents of Chesapeake
City of Virginia Beach	100% of Virginia Beach

*Assuming that the total population served by Franklin Water System in 2010 is 9,000, this number was projected to future years using population growth rates for the city of Franklin.

2.3 Profiles of Large Municipal Groundwater Users

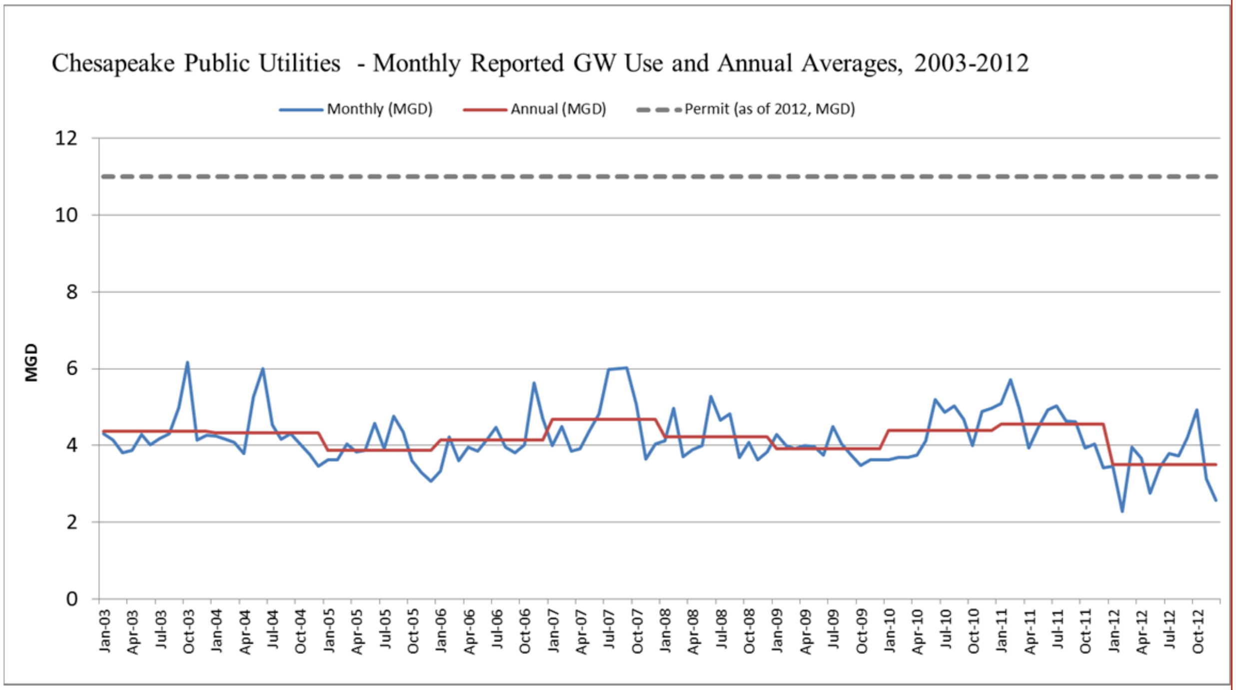
This section summarizes the current water use, including sources, treatment and other aspects among 9 large municipal systems. In addition, a range of possible future water use is presented for each system.

2.3.1 Chesapeake Public Utilities Department – Current Use

The City of Chesapeake Public Utilities includes the Northwest River, Western Branch, and South Norfolk systems. Average daily water use in these systems in 2007 was: 11.17 MGD for Northwest River, 2.92 MGD in Western Branch, and 2.62 MGD in South Norfolk (HRRWSP 2011; communication with Chesapeake Public Utilities). In 2007, total residential use was 11.31 MGD, CIL (commercial, institutional, light industrial) use was 4.59 MGD, and unaccounted for water (UAW) was 0.94 MGD.

The Northwest River system is Chesapeake's largest system and relies on several water sources: surface water from the Northwest River, groundwater (4 Northwest River wells and 3 Western Branch wells), and raw water purchased from Norfolk (contract through 2042 for 7 MGD raw). The Northwest River system currently has a groundwater permit for 11 MGD and the average annual groundwater withdrawal from 2003-2012 was 4.19 MGD (see Exhibit 2-6). Chesapeake's other systems each have a single water source: the South Norfolk system uses finished water purchased from the City of Norfolk (contract through 2042 for a minimum of 2 MGD), and the Western Branch system uses finished water purchased from the City of Portsmouth (contract until 2020 for 4 MGD; from 2020 to 2026 it is for 5 MGD).

Exhibit 2-6: Groundwater Withdrawals by Chesapeake Public Utilities Department



Chesapeake's purchased water contracts with Norfolk and Portsmouth are "take and pay contracts," which means that Chesapeake pays for a minimum amount whether or not they use the water. Since the contracts are not guaranteed, Chesapeake has lower priority in the event of a water shortage.

Chesapeake has two water treatment plants (WTPs): Northwest River WTP and Lake Gaston WTP. At the Northwest River WTP, surface water from the river is blended with groundwater from the Northwest River wells. The water from the Northwest River and wells is brackish and is treated with reverse osmosis. Reverse osmosis is more costly than traditional filtration and has large treatment losses. According to the Chesapeake Public Utilities Department, the Northwest River WTP has 30% production losses. The raw water purchased from Norfolk is treated at the Lake Gaston WTP (using a membrane technology) and blended with groundwater from the Western Branch wells. The groundwater from the Western Branch wells is naturally high in fluoride and provides a low cost fluoride source for the Lake Gaston WTP. Treatment losses at Lake Gaston WTP are about 10%. The City of Chesapeake Public Utilities Department noted that there have been fluctuations in salinity at the Western Branch wells, with no clear trend.

Chesapeake also has access to 10 MGD of water from the Lake Gaston pipeline. The City of Chesapeake Public Utilities Department plans to start using this water before the Portsmouth contract ends in 2026. The Lake Gaston WTP would need to be expanded to treat water from the pipeline. This expansion is currently scheduled to occur in 2024-25. After estimated treatment losses, this will provide Chesapeake about 8.5 MGD of finished water.

Together these sources will give Chesapeake a total water supply after production losses of about 27 MGD in 2020 and 31.5 MGD in 2030 and 2040, assuming that the Lake Gaston pipeline share (about 8.5

MGD of finished water) comes online between 2020 and 2030, and the purchase from Portsmouth ends in 2026.

Chesapeake's water systems served a total of 174,586 people, including 102,434 in the Northwest River System, 38,640 in the Western Branch System, and 33,512 in the South Norfolk system (HRRWSP 2011; communication with Chesapeake Public Utilities). A substantial share of residents also withdraws groundwater within the city from unregulated self-supplied wells (including many wells for residential lawn watering and for irrigation). In 2007, approximately 41,000 people were served by smaller CWSs or were unregulated self-supplied users (communication with Chesapeake Public Utilities).

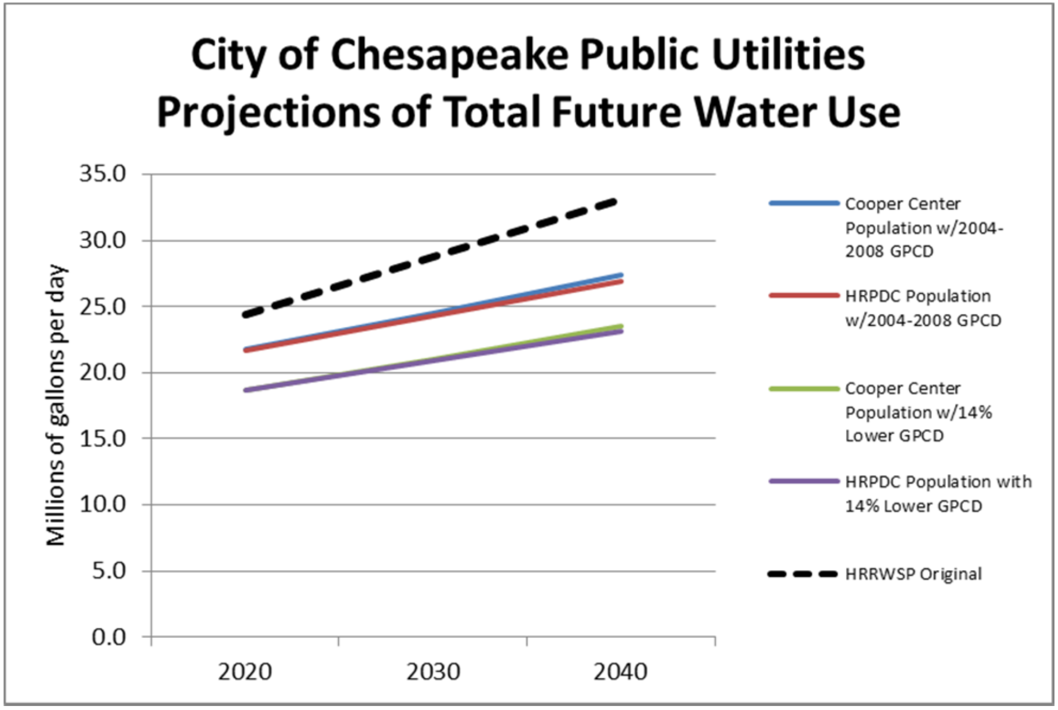
2.3.2 Chesapeake Public Utilities Department – Future Use

Data from Attachment 1 of the HRRWSP show that per capita water use in Chesapeake decreased between 2000 and 2003, then increased from 2004-2008. The average water use for 2004-2008 was 96.9 gallons per capita per day (gpcd), excluding production losses. Total distributed water is currently averaging about 17 MGD (with a peak of about 21-22 MGD). Total water use was steady since 2007 but utility managers report some evidence of recent growth. In addition, Chesapeake staff noted that a major self-supplied user may come onto the system. The utility plans to move away from finished water purchases, due to the high prices negotiated before Chesapeake had sufficient treatment capacity and the uncertainty about the availability of water during a shortage.

According to the City of Chesapeake Public Utilities Department, the city's population grew rapidly from 1980-2005 (see Appendix 1). There are new houses and higher occupancy in apartments and rentals, and growth will be concentrated in the area served by public water. Population projections indicate that this trend will continue, with an overall population growth rate from 2010-2040 of approximately 42-43%, or an average annual growth rate of 1.2% (according to the Weldon Cooper Center for Public Service and the HRPDC). The proportion of the population served by public water is projected to be 89% by 2020 and remain at that level (HRRWSP 2011).

Exhibit 2-7 shows water use projections for Chesapeake, based on per-capita water use and population projections from the Cooper Center and the HRPDC. Since the population projections from both sources are quite similar, the water use projections are also similar. If per-capita water use remains constant at 96.9 gpcd, total water use would be approximately 27 MGD by 2040. If per-capita water use decreases by 14% (from 2004-2008 levels), total water use in 2040 is projected to be between 23-24 MGD. Note that these projections are lower than those calculated in the 2011 HRRWSP, primarily because the plan predicted more rapid population growth in recent years (271,961 by 2010), but the city's actual population in the 2010 U.S. Census was 222,209. The updated HRPDC projections use the 2010 Census population estimate.

Exhibit 2-7: Water Use Projections for the Chesapeake Public Utilities Department



2.3.3 City of Franklin – Current Use

The City of Franklin's publicly-owned CWS served 9,000 people in 2007 (HRRWSP 2011), including the City's total population, two neighborhoods in Southampton County, and Isle of Wight County's Camptown Development Service District. The International Paper mill and Ashland Incorporated are located in Franklin's service area but supply their own groundwater. Residential water use in 2007 was estimated as 0.675 MGD, while CIL water use was 0.399 MGD (HRRWSP 2011).

Franklin's four wells are permitted for 2.88 MGD, which equals the City's available water supply (HRRWSP 2011). All 4 wells are over 400 feet deep and withdraw from the Potomac aquifer. Average annual groundwater withdrawal between 2002 and 2012 was 1.07 MGD (see Exhibit 2-8).

2.3.4 City of Franklin – Future Use

Per capita water use in Franklin decreased between 2000 and 2004, and then increased between 2004-2007 (HRRWSP 2011, Attachment 1). The average per capita water use for 2004-2007 was 132.6 gpcd.[7] Population projections suggest overall growth rates from 2010-2040 of approximately 24% (according to the Weldon Cooper Center for Public Service) and 26% (from the HRPDC), or average annual growth rates of 0.7% (from the Cooper Center) and 0.8% (from the HRPDC). The proportion of the Franklin city population served by public water is projected to remain constant at 100% (HRRWSP 2011).

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[7] Note that the data for the City of Franklin do not specify whether water use rates include UAW. This analysis assumes that the rate includes UAW.

Exhibit 2-9 shows water use projections for Franklin, based on per-capita water use and population projections. If per-capita water use remains constant at 132.6 gpcd, total water use would be 1.4 or 1.5 MGD by 2040 (with higher estimates based on population projections from the Cooper Center). If per-capita water use decreases by 14%, total water use in 2040 is projected to be 1.2-1.3 MGD.

Exhibit 2-8: Groundwater Withdrawals by the City of Franklin

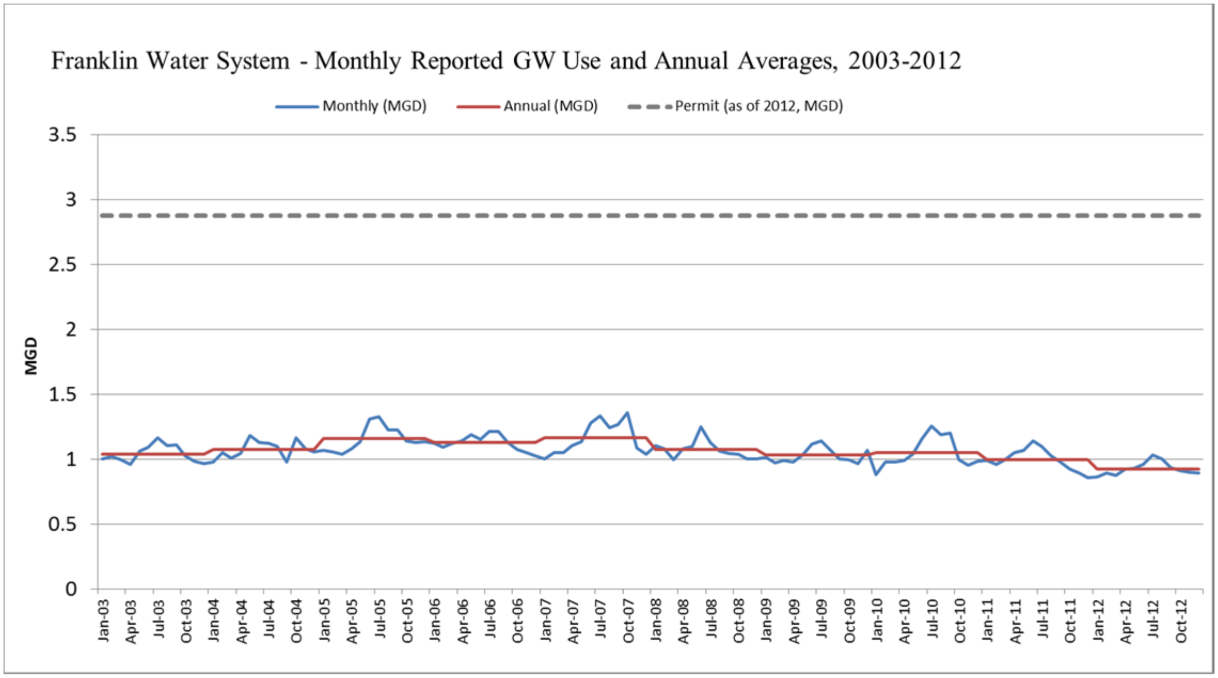
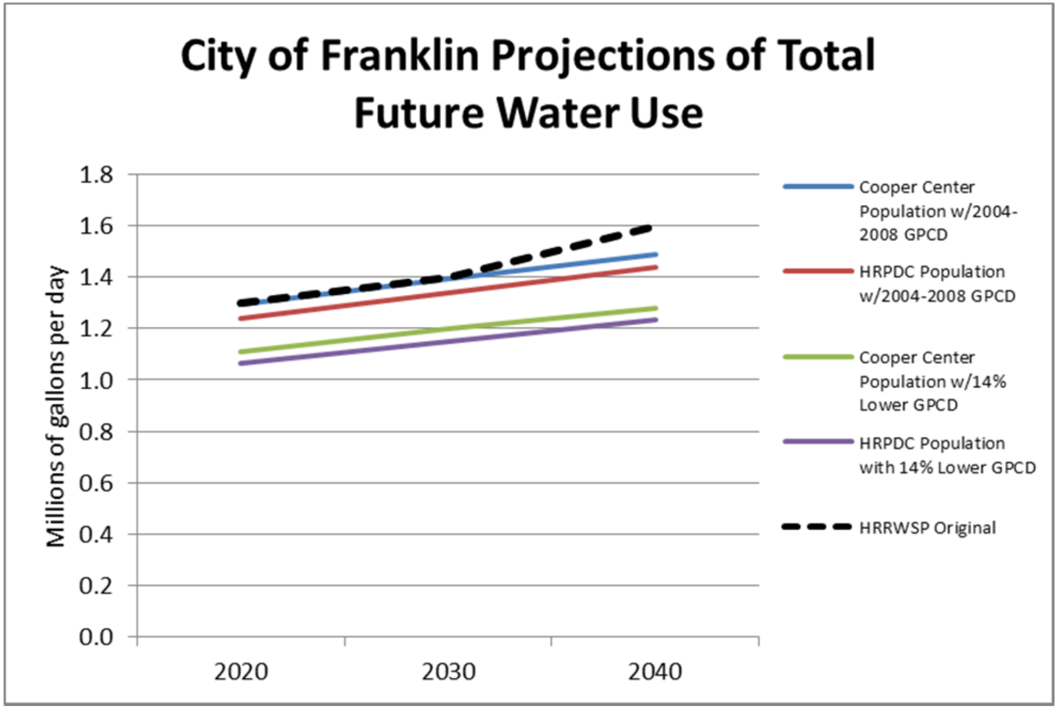


Exhibit 2-9: Water Use Projections for the City of Franklin

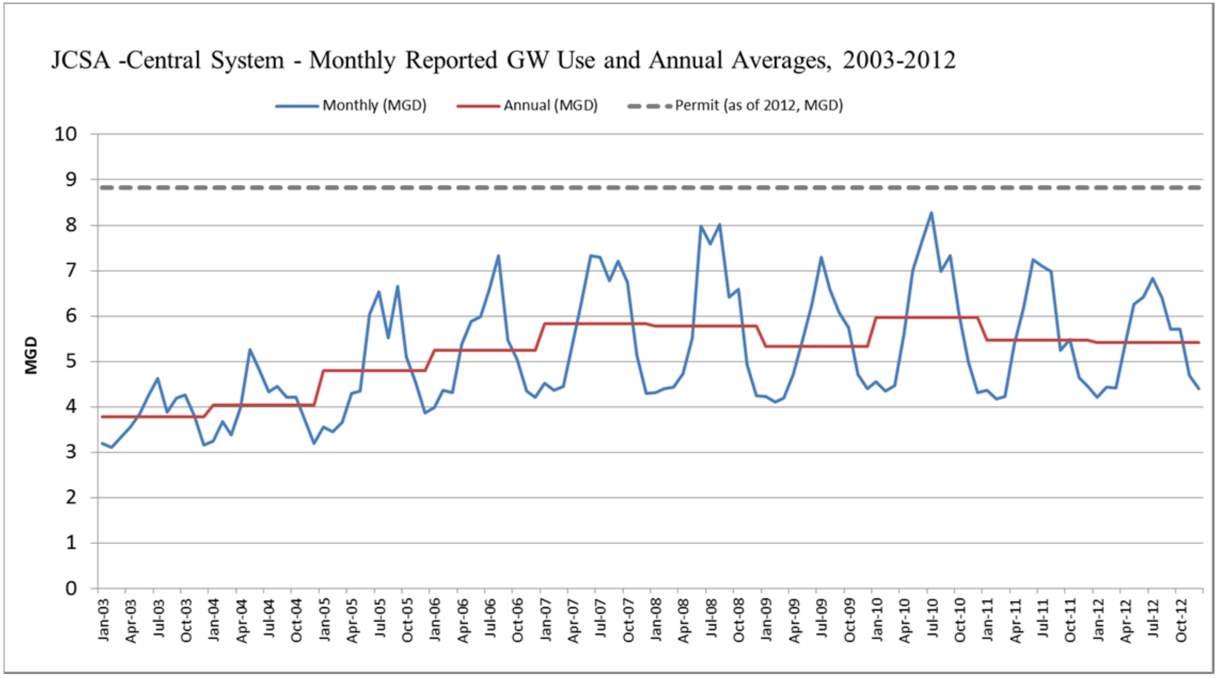


2.3.5 James City Service Authority – Current Use

The James City Service Authority (JCSA) operates 8 CWSs that provide water to approximately 51,000 people (based on JCSA customer database). While all eight systems rely on groundwater, one CWS does not require a withdrawal permit. JCSA holds DEQ groundwater withdrawal permits for each of the other seven CWSs, which are not interconnected. Another CWS is under construction and is scheduled to come online in summer 2014 (draft permit for approximately 8.7 million gallons per year and 1.8 million gallons per month). As the water provider to approximately 20,750 customer accounts in the James City County area, James City Service Authority is one of the largest public utilities in Virginia that relies solely on groundwater.

JCSA's Central System is the largest system, serving almost 50,200 people (based on JCSA customer database). JCSA's Central System has a groundwater permit for 8.83 MGD and had average annual withdrawals from 2003-2012 of 5.16 MGD (see Exhibit 2-10). Groundwater from the Central System's deep wells is from the Potomac aquifer and is brackish, and is treated by reverse osmosis and blended with higher quality groundwater at the Five Forks Water Treatment Facility. Water from JCSA's Chickahominy Piney Point aquifer wells is not blended. JCSA reported that there are no concerns about water quality. In 2013, residential use in the Central System was 3.272 MGD, while CIL use was 1.271 MGD. Overall production losses ranged from zero to 0.6881 MGD from 2004-2013 (based on JCSA production data).The system's reported groundwater use since 2003 was highest in 2010 and has declined since then (see Exhibit 2-10). JCSA accepted a 1.355 MGD reduction or 13.7% of its permitted groundwater withdrawal in the last 10 years.

Exhibit 2-10: Groundwater Withdrawals by the James City Service Authority



JCSA operates inside the Primary Service Area (PSA) of James City County, the area designated by the County's Board of Supervisors for the provision of water and sewer services. Water availability in the PSA is the main growth management and economic development tool in James City County. Local regulations require new homes to connect to the system for indoor water use if they are within a certain distance of a water main. The same requirement applies if a home's existing well fails. JCSA is seeing a trend of homeowners installing unregulated shallow irrigation wells, which has an impact on the aquifer. Health Department and JCSA inspection records suggest the number of new wells is approximately 20-25 per year. Anecdotal evidence, such as number of drill rigs observed by field staff, suggests the actual number may be higher.

2.3.6 James City Service Authority – Future Use

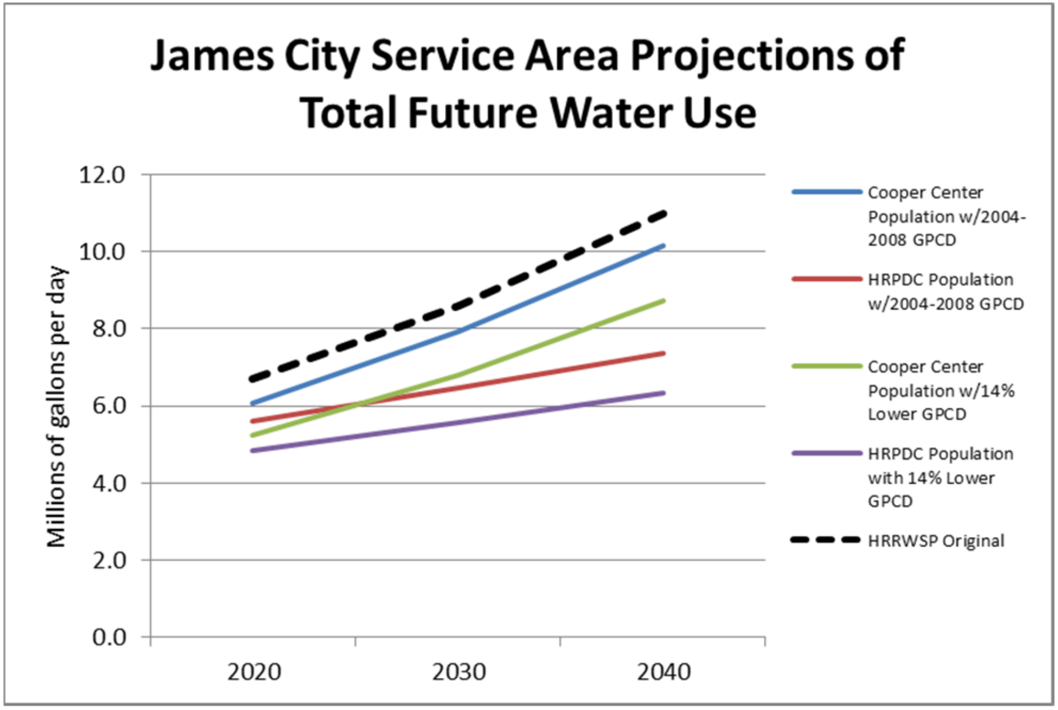
Data from Attachment 1 of the HRRWSP show that per capita water use in James City County fluctuated between 2001 and 2008. The average per capita water use for 2004-2008 was 105.7 gpcd. Population projections estimate rapid population growth, with overall growth rates from 2010-2040 of approximately 104% (according to the Weldon Cooper Center for Public Service) and 56% (from the HRPDC), or average annual growth rates of 2.4% (from the Cooper Center) and 1.5% (from the HRPDC). In addition, the proportion of the James City County population served by public water is projected to increase from 79% to 83% by 2040 (HRRWSP 2011).

JCSA has a contract with Newport News that originally made JCSA a participant in the proposed King William Reservoir. The contract stipulates that JCSA can buy finished water from Newport News (with or without the now terminated reservoir project). JCSA can currently buy up to 4 MGD, for which they paid a one-time fee of $25 million and would pay for any water used at an annually adjusted rate per 1,000 gallons (the water rate adjusts based on treatment costs). The FY 2015 rates are $1.22 per 1,000 gallons for treated water and $0.12 per 1,000 gallons for raw water. In 2019, JCSA can opt to continue their purchase from Newport News at 4 MGD, but extending the 4 MGD contract would require JCSA to pay Newport News another $25 million.[8] If JCSA does not pay the additional $25 million in 2019, JCSA still may purchase 2 MGD from Newport News.

In 2014, JCSA expects to accept a ninth CWS (already constructed by a developer) to be supplied by two new wells. Once growth exceeds the capacity of JCSA's groundwater system, JCSA expects to start purchasing water from Newport News, though the exact timing remains uncertain. JCSA does not yet have the infrastructure (e.g., treatment, pumps and storage) in place to distribute finished water from Newport News.

Based on updated population projections, JCSA's projected 2040 water use ranges from 6.7 to 10.2 MGD (see Exhibit 2-11). If per-capita water use remains constant at 105.7 gpcd, total water use could be as high as 10.2 MGD (based on Cooper Center projections) or 7.4 MGD by 2040 (based on HRPDC projections). If per-capita water use decreases by 14%, total water use in 2040 is projected to be 8.7 or 6.3 MGD. These projections are lower than those calculated in the 2011 HRRWSP, due to differences between the projected population growth predicted in the plan and the growth predicted by the Cooper Center and HRPDC for 2040.

Exhibit 2-11: Water Use Projections for the James City Service Authority



2.3.7 Newport News Waterworks – Current Use

Newport News Waterworks (NNWW) serves approximately 410,000 people (HRRWSP 2011). The NNWW service area includes the entire cities of Newport News, Hampton, and Poquoson, as well as a

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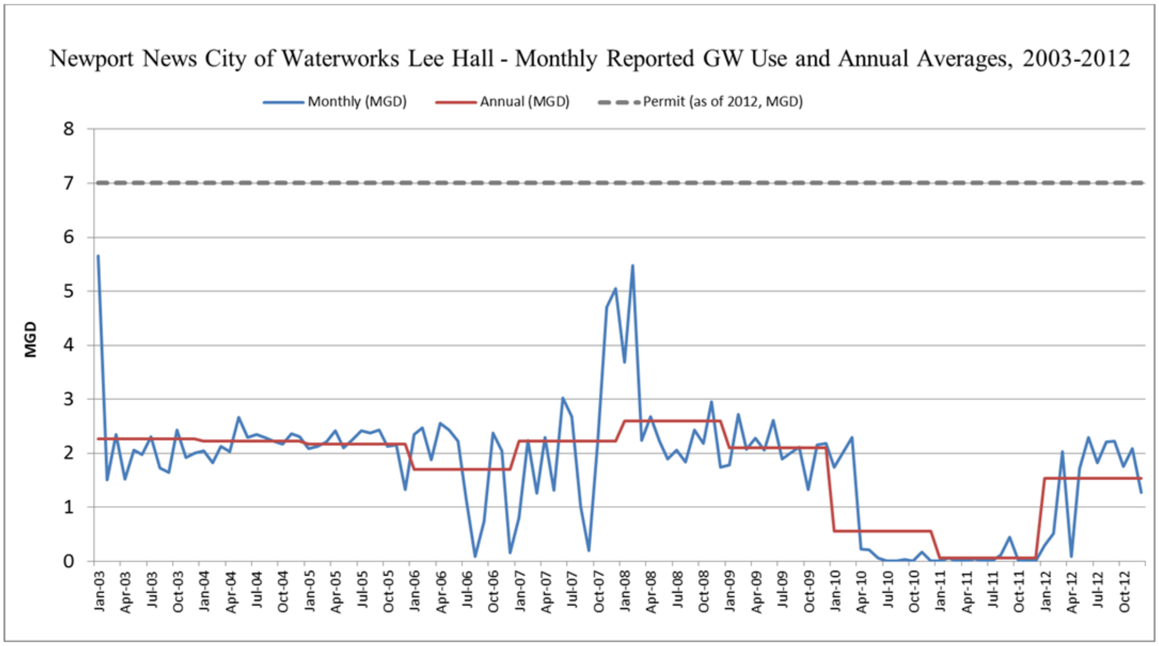
[8] This amount will be adjusted for inflation using the Engineering News Record Building Cost Index.

small portion of James City County and most of York County. The system uses groundwater and surface water from the Chickahominy River and five reservoirs. Surface water and groundwater are treated separately, and then blended together at the Lee Hall WTP before distribution (HRRWSP 2011). NNWW also operates another WTP (Harwood's Mill WTP) that treats only surface water. NNWW indicated in an interview that their cost to pump and treat brackish groundwater for blending at the Lee Hall WTP (using reverse osmosis) is generally comparable to the cost for pumping and treating fresh surface water. NNWW is not seeing any trends in the salinity of their wells. Total water use in 2007 was 48.16 MGD. Approximately half of water use (25 MGD) is residential. Other uses include CIL, heavy industrial, and military installations. Overall production losses from 2004-2008 averaged 0.07 MGD (HRRWSP 2011, Attachment 1).

The primary source of drinking water for the NNWW system is surface water, with a raw surface water supply of 54.8 MGD (HRRWSP 2011). NNWW uses groundwater as a secondary water source and withdrew an average of 1.74 MGD of groundwater from 2003-2012 (see Exhibit 2-12). During a statewide drought in the second half of 2002, average monthly withdrawals ranged from 1.7 MGD to 6.8 MGD. Newport News' existing permit authorizes the withdrawal of 7MGD annually, but a new permit is being finalized with DEQ. The new permit will likely authorize average annual withdrawals of 2.3 MGD, but will also grant NNWW the authority to withdraw 7.0 MGD during droughts or other emergencies. In addition, NNWW acquired the Lightfoot groundwater system from York County in 2009. This system is permitted separately, with a permit to withdraw 0.7 MGD annually.

Exhibit 2-12: Groundwater Withdrawals by Newport News Waterworks



2.3.8 Newport News Waterworks – Future Use

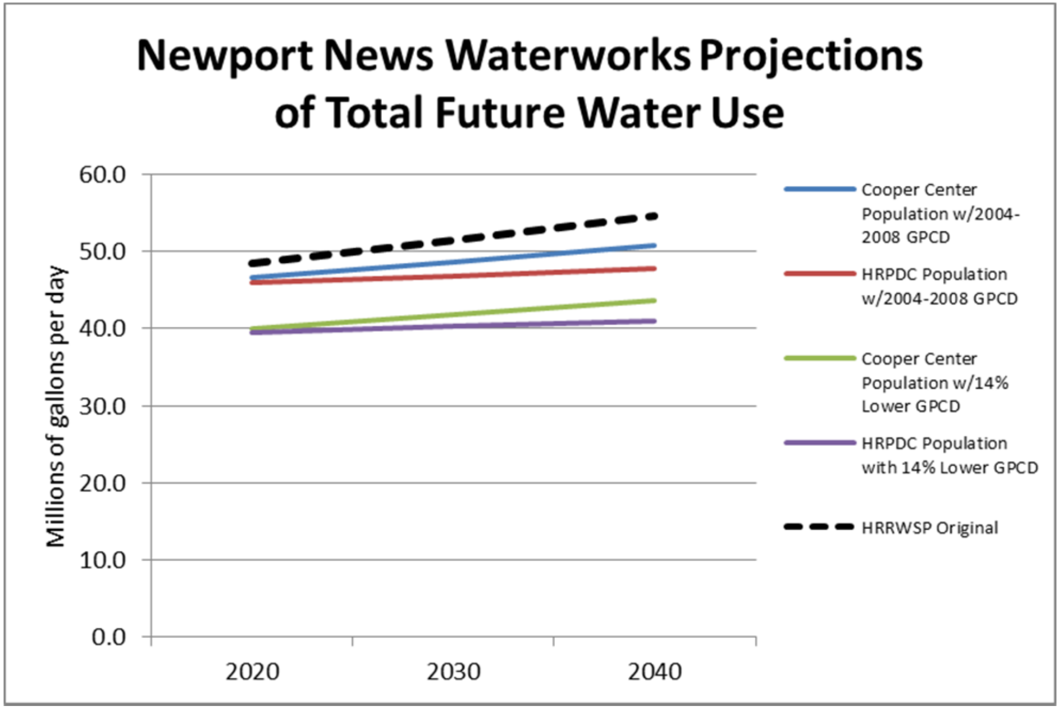
Per capita water use by NNWW during 2000-2008 peaked in 2005 and then declined (HRRWSP, Attachment 1). The average per capita water use for 2004-2008 was 112.2 gpcd. NNWW reports that the system has seen an overall drop in total water use of about 20% despite some population growth, and a

25% drop in per-capita water use. NNWW believes that this drop was due to several factors, including the shutdown of a refinery (the York refinery), military cutbacks, changes in outdoor watering/irrigation, and adoption of water efficiency measures by commercial and industrial users (e.g., Anheuser Busch reduced use from 5 to 2 MGD). NNWW expects that declines in per capita water use will slow down.

HRPDC and Weldon Cooper both project modest population growth for urban centers in the NNWW service area. The Weldon Cooper Center for Public Service projects the following overall population growth rates from 2010-2040: 7% in Newport News, 2% in Hampton, 37% in Poquoson, and 49% in York County (with annual average growth rates of 0.2%, 0.1%, 1.0%, and 1.3%, respectively). HRPDC population projections suggest overall lower population growth rates from 2010-2040: 5% in Newport News, -0.2% in Hampton, 2% in Poquoson, and 26% in York County (with annual average growth rates of 0.2%, -0.01%, 0.1%, and 0.8%, respectively). The largest populations in the service area are in Hampton and Newport News. In those two localities, the population projections from the Cooper Center and the HRPDC are similar for 2020, while the Cooper Center predicts faster growth through 2030 and 2040. The proportion of the Newport News, Hampton, and Poquoson populations served by public water are projected to remain constant at 100%, while York County's population served by public water is projected to increase slightly, from 95% in 2010 to 98% in 2040 (HRRWSP 2011).

Total projected future water use in 2040 ranges from approximately 41-51 MGD. If per-capita water use remains constant at 112.2 gpcd, total water use would be 47.7 (using HRPDC population projections) or 50.8 MGD (using Cooper Center projections) by 2040 (see Exhibit 2-13). If per-capita water use decreases by 14%, total water use in 2040 is projected to be 41.0 (using HRPDC projections) or 43.7 MGD (using Cooper Center projections). These projections are lower than those calculated in the 2011 HRRWSP, due to differences in the population growth rates. Most of the projections shown in Exhibit 2-13 also reflect a drop in water use in 2020 compared to 2007 (when total water use was 48.16 MGD). NNWW provided data showing that total sales dropped 21% from 2008 to 2013, and noted that they expected the declines in per capita water use to slow down.

Exhibit 2-13: Water Use Projections for Newport News Waterworks

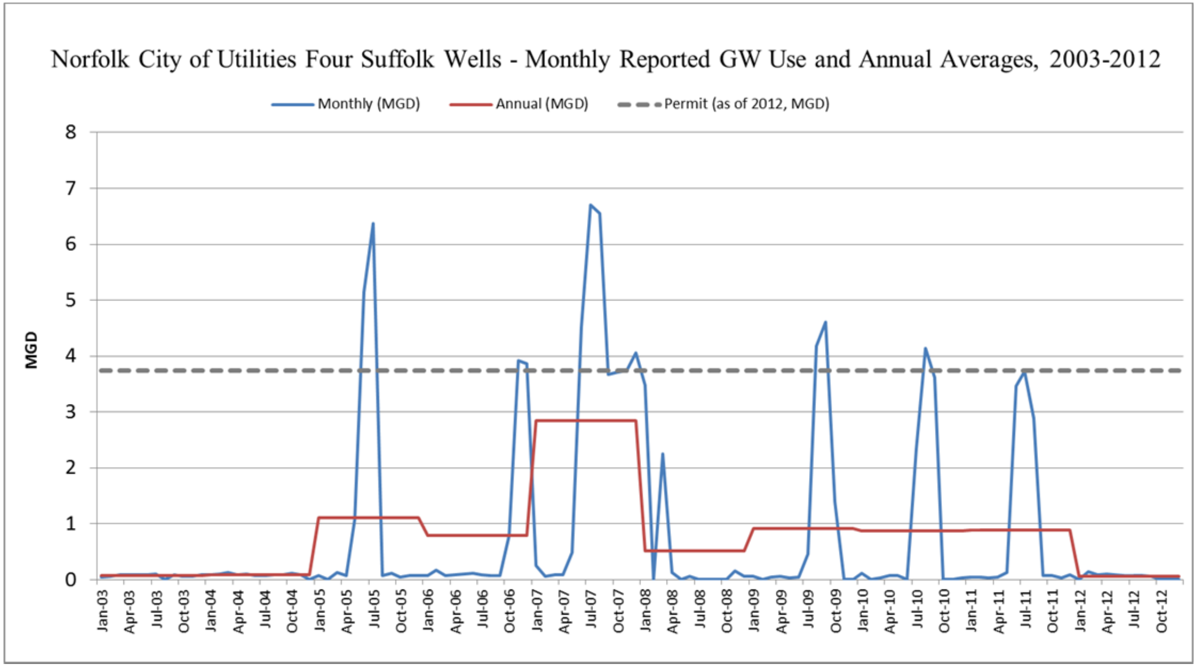


2.3.9 Norfolk Department of Utilities – Current Use

The City of Norfolk's CWS serves the entire city (HRRWSP 2011). Norfolk's total water use in 2007 was 28.73 MGD, including 11.1 MGD for residential use. Other uses include CIL (5.2 MGD), heavy industrial (2.04 MGD), and military (4.79 MGD). Water sources include surface water (from several reservoirs, lakes, and rivers) and groundwater from four deep wells that augment storage in the reservoirs. The wells are permitted under a DEQ groundwater withdrawal permit for 3.74 MGD (annual average) during normal conditions and up to 16 MGD when certain drought triggers are exceeded (but the annual average of 3.74 cannot be exceeded). Average annual groundwater withdrawal from 2003-2012 was 0.81 MGD (see Exhibit 2-14).

Norfolk operates two WTPs that treat surface water: 37th Street WTP and Moores Bridges WTP. Data from the water supply plan indicates that about 3.3% of water is lost in transmission and 0.8 MGD is lost in treatment.

Exhibit 2-14: Groundwater Withdrawals by Norfolk Department of Utilities



Note – the permit amount shown is for average annual withdrawals; the permit allows for up to 16 MGD during certain drought conditions

2.3.10 Norfolk Department of Utilities – Future Use

Norfolk's per capita water use declined between 2000 and 2008 (HRRWSP, Attachment 1) and average per capita water use for 2007 was 121.8 gpcd.[9] HRPDC and Weldon Cooper Center project population to increase approximately 4% and 7%, respectively, between 2010 and 2040 (equaling average annual growth rates of 0.1 to 0.2%). The proportion of the Norfolk's population served by public water is projected to remain constant at 100% (HRRWSP 2011).

The water use projections using the Cooper Center and HRPDC population projections are similar but substantially below the projections reported in the HRRWSP (2011). If per-capita water use remains constant at 121.8 gpcd, total water use would be approximately 31 MGD by 2040 (see Exhibit 2-15). If per-capita water use decreases by 14%, total water use in 2040 is projected to be approximately 27 MGD. These water use projections are lower than those reported in the 2011 HRRWSP, which were provided by the Norfolk Department of Public Utilities.

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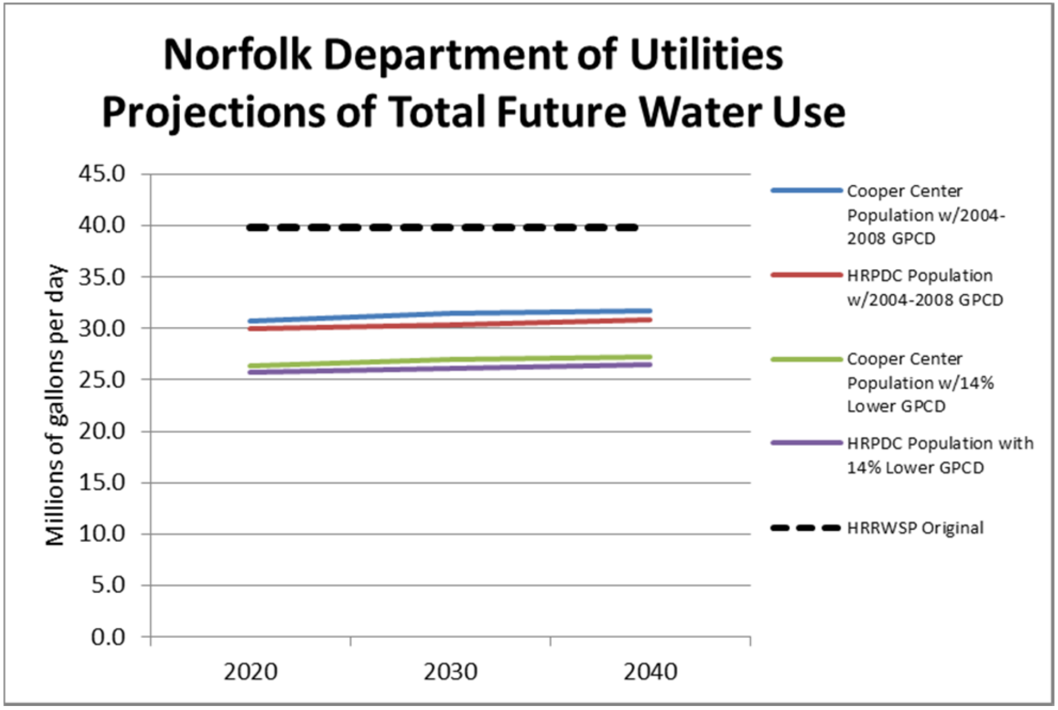
[9] The per capita water use for Norfolk reported in the 2011 HRRWSP did not include unaccounted-for water. Therefore, per capita use was calculated by dividing total use (from page 2-15 of HRRWSP 2011) by total population (from HRRWSP, Attachment 1).

Exhibit 2-15: Water Use Projections for Norfolk Department of Utilities

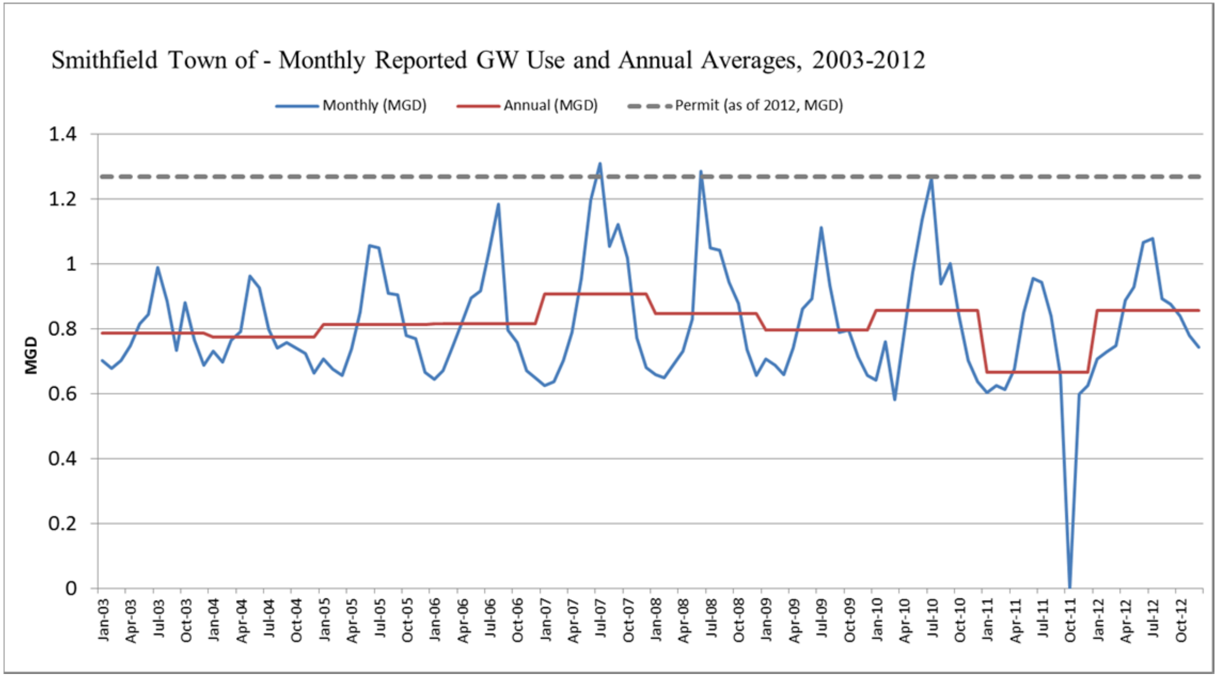


2.3.11 Town of Smithfield – Current Use

The Town of Smithfield is located in Isle of Wight County. The town's water system served approximately 7,200 people in 2007, including the population served by the Gatling Pointe CWS (HRRWSP 2011). Gatling Pointe is part of Isle of Wight County, not the town of Smithfield. 90% of the town water system's customer base is residential, with the remainder being CIL. Note that Smithfield's 2007 water use was significantly greater than the average annual water use of 0.83 MGD for 2004-2006 and 2008-2010. The 2007 water use reflects increased water use for extensive construction activity (HRRWSP 2011).

The Town of Smithfield operates seven wells and is authorized to withdraw a total annual average of 1.27 MGD. Because of requirements from the Virginia Department of Health, some fluoride is removed from the water at a reverse osmosis WTP. This plant has treatment losses of approximately 20%. Town personnel indicated that they are trying to reduce these losses through upgrades and operational changes. Due to the location of the treatment plant, the Town is gradually phasing out the regular use of six wells. In terms of water quality, Town personnel noted that there is some saltwater intrusion, but no noticeable change in trends. Two wells are currently in use. Annual average groundwater withdrawals for 2003-2012 were 0.81 MGD (see Exhibit 2-16).

Exhibit 2-16: Groundwater Withdrawals use by the Town of Smithfield



2.3.12 Town of Smithfield – Future Use

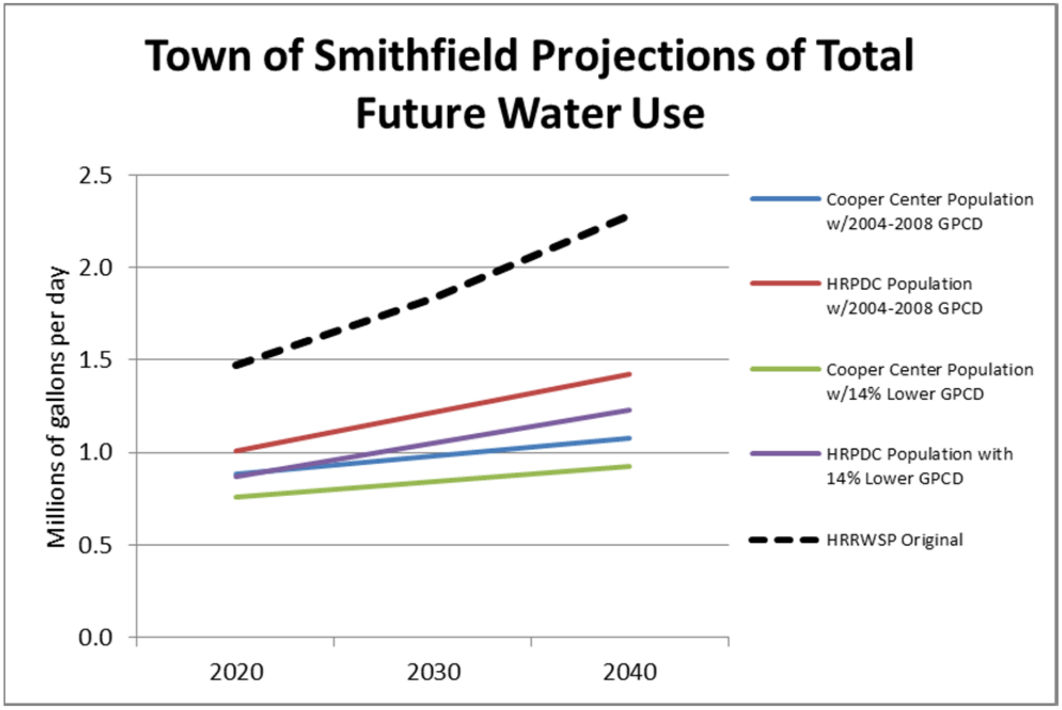
Smithfield's per capita water use was unusually high in 2007 (197 gpcd), contributing to an average per-capita rate for 2004-2008 of 141.3 gpcd (HRRWSP, Attachment 1). Calculating per captia use without 2007 data yields a rate of 127 gpcd. This is a higher estimate compared to most other utilities in the region and would result in total water use projections for 2020 that would exceed Smithfield's groundwater permit. Town personnel suggested that this is unlikely to occur given the growth they currently are experiencing. Therefore, more recent data were used to calculate per capita water use. In 2010, the Town's average groundwater withdrawals were 0.86 MGD. Given production losses of 16% (provided by Town personnel) and 2010 U.S. Census population of 8,089, per capita water use was 88.9 gpcd in 2010.

Population projections were unavailable for Smithfield specifically, and, instead, projected population growth rates for Isle of Wight County are used to project Smithfield population. For Isle of Wight County, population projections suggest growth rates from 2010-2040 of approximately 27% (according to the Weldon Cooper Center for Public Service) or 78% (from the HRPDC); these equate to average annual growth rates of 0.8% (from the Cooper Center) and 1.9% (from the HRPDC).

The 2011 HRRWSP projected a 104% growth rate for Isle of Wight County and a 98% growth rate by 2040 for Smithfield specifically. The proportion of Smithfield's population served by public water is projected to remain constant at 98% (HRRWSP 2011).Town personnel consider the 2011 HRRWSP population projections to be realistic. The town is not actively recruiting any high-volume industrial users and instead is focusing on tourism. About 24-30 new homes are added each year and a few hundred acres could be annexed in the future.

Exhibit 2-17 shows water use projections for Smithfield based on these population projections. Given the Weldon Cooper and HRPDC population estimates, constant per-capita water use of 88.9 gpcd would result in total water use of 1.1 to 1.4 MGD by 2040. If per-capita water use decreases by 14%, total water use in 2040 would be 0.9 to 1.2 MGD. These water use projections are generally lower than those reported in the 2011 HRRWSP.

Exhibit 2-17: Water Use Projections for the Town of Smithfield



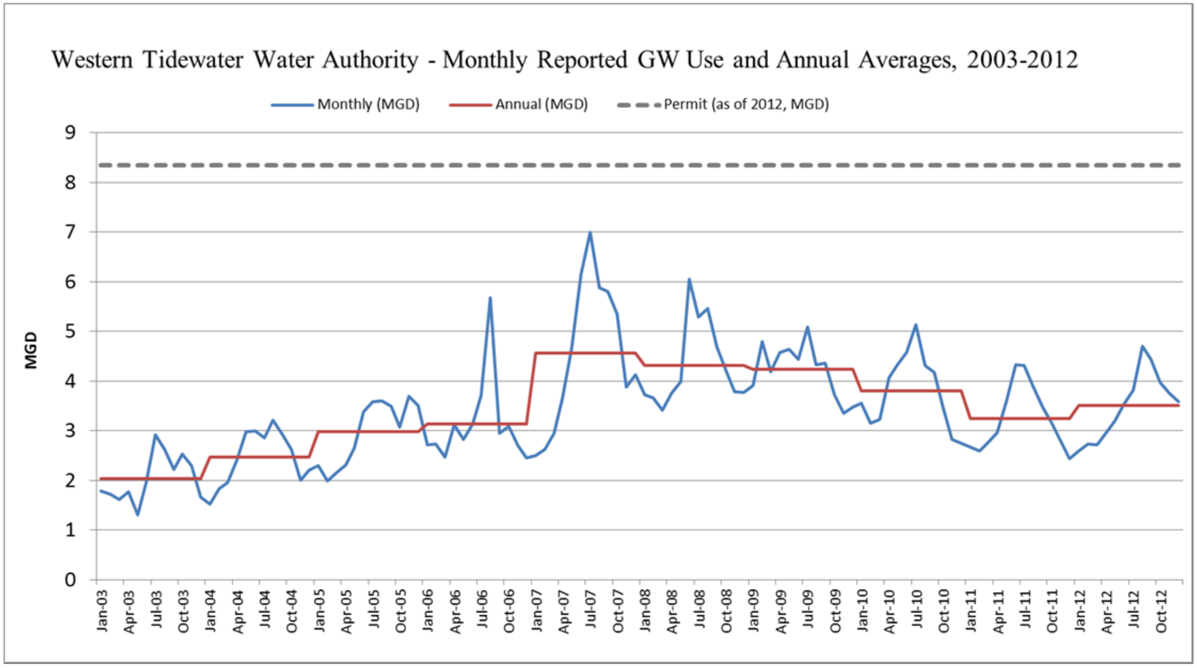
2.3.13 Western Tidewater Water Authority – Current Use

The Western Tidewater Water Authority (WTWA) serves all of Suffolk and Isle of Wight County's Newport Development Service District (DSD). In 2007, Suffolk's CWSs served 65,626 people and the Newport DSD served 1,284 people (HRRWSP 2011). Suffolk's water use was mostly residential (5.75 out of 7.37 MGD). The Newport DSD's total water use was 0.36 MGD, with 0.232 MGD for residential and 0.125 MGD for CIL. WTWA has observed a trend towards individual wells for residential irrigation, especially in more affluent parts of Suffolk.

The agreement establishing WTWA stipulates that 25% of total water supply be reserved for Isle of Wight County and 75% for Suffolk (HRRWSP 2011). Current water sources include contracts with the cities of Portsmouth (2.54 MGD of treated water under a take and pay contract), raw surface water (supply of 1.20 MGD), and groundwater. WTWA operates under a groundwater permit authorizing withdrawal of 8.34 MGD annually and covers three production wells in Suffolk and one WTWA well. This permit expires in 2015. Average annual groundwater withdrawals from 2003-2013 was 3.43 MGD (see Exhibit 2-18).

WTWA treats surface water and groundwater at the G. Robert House WTP, which has a capacity of 6.25 MGD. This treatment facility uses electrodialysis reversal (EDR) membrane technology to remove fluoride from the groundwater. Groundwater is treated and then mixed with treated surface water to reach the desired level (1.0 ppm) of fluoride.

Exhibit 2-18: Groundwater Withdrawals by the Western Tidewater Water Authority



2.3.14 Western Tidewater Water Authority – Future Use

WTWA's average per capita water use for 2004-2008 was 106.3 gpcd.[10] Population projections from the Cooper Center and HRPDC for Suffolk and Isle of Wight County vary greatly. Cooper Center projections suggest overall population growth of 27% in Isle of Wight County and 56% in Suffolk between 2010 and 2040 (average annual growth rates of 0.8% in Isle of Wight County and 1.5% in Suffolk). HRPDC projected populations to grow by 78% in Isle of Wight County and 116% in Suffolk over the next 30 years (average annual growth rates of 1.9% in Isle of Wight County and 2.6% in Suffolk). Based on an interview with WTWA, the localities expect population to increase as additional roads are constructed to connect the region to the Naval base and the Port of Virginia area. WTWA also expects a larger service area in 20-25 years as the growth in south Hampton Roads continues its progression westward. Zoning rules require new developments to be in an urban district and to connect to the central system instead of developing individual domestic wells. Developments in agricultural areas must be rezoned but are required to connect to the public water system and pay for the new distribution infrastructure. In addition, Isle of Wight County's Windsor Development Service District will be served by the WTWA and Suffolk facilities in the near future.

The proportion of Suffolk's population served by public water is projected to increase from 78% in 2010 to 98% by 2040, while Isle of Wight County's population served is projected to increase from 22% in

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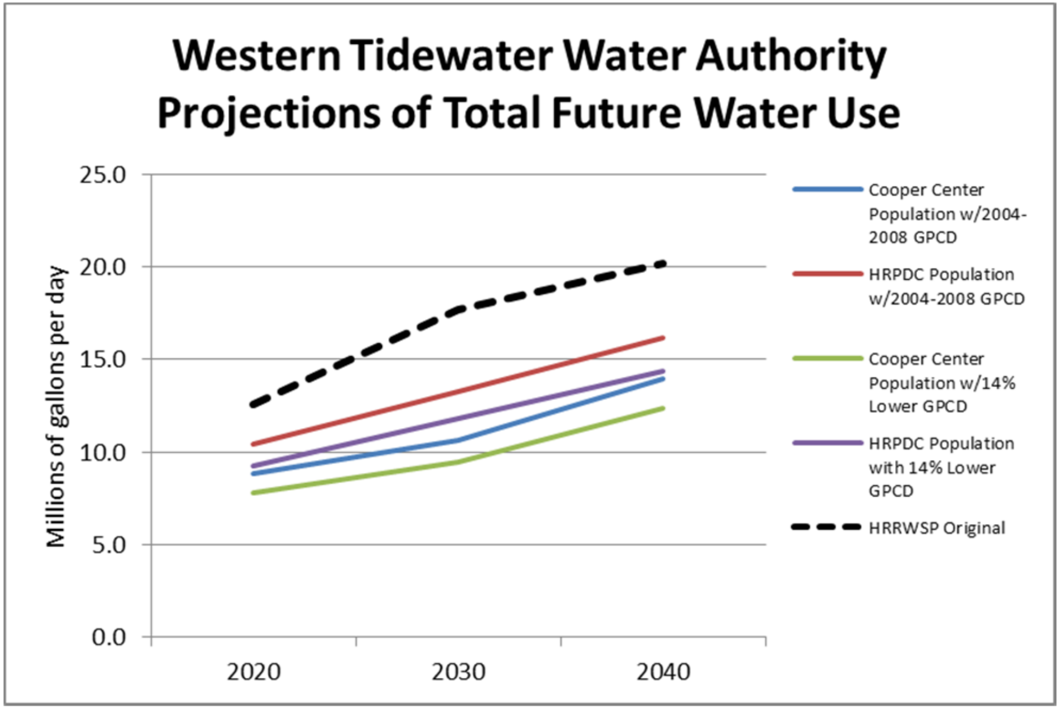
[10] Calculated as the population-weighted average of per-capita water use rates in Suffolk and Isle of Wight County's Newport DSD.

2010 to 56% by 2040 (HRRWSP 2011). Water use projections for the WTWA range from 12.1 to 20 MGD by 2040 (see Exhibit 2-19). If per-capita water use remains constant at 2004-2008 levels, total water use may range from 13.9 to 16.2 MGD by 2040 (depending on population projections). If per-capita water use decreases by 14%, total water use in 2040 is projected to range from 12.4-14.4 MGD. These water use projections are lower than those reported in the original 2011 HRRWSP, which were provided by WTWA to be 20.2 MGD.

Exhibit 2-19: Water Use Projections for the Western Tidewater Water Authority



2.3.15 City of Portsmouth – Current Use

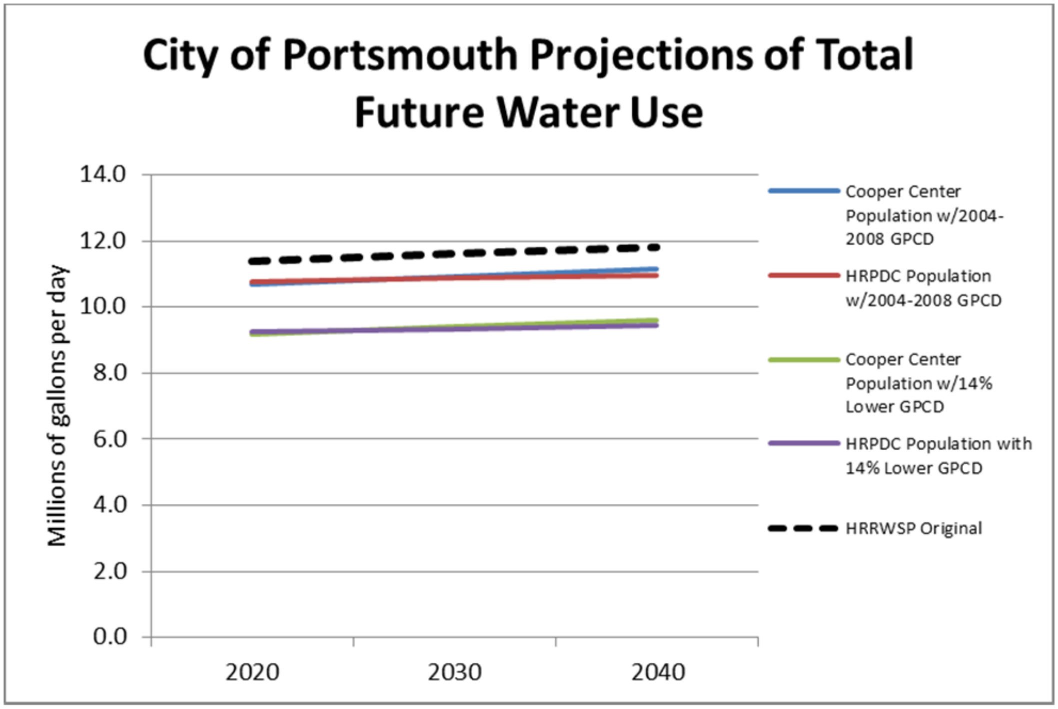
The City of Portsmouth's CWS serves the city's entire population and 484 Chesapeake residents. In 2007, the system served 97,851 people and total water use was 10.99 MGD (HRRWSP 2011). Water use included 5.20 MGD residential, 3.10 CIL, and 0.98 military. Water sources include four interconnected reservoirs located in Suffolk with a total water supply of 19.1 MGD. In addition, Portsmouth has five deep wells (two for production and three for drought relief), which are pumped to the Lake Kilby treatment plant. Lake Kilby WTP treats both surface water and groundwater. The groundwater wells provide natural fluoridation and the city maintains a mix of about 75% surface water and 25% groundwater. Current groundwater withdrawals are based on a historic use certificate but the city has submitted a DEQ groundwater withdrawal permit application, requesting 5.4 MGD for the production wells and 6.22 MGD for the drought wells.

2.3.16 City of Portsmouth – Future Use

Portsmouth's average per capita water use for 2004-2008 was 111.7 gpcd (HRRWSP 2011, Attachment 1). Population projections estimate population growth rates from 2010-2040 of approximately 5% (according to the Weldon Cooper Center for Public Service) and 3% (from the HRPDC), or an average annual growth rate of 0.1%. The proportion of the population served by public water is projected to remain constant at 100% (HRRWSP 2011).

The water use projections based on the Cooper Center and HRPDC population projections are similar (see Exhibit 2-20). If per-capita water use remains constant at 111.7 gpcd, total water demand would be approximately 11 MGD by 2040. If per-capita water use decreases by 14%, total water use in 2040 would be approximately 9-10 MGD. These projections are lower than those calculated in the 2011 HRRWSP, since the plan assumed more rapid population growth than has actually occurred in recent years.

Exhibit 2-20: Water Use Projections for the City of Portsmouth



2.3.17 City of Virginia Beach – Current Use

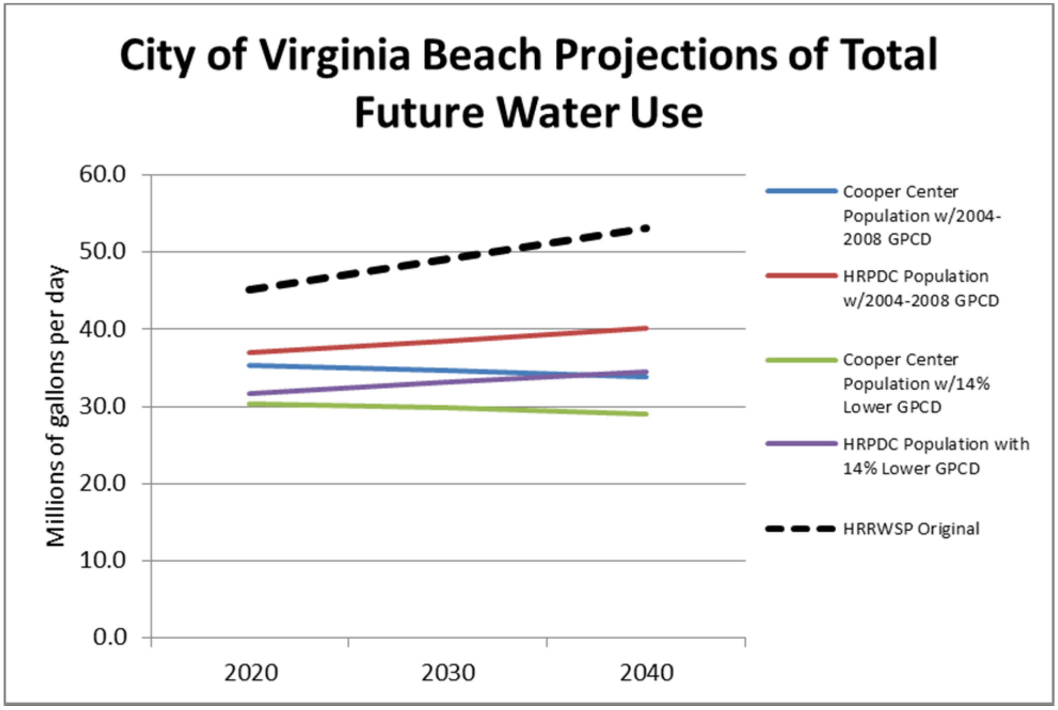
The City of Virginia Beach's total water use was 36.07 MGD in 2007, including 26.3 MGD for residential use and 5.7 MGD for CIL use (HRRWSP 2011). Virginia Beach does not have its own water treatment facilities and all water is treated under contract by the City of Norfolk. Virginia Beach has a permit from the U.S. Army Corps of Engineers to withdraw 60 MGD from Lake Gaston. The Lake Gaston pipeline transports water from Lake Gaston to Norfolk's Lake Prince in Isle of Wight County. Chesapeake is a partner with Virginia Beach on the Gaston water and will receive 10 of the 60 MGD in the future. Virginia Beach also owns Stumpy Lake, which provides an emergency source of water. Supporting data from the HRRWSP indicate transmission and treatment losses of 5 MGD (or 10%) for Virginia Beach's Lake Gaston water. The City of Virginia Beach is not a major groundwater user, but as an owner of substantial water supply, there is the possibility that they could sell water to other cities to help make up for any reductions in permitted groundwater use.

2.3.18 City of Virginia Beach – Future Use

The average per capita water use in Virginia Beach in 2007 was 83.1 gpcd.[11] Population growth rates for 2010-2040 for the city vary. The Weldon Cooper Center for Public Service predicts a 4% decline (with an annual average growth rate of -0.1%) in population by 2040, while the HRPDC estimates a positive growth rate of 14% (with an annual average growth rate of 0.4%). The proportion of the population served by public water is projected to remain constant at 97% (HRRWSP 2011).

Virginia Beach water use projections are driven largely by the differences in the future population estimates and assumed future per capita use rates (see Exhibit 2-21). If per capita use stays constant at 83.1 gpcd, water use in 2040 might range from 33.8 MGD (based on the Cooper Center population projection) to 40.1 MGD (using the latest HRPDC population projection). If per capita use drops by 14%, then future use might be between 29.1 MGD (Cooper Center population) and 34.5 MGD (HRPDC population) in 2040. The water use projections reported here are substantially lower than the projection from the 2011 HRRWSP (provided by the City of Virginia Beach).

Exhibit 2-21: Water Use Projections for the City of Virginia Beach



2.4 Profiles of Large Industrial Groundwater Users

The two largest users of groundwater in the EVGWMA are the RockTenn West Point Paper Mill and the Franklin Paper Mill. Together these mills represent between 40% and 60% of total permitted groundwater withdrawals between 2003 and 2012. Other substantial groundwater users in the industrial

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[11] Per capita use was calculated by dividing total use (from Figure 2-14 of HRRWSP 2011) by total population (2007 estimate from the Cooper Center).

sector include Ashland, Inc. (a chemical manufacturing plant near Courtland, Virginia), Portsmouth Genco (a power plant near Smithfield, Virginia), Smithfield Foods (a meat processing facility near Smithfield), and Colonial Williamsburg (a nonprofit that manages the historical Colonial Williamsburg).

2.4.1 Water Use in Pulp and Paper Mills

Pulp and paper operations are water intensive, but the industry has emphasized improvements in its environmental impacts, including water efficiency. To assess water use at the two mills in the EVGWMA, it will be useful to describe industry trends and standards. Publicly available and peer-reviewed information on water use in the pulp and paper industry is limited. A report from the Lawrence Berkeley National Laboratory (Kramer et al, 2009) describes the challenge of finding adequate data to profile water use in the pulp and paper industry (see pages 113-114). Based on the available literature, the industry has reduced its water use intensity, typically defined as water use per ton of finished product. Bryant et al. (1995) report that mean per unit water use across the industry dropped from 26,700 gallons per ton of production in 1975 to 16,000 gallons per ton in 1995. More recent data are limited, but information provided by RockTenn indicates the median use across the industry may now be as low as about 9,300 gallons per ton of finished paper product.

Water use intensity varies considerably across paper products and processes (Bryant et al, 1995). Bleaching is one of the most water intensive processes in paper manufacturing (Bryant et al, 1995) and both mills discussed here manufacture bleached products. The report by Bryant et al. showed that water use in bleach kraft operations was about 23,500 gallons per ton of production in the mid-1990s. It may be substantially lower today.

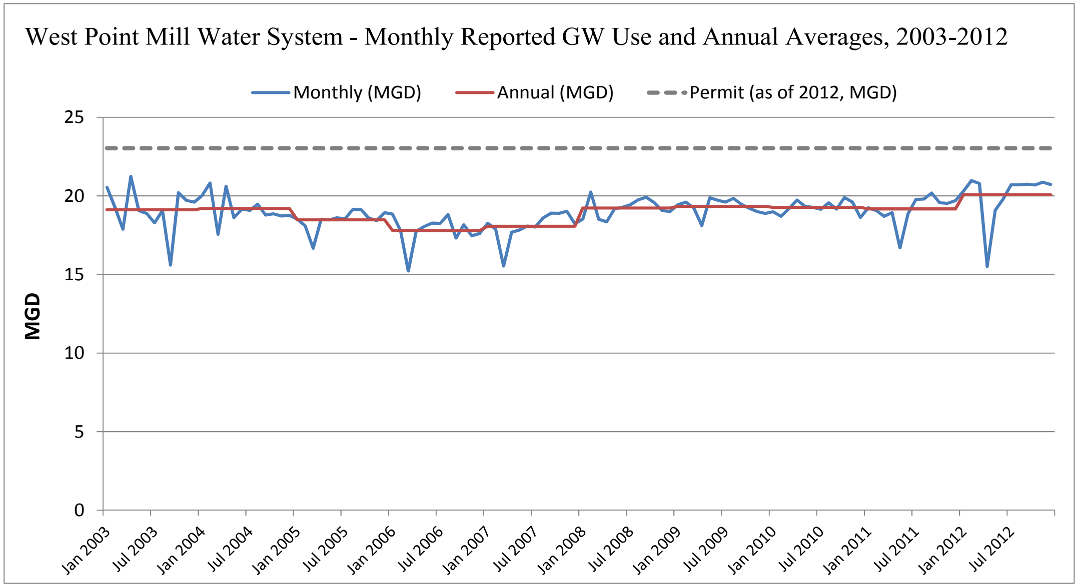
2.4.2 RockTenn West Point Mill – Overview and Current Water Use

The paper mill in West Point, Virginia is owned by RockTenn, CP, LLC. The mill runs 3 paper machines: one for bleached white top Kraft linerboard, one for brown linerboard and bleached white top Kraft linerboard, and the third for corrugated medium (made from 100% recycled cardboard). RockTenn is the largest employer in King William County, with over 500 employees (County of King William, 2014). RockTenn is also the largest principal taxpayer, accounting for about 2 percent of total assessed valuation and having a taxable assessed value, excluding land use values, four times higher than the next leading principal taxpayer (County of King William, 2013). RockTenn sources many of the inputs for the West Point Mill from Virginia, including trees for pulp and recycled cardboard. RockTenn provided the following statistics for the West Point Mill:

- Employees: 506
- Payroll: $39.8 Million
- Payroll Taxes: $3.5 Million
- Property Taxes: $3.9 Million
- Other Taxes: $0.36 Million

Groundwater withdrawals by the West Point Mill have been steady over the last decade (see Exhibit 2-22), averaging 20.07 MGD. RockTenn’s groundwater permit authorizes average annual withdrawals up to 23.03 MGD. Like most paper mills, the West Point Mill uses water in a variety of industrial processes throughout the pulping and paper-making process, including for pulping, pulp washing, bleaching, power and steam generation, paper-making, air pollution devices, such as scrubbers and more. The majority of the mill’s products are food grade (primarily for food packaging) and a substantial share of production is bleached Kraft. The mill reports that its overall water use intensity of about 8,000 gal/ton of production, over 1,000 gal/ton below the National Council for Air and Stream Improvements(NCASI) median for all mills. The West Point Mill has held its water use intensity relatively constant despite increasing production of bleached Kraft, which is among the most water intensive paper products to manufacture. According to information shared by the company, the West Point Mill has invested millions of dollars over the last two decades to improve water conservation, primarily through internal recycling technologies and processes. The mill recycles water up to 15 times during the manufacturing process, but new water is used for steam power generation, bleaching, and paper making because of the need for high quality water in these processes. The mill treats wastewater onsite and has a National Pollutant Discharge Elimination System (NPDES) permit for discharge of treated wastewater.

Exhibit 2-22: Groundwater use at the West Point Paper Mill



2.4.3 West Point Mill – Future Water Use

The West Point mill reports that there are no plans to request a higher permit amount for its groundwater withdrawal. The mill does plan to increase production of bleached Kraft, which will require more water, but plans for further investments in water conservation will enable them to hold water use constant. The RockTenn plant managers are considering a number of water conservation and alternative water source options, including:

- Using about 0.5 to 1 MGD of treated municipal wastewater from the town of West Point or from the mill's wastewater treatment plant in an air pollution control scrubber;
- Installing river bank pumps along the Pamunkey River; and
- Providing treated wastewater from the mill to other local business for non-potable uses, such as to West Point Veneer, LLC (offsetting about 0.04 MGD of groundwater use).

West Point Mill representatives discussed past challenges in pursuing surface water from the Pamunkey River, which was met with strong local opposition over fears that a large withdrawal from the river would impact the local sport fishery. Mill representatives assume that any future attempts to secure surface water, including the river bank pumps mentioned above, would meet similar public opposition.

2.4.4 Franklin Paper Mill – Overview and Current Water Use

International Paper owns the paper mill in Franklin, Virginia. The mill shut down temporarily from 2009 to 2012, resulting in the lay-off of over 1,000 people. The mill reopened in 2012 and now employs about 240 people. In addition, International Paper leases part of the facility to ST Tissue, which employs another 65 people. Approximately another 50 people are employed at the mill as contract technical and support staff. International Paper is the largest taxpayer in the county. According to the county, International Paper accounted for 6.4 percent of total revenue for the county in 2009. Before the mill closed in 2009, International Paper accounted for nearly 3 percent of the county's total assessed valuation for real estate and 56 percent of the county's total assessed valuation of personal property. International Paper's assessed valuation for real estate and personal property was more than twice as high and eight times as high, respectively, than the next leading principal property taxpayer in 2009. The county anticipated $985,000 in revenue loss in fiscal year 2011 and an additional $6.2 million in losses in fiscal year 2012 due to the mill's closure (County of Isle of Wight, 2009). Even though total employment at the plant is less than half of the level before the closing, International Paper remains the leading principal property taxpayer in the county in 2013 (County of Isle of Wight, 2013).

International Paper remodeled the plant to produce fluff pulp for use in various personal care and medical products (e.g., diapers). ST Tissue repurposed the machines to produce tissues and paper towels and plans to add three more machines over the next decade.

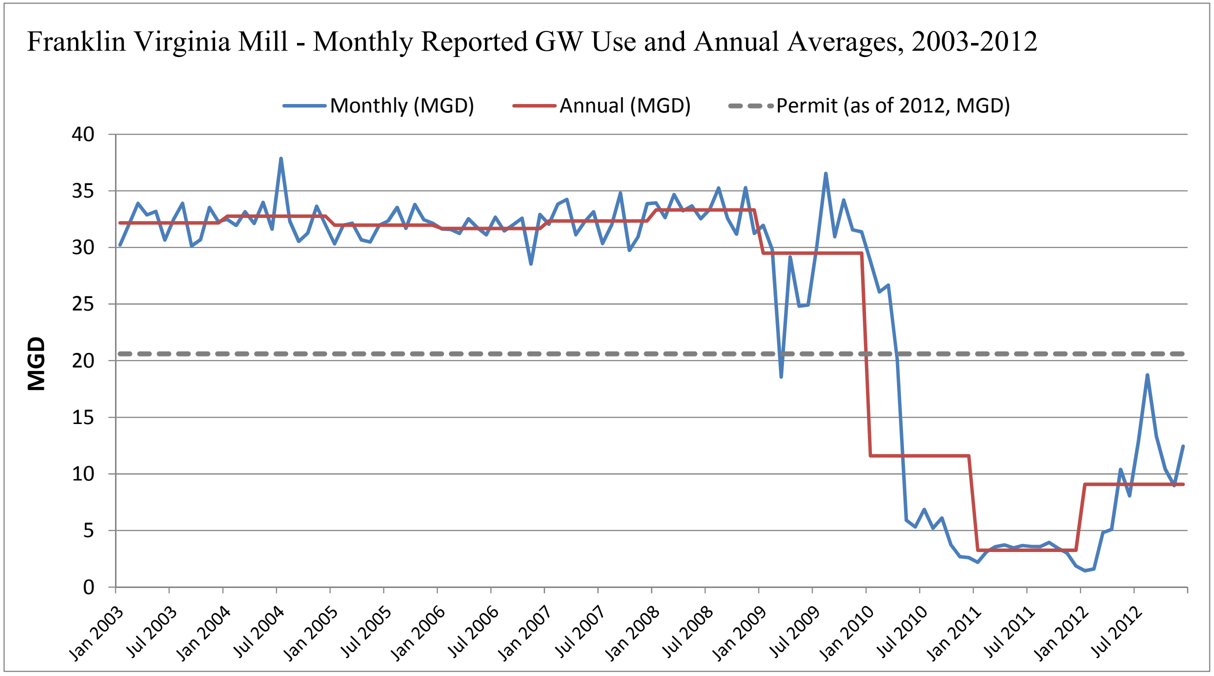
As a result of production changes, groundwater withdrawals at the Franklin Paper Mill have varied substantially over the last decade (Exhibit 2-23). Before the 2009 closure the mill was consistently withdrawing over 32 MGD to produce different grades of paper products. One pump was kept running during the closure of the mill and withdrawals reached a low of 3.3 MGD in 2011 Due to International Paper resuming production and ST Tissue's new production (which began in 2013) groundwater withdrawals have rebounded. Groundwater withdrawal data from DEQ show that the mill withdrew an average of 9 MGD in 2012. Current reported use averages about 13 MGD. In addition, the mill withdraws about 2.4 MGD from the Blackwater River for non-contact uses, such as seal water for pumps. International Paper reported that their water use intensity (gal/ton of production) is within industry standards (relevant data were not provided).

2.4.5 Franklin Paper Mill – Future Water Use

International Paper does not expect to increase production substantially over the next 10-20 years. Any increases will be driven by optimizing existing processes. ST Tissue, however, does plan to expand operations. ST Tissue currently runs one paper machine, and plans to add three additional machines over the next decade. As such, International Paper (which holds the groundwater permit) plans to use about 20-21 MGD and is requesting that amount for its groundwater permit renewal.

For the analyses in this report, future water use for the Franklin Mill is assumed to be 21 MGD through the year 2040

Exhibit 2-23: Groundwater use at the Franklin Paper Mill



2.4.6 Ashland, Inc. – Overview and Current Water Use

The former Hercules Inc. plant in Courtland, Virginia is now home to three companies: Ashland Inc., Eastman Chemical Resins, and Arkema Inc. Hercules Inc. sold two of the businesses located at the plant in 2001; the tall oil distillation unit and the Pamolyn unit (for rosin manufacturing) went to Eastman, which discontinued tall oil operations in May 2008, while the organic peroxides unit was sold to Arkema. The remaining business unit, the Aqualpel manufacturing unit, then became part of Ashland Inc.'s operations when it acquired Hercules Inc. in 2008 (Ashland, 2008). A total of 72 people are employed at the facility, 68 for Ashland, Inc., and 2 each with Arkema and Eastman.

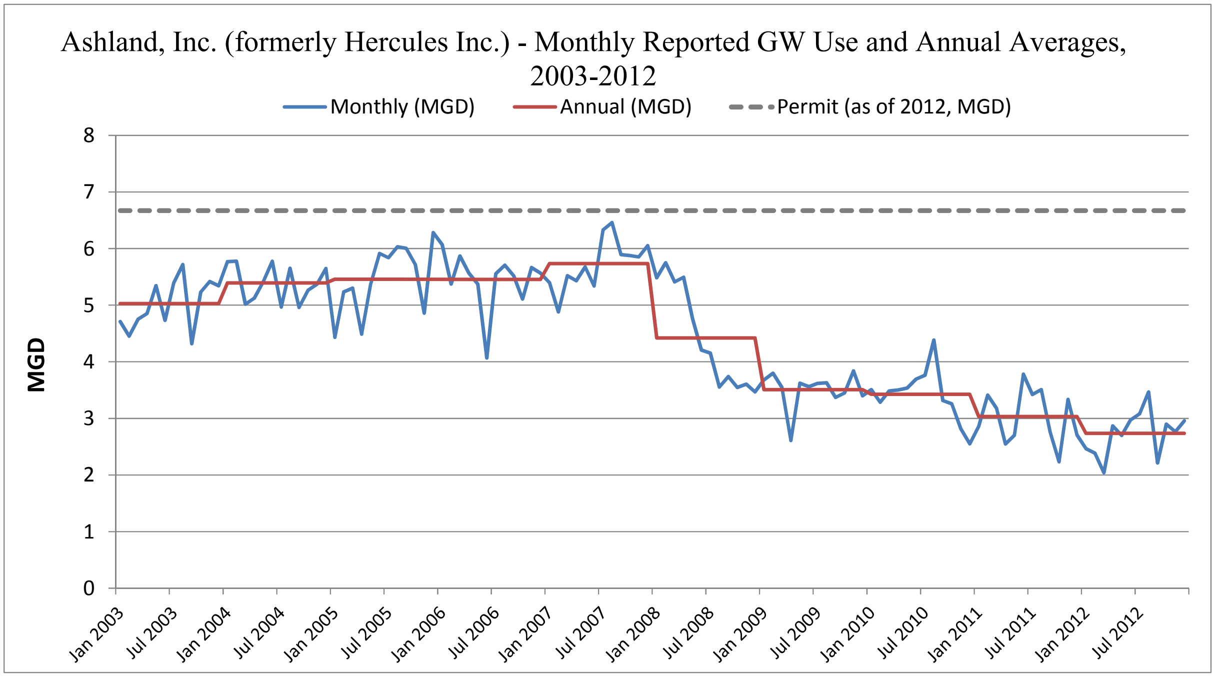
Groundwater withdrawals for this plant varied between 5 and 6 MGD before 2008, when the tall oil operations were discontinued. Since then withdrawals have averaged about 3.2 MGD (see Exhibit 2-24). The largest share of groundwater at the plant is used for cooling exothermic chemical reactions that are a necessary part of the manufacturing processes. Recycling of water is employed to an extent (no data were provided). Ashland also uses water for two gas fired boilers and operates a reverse osmosis treatment process to remove silica and other impurities in the boiler feed water. In addition, Ashland provides about 0.86 MGD to the neighboring thermal power plant owned by Dominion Power.

2.4.7 Ashland, Inc. – Future Water Use

Ashland is currently in the process of renewing its groundwater permit and has requested that their permit amount remain at 6.67 MGD. Ashland is investigating a potential investment in a new manufacturing process at the site in the next several years, which would likely increase water use for cooling or other uses. Since it is unknown what this new process might be, it is difficult to project how much water it will require. Further recycling in the future may be a challenge for the plant because much of the water is used for cooling of chemical reactions. After initial use, the water is much warmer than when it is pumped from the ground. Recycling would require the installation of cooling towers or chillers. A 2009 feasibility study done for Ashland estimates the necessary cooling towers would require capital investment of about $7 million and annual operations and maintenance costs of about $700,000 (both in 2013 dollars). These estimates are within the range of estimates produced for other purposes.

For the analyses in this report, future water use for the Ashland plant is assumed to be 6.67 MGD through the year 2040 (the amount in their current permit).

Exhibit 2-24: Groundwater use at the Ashland, Inc. Chemical Facility

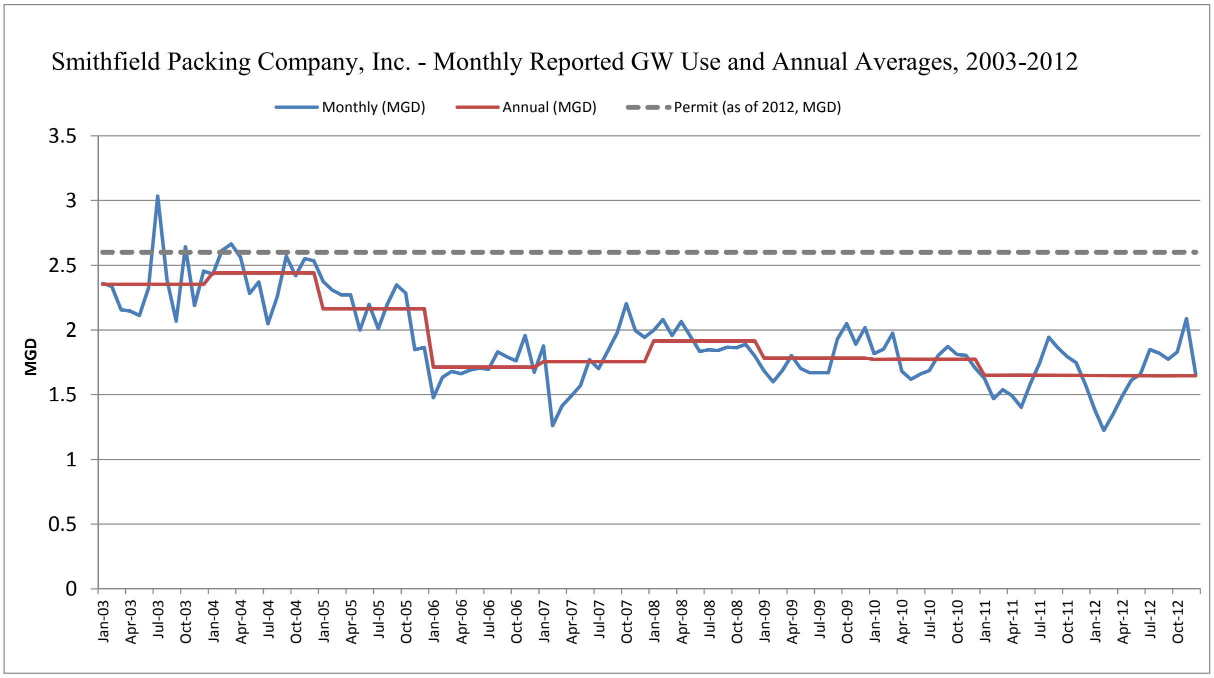


2.4.8 Smithfield Packing Company, Inc. – Overview and Current Water Use

Smithfield Packing Company has a pork processing plant in Smithfield, Virginia. Operations at the plant include slaughter, meat processing, and rendering. The plant employs 2,000 to 3,000 people across three shifts and the company paid over $5 million in taxes to Virginia in 2013 (Smithfield has more than one facility in Virginia).

Smithfield's permit allows groundwater withdrawals of up to 2.6 MGD (average annual) and annual withdrawals have averaged 1.7 MGD (for 2006-2012). The permit was renewed in 2013. The company's groundwater withdrawals were higher in the past, but withdrawals decreased after the company shut down some operations due to changing market conditions around 2005 (see Exhibit 2-25). Representatives of the company reported that about 60% to 70% of the overall water use is for sanitation and cleaning of the plant's equipment. Sanitation requires high quality food grade water and groundwater is the plant's primary water source. A small amount of water is used for finished products, such as brines and marinades. The plant uses a limited amount of water recycling of non-contact cooling water for cleaning shipping trailers. Smithfield representatives report that there have been no changes in their groundwater quality. Wastewater is pretreated onsite and then goes to HRSD for full treatment.

Exhibit 2-25: Groundwater use at the Smithfield Packing plant in Smithfield, Virginia



2.4.9 Smithfield Packing Company, Inc. – Future Water Use

Smithfield reports that there is physical space onsite for future growth, but there are no current plans to expand at this time. For the analyses in this report, the baseline water use for the Smithfield packing plant is assumed to be 2.6 MGD through the year 2040 (the amount in their current permit).

2.4.10 Portsmouth Genco – Overview and Current Water Use

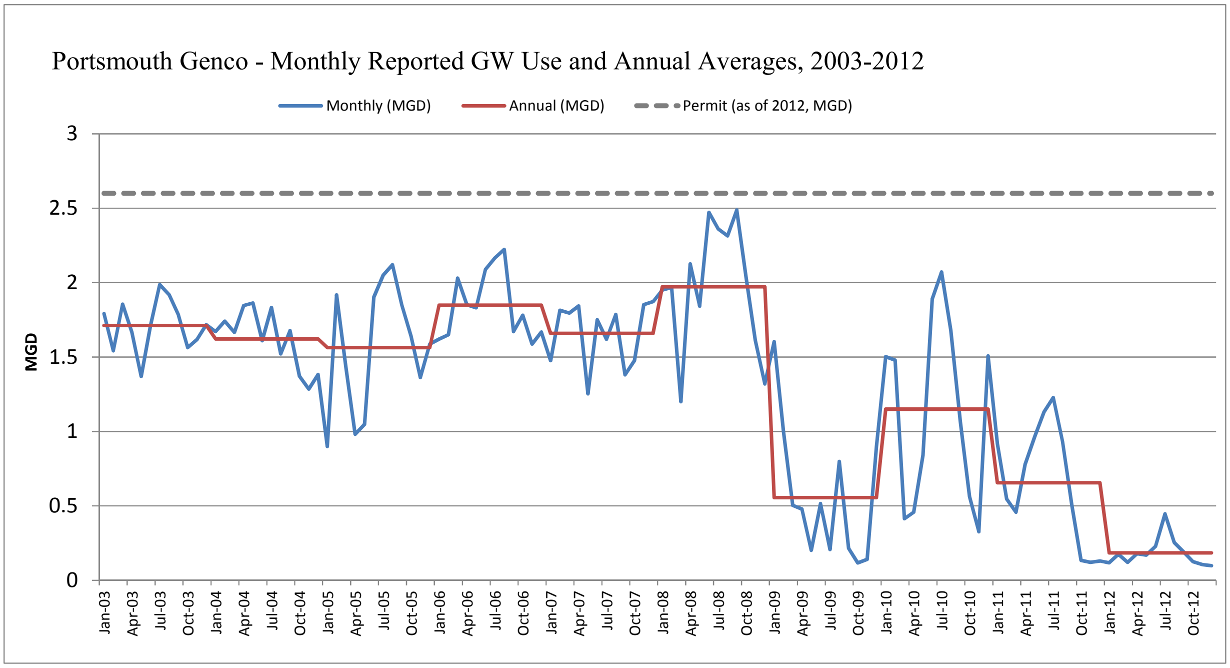
Portsmouth Genco operates a coal-fired steam power plant in Portsmouth, Virginia. The plant came online in 1988. The capacity of the plant is 115 MW and operates under a contract with an individual customer. The plant uses water for steam, cooling towers and other purposes. Groundwater is their primary source, but the plant can use municipal water from the City of Portsmouth. The plant prefers to use groundwater because the cost of maintaining wells is much less costly than buying water from Portsmouth. In past years, the company ran the plant for baseload power. Since baseload power delivers relatively steady output, groundwater withdrawals were historically steady. Due to changing market conditions, the plant has been operated more as a load-following plant and consequently groundwater withdrawals have fluctuated. The average withdrawal from 2003 to 2012 was 1.3 MGD, but monthly averages vary from 0.2 MGD to 1.9 MGD (see Exhibit 2-26). The Portsmouth Genco groundwater withdrawal permit is for 2.6 MGD.

Portsmouth Genco operates two reverse osmosis (RO) processes onsite. One RO process is used to provide high quality water for boilers. The other RO process removes dissolved solids from water entering the cooling towers. Treating water before use in cooling towers allows Portsmouth Genco to reuse water without risking damage to the equipment, which saves some water. There are no big fluctuations in water quality.

2.4.11 Portsmouth Genco – Future Water Use

Future water use at the Portsmouth Genco power plant will be driven primarily by the dynamics of the energy sector. The economic viability of coal-fired power plants depends on the relative price of energy sources. Any number of factors could put further downward pressure on the use of coal-based electricity, including the potential for continued low natural gas prices, potential greenhouse gas regulations, and competition from other energy sources, such as renewables, either because of government subsidy or technology advances that lower prices. In its renewal application for a groundwater permit, Portsmouth Genco has sought different limits for monthly average, annual average and ten-year total withdrawals. For the analyses in this report, future water use for the Portsmouth Genco power plant is assumed to be 1.23 MGD through the year 2040, which is the total amount requested for the 10-year permit converted to a daily average withdrawal.

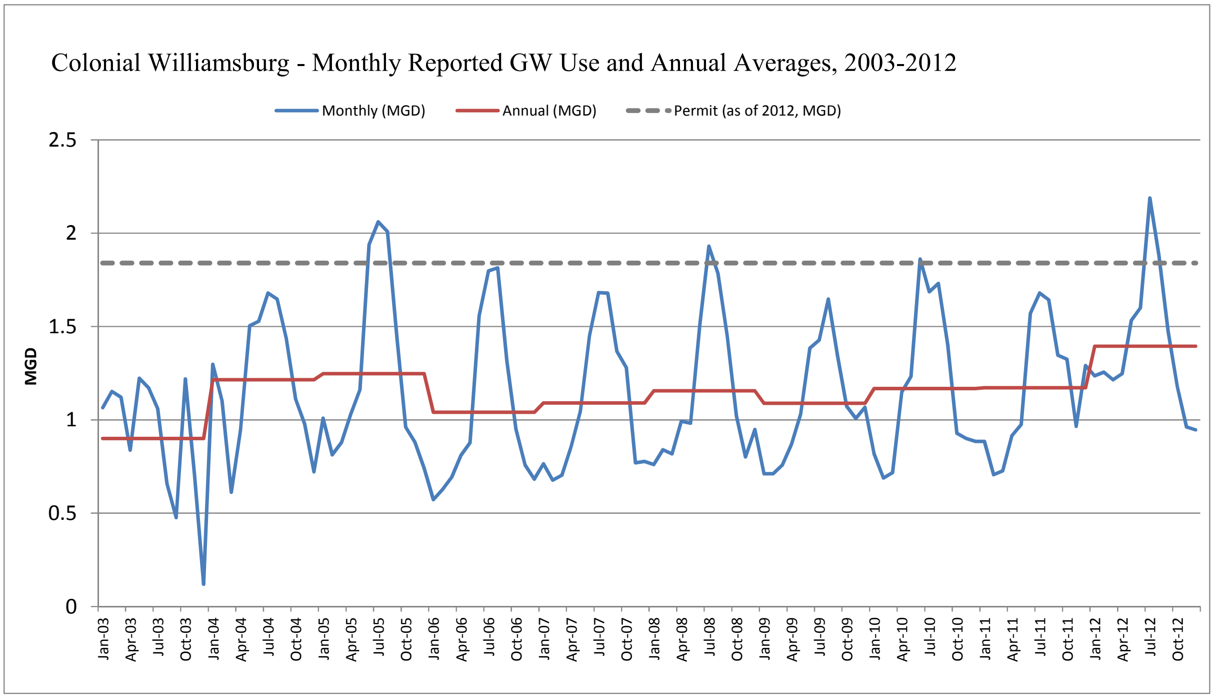
Exhibit 2-26: Groundwater use at the Portsmouth Genco power plant in Portsmouth, Virginia



2.4.12 Colonial Williamsburg Foundation – Overview and Current Water Use

The Colonial Williamsburg Foundation uses groundwater for cooling and heating buildings in the Historic Area of Colonial Williamsburg. The Foundation strives to maintain an authentic 18th century environment in the Historic Area, including hiding necessary modern infrastructure such as water meters, electrical transformers, and electric meters. Groundwater is used in geothermal heat pumps and other water cooled equipment in the Historic Area because electric, air-cooled condensers or cooling towers would be inconsistent with the Foundation’s goal of maintaining authenticity because of their noise and aesthetics. The Foundation has emphasized good stewardship of the groundwater resource and, as part of current permit review with DEQ, has been making investments to reduce groundwater use, primarily by converting buildings outside the core historic area (e.g., hotels and office buildings) to other heating and cooling technologies. Colonial Williamsburg currently has about 90 buildings which use groundwater for cooling and/or heating. Exhibit 2-27 shows recent groundwater use by Colonial Williamsburg. The facility uses about twice as much water during the summer cooling season as it does during the winter heating season. Overall average use from 2003 to 2012 was 1.14 MGD, but peak summer use approaches 2 MGD. The primary need in terms of water quality is for cool water (generally between 50 and 70 degrees) which allows for more efficient heat exchange for air conditioning.

Exhibit 2-27: Groundwater use at the Colonial Williamsburg Foundation



In terms of regional economic impact, Colonial Williamsburg is a major tourist attraction for the Hampton Roads region, employing about 2,500 people and paying $6 million in taxes to the City of Williamsburg in 2012 and $4 million to the state.

2.4.13 Colonial Williamsburg Foundation – Future Water Use

Representatives of Colonial Williamsburg report that there are no major growth or expansion plans that would increase their groundwater use in the future. In fact, as mentioned above, they have been making investments to reduce groundwater use by converting to other heating/cooling methods outside the main Historic Area. For example, one conversion outside the Historic Area at one of their hotels reduced groundwater use by about 2,100 gallons per minute during summer cooling season. For purposes of this report, it is assume that Colonial Williamsburg will continue to use at least 1.14 MGD.

2.5 Other Permitted Users

In addition to the large permitted users, a total of 113 smaller permitted users withdraw groundwater in the original EVGWMA. These groundwater users have individual permits for 0.7 MGD or less and the total permitted amount across the entire group is 10.5 MGD. Total use among these smaller permitted users was about 5.3 MGD in 2012. Small permitted users use groundwater for a variety of purposes, including municipal supply for small towns or developments, light industrial uses, and irrigation of parks and golf courses.

DEQ provided data containing annual water use and permitted amounts for 2003-2012. The dataset identifies the county where each user is located, and indicates whether the permit is currently active. Future water use among smaller permit holders was projected using these data. Inactive permits were removed and the remaining records were grouped into three categories: municipal/residential, outdoor (e.g., agriculture, golf courses), and industrial/commercial/institutional. For each category, the average water use (in MGD) in each county was calculated.

To calculate projections to future years, the average water use rates were multiplied by the county-level population growth rates from the Weldon Cooper Center. The other sources of population projections used in this report (i.e., the 2011 HRRWSP and the updated HRPDC projections) only cover the Hampton Roads region, while the Cooper Center data cover all counties in the area. Thus, the projections for the smaller permitted users were calculated using only Cooper Center population projections. The authors of this report assume that the smaller permitted users will be impacted by any new regulations and management actions, but do not assume any change in water use trends (e.g., no declines in per-capita use) when calculating projects. While different projections could be calculated based on alternative population projections and water use trends, these smaller permitted users only account for a small portion (5.3 MGD) of total current groundwater use, and therefore they are not an emphasis of this analysis.

The results are shown in Exhibit 2-28. Assuming that growth among these small groundwater users will roughly follow county-wide population growth, it is not expected to place a substantial new burden on the aquifers. The authors of this report assume that the future groundwater use among all small permitted users will be 6.3 MGD by 2040.

Exhibit 2-28: Projected use among small permittees

County	**Project Use Among Small Permitted Users (<0.7 MGD)**		
	2020	**2030**	**2040**
Charles City	0.1	0.1	0.1
Chesapeake	0.4	0.5	0.6
Chesterfield	0.3	0.4	0.4
Franklin	0.0	0.0	0.0
Hampton	0.0	0.0	0.0
Hanover	0.6	0.7	0.8
Isle of Wight	0.3	0.3	0.4
James City	0.2	0.3	0.4
King William	0.6	0.6	0.6
New Kent	0.7	0.8	0.8
Newport News	0.2	0.2	0.2
Norfolk	0.1	0.1	0.1
Portsmouth	0.3	0.3	0.3
Southampton	0.8	0.8	0.8
Suffolk	0.1	0.1	0.1
Surry	0.1	0.1	0.1
Sussex	0.2	0.2	0.2

Exhibit 2-28: Projected use among small permittees

County	Project Use Among Small Permitted Users (<0.7 MGD)		
	2020	2030	2040
Virginia Beach	0.2	0.2	0.2
Williamsburg	0.0	0.0	0.0
York	0.1	0.1	0.1
TOTAL	**5.4**	**5.8**	**6.3**

2.6 Unpermitted Groundwater Users

Unpermitted self-supplied users withdraw a substantial amount of groundwater from Virginia’s coastal aquifers. The exact amount of unpermitted withdrawals is not known, since this information is not measured or reported in Virginia (Pope et al., 2008), but several estimates have been developed. The U.S. Geological Survey estimated that self-supplied domestic groundwater use in the entire Virginia Coastal Plain localities (including the Eastern Shore) was 38.5 MGD in 2000 (Pope et al., 2008). The region contains shallow surficial aquifers and several deeper, confined aquifers. Most of the estimated 200,000 private domestic wells in the region (78%) draw from the confined groundwater system. USGS estimated that the population served is over 15% of the area’s total population. Private domestic wells are the primary water source in some rural counties. Furthermore, USGS domestic groundwater withdrawals estimates were adjusted to account for the degree to county totals impacted the Coastal Plain aquifers. After these adjustments, Pope et al (2008) estimate domestic use to be 29 MGD.

DEQ also provided domestic groundwater withdrawal estimates developed by local and regional water supply plans. Using the estimation county weighting procedure as Pope et al (2008), local water supply domestic groundwater withdrawal estimates were used to provide another estimate of domestic water use. The water supply plan data also estimate total domestic groundwater withdrawals to be approximately 29 MGD.

For the Hampton Roads region, the 2011 HRRWSP projected water use by unpermitted self-supplied users (private business and residential wells using less than 300,000 gallons per month) as 11 MGD in 2010 (10 MGD by residential and 1 MGD by business users) and 13 MGD in 2040 (12 MGD by residential and 1 MGD by business users). The growth in future use is based on increased residential use driven by population growth outside publicly-owned CWS service areas. HRPDC assumed that private business well users would have constant water use from 2010-2050.

Agricultural users do not appear to be a major groundwater user. Heywood and Pope (2009) estimate reported agricultural water use from Coastal Plain aquifers to be less than 1 MGD. This estimate does not include unreported agricultural groundwater withdrawals.

3. Alternatives to Groundwater Use

For purposes of this report, the target for total withdrawals is 90-100 MGD across the entire EVGWMA. This 90-100 MGD could be allocated to different sectors of groundwater users (i.e., large municipal users, large industrial users, small permitted users, and unregulated small self-supplied users) in various ways. The total groundwater withdrawal target assumed here is 55-65 MGD across all permitted users and approximately 30 MGD for unregulated small self-supplied users. For purposes of this report, no distinction is made between withdrawals from the different aquifers.

It is worth considering the potential impact of this target on the regional balance between water use and water supply (impacts on individual groundwater users are described in Section 4). Because most of the impact is focused in the original EVGWMA, this discussion is limited to that area. Further, this discussion focuses primarily on large municipal groundwater users (i.e., CWSs), but potential impacts on self-supplied industrial users are also described.

If DEQ moves forward with new strategies that reduce groundwater use, and if the region's water supply managers decide to pursue alternative supplies, there are a variety of options to consider. These are described below. A chart comparing amortized costs of these alternatives (for those for which data is available) is presented at the end of this section.

3.1 Regional Water Sharing Among Municipal Water Systems

There is a simple reason to look at the problem on a region-wide basis: if there appears to be sufficient water supply in the region to meet the suggested groundwater use target of 55-65 MGD and still meet overall projected water use, then one possible response to reduced groundwater availability would be increased water purchases and transfers among users in the region. If there is insufficient supply to meet the groundwater target and projected use, then the region will need to secure new water sources and/or reduce water use through conservation programs.

Focusing only on municipal CWSs in the Hampton Roads region of the EVGWMA,[12] data from the 2011 HRRWSP suggests that the total water supply in the region should be adequate to meet water use through at least 2040 and probably beyond (see Exhibit 3-1). The plan breaks out the balance between supply and use in three sub-regions, and suggests that total water supply is likely to be adequate in the Southside/Western Tidewater sub-region, which includes Norfolk, Virginia Beach, Chesapeake, Suffolk and other areas. However, the plan suggests that water supply will be tight in the York-James peninsula, which includes Newport News and James City County, by 2030. The potential shortfall in the York-James peninsula would likely be much smaller than the surplus in the Southside/Western Tidewater region. Overall the plan suggests supply will exceed water use in 2040 by about 33 MGD. This calculation assumes that regional supply includes the total permitted groundwater allocations as of 2011.[13]

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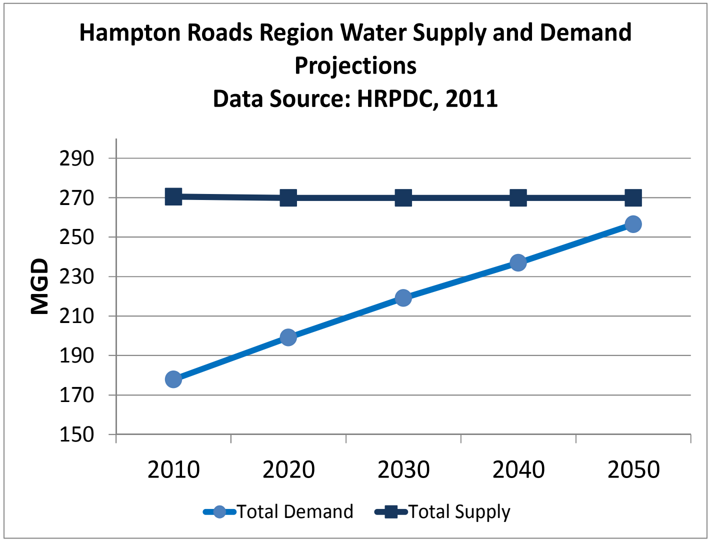
[12] The large industrial self-supplied groundwater users do not currently impact the regional water yield and water use balance. There are no currently no plans for any of these water users to connect to a CWS as a primary source of water for their operations.

[13] The plan was developed before Norfolk's new groundwater withdrawal permit, which includes different levels of allowable withdrawals based on certain drought metrics. The effect of this new permit structure on Norfolk's safe yield is not clear. For lack of better information, this analysis was developed assuming that the permit will have no

As discussed above, there is substantial evidence that total and per capita water use is dropping in the region. In addition, new population projections that account for Census 2010 data result in lower population estimates in 2040 than previously projected. To account for these trends, new water use projections were developed for this report (see Section 2). The new water use projections suggest that total regional water use could be less than what was estimated for the 2011 water supply plan by about 44-71 MGD in the year 2040 (see Exhibit 3-2). With these lower projections of water use, the surplus supply would be larger than what was estimated in the 2011 water supply plan. The future water use estimates developed for this report suggest a potential regional supply excess of 77-104 MGD in 2040.

Exhibit 3-1: Water supply and demand balance in the Hampton Roads Region as projected in the 2011 Regional Water Supply Plan (HRPDC, 2011)



As described earlier, DEQ is considering management strategies that would reduce groundwater use in the EVGWMA. DEQ's preliminary modeling suggests that to stabilize aquifer levels, total withdrawals should be no more than 90-100 MGD across the entire EVGWMA.[14] There are various ways that the 90 to 100 MGD could be apportioned to different users and different sectors. For purposes of this discussion, we can simply focus on the potential range of cutbacks in groundwater that the CWSs may face. Currently, the total amount of groundwater permitted to the large CWSs in the region is about 49 MGD including Portsmouth, (it was about 55.6 at the time of the HRRWSP). Even if all groundwater was eliminated, the regional total supply might still exceed regional total water use. If groundwater permits for CWSs are reduced to a total of 20 MGD (which is roughly average total reported groundwater use among these CWSs from 2003 to 2012), there would be a total supply surplus between 42 and 67 MGD in 2040 under these revised demand projections.

The point of this analysis and discussion is that, overall, projected future water use could be served by a regional water sharing system even with a substantial reduction in groundwater availability that could come about under new DEQ groundwater management strategies.

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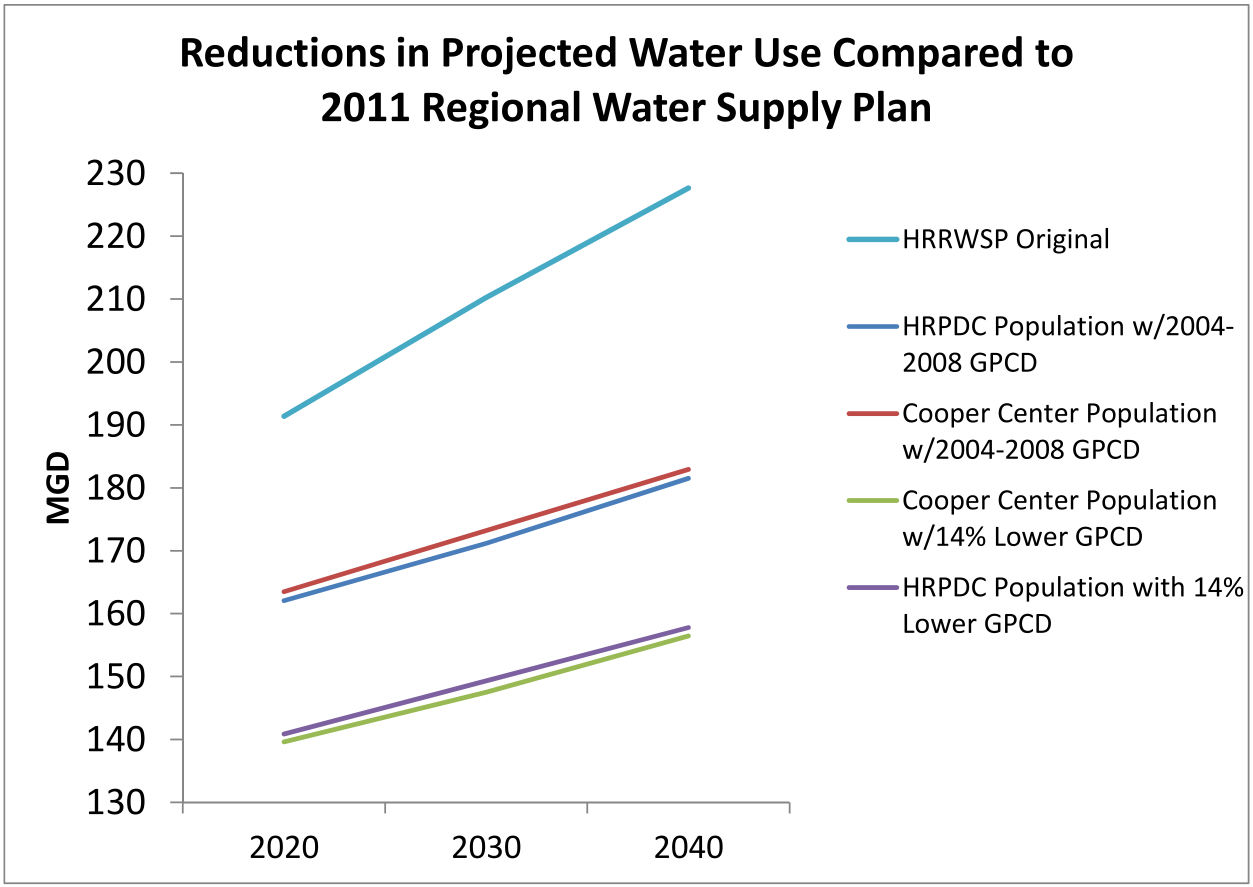
impact on the safe yield provided in the Water Supply Plan (92.5 MGD). This assumption will require rigorous modeling and testing to support actual State or city decisions.

[14] These are preliminary targets based on current model results. DEQ continues to refine the model and input data and so these targets may change as new model results are produced. These targets are used as a tentative target to structure this investigation.

Exhibit 3-2: Comparing water use projections



While the projections presented here are based on recent data and standard assumptions, the prospects for water sharing need further critical evaluation. First, the updated demand projections do not incorporate potential growth in non-residential use. Growth in the non-residential sector could result in an increase in total water use, so holding some supply in reserve might be justified. Another reason to hold some reserve is that current declines in per capita residential water use might reverse. Further, a regional surplus of supply is of little relevance if municipalities with projected surplus water are unable (due to distance, physical or engineering constraints) or unwilling to sell their water at rates that other communities are able or willing to pay. Prices for existing water purchases in the region range from $1.26 per 1,000 gallons of raw water to $7.13 per 1,000 gallons of treated water.[15] In addition the analysis suggests a surplus of water through about 2040, but growth in water use may occur beyond that time and eventually require new supplies and/or enhanced conservation.

This analysis does suggest that there are opportunities to reduce allowable groundwater withdrawals without creating risk of water shortages if there is water supply sharing. Such water sharing arrangements will themselves impose new costs. First, they may require some investment in new infrastructure, such as transmission lines, pumping stations, and modified treatment facilities. More importantly, sharing

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[15] This range covers several contracts with different characteristics.

agreements may require a collaborative process, perhaps led by DEQ that engages all users and supply sources in designing water supply contracts that can benefit all the parties involved. Such regionalization can be controversial, but regionalization has been successful in reducing groundwater use in other areas (Box 3-1).

Box 3-1: Regional Water Supply System in Western Central Florida

The area surrounding Tampa Bay began experiencing reductions in aquifer levels in the 1960s. Early attempts at regionalization resulted in the establishment of the West Coast Regional Water Supply Authority in 1974. The Authority was a cooperative arrangement between participating localities with water infrastructure assets still owned by members. As population grew, the Authority struggled to finance infrastructure improvements within its existing organizational structure. From the attempts to establish consistent rates and secure adequate water supply funding, the six municipalities (Hillsborough County, Pasco County, Pinellas County, New Port Richey, St. Petersburg and Tampa) agreed to form a single regional utility in 1998, called Tampa Bay Water (TBW).

TBW immediately began taking steps to develop new sources and preserve the aquifer. With ownership and control of all the large utility well-fields (the Central System Facilities), TBW centralized groundwater withdrawal permits under a single entity. Phased groundwater reductions for the entire region were implemented. Total permitted withdrawals from the Central System Facilities went from 158 MGD in 1998 to 121 MGD in 2003, and by 2008 were permitted for a 12-month moving average of 90 MGD.

TBW initiated several infrastructure projects to reduce groundwater pumping including enhanced surface water system for the Alafia and Hillsborough rivers and Tampa Bypass Canal (with associated treatment facility), a 1.5 billion gallon reservoir, desalination facilities, a new well-field and regional interconnections. To supplement this construction TBW aggressively addressed water conservation and demand, saving upwards of 30 MGD. With these investments, the regional water authority was able to produce enough water for environmental restoration projects in the area. Through 2013, TBW has spent over $900 million developing alternative water sources, with approximately $375 million in federal and state contributions.

3.2 Wastewater Reuse as Alternative Supply

Reuse of treated wastewater is increasingly considered as a viable source of water for both potable and non-potable purposes. HRSD treated and discharged approximatly158 MGD of wastewater in 2013 (HRSD, 2013). This wastewater was spread across nine wastewater treatment plants, ranging from 8.9 MGD to 31.9 MGD. Treated wastewater has been considered as an alternative supply within the region on a limited basis (HRPDC, 2011). Delivering treated wastewater to one of the paper mills has been discussed, although no detailed studies have been performed. The possibility of using treated wastewater for direct or indirect potable use has not been discussed extensively.

Box 3-2: Wastewater Reuse

In this report, the term *wastewater reuse,* or simply *reuse*, is distinguished from the term *recycling.* Reuse is reserved for the idea of using treated municipal or industrial wastewater in place of new surface or groundwater withdrawals. Reuse can occur at the same facility or the treated wastewater can be piped to another facility. The level of treatment will depend on the end use.

Recycling is used for situations in which water is used multiple times (without treatment) within a single production stream. This is a common practice at the industrial facilities covered in this report.

There are numerous examples of reusing treated wastewater for potable and non-potable uses (e.g., see National Research Council (NRC), 2012, and EPA, 2012). One example comes from the Hampton Roads region: HRSD delivered 0.5 MGD of highly treated wastewater to Giant Industries' Yorktown refinery until the refinery closed in 2011. Other examples are summarized in Appendix 2. Many successful projects tend to be in the western U.S. where water is scarcer. However, Virginia, Florida, Georgia, and Massachusetts all contain significant wastewater reuse facilities. In the EVGWMA, concerns over the groundwater system may lead to reductions in what had been considered as available supply. These reductions, combined with increasing regulatory requirements for ambient water quality, such as in the Chesapeake Bay, is directing attention to wastewater reuse as a way to secure a reliable water supply and meet water quality goals.

There are three major challenges to increasing wastewater reuse: costs for treatment and distribution, regulatory requirements governing water in food and food related product manufacturing, and public perception. The prospects for wastewater reuse for non-potable and potable uses are described below.

3.2.1 Wastewater Reuse for Non-Potable Purposes

As described above there are six large industrial groundwater users in the EVGWMA and dozens of smaller industrial groundwater users (meaning that they use less than about 1 MGD). The six large groundwater users may withdraw up to 57.3 MGD in 2040. In addition, industrial water users use water from publicly owned water systems, some of which comes from groundwater. For example, Newport News and Norfolk, both municipal groundwater users, deliver a total of almost 12 MGD to heavy industrial customers (HRPDC, 2011). Wastewater reuse for industrial purposes could eliminate a substantial amount of groundwater use in the EVGWMA. However, the economic and financial feasibility will depend on water quality requirements, which will dictate the necessary level of treatment, and the proximity of end users to wastewater treatment plants, which will determine the necessary amount of pipeline and pumping.

The National Research Council (NRC, 2012) provides the most comprehensive summary of wastewater reuse costs currently available. Based on data from seven large wastewater reuse projects, the NRC reports that total capital costs for non-potable reuse can vary widely, from $1.14 to $18.75 per 1,000 gallons of capacity (2009 dollars; annualized at 6 percent for 20 years, annual costs range from $0.10 to $1.63 per 1,000 gallons per year of capacity). NRC found that additional treatment beyond what was required for wastewater discharge and pipeline and distribution system uses were the major drivers of capital cost. The two most expensive cases presented in the NRC report required both additional treatment and major pipeline investments. The NRC study cites work by the Southwest Florida Water Management District that showed that pipelines can add capital costs of $5 to $9 per inch of diameter per linear foot, which can quickly amount to tens of millions for substantial projects.

Feasibility studies of wastewater reuse projects in EVGWMA suggest similar or higher capital costs. For example, CH2M HILL (2008) prepared screening level cost estimates for possible reuse of HRSD wastewater at a Northrop Grumman shipyard in Newport News. That study showed a range of total capital costs from $10.30 to $19.84 per 1,000 gallons of capacity. The CH2M HILL study focused on a small capacity (0.16 MGD) project with additional treatment with reverse osmosis (due to very stringent water quality requirements, much more than is typical for industrial reuse) and pipeline costs to deliver the water.

Operating and maintenance (O&M) costs can also vary widely. NRC (2012) reports a range of $0.05 to $1.18 per 1,000 gallons per year. The CH2M HILL study cited above showed a range of O&M costs of $9.13 to $15.76 per 1,000 gallons per year. Significant drivers of O&M costs include labor and energy.

This wide range of costs can make it difficult to determine the feasibility of wastewater reuse for non-potable purposes in the EVGWMA. Targeting such projects at a limited number of large industrial users can allow for scale efficiency and minimize costs associated with pipelines and other distribution infrastructure. Two of the largest clusters of groundwater use in the EVGWMA are located around the two paper mills. Three substantial groundwater users are located in the region around Franklin, Virginia: the Franklin paper mill, the Ashland, Inc. chemical plant, and the City of Franklin municipal supply (the extent of reuse benefit for the Ashland plant is dependent on the temperature since the main benefit of groundwater use is for cooling) The total projected use in 2040 among these three is about 29 MGD. The RockTenn paper mill is projected to use 23.03 MGD in 2040 and there are several smaller groundwater users in that area. The closest HRSD municipal wastewater treatment plants are 30-40 miles away from Franklin and 25-30 miles away from West Point. The capital cost required to treat and pipe HRSD water to the either region might make such an option cost-prohibitive.

Wastewater reuse options that would not require substantial piping or distribution might be more cost-effective to implement. For example, each paper mill has a substantial treated wastewater discharge. These discharges could offer opportunities for reuse at the mills or for other local non-potable or potable uses. Because each of the mills requires high quality water, wastewater reuse for the mills would require advanced treatment, increasing costs (see subsequent section for costs associated with potable reuse). However, pipeline costs would be minimal.

3.2.2 Wastewater Reuse for Production of Food, Food Packaging, and Human Contact Products

Three industrial facilities in this region make products that introduce additional challenges for wastewater reuse. The West Point Paper Mill produces bleach kraft and other paper products that are used for food packaging. The Franklin Paper Mill produces fluff pulp for human contact products (e.g., diapers, feminine hygiene products), as well as facial tissues. The Smithfield Packing plant processes pork and makes various finished meat products. In each case, wastewater reuse may have very high regulatory requirements and may impose business risks that are seen as unacceptable by the companies.

For food and food contact products, the Food and Drug Administration (FDA) requires that raw materials, which include process water, be free from contamination. While the FDA does not stipulate which contaminants must be measured and removed, the pulp and paper industry, in conjunction with FDA experts, has developed an industry standard protocol that covers 150 contaminants. This protocol would likely need to be modified to be applied to treated wastewater, which could impose a significant additional cost. Smithfield Packing would face a similar issue. Current Virginia regulations prohibit use of treated wastewater for food production (9VAC25-740-50). It is not clear how this regulation would be applied to the use of treated wastewater for cleaning food production equipment, a primary use of water at Smithfield.

In addition to the regulatory requirements, wastewater reuse might create business risks. Reusing wastewater could hurt a company's market position if public perceptions about treated wastewater eroded trust in their products (public perception for potable uses is covered below). Perhaps more significant is the possibility that use of treated wastewater could result in contamination of their facilities and/or products with chemicals or microbes in sufficient quantities to require a recall or to compromise their ability to meet voluntary quality standards. It is difficult to assess how significant these potential business risks are, but each company asserts that these are obstacles that must be overcome for wastewater to be a viable alternative to groundwater. While wastewater reuse is increasingly common for industrial purposes, *no examples were identified in the United States* in which wastewater is reused for food processing, production of food packing materials, or production of human contact products.

3.2.3 Wastewater Reuse for Potable Purposes

Eight municipal water suppliers in the original EVGWMA are authorized to withdraw more than 1 MGD of groundwater. Total recent use among these eight has been about 20 MGD and future use could be higher given growth trends. There are two possible approaches to wastewater reuse for potable purposes. One is direct potable reuse, which means feeding treated wastewater directly into a distribution system for immediate use by customers. There is very little experience in the U.S. with this alternative. The second is to use treated wastewater for indirect potable purposes, such as aquifer storage and recovery (ASR) or inflow augmentation for reservoirs or other surface water. Injecting treated wastewater for ASR currently requires treatment of wastewater to potable standards under existing regulations in Virginia.

NRC (2012) includes cost information for six wastewater reuse projects that produce potable water. Total capital costs vary from $3.90 to $31 per 1,000 gallons of treatment capacity (2009 dollars; annualized at 6 percent for 20 years, the range is $0.34 to $2.68 per 1,000 gallons per year). Operation and maintenance costs range from $0.31 to $2.38 per 1,000 gallons per year.

From a cost standpoint, reusing HRSD treated wastewater might be more feasible for municipal supply than for industrial uses because the wastewater treatment plants are located closer to many of the region's drinking water treatment plants and distribution systems, reducing the need for extensive pipelines. In addition, many of the HRSD wastewater treatment plants are located near the region's surface water reservoirs, where high quality treated effluent could be used to augment reservoir inflow. In most cases, this approach would increase the reliable supply of a reservoir and could offset some groundwater use.

It should be noted that the country's first project to use treated wastewater as reservoir inflow occurred in Virginia. This project was by the Upper Occoquan Service Authority and has capacity to treat up to 54 MGD of effluent (current treatment ranges from the 31 to 34 MGD) which is then discharged directly into Occoquan Reservoir, a primary drinking water source for Northern Virginia. The Upper Occoquan Service Authority uses conventional wastewater treatment, advanced treatment to remove suspended solids and nutrients, and disinfection before the water is released into Occoquan Reservoir. Schimmoller and Kealy (2014) estimate the incremental cost of treating wastewater from secondary treatment standards to indirect potable reuse levels for the Occoquan treatment facility to be about $1.07 per 1000 gallons of treatment capacity (or $1.83 per 1000 gallons of treated water). Incremental operation and maintenance costs from the Occoquan were $0.36 of treatment capacity (54 MGD design flow) and $0.62 per 1000 gallons for treated water (31.5 MGD of treated water). Using a capital cost estimation model, the annualized capital costs of treatment capacity using granular activated carbon technologies was estimated to be $0.71/kgal (annualized at 5%, over 20 years). For comparison purposes, some localities in the EVGWMA pay $1.26 per 1000 gallons for raw water.

3.2.4 Other Issues for Wastewater Reuse

Public perception can be a substantial challenge for potable reuse of wastewater especially when combined with the fact that wastewater reuse will often be more expensive than other water supply options and may lead to higher water rates. The perception issue is often dubbed the "yuck factor" (see Hartley, 2006; Schmidt, 2008) and it can lead to delays and modifications to proposed projects. For example, water managers in Orange County, California inject highly treated wastewater into the ground for what they describe as "psychological reasons" (Roythe, 2008). In other words, despite substantial public relations work, opposition to the idea of drinking treated wastewater forced water managers to add the injection step instead of delivering the treated wastewater directly to the distribution system. Engineers say the water is actually less pure after it is removed from the ground. Los Angeles pursued a wastewater reuse program but was forced to terminate the plan in 2000 after significant public opposition. What is reportedly the country's first project involving direct wastewater reuse is about to come online in Wichita Falls, Texas (Preston, 2014). This project, motivated by drought, will put treated wastewater directly into the distribution system, but it is not without public controversy.

If they choose to pursue potable wastewater reuse, water utilities and the state government will need to address issues of public perception by investing in public involvement and communications. It is difficult to estimate how much public involvement and communications would add to the cost of a project. NRC (2012) does not offer cost data, but suggests that public opposition is a major concern among water utilities. Public opposition can delay projects and add cost primarily because they extend the time and broaden the scope of environmental and public health regulatory reviews of proposed projects.

3.3 Large Scale Desalination as an Alternative Supply

The EVGWMA area has ample access to saltwater and brackish water in the Chesapeake Bay and Atlantic Ocean. Desalination is an increasingly common source of drinking water as new technologies bring down the cost. There are currently no seawater desalination plants in Virginia, but several water utilities desalinate brackish groundwater and surface water, including Chesapeake Utilities and Newport News Waterworks. Despite improvements, seawater desalination remains a comparatively costly alternative. Exhibit 3-3 summarizes annualized unit costs for capital and O&M from a selection of available literature for a range of capacities of desalination plants (cost per 1000/gallons of capacity). Unit costs of treated water would be higher than reported in the table below since plants do not operate at full capacity.

Major components of desalination cost can include disposal of brine concentrate and cost of electricity. In addition, scale can make a significant difference. NRC (2008) indicates that capital cost per unit of output can be 20% less for a 100-MGD plant than for a similar 10-MGD plant.

Exhibit 3-3: Summary of Desalination Costs from various sources ($/kgal capacity/yr)

	Capital, $/kgal, 2013 Dollars		O&M, $/kgal, 2013 Dollars		Total, $/kgal, 2013 Dollars		
Treatment/Technology	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Source**
Desalination of seawater [1]	$4.05	$6.37	$0.84	$1.06	$4.89	$7.43	Younos (2004)
Desalination, seawater; surface water intake	$1.06	$2.26	$2.09	$2.74	$3.15	$5.01	USBR (2003) *

Desalination, seawater; well intake	$1.14	$1.99	$1.84	$2.02	$2.98	$4.01	USBR (2003) *
Desalination, seawater, RO	$0.23	$3.20	Not provided				Bergman et al (2012)
Desalination, brackish; surface water intake	$0.34	$1.14	$0.77	$1.43	$1.11	$2.56	USBR (2003) *
Desalination, brackish; well intake	$0.31	$0.86	$0.87	$1.41	$1.18	$2.27	USBR (2003) *

*U.S. Bureau of Reclamation (2003)

(1) Seawater means total dissolved solids (TDS) greater than 10,000 mg/L.

(2) Brackish water means TDS of 1,000 mg/L to 10,000 mg/L.

3.4 New Surface Water Development

Most of the water used in the EVGWMA currently comes from fresh and brackish surface water and this will continue to be the case for the foreseeable future. New surface water development could potentially provide additional water supply for the region, but it is not without challenges. The last major surface water project proposed in the region, the King William Reservoir proposed by Newport News Waterworks, generated substantial controversy and resulted in a drawn-out regulatory process that lasted nearly 20 years. After a permit for the reservoir was invalidated by a Federal court in 2008, the city decided to discontinue the project. Newport News reportedly spent over $51 million on planning, environmental impact studies and land acquisition (Hirschauer, 2009).

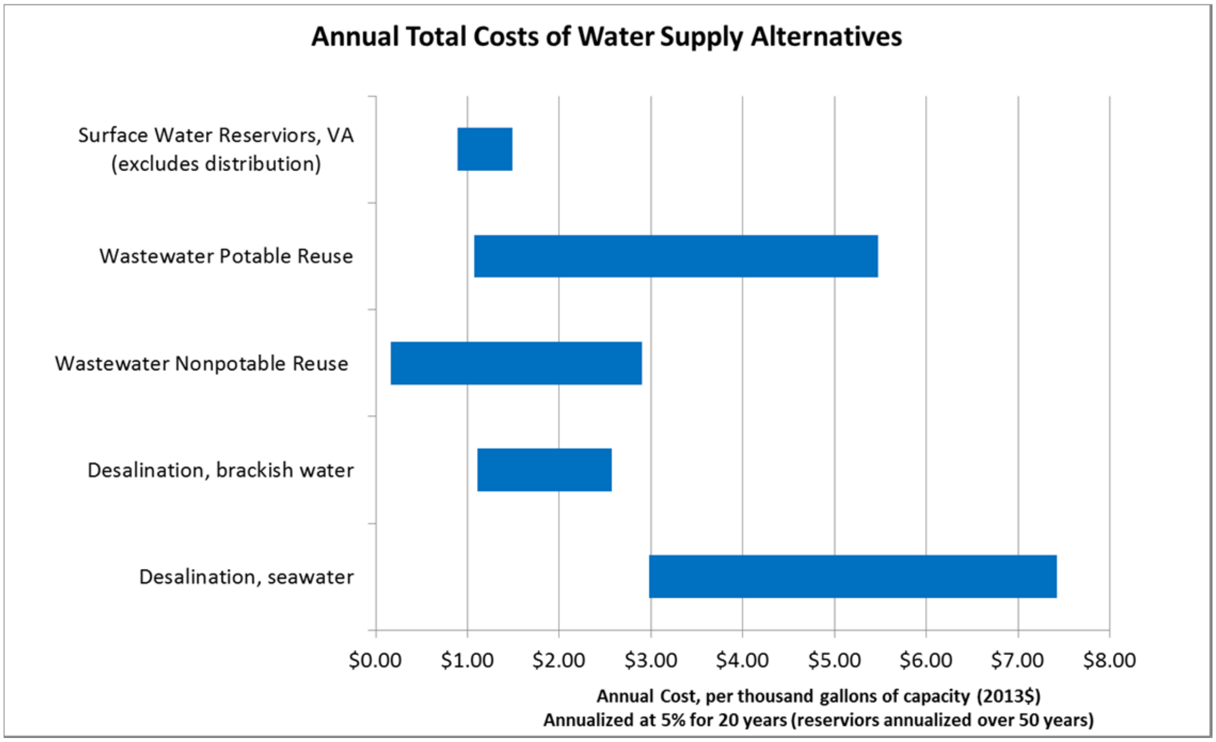
Regulatory processes will continue to be the biggest risk for new surface water development, with controversies, delays and associated costs driven by concerns over environmental impacts and inter-state disputes over water rights. However, surface water might still be a cost-effective alternative for new supply. In 1997, Virginia Beach was able to secure 60 MGD of surface water from Lake Gaston at a cost of $150 million, but spent $11 million over several years on legal fees associated with permitting the project. In 2013, Henrico, Cumberland, and Powhatan Counties secured a permit for Cobbs Creek Reservoir, which is a pump-storage project: water is withdrawn from the James River during high flow, and pumped to the storage reservoir which is located in Cumberland County. Cobbs Creek is expected to yield 47 MGD with capital cost of $280 million ($16.32 per 1,000 gallons, $0.89 per 1,000 gallons annualized at 5% for 50 years). Stafford County recently finished construction on the 500-acre Rocky Pen Run Reservoir. The reservoir, providing over 14 MGD in yield, took over 20 years and $139 million to complete ($1.49 per 1,000 gallons at 5% for 50 years). If built, King William Reservoir was expected to yield 20 MGD at a capital cost of $8.5 million per MGD. Other communities that have recently completed or are permitting surface water storage projects include Charlottesville (expansion of Ragged Mountain reservoir), Greene County (White Run Pumped Storage Reservoir), and Greenville County reservoir (pump storage facility).

New surface water development in the region might be used to offset reductions in groundwater use for two reasons. First, if groundwater use is required to be reduced, surface water projects could be developed to replace some of the forgone supply. Surface water projects might serve one CWS or there could be regional projects. A second reason for new surface water development would be to provide a new source for groundwater users who may lose access to groundwater if aquifer levels in certain regions continue to decline. As described earlier, areas that are at particular risk for losing groundwater are located along the fall line, especially north of Richmond. It may be possible to augment water supplies in these regions where topography and freshwater surface water conditions are generally more favorable for development. .

In addition to regulatory and cost issues, climate change impacts on weather and hydrology may give reason to be cautious about relying on surface water for future water supply. Water resource managers have known for several years that climate change introduces new risks for surface water management (see Milly et al, 2008; Brown, 2010) but the specific future impacts for surface water in Virginia remain very uncertain. The recent National Climate Assessment (Carter et al, 2014) suggests an increase in very hot days for the EVGWMA region, which could decrease water availability, and it does suggest greater water supply risk for Virginia, but there are few regional details. Water managers will need to consider the potential risks imposed by climate change and whether those risks decrease the value of surface water as an alternative to groundwater.

A comparison of general source water development alternatives is shown in Exhibit 3-4. New raw water supplies could come from new surface water development or wastewater reuse (used for a variety of purposes). The annual costs ($/kgal capacity/yr) reported below are estimated costs from existing projects across the United States, as well as Virginia. Desalination costs are costs to deliver finished water and are derived from cost models. As explained above and summarized in Exhibit 3-4, source water alternatives can have large variations in unit costs and can be quite expensive. Conversely, the low end of the cost range for several alternatives, such as potable and nonpotable reuse, can be low enough to be comparable to new surface water reservoir development capacity costs. Costs are sensitive to scale economies, existing infrastructure, spatial arrangements, and source water quality.

Exhibit 3-4: Comparison of costs for source water alternatives



Costs for desalination options and wastewater reuse for potable purposes represent finished drinking water, while surface water reservoir costs and potable reuse represent raw water costs. All costs are

Exhibit 3-4: Comparison of costs for source water alternatives

are reported in $/kgal capacity/yr.

3.5 Water Conservation

Water use has been declining around the U.S. (Rockaway, 2011) and the EVGWMA has had a similar trend (HRPDC, 2013; see Exhibit 2-1). Exhibit 3- shows per capita use rates for most of the municipal water systems in the Hampton Roads region. Rigorous analysis of recent declines in water use has not been conducted for this region but water conservation practices likely have contributed to the decrease in per capita water use in the region (and nationally). Most of the localities within the Hampton Roads region already have some type of water efficiency and/or water conservation program, with the most common approach being public education (HRPDC, 2011). It appears that the reductions to date have been the result of installation of water saving technology in industry and in new housing (new appliances with water and energy use requirements and plumbing codes on new construction), behavioral changes motivated by public information and education programs, and increased prices for water.

There has been substantial interest in the impact of economic recession on water use (see Hughes et al, 2009). Recession can reduce water use because businesses may reduce production or close (which occurred with the Franklin Paper Mill), households may cut back, and, particularly relevant for the 2008-2010 recession, houses and other dwellings may be vacant. The magnitude and pattern of the impacts of recession is not yet understood, but there is ongoing research on this issue (Water Research Foundation, 2014).

Exhibit 3-5: Per capita water use in the Hampton Roads region Based on data from regional water supply plan (HRPDC, 2011)

Locality	Total Daily Per Capita Water Use, gallons	Residential Daily Per Capita Water Use, gallons
Chesapeake	97	66
Franklin	133	75
Hampton	112	58
James City County	106	71
Newport News	112	58
Norfolk	122	47
Poquoson	112	58
Portsmouth	112	53
Town of Smithfield	89*	89*
Virginia Beach	83	61
Western Tidewater Water Authority	106	74
York County	112	58

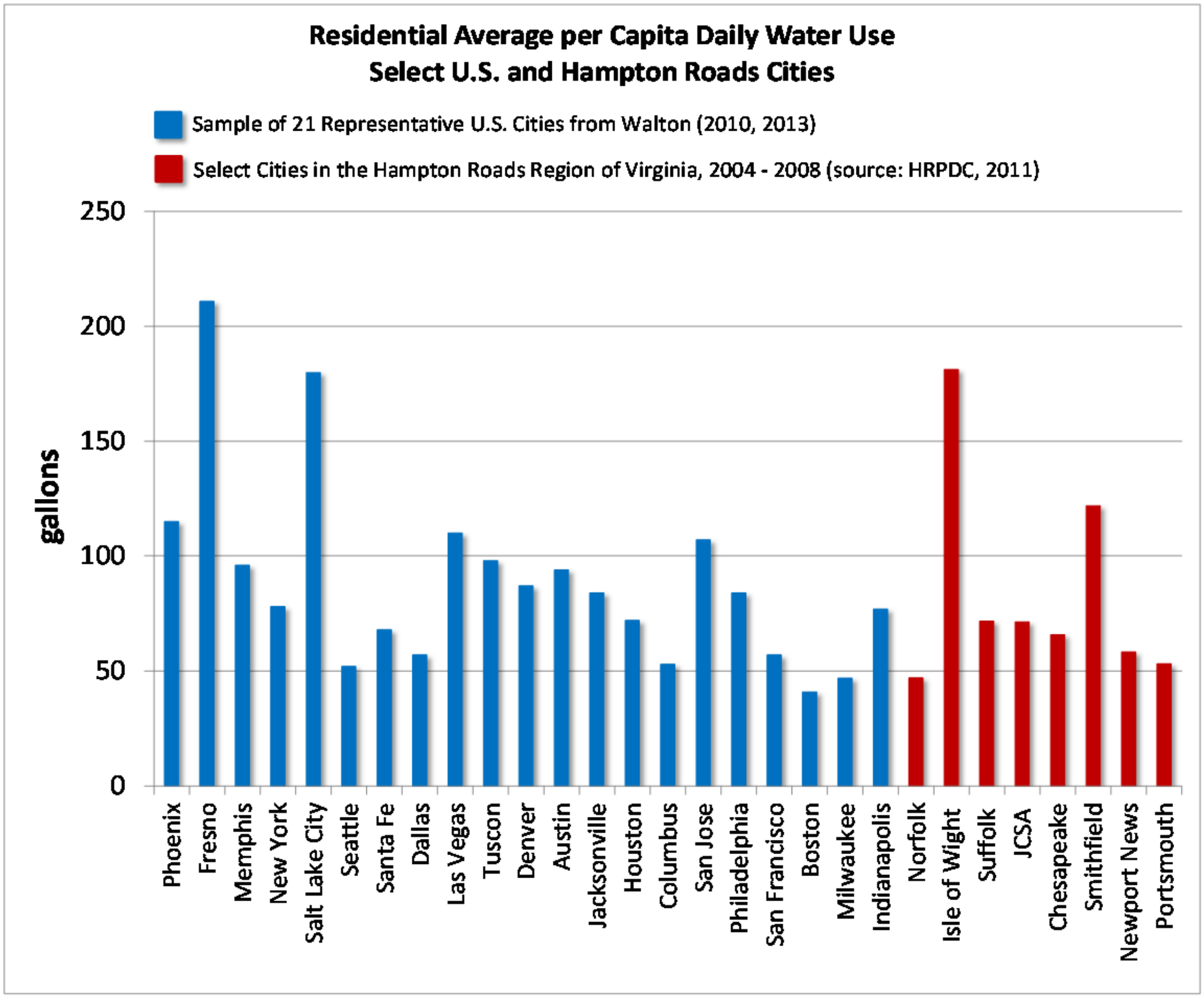
Note: Total per capita use includes commercial and industrial uses.
*Because Smithfield's per capita use was calculated differently from others, a different total and residential rate could not be estimated.

Current use rates in the Hampton Roads region compared to other regions can help identify how much additional water use reduction might be possible. Exhibit 3- displays average residential per capita water use rates for a range of U.S. cities (Walton, 2010) and for water systems in the Hampton Roads region of Virginia. The median residential use among the sample of U.S. cities is 81 gallons and the median for eastern cities is 77 gallons. The use rates may be lower now, as a recent update to the survey (Walton, 2013) found that prices had increased in the surveyed cities by an average of 25% since 2010. Most of the regions considered in this report have per capita use rates lower than the median from the survey by Walton (2010), but the comparison does suggest that some localities in the EVGWMA might be able to reduce their residential use even lower. For example, average per capita daily use in Boston, which has a history of aggressive water conservation practices (Postel, n.d.), is only 41 gallons. While Boston has some advantages when it comes to reducing water use (cooler and wetter climate, dense urban development with smaller residential lots and more apartment dwellers), its history of conservation investments provides a benchmark for other cities.

Several general strategies for water conservation are discussed below. The future effectiveness of such programs in further reducing water use will depend on current levels of water use both inside and outside the home, characteristics of current and future housing stock (e.g., single family versus multiple family dwellings), age of the plumbing and appliance stock, size distribution of residential lots and lawn irrigation behavior, the amount of commercial and industrial water use, future pricing structures, and socio-economic characteristics of the community. The costs of implementing any of the strategies discussed below will also depend on the characteristics of each water system and community.

The region might be able to reduce water use by seeking to reduce outdoor water use, especially for residential and commercial lawn irrigation. The regional water supply plan (HRPDC, 2011) indicates that all of the larger localities have some form of irrigation management as part of their conservation efforts. Supporting data from the plan suggest a summer peaking factor of 1.5, indicating that water use jumps by 50% during the summer (which was generally confirmed in interviews with personnel from several water systems). This estimate may be conservatively high for planning purposes, but data are not available to determine actual seasonal patterns. If summer water use in the region does increase by about 50%, conservation programs could target reductions in irrigation in two ways. One approach would target outdoor water use on an ongoing basis to reduce average water use. This approach might include outdoor water metering and separate prices, outdoor water use restrictions (e.g., designated watering days), building codes to limit automatic watering systems, and incentives for property owners to invest in drought tolerant landscaping. Another approach would be to impose restrictions and escalating fines for outdoor water use during periodic drought conditions. This approach may be attractive for localities whose water supplies are particularly vulnerable to drought conditions (such as those with little or no storage).

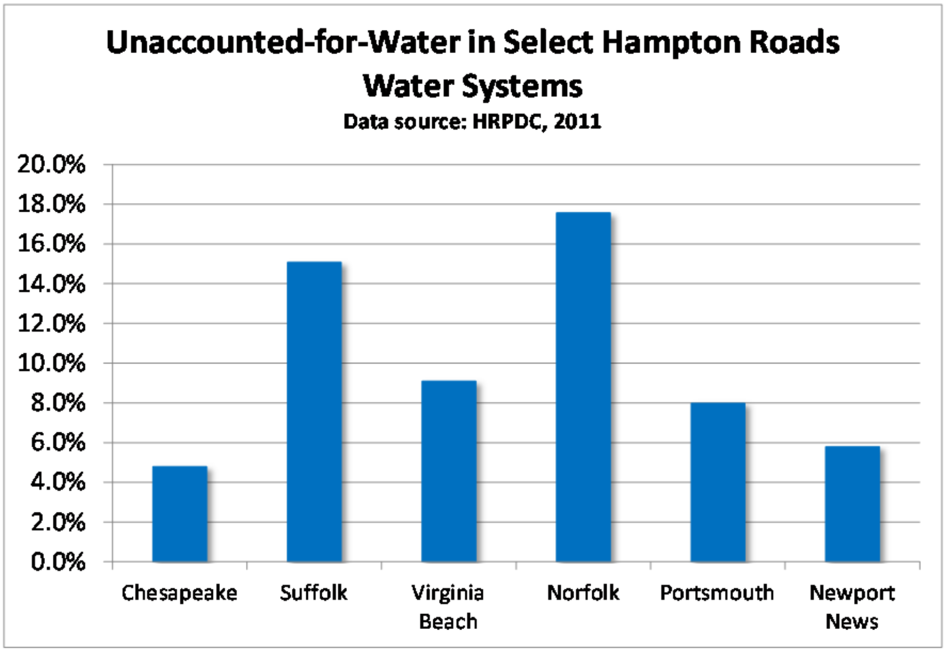
Exhibit 3-6: Residential Per Capita Water Use



Data on the effectiveness of outdoor water conservation methods are mixed. Kenney et al. (2008) reviewed the literature and report that mandatory restrictions have shown to be very effective, with up to 30% reductions in total water use, while voluntary programs are much less effective. Halich and Stephenson (2009) found similar levels of reduction during the 2002 drought in Virginia. Data on other approaches are more limited. Costs for these approaches will vary from situation to situation but may include capital costs for meters and separate distribution systems, costs for public communications, and costs to support enforcement of codes, regulations, or water use restrictions.

Another water conservation strategy is to invest in reducing water that is lost to leaks or in other ways between treatment plants and end customers (typically labeled "unaccounted-for water"). It is typically calculated as the difference between the amount of water fed into the drinking water distribution system (after treatment or straight from groundwater wells) and the amount of metered water used by customers. Unaccounted-for water varies from location to location, with older water systems typically experiencing greater losses. Exhibit 3-77 shows unaccounted-for water percentages in several Hampton Roads region's public water systems. There is no industry standard for what percentage of unaccounted-for water is acceptable or optimal. Reducing unaccounted-for water would require investments in technologies to detect leaks and investments to repair leaks, such as repairing or replacing pipes.

Exhibit 3-7: Unaccounted-for Water



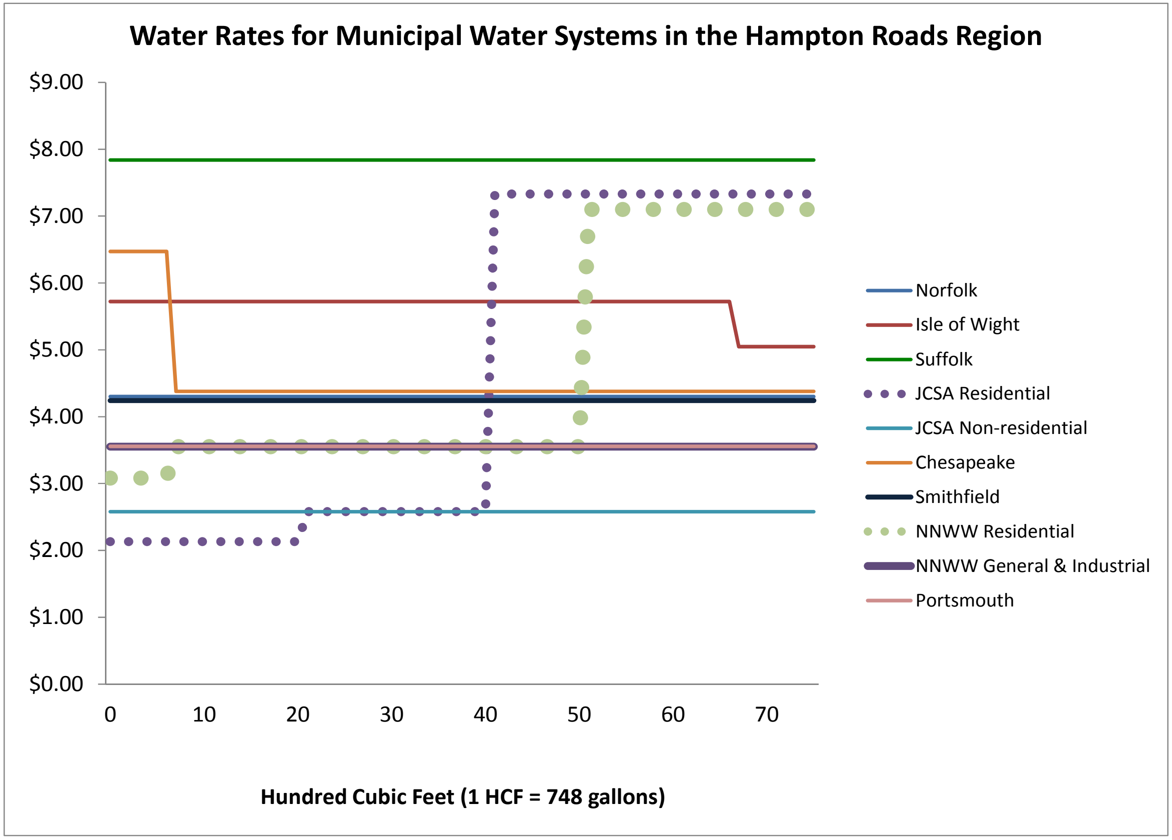
The State or EVGWMA localities will want to match future use and supply. In so doing, they will need to compare the timeliness, transaction and investment costs, reliability and acceptability of further water conservation actions to various supply-side solutions. The literature on residential water demand has expanded in recent years, especially quantitative studies of the effectiveness of various conservation practices, including pricing, though there is no clear quantitative evidence on which approaches are most effective in general or in particular situations (Kenney et al, 2008). Some economists (see Olmstead and Stavins, 2009) argue that price signals offer the most efficient approach for reducing water use, though there are often concerns about social justice given the importance of water for basic quality of life. Exhibit 3-8 shows price structures for the region's localities. It is commonly argued that water utilities should use increasing block rate structures in order to charge socially fair prices for basic water use, but higher prices for less essential uses, such as lawn irrigation. Only two of the public water systems in the Hampton Roads region use increasing block rate structures (Newport News Waterworks and James City Service Authority).

While many communities in the region do not use increasing block rate structures, overall monthly water costs, which may be more important in driving consumption behavior (Olmstead and Stavins, 2009), appear to be comparable to other U.S. cities. Exhibit 3-9 shows the monthly water bill that would be generated by a household of four using 100 gallons per person per day. This information is shown for the same sample of U.S. cities discussed above (Walton, 2010, 2013) and the Hampton Roads public water systems. From the sample of 21 U.S. cities, the median monthly cost is $52.00 and the median for eastern cities is $52.52. Most of the Hampton Roads communities fall within the upper range of the larger sample, and all but one is higher than the median of the larger sample. It is important to note that these numbers do not include costs for wastewater collection and treatment, which are charged for total water use (i.e., outdoor water use is not metered separately). Because of water quality goals for the Chesapeake Bay, wastewater charges for Hampton Roads communities tend to be high and have been increasing.

The opportunities for water conservation and the cost-effectiveness of various strategies will differ from locality to locality. Each locality will need to consider current water use profiles of their customers (e.g., penetration of water efficient washing machines or low flow shower heads, irrigation behavior) in order to understand the water conservation opportunities. Water prices in the Hampton Roads region are already high compared to other U.S. cities, though not among the very highest. There may be opportunities for reducing water losses in some systems, but none of the loss rates are exceptionally high. Data on outdoor water use are limited, but available peaking factors for summer water demand suggest there may be opportunities for reductions in this category. The bottom line is that residential water use in the region appears to be comparable to other cities, though it could be reduced more. Each community will need to assess the particulars of its system and its customers to understand which approaches might be most cost-effective. Standard methods for planning water conservation may prove useful (e.g., American Water Works Association, 2006).

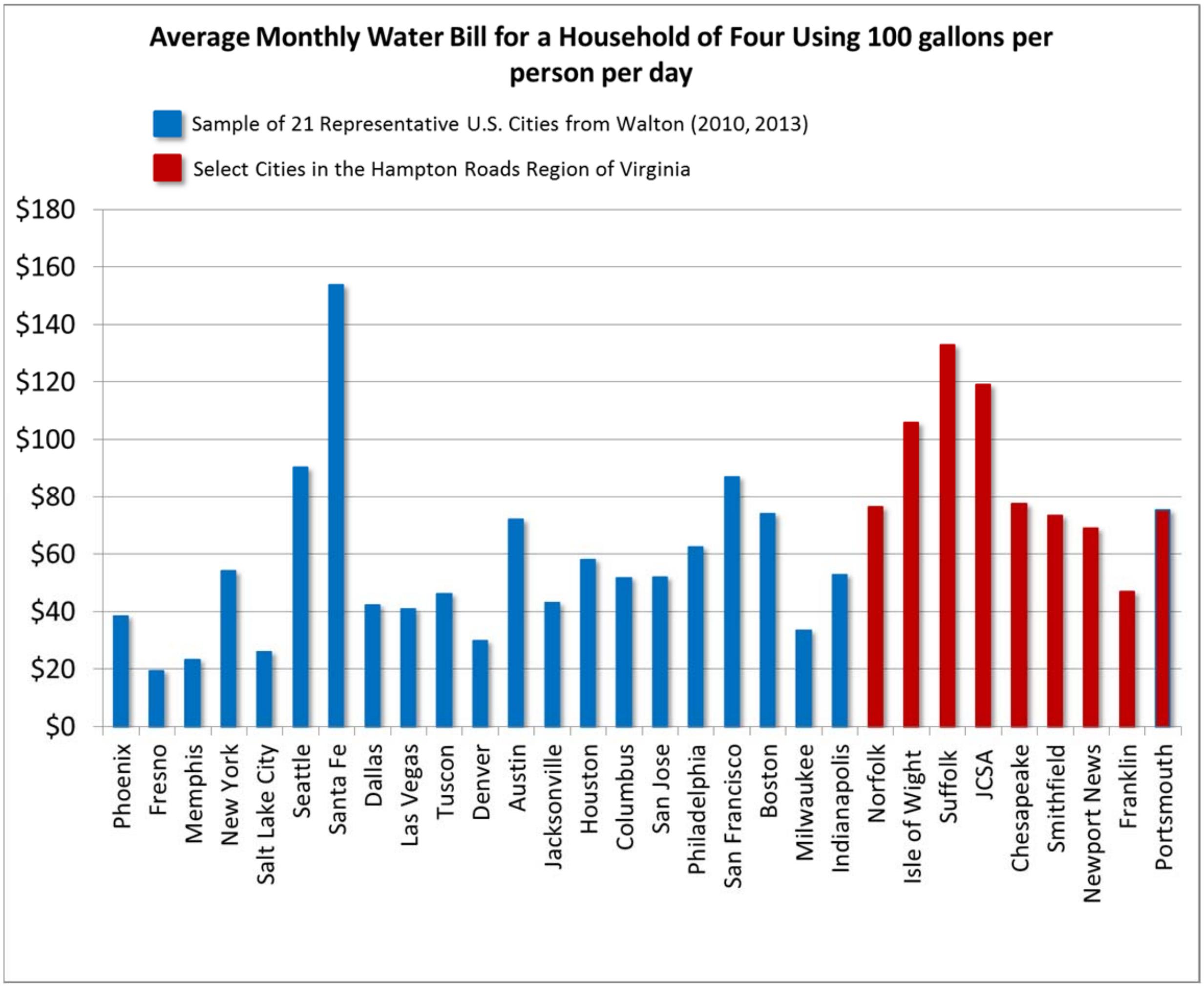
Commercial and industrial water uses are more varied and, therefore, so are opportunities for conservation in these sectors. Conservation options for each of the large industrial groundwater users are discussed in Section 4.

Exhibit 3-8: Water rates in the Hampton Roads Region



All rates shown are billed bi-monthly
Chesapeake charges a minimum of $38.82 for up to six hundred cubic feet per cycle; this is shown as a rate of $6.47 per HCF
Newport News Waterworks charges Industrial customers $3.08 per HCF above 40,000 HCF per bi-monthly billing period.

Exhibit 3-9: Monthly Water Costs for a Household of Four



4. Impacts to Groundwater Users

As described in Section 1, possible groundwater withdrawal targets are as follows:

- Total withdrawals among current permitted and unregulated users across the entire EVGWMA: 90 to 100 MGD;
- Total withdrawals among permitted users in the original EVGWMA: 55 to 65 MGD; and
- Total withdrawals among unregulated self-supplied users: 30 MGD.

This section of the report focuses on possible economic consequences to maintain total withdrawals among the permitted sector in the original EVGWMA between 55 and 65 MGD. More than half of total withdrawals from the Virginia Coastal Plain aquifers are in this sector, and the total permitted capacity is much higher than current use. In addition, DEQ already has the authority to regulate withdrawals in this sector. Therefore, this section focuses on the economic impacts of reducing permitted capacity and groundwater use through the implementation of existing permitting authorities.

The largest 14 groundwater users represent over 90% of current use and permitted capacity (see Exhibit 4-1).[16] Therefore, if permitted groundwater useis reduced many or all of the largest 14 users will be impacted. The remaining permitted sector represents only about 4.4 MGD of current use in the original EVGWMA. New actions may apply to these smaller permitted users as well, but the potential benefits for reducing load on the aquifer are small.

4.1 Permit Reduction Strategies

The largest 14 users have current permitted capacity of about 100 MGD. As shown in Exhibit 4-1, groundwater withdrawals in 2012 totaled about 54 MGD. To maintain withdrawals within a target between 55 and 65 MGD, DEQ will have to cut back the permitted amounts substantially. Under current law and regulations as implemented by DEQ, DEQ would need to determine which groundwater users will be cut back and by how much.

DEQ can employ numerous alternative allocations to reduce groundwater use and each alternative will impact individual groundwater users in different ways. DEQ currently is required to limit groundwater use according to the 80% criterion. Conceptually, this approach limits groundwater withdrawals to reduce or avoid certain type of adverse impacts on other groundwater users. Another approach would be to reduce permit amounts to match levels of recent use. If these reductions were applied across the board, total groundwater permitted capacity would fall within the preliminary target range of 55 to 65 MGD. Other prioritization schemes can also be based on various economic criteria. For instance, one need-based criterion would grant priority access to users whose only source of water is groundwater and reduce permitted groundwater use to those users who already have alternative sources. The rationale behind this approach is that it would be more costly for users that rely solely on groundwater to develop new sources in anticipation of future growth than it would be for users with multiple sources to shift use

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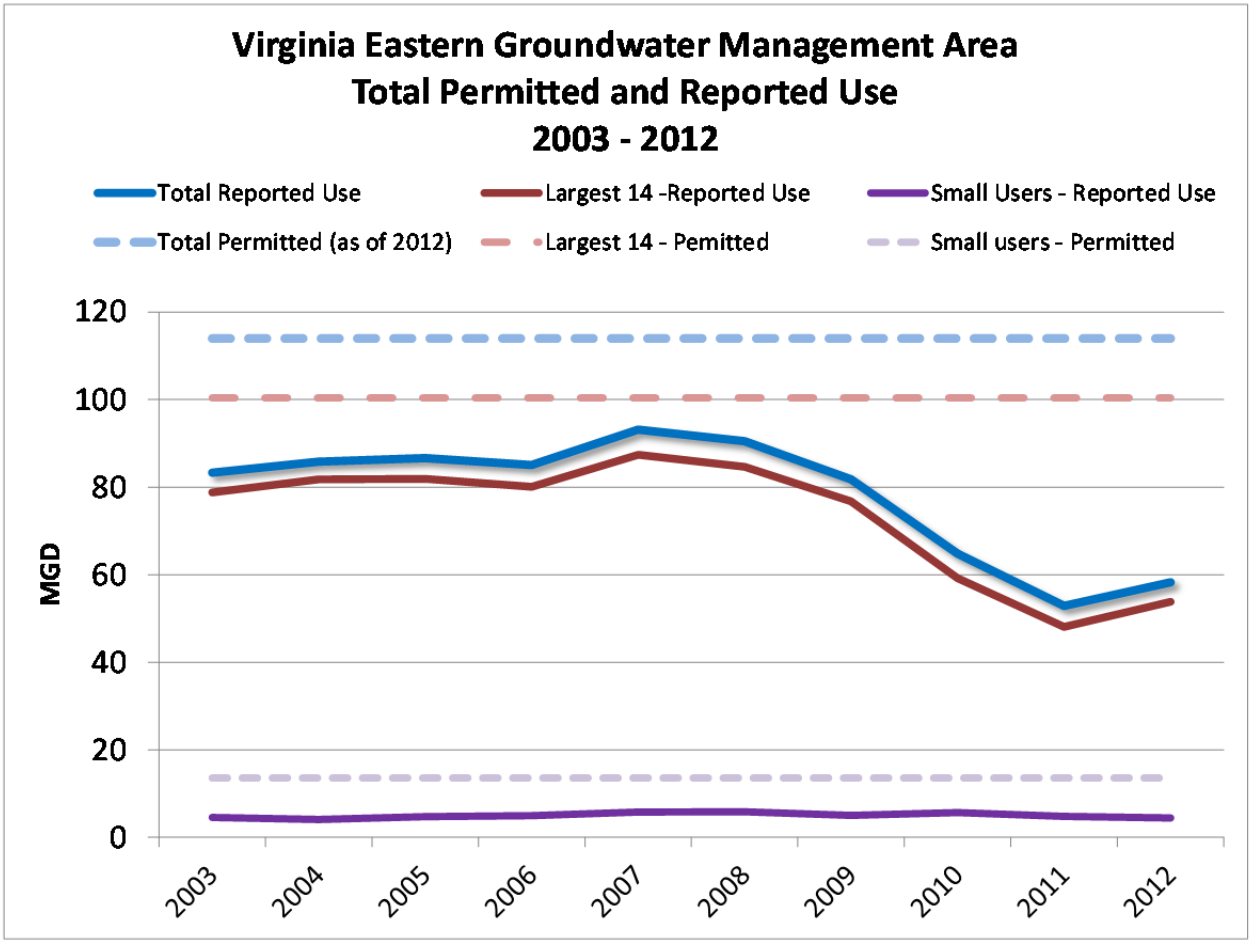
[16] For purposes of this discussion, Portsmouth Utilities, which operates under a Certificate of Groundwater Rights, is included as one of the large permitted users. Portsmouth Utilities is in the process of obtaining a groundwater withdrawal permit.

to existing surface water sources. An additional approach would be to move the largest users, particularly the two paper mills, off groundwater entirely, or for a significant share of their current use.

In the following sections, the potential impacts of potential groundwater permit reductions are characterized and, where possible, quantified. The discussion examines the potential impact of reduced groundwater on each municipal system's supply and compares these potential impacts to future water use projections. If the comparison suggests that a reduction in permitted groundwater withdrawals would leave the municipality with projected use in excess of water supply, the most likely alternative sources are discussed. Many of these alternatives were suggested during interviews with the municipalities. A similar discussion is presented for industrial users. In each case, the impacts of groundwater cutbacks are discussed and the potential costs of alternative sources or water use reduction practices are described.

Exhibit 4-1: Permitted totals and reported use among large and small groundwater users



The largest 14 includes Portsmouth Utilities, which currently operates under a Certificate of Groundwater Rights but is in the process of obtaining a groundwater withdrawal permit

4.2 Impacts of Potential Groundwater Cutbacks

4.2.1 Impacts on Chesapeake Utilities

Chesapeake relies on groundwater, surface water from the Northwest River, and purchases from other jurisdictions. Groundwater provides about one third of Chesapeake's current raw water supply, though current use is substantially less than the amount allowed under the existing permit. Chesapeake's average use from 2003 to 2012 was 4.2 MGD. If Chesapeake's groundwater permit allocation were cut back to 4.2 MGD, the authors assumed for this analysis that this reduction would be split across Chesapeake's Northwest River and Western Branch wells in about the same proportion as their current permit. This split would mean about 1.9 MGD for the Northwest River wells and about 2.3 MGD for the Western Branch, reducing Chesapeake's current and future finished water supply by about 5.9 MGD.

Exhibit 4-2 shows the effect of permit cutback to current use levels on Chesapeake Utilities' finished water supply and compares the reduced supply to future water use projections. The future water supply figures include new water supplies that representatives of Chesapeake indicated they plan to bring online within the time horizon of this investigation, including the Lake Gaston Pipeline coming online between 2020 and 2030.

Exhibit 4-2 supports several conclusions. First, if per capita water use in Chesapeake has dropped as it has elsewhere in the region and does not rebound, then even with groundwater reduced to 4.2 MGD, Chesapeake is likely to have sufficient supply to serve future water use through at least 2040 (see the bottom two rows of Exhibit 4-2). If per capita water use has not dropped in Chesapeake or if it rebounds to levels experienced in 2004-2008, then reducing Chesapeake's groundwater to current use may have more impact. Under these higher water use projections, supply may be just barely sufficient by 2040 and would likely carry enough risk of shortfall to push Chesapeake to make new investments in alternative supply or conservation (beyond those already planned).

Exhibit 4-2: Chesapeake Finished Water Yield and Future Use with Groundwater Permit Cut to Recent Use (4.2 MGD)

	2020	2030	2040
Yield with Current Permit and other planned resources	29.8	33.3	33.3
Yield with Reduced Permit (4.2 MGD)	23.9	27.4	27.4
Yield with Zero Groundwater	20.3	23.8	23.8
Project future water use (MGD)			
From HRRWSP, 2011	24.4	28.7	33.1
Flat GPCD, HRPDC New Pop. Growth	21.7	24.3	26.9
Flat GPCD, Cooper Ctr. Pop. Growth	21.7	24.5	27.4
14% drop in GPCD, HRPDC New Pop. Growth	18.6	20.9	23.2
14% drop in GPCD, Cooper Ctr. Pop. Growth	18.7	21.0	23.5

Restricting Chesapeake's groundwater use further (i.e., less than 4.2 MGD) is more likely to have a significant impact. With zero groundwater, Chesapeake's supply would be insufficient, as soon as 2020, if water use tracks along the higher estimates shown in Exhibit 4-2.

This analysis suggests that if its groundwater withdrawal permit were reduced to 4.2 MGD, Chesapeake would be unlikely to make new investments in alternative supply or conservation to replace the forgone groundwater before 2030. When Chesapeake does require additional water supply, their options may be limited. Their permit for surface water from the Northwest River is already quite restrictive and it is unlikely that they would get necessary permits for increasing those withdrawals. Chesapeake could pursue additional purchases from the neighboring cities of Portsmouth or Norfolk. For example, Chesapeake could negotiate to extend its finished water purchase from Portsmouth beyond 2026 or increase its purchases from Norfolk. Chesapeake's current costs for purchased water are $1.26 per 1,000 gallons for raw water and $7.13 for finished water. As described earlier, Chesapeake injects about 1 MGD of excess finished water into its ASR project and it has injected a total of 2.6 billion gallons. If Chesapeake was credited for augmenting groundwater supply, the ASR water could provide a small amount of additional supply at relatively low incremental cost (i.e., it is less expensive to run the treatment plant at a constant level and inject excess finished water than it is to ramp up and down at the plant).

In addition, a groundwater permit cutback could limit Chesapeake's ability to pump sufficient water from the Western Branch wells to meet targets for fluoride in its finished water. If their Western Branch permitted amount becomes too low to meet fluoride targets, they would need to invest in a fluoridation process to make up the difference. Finally, a reduced permit would leave Chesapeake's Northwest River reverse osmosis plant underutilized, creating a stranded asset.

Conclusions: *The City of Chesapeake is highly reliant on groundwater today and has made investments that anticipate access to groundwater in the future. A reduced permit could result in a need for new water supply by 2040. Without any additional groundwater beyond current use, or with reduced groundwater access, the city would be highly likely to pursue new sources by 2020. Reduced groundwater would result in a partially stranded asset (the Northwest River reverse osmosis plant).*

4.2.2 Impacts on the City of Franklin

Groundwater is currently the only source of water for the City of Franklin. Because they do not need to treat their groundwater, their finished water supply is the same as the amount allowed in their groundwater withdrawal permit, 2.88 MGD. Reductions in the groundwater permit would result in the same reduction to the city's water supply. The current permitted amount is more than enough to meet likely future water use. The City's average use from 2003 to 2012 was about 1.1 MGD. Reducing the permit to this amount to current use would likely leave the city with insufficient supply to meet the lowest water use projections, perhaps before 2020.

The City reported that their permit is expired and that DEQ is considering reducing their allowable withdrawal to 1.5 or 1.6 MGD. The water use projections shown below suggest that 1.6 MGD would likely be sufficient to meet the city's needs through 2040.

Exhibit 4-3: Franklin Future Water Use (MGD)

	2020	2030	2040
From HRRWSP, 2011	1.3	1.4	1.6
Flat GPCD, HRPDC New Pop. Growth	1.2	1.3	1.4
Flat GPCD, Cooper Ctr. Pop. Growth	1.3	1.4	1.5
14% drop in GPCD, HRPDC New Pop. Growth	1.1	1.2	1.2
14% drop in GPCD, Cooper Ctr. Pop. Growth	1.1	1.2	1.3

If Franklin needed an alternative source of water, their options would be limited. The city is located along the Blackwater River, but they report that additional surface water withdrawals from the Blackwater River are not available due to existing withdrawals from the river. Norfolk draws water from the Blackwater and HRPDC (2011) reports that there are no permit limits to Norfolk's withdrawals from the river. The Franklin Paper mill also takes water from the Blackwater River. Another potential option would be for Franklin to tap into Virginia Beach's Lake Gaston pipeline, which passes roughly 10 miles north of Franklin (Franklin previously declined to participate in the Lake Gaston project). Rates for raw water purchases in the region are $1.25 per 1,000 gallons and are usually adjusted annually for inflation; purchasing Lake Gaston water from Virginia Beach is likely to have a similar price. If the city pursued a new surface water source, they would need to build a new water treatment plant. Using estimates from EPA (2007), a conventional plant with a capacity of 2 MGD could cost between $5.8 and $29.6 million.

Another option would be to purchase finished water from a neighboring city. Portsmouth sells finished water to Chesapeake and the WTWA, with prices between $4.16 and $7.13 per 1,000 gallons. Franklin does not treat its groundwater and currently charges customers $3.78 per 1,000 gallons for water, which would include debt service and costs for operations and maintenance of the system. Paying over $4.16 per 1,000 gallons would represent an increase in costs, and could drive up water rates in the city. In addition to the water cost, this option would require Franklin to construct a pipeline and other infrastructure to bring water in from a neighboring city. There are many variables that would drive the cost for such a pipeline, including cost for rights of way, but published unit costs (e.g., Town of Vienna, 2011; South Central Texas Regional Water Planning Group, 2011) suggest that a pipeline from Portsmouth to Franklin, which would span at least 35 miles, would cost tens of millions of dollars to construct. A short pipeline (<5 miles) connecting Lake Prince and Lake Cohoon cost WTWA about $5.1 million in 2003 (HRPDC, 2011).

These options could be cost prohibitive for a small city like Franklin. As such, the city reported that its most likely course of action if it needed more water supply would be to request from DEQ a new permit with a higher allowable groundwater withdrawal.

<u>Conclusions:</u> *Groundwater is the sole water source for the City of Franklin, and alternatives are limited. Current permit amount of 2.88 MGD is well in excess of projected future water use and reductions in the permit are unlikely to result in new investments by the city. With higher than average per capita water use, there may be opportunities for new conservation.*

4.2.3 Impacts to James City Service Authority

Groundwater is the primary source of water for JCSA and the only source they control independently. JCSA also has a contract to purchase finished water from Newport News, but they are not yet buying this water (the amount may vary, see section 2.3.5). JCSA's Central System has a groundwater withdrawal permit for 8.83 MGD and used an average of 5.2 MGD between 2003 and 2012.

Exhibit 4-4 compares the supply that JSCA would have with current and reduced groundwater permits, different levels of water purchases from Newport News, and a range of future projections for water use. The water supply estimates assume treatment losses of 30% for JCSA's groundwater, which is brackish and treated with reverse osmosis.

JCSA's current water supply (groundwater at 8.83 MGD, minus 30% treatment losses, plus 4 MGD from NNWW) is likely to be sufficient to meet future water use through 2040, though the highest of the newly updated water use projections equals their current supply. If JCSA's groundwater permit is reduced to recent use (~5.2 MGD), supply would likely be insufficient to meet projected water use, potentially as soon as 2020. With groundwater reduced to 5.2 MGD, JCSA would likely begin buying water from NNWW in the near future, which would require an investment of at least $5-$6 million for pipelines and pump facilities.[17] The purchases would cost at least $1.22 per 1,000 gallons of water purchased (the amount varies with cost of treatment), though this is comparable to typical costs for reverse osmosis and may not represent any increase in cost to JCSA.

Exhibit 4-4: JCSA Yield and Future Use Scenarios

	2020	2030	2040
Potential water supply			
Finished water supply with current groundwater permit and 4 MGD from Newport News (MGD)	10.2	10.2	10.2
Finished water supply with current groundwater permit and 2 MGD from Newport News (MGD)	8.2	8.2	8.2
Finished water supply with reduced groundwater permit (~5.2 MGD) and 4 MGD from Newport News (MGD)	7.6	7.6	7.6
Finished water supply with reduced groundwater permit (~5.2 MGD) and 2 MGD from Newport News (MGD)	5.6	5.6	5.6
Project future water use (MGD)			
From HRRWSP, 2011	6.7	8.6	11
Flat GPCD, HRPDC New Pop. Growth	5.6	6.5	7.4
Flat GPCD, Cooper Ctr. Pop. Growth	6.1	7.9	10.2
14% drop in GPCD, HRPDC New Pop. Growth	4.8	5.6	6.3
14% drop in GPCD, Cooper Ctr. Pop. Growth	5.2	6.8	8.7

Assumes 30% losses for reverse osmosis treatment of brackish groundwater

Further, unless future water use tracks along the lowest of the projections in Exhibit 4-4, a reduced groundwater permit would likely force JCSA to make the second capital payment to NNWW to continue their purchase at 4 MGD (if they do not make this payment their purchase from NNWW decreases to 2 MGD; see section 2.3.5). Their supply with 5.2 MGD of groundwater and only 2 MGD of finished water from NNWW would be about 5.6 MGD; projected water use in 2030 ranges from 5.6 to 7.9 MGD, with all but one estimate exceeding 6.2 MGD. Therefore, with a reduced groundwater permit, JCSA would likely make the additional payment of over $25 million[18] to NNWW, plus at least $1.22 per 1,000 gallons for the purchases. In addition, JCSA reports that the payment would be financed, adding costs for debt service. A reduced groundwater permit would also result in a partially stranded asset because they would not need the full capacity of the reverse osmosis plant that is used to treat JCSA's brackish groundwater.

With a reduced permit (5.2 MGD range) and 4 MGD for NNWW, JCSA might still need more water supply by 2040. Reducing the permit further would increase the likelihood that JCSA will seek additional water (beyond the options already in their plans), perhaps as soon as 2020. The source and cost of additional alternative water supplies beyond the 4MGD from NNWW is unknown. The willingness and ability for NNWW to provide additional supplies is highly contingent on potential changes in their permitted groundwater withdrawals (see below).

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[17] This cost was provided by representatives of JCSA and is in 2013 dollars.

[18] The payment of $25 million is to be adjusted based on the Engineering News Record Building Cost Index, with the base value from January 2008. The current cost, using BCI through 2013, would be $28.95 million.

<u>Conclusions:</u> *Groundwater is the primary source of water for JCSA. Reducing permit levels to current use makes it highly likely that JCSA will need to make a capital payment of over $25 million to NNWW by 2019, and would need to secure additional supplies by 2040. Reduced groundwater would result in a partially stranded asset (the reverse osmosis plant used to treat brackish groundwater).*

4.2.4 Impacts to Newport News Waterworks

NNWW relies primarily on a surface water system to supply water to its customers. They currently have a groundwater withdrawal permit for 7 MGD, but average use between 2003 and 2012 was 1.7 MGD. The groundwater is brackish and is treated by reverse osmosis, which was brought online in 1990. They currently run one skid at the reverse osmosis plant so that it is available for rapid ramp up in case of an emergency. The groundwater is also used as drought emergency supply.

It is likely that NNWW's existing supply will be more than enough to meet future water use through at least 2040 (note that this discussion excludes their Lightfoot system, which serves a separate area). According to representatives from NNWW, DEQ is considering reducing their permitted groundwater withdrawal to an amount closer to current use, with provisions to increase withdrawals when certain drought conditions are met (similar to the recently updated permit for Norfolk). The potential impact of a reduction in their groundwater permit hinges primarily on whether future water use tracks along the higher or lower estimates produced for this report. If their permit is reduced to 1.7 MGD (ignoring any drought contingencies), their total supply would drop to about 48.6 MGD. This amount would be sufficient to meet many of the estimates of future water use developed for this report (see Exhibit 4-5), but could fall short of the higher estimates by 2030. NNWW provided data showing that water use has dropped by roughly 20% in recent years, suggesting the lower future water use projections may be more realistic. If future water use is close to the lower estimates in this report, NNWW would be unlikely to pursue any new sources of water before 2040 if its groundwater permit is reduced to 1.7 MGD, especially if a reduced permit included provisions for higher withdrawals during drought conditions. The reduction could impact operations and costs at its reverse osmosis plant that is used to treat the brackish groundwater.

Stemming from agreements with JCSA and Williamsburg to participate in the proposed King William Reservoir project, NNWW has commitments to sell 4 to 6 MGD to these communities. If NNWW's groundwater permit were reduced to 1.7 MGD, it may not have enough water to supply its own customers and maintain these sales commitments to JCSA and Williamsburg (e.g., if in 2040 NNWW's supply is 48.6 MGD and water use is in 2040 43.7 MGD, one of the lower estimates, they would not have enough for the 6 MGD of sales commitments). As noted above, NNWW reports a roughly 20% reduction in water use in recent years, suggesting that future use is more likely to follow one of the lower trends presented here. With the lower use projections, NNWW appears to have sufficient supply to meet its service area water use and sales commitments to JCSA and Williamsburg through 2030, but the total of their future water and sale commitments will approach available supply by 2040.

A reduced permit would result in a stranded asset: the Lee Hall reverse osmosis plant, which was opened in 1990 at a cost of $16 million. The plant's capacity is 7 mgd and a reduced permit would leave some of that capacity unused indefinitely.

Exhibit 4-5: Newport News Finished Water Supply and Future Use with Groundwater Permit Cut to Recent Use (1.7 MGD)

	2020	2030	2040
Supply with current permit	53.1	53.1	53.1

Supply with Reduced Permit (1.7 MGD)	48.6	48.6	48.6
Supply with Zero Groundwater	47.1	47.1	47.1
Project future water use (MGD)			
From HRRWSP, 2011	45.8	48.5	51.4
Flat GPCD, HRPDC New Pop. Growth	45.9	46.8	47.7
Flat GPCD, Cooper Ctr. Pop. Growth	46.6	48.7	50.8
14% drop in GPCD, HRPDC New Pop. Growth	39.5	40.2	41.0
14% drop in GPCD, Cooper Ctr. Pop. Growth	40.1	41.9	43.7
Current commitment for sales to other jurisdictions (MGD)	6	6	6

Conclusions: *Groundwater is a relatively small component of NNWW water supply, but a reduced permit or complete elimination of groundwater could make it difficult for NNWW to meet its future water use and sales commitments by 2040. With a reduced permit, NNWW could likely meet water supply commitments through 2030, especially if a reduced permit included provisions for elevated withdrawals during drought conditions. There is some chance that restricting NNWW's groundwater would limit their ability to sell water to JCSA, Williamsburg or localities. Reduced groundwater would result in a stranded asset (the reverse osmosis plant).*

4.2.5 Impacts to Norfolk Utilities

Norfolk's primary source of water is its system of surface water diversions and reservoirs. Norfolk uses groundwater to augment storage in its reservoirs. Norfolk's groundwater withdrawal permit was renewed in 2013. In the new permit, DEQ reduced the allowable withdrawal from 16 MGD to 3.74 MGD. Norfolk may withdraw more groundwater when drought conditions are met (up to 16 MGD per year under the most severe drought conditions), but its average over the 10-year life of the permit must not exceed 3.74 MGD. Before this new permit, Norfolk's allowable withdrawal was 16 MGD, with no restrictions. Available information (HRPDC, 2011) indicates that the reliable supply of Norfolk's system is 92.5 MGD, or 87.5 MGD after production and other losses. It is not clear what impact the new permit has on the system's reliable supply; it may very well be less than 92.5 MGD now, but it is beyond the scope of this report to investigate this issue in any detail. One conservative assumption is to assume that Norfolk's available supply is reduced by the difference in the baseline withdrawal amount (16 MGD – 3.74 MGD = 12.26 MGD), which, after losses, would result in a supply of about 75.2 MGD.[19]

Exhibit 4-6 summarizes supply and future water use estimates for Norfolk. Even with conservatively low estimates of supply (75.2 MGD), Norfolk has more than enough water to meet projected future water use and its commitments for water sales to other jurisdictions. The fact that Norfolk's existing permit allows for higher withdrawals in droughts probably increases this potential surplus. Even if groundwater withdrawals were restricted further, Norfolk appears to have a surplus of supply. As a result, Norfolk is unlikely to take any action to increase supply in response to its most recent groundwater permit or any future reductions that might result from new policies. Norfolk's surplus supply could be a source of water

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[19] Norfolk's safe yield is unlikely to be affected this much because they will increase groundwater withdrawals during droughts (up to their historical permitted use) and yield is typically defined as the amount of water that can be supplied during a critical drought (see Section 1).

for other jurisdictions or industrial water users, beyond those that already have contracts to purchase water from Norfolk.

Exhibit 4-6: Norfolk Yield, Future Use, and Water Sales Commitments			
	2020	**2030**	**2040**
High estimate of supply (MGD)	87.5	87.5	87.5
Low estimate of supply (MGD)	75.2	75.2	75.2
Project future water use (MGD)			
From HRRWSP, 2011	39.9	39.9	39.9
Flat GPCD, HRPDC New Pop. Growth	30.0	30.4	30.8
Flat GPCD, Cooper Ctr. Pop. Growth	30.7	31.5	31.7
14% drop in GPCD, HRPDC New Pop. Growth	25.8	26.2	26.5
14% drop in GPCD, Cooper Ctr. Pop. Growth	26.4	27.1	27.3
Commitment for sales to other jurisdictions (MGD)	15	20	24

Conclusions: *Groundwater is a relatively small component of Norfolk's water supply and the city is likely to have excess supply through at least 2040, even if its groundwater is reduced further.*

4.2.6 Impacts to Portsmouth

Portsmouth relies primarily on supply from surface water reservoirs, but uses groundwater to augment storage in those reservoirs. The reliable supply from the reservoir system is 19.1 MGD (HRPDC, 2011). They operate under a Certificate of Groundwater Rights which allows 5.4 MGD of withdrawals under normal conditions (labeled "production wells") and an additional 6.2 MGD in drought conditions. Portsmouth is currently in the process of applying for a permit for its groundwater withdrawals. Portsmouth's average use from 2003 to 2012 was 3.5 MGD. It is not clear how the additional withdrawals in drought conditions affect total reliable supply. For purposes of this discussion, it is assumed that Portsmouth's total water supply is the sum of its surface water supply and its production wells. After 12.2% production losses (see attachments to HRPDC, 2011), the total supply is 21.5 MGD.

If Portsmouth's allowable groundwater withdrawal is reduced to 3.5 MGD (average recent use), then the city's water supply would be reduced to 19.8 MGD. Exhibit 4-7 compares Portsmouth's supply with a reduced groundwater allocation and multiple projections of future water use. Portsmouth's reliable supply is more than enough for projected water use within its system. With commitments to sell up to 5 MGD of water to Chesapeake from 2020 to 2026 and 2 MGD to WTWA through 2040, Portsmouth's excess supply will be lower through 2026. If water use in Portsmouth grows according to the higher projections presented here (i.e., if per capita water use has not declined or rebounds) then there is some chance that Portsmouth will have to cut back on its sales to Chesapeake and/or WTWA. This investigation suggests that Portsmouth is unlikely to pursue additional resources or conservation measures if their groundwater permit is reduced to 3.5 MGD or less.

Exhibit 4-7: Portsmouth Yield, Future Use, and Water Sales Commitments			
	2020	**2030**	**2040**
Yield with current permit (MGD)	21.5	21.5	21.5
Yield with Reduced Permit (3.5 MGD)	19.8	19.8	19.8
Yield with Zero Groundwater	16.8	16.8	16.8

Exhibit 4-7: Portsmouth Yield, Future Use, and Water Sales Commitments			
	2020	**2030**	**2040**
Project future water use (MGD)			
From HRRWSP, 2011	11.4	11.6	11.8
Flat GPCD, HRPDC New Pop. Growth	10.8	10.9	11.0
Flat GPCD, Cooper Ctr. Pop. Growth	10.7	10.9	11.2
14% drop in GPCD, HRPDC New Pop. Growth	9.3	9.3	9.4
14% drop in GPCD, Cooper Ctr. Pop. Growth	9.2	9.4	9.6
Current commitment for sales to other jurisdictions (MGD)	7.54	2.54	2.54

Conclusions: *Groundwater is a relatively small component of Portsmouth's water supply and the city is likely to have sufficient through at least 2040, even if its groundwater is reduced to current use. Groundwater reductions could limit Portsmouth's ability to sell water to neighboring jurisdictions.*

4.2.7 Impacts on the Town of Smithfield

Smithfield relies entirely on groundwater for its water supply. The Town's current permit, which was renewed in 2013, reduced its allowable withdrawal from 1.8 MGD to 1.27 MGD. The water is treated by reverse osmosis to reduce fluoride levels and current treatment losses reach 16%, but they plan to reduce losses through improved operations. Town representatives indicated that they are comfortable with 1.27 MGD for the next 10 years; however, the highest water use projections developed for this report (see Exhibit 4-8) suggest that the town may bump up against that allowable withdrawal limit by 2020.

Alternative water sources for the town may be considerably more expensive. In recent years, they had an opportunity to join Isle of Wight County in purchasing water from Norfolk, but decided it would be more economical for the town to build the reverse osmosis treatment plant and continue using groundwater. Costs for purchasing finished water in the region currently range from about $4.16 to $7.13 per 1,000 gallons.[20] Smithfield currently charges customers $4.24 per 1,000 gallons, which would cover capital, variable treatment costs and other costs. Therefore, purchases from other cities at the rates above would likely be more expensive than Smithfield's current groundwater source. The town could consider surface water sources, but this would require new treatment capabilities for disinfection and other purposes, which might be cost prohibitive (using data from EPA [2007], a 1 MGD plant could cost from $2.9 to $14.8 million).

Conclusions: *Groundwater is crucial for the Town of Smithfield, and alternatives may be considerably more expensive. The current permit amount of 1.27 MGD may be insufficient for projected water use as soon as 2020. Reducing the permit further would likely force the city to seek alternative supplies, such as purchases from neighboring cities. With higher than average per capita water use, there may be opportunities for new conservation.*

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[20] These are based on purchases from Portsmouth Utilities. No information is available on rates for finished water purchases from Norfolk.

Exhibit 4-8: Smithfield Projected Future Water Use (MGD)

	2020	2030	2040
From HRRWSP, 2011	1.5	1.8	2.3
Flat GPCD, HRPDC New Pop. Growth	1.6	1.9	2.3
Flat GPCD, Cooper Ctr. Pop. Growth	1.4	1.6	1.7
14% drop in GPCD, HRPDC New Pop. Growth	0.9	1.0	1.2
14% drop in GPCD, Cooper Ctr. Pop. Growth	0.8	0.8	0.9

4.2.8 Impacts on Western Tidewater Water Authority

WTWA's largest current source of water is groundwater, but the Authority also relies on a small surface water reservoir and purchases from other utilities. Their current groundwater withdrawal permit is for 8.34 MGD. Their surface water supply is about 1.2 MGD and they buy up to 2.54 MGD of finished water from Portsmouth. Finally, WTWA has a contract with Norfolk to purchase raw water. That contract allows for 3 MGD of raw water starting in 2014 and increases by 1 MGD every other year, up to a maximum of 15 MGD. WTWA does not yet have treatment facilities to begin using the water from Norfolk and plans to expand treatment facilities to use that water in order to serve future growth. WTWA's average groundwater use from 2003 to 2012 was 3.4 MGD.[21]

Exhibit 4-9 summarizes WTWA's finished water supply and future water use projections. WTWA reports that the water from Norfolk and the necessary treatment plant make up their long-term water supply plan and they expect to begin investing in the new treatment facility within 5-10 years. Exhibit 4-9 adds the Norfolk water starting in 2030. The supply from WTWA's surface water sources, groundwater withdrawals and existing purchase contracts are likely to exceed projected water use through 2040. Yield without Norfolk water and a reduced groundwater permit would be about 9.6 MGD in 2020, which is less than the higher water use projections. Therefore, reducing WTWA's groundwater permit might increase the urgency for WTWA to invest in the treatment plant for purchased raw water from Norfolk and might lead them to initiate the project and incur capital and debt costs sooner. A 15 MGD conventional treatment plant could cost $43.5 to $222 million (EPA, 2007). WTWA expressed concern about the fact that each member locality has among the highest rates in the region (see Exhibit 3-8) and that investing in new infrastructure sooner than absolutely necessary would drive those rates even higher.

In addition, a reduced groundwater allocation would result in a partially stranded asset as WTWA would be unable to use the full capacity of the EDR (electrodialysis reversal) plant that was brought online in 2008; the Authority is still servicing debt from that investment.

<u>Conclusions:</u> *Groundwater is the primary source of water for WTWA, with planned purchases from Norfolk providing an increasing share beyond 2020. A reduced groundwater permit would make it highly likely that WTWA will invest sooner in infrastructure to begin using purchased water from Norfolk. Reduced groundwater would result in a partially stranded asset (the electrodialysis reversal plant which was opened in 2008).*

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[21] WTWA was established in 2009; groundwater use data from before 2009 combines use from WTWA member jurisdictions (Suffolk and Isle of Wight County).

Exhibit 4-9: WTWA Finished Water Yield and Future Use			
	2020	**2030**	**2040**
Yield with all available resources (MGD)	14.2	21.4	25.0
Yield with Reduced Permit (3.4 MGD)	9.6	16.8	20.4
Yield with Zero Groundwater	6.4	13.6	17.2
Project future water use (MGD)			
From HRRWSP, 2011	12.6	17.7	20.2
Flat GPCD, HRPDC New Pop. Growth	10.4	13.3	16.2
Flat GPCD, Cooper Ctr. Pop. Growth	8.8	10.6	13.9
14% drop in GPCD, HRPDC New Pop. Growth	9.2	11.8	14.4
14% drop in GPCD, Cooper Ctr. Pop. Growth	7.8	9.4	12.4

4.2.9 Impacts to the Franklin Paper Mill

International Paper's Franklin Paper Mill uses both groundwater and surface water. The mill reports that they draw about 2.4 MGD from the Blackwater River, which is used for seal water for some of their pumps. Groundwater is used for all other manufacturing processes. The mill is currently using about 13 MGD of groundwater and with anticipated growth it expects to use up to about 21 MGD within 10 years. Most of the groundwater is not treated, but about 0.7 MGD for a boiler is treated with reverse osmosis. Baseline costs for the untreated water are minimal, consisting of capital and O&M costs for the wells and pumps.

Representatives of the mill report that alternative water sources are not feasible for the mill because of the need for high quality water to meet regulatory or voluntary standards for their products, as well as maintenance issues (e.g., scaling in boilers when using lower quality water). If the Franklin Mill's groundwater permit were reduced below current or expected future needs, the mill could consider several alternatives. The mill might be able to use more water from the Blackwater River, but it would require treatment to remove solids/sediment and perhaps other contaminants. The cost of the necessary treatment plant could run into the tens or hundreds of millions of dollars (depending on capacity and level of treatment).

Reusing wastewater from the mill could also be an option. In addition to costs (see Appendix 2 for examples), the mill worries that reusing wastewater would erode trust in their products in some of their markets (as discussed in section 3.2.2), which would hurt sales. This was especially true for reusing municipal wastewater but reusing the mill's wastewater could also pose a concern. Wastewater reuse costs can range from $1.6 million to $12.3 million per MGD of capacity when treating to drinking water standards (NRC, 2012), and $0.47 million to $4.6 million for non-potable uses. There may be opportunities at the Franklin Mill to use surface water or reuse wastewater for portions of their operations that would not bring these water sources in contact with finished products, which could avoid the market risk. However, available information suggests that non-contact water use in bleach kraft operations is a small portion of overall water use, roughly 10% (Kramer et al, 2009). This information suggests that there may be 1-2 MGD of potential non-contact water that could be supplied from surface water or treated wastewater.

While the mill reports that its water use intensity (gallons of water used per ton of output) is within industry standards, no data are available to examine the details. It is possible that the mill could invest in internal water recycling technologies (i.e., processes for using water more than once in the production process before discharge) so that it could maintain current and planned future output with less water. The extent and cost of achieving reductions in groundwater withdrawals from such investments is uncertain.

In any case, International Paper would conduct cost-benefit analysis and make a business decisions about whether it could invest in one of these alternative sources and maintain profitability at the Franklin Mill. Given the recent shutdown of the mill, it is unknown whether it is financially feasible to make major new investments in water sources and keep the mill profitable.

Conclusions: *Groundwater is the primary source of high quality water for the Franklin Mill. If the mill's groundwater withdrawal permit is reduced below expected future use (20.6 MGD), incremental gains in water use efficiency is possible, but the cost and extent to which water reductions could be achieved is uncertain. Large scale alternative water supply sources do not currently exist. The mill might instead opt to reduce production.*

4.2.10 Impacts to the West Point Mill

The West Point Mill relies entirely on groundwater for its operations. It has a groundwater withdrawal permit for 23.03 MGD and withdrawals averaged 19.98 MGD from 2003 to 2012. The mill expects to increase use to near its current permit amount as it expands production of bleach kraft products. Most of the groundwater is not treated, but about 2.6 MGD for boilers is treated with reverse osmosis. Baseline costs for the untreated water are minimal, consisting of capital and O&M for the wells and pumps.

The West Point mill is investigating the feasibility of several options for alternative water sources. First, it is studying whether river bank pumps along the Pamunkey River would be a feasible option. In the past there has been local opposition to the mill using water from the Pamunkey because of possible impacts on the sport fishery. River bank pumps are expected to have less impact on aquatic resources. In addition, the West Point mill is studying the possibility of using treated wastewater from the town of West Point to run its air emissions scrubbers, which would offset less than 1 MGD of groundwater use. Costs for implementation would include a pipeline stretching up to one mile and pump facilities, perhaps exceeding $2 million (Rock Tenn's study will produce specific costs estimates). As discussed earlier, the West Point Mill could make investments to reuse its own treated wastewater. Reusing wastewater in the paper-making process could bring regulatory or market risks (see section 3.2.2) but the mill could establish wastewater reuse for processes that do not contact the final product, such as energy generation. As noted earlier, non-contact water in bleach kraft operations tends to be about 10% of overall water use, suggesting about 2 MGD at the West Point Mill. Peer reviewed data (NRC, 2012) indicates non-potable wastewater reuse costs from $0.47 million to $4.6 million per MGD of capacity, or $0.94 to $9.2 million for 2 MGD of potential non-contact water at West Point.

The mill reports that water intensity at the plant is lower than industry average for bleach kraft products, largely due to past investment in efficiency and internal recycling. While the mill could likely reduce its water intensity further, they report that the most cost-effective projects have already been completed. The extent and cost to which water use could be reduced through new water conservation investments, however, could not be estimated within the timeframe of this report.

With a reduced groundwater permit, Rock Tenn would investigate the engineering and cost feasibility of the options discussed above. The mill might also investigate the possibility of reducing production or shifting to less water intense products (such as unbleached products).

Conclusions: *Groundwater is the primary source of high quality water for the West Point Mill. If the mill's permit is reduced below anticipated future use (23.03 MGD), the most likely alternative sources would require more treatment and could be too costly to maintain profitability. The mill might instead opt to reduce production or shift to less water intensive products.*

4.2.11 Impacts to Ashland, Inc.

The chemical facility owned by Ashland, Inc. (formerly owned by Hercules, Inc.) relies entirely on groundwater for three manufacturing and other processes. Its groundwater withdrawal permit allows for 6.67 MGD, but recent use has averaged 3.17 MGD. They treat a small amount of the water with reverse osmosis (water for boilers); the rest is not treated.

If Ashland's groundwater withdrawal permit were reduced, a likely alternative would be for the plant to increase internal recycling. As discussed in section 2.4.7, Ashland has prepared a preliminary cost estimate for installing cooling towers and chillers that would enable recycling of water used for cooling of chemical reactions that are part of manufacturing processes. The study estimates that the necessary cooling towers and chillers would require capital investment of about $7 million and annual O&M costs of about $700,000 (both 2013 dollars) for cooling and chilling about 4.5 MGD given typical weather conditions for the region (the study was initiated when water use was higher before Ashland shut down a tall oil operation). Thus, recycling would cost about $1.6 million per MGD of capacity and about $155,000 in annual O&M costs per MGD. These estimates are consistent with estimates produced for other purposes. Information provided by Ashland suggests that about 94% of its water use is available for recycling; 94% of recent use is about 3.0 MGD. Some water would be lost to evaporation, but the feasibility study does not provide this detail.

Surface water as an alternative to groundwater is less feasible for Ashland because of water quality and water temperature. The local surface water source would need to be treated with reverse osmosis or similar advanced technology to remove solids and other contaminants and it would need to be cooled. Recycling its groundwater as described above would be more cost effective. Reusing treated wastewater (e.g., from the City of Franklin or the Franklin Paper Mill, which are about 5 miles away) would bring similar water quality and temperature challenges.

Conclusions: *Groundwater is the primary source of sufficiently cool water for Ashland's chemical manufacturing processes. If Ashland's groundwater permit is reduced, the most likely alternative would be to install cooling towers for recycling cooling water, at a cost of about $1.6 Million per MGD of capacity.*

4.2.12 Impacts to Smithfield Packing Company, Inc.

Smithfield Packing relies entirely on groundwater, with a permit for 2.6 MGD and average recent use of about 1.7 MGD. The company does not treat the groundwater, so baseline costs for water are minimal, consisting of capital and O&M for the wells and pumps. Representatives of Smithfield Packing indicated that the facility has the room to grow, but there are no current plans to expand operations.

Smithfield Packing's groundwater withdrawal permit could be reduced to a level just above current use with minimal impact, since the plant has no immediate expansion plans. However, such a reduction could potentially constrain growth further out into the future.

Reducing the permit below about 1.7 MGD would require the company to make new investments in alternative sources and/or water use efficiency. The company reports that about 60% to 70% of their water use is for cleaning processing facilities each day, which amounts to roughly 1 MGD of recent water use. Because it is used for cleaning food processing equipment, high quality water is required. The company suggested that it would be challenging to use treated wastewater for this part of their operations (see section 3.2.2). To use treated wastewater, they would likely need to treat to drinking water standards; existing wastewater reuse case studies suggest that it would cost $1.6 million to $12.3 million for a 1 MGD capacity process (NRC, 2012). Alternatively, Smithfield could seek to use treated drinking water from the nearest municipal water system that uses surface water. The nearest source might be Portsmouth's treatment plant at Lake Kilby, which is about 18 miles from the Smithfield Plant. Purchases for finished water from Portsmouth range in price from about $4.16 to $7.13 per 1,000 gallons. For 1 MGD this could total $1.5 million to $2.6 million per year. In addition to the water cost, Smithfield would likely need to construct a pipeline to bring the water in from Lake Kilby, with potential of $6 million to $30 million.

As with the other industrial users, Smithfield Packing would have to evaluate the costs and benefits of these alternatives and would make a business decision about whether to invest in one of them. If they are not cost-effective, the company might choose to reduce production.

<u>Conclusions:</u> *Groundwater is the primary source of high quality water for Smithfield Packing, especially for cleaning food processing equipment. If Smithfield's permit is reduced below about 1.7 MGD, alternative water source (wastewater reuse or treated drinking water purchased from Portsmouth) could cost tens of millions of dollars. The company might opt to reduce production instead.*

4.2.13 Impacts on Portsmouth Genco

Portsmouth Genco relies primarily on groundwater for its thermal steam power plant in Portsmouth. Their groundwater withdrawal permit allows up to 2.6 MGD, but recent use has varied. Portsmouth Genco does have an agreement with the city of Portsmouth to use potable drinking water as a back-up supply. Most of the groundwater used is treated with reverse osmosis to removed dissolved solids.

As described earlier, the Portsmouth Genco plant was historically used for baseload power, but recent market conditions have driven the company to use the plant as a load-following power source. The company would like to maintain the ability to return to baseload operations in the future. Reducing the Portsmouth Genco's groundwater withdrawal permit could constrain their ability to do so. With less groundwater, the plant's most readily available alternative is to use water from the city of Portsmouth. Potable water from Portsmouth would be high quality and might not require treatment, but representatives of the company report that it exceeds the cost of withdrawing and treating groundwater. The current Portsmouth water rate is $4.75 per 1,000 gallons, while a typical O&M cost for reverse osmosis of brackish groundwater is $0.87 to $1.41 per 1,000 gallons. At 2.6 MGD, this could add $3.2 million to $3.7 million to annual operating costs. The plant can already use water from Portsmouth so there would be new costs for pipelines or other infrastructure. Such an increase in cost could make it difficult for the plant to compete with natural gas or other coal plants.

<u>Conclusions:</u> *Groundwater is the primary source of water for the* Portsmouth Genco *thermal power plant in Portsmouth. If* Portsmouth Genco *'s groundwater permit is reduced, the mostly likely alternative would be purchased drinking water from Portsmouth (assuming Portsmouth would be able and willing to sell additional water) which could add up to $3.7 million to annual operating costs.*

4.2.14 Impacts on Colonial Williamsburg

Colonial Williamsburg uses only groundwater for heating and cooling buildings in the historic sections. Average recent use has been less than their permit limit (1.14 MGD versus 1.84 MGD). They are making investments to reduce groundwater use and expect their renewed permit to reduce their allocation. Reducing their permit to a value closer to recent use is unlikely to have additional impact. However, given the number of buildings in the historic area, current geothermal facilities, and the heating and cooling needs, there is a minimum amount of groundwater that Colonial Williamsburg must use. The exact number is not known.

If Colonial Williamsburg Foundation's permit was reduced below this minimum, their alternative options would be costly, disruptive to their mission, or both. Municipal water would not be a good option because the water would often be too warm for geothermal cooling, especially in summer (which is when water use in Colonial Williamsburg peaks). Colonial Williamsburg could consider ASR, pumping the water they withdraw from the ground back into the aquifer. ASR would pose two challenges. First, because of uncertainties about groundwater hydrology, DEQ does not yet credit groundwater users for ASR injections. The second challenge is that currently used water is discharged into the city stormwater system in many locations. ASR would require new piping to collect and recirculate the water to an injection site, which would be costly and, perhaps more important to Colonial Williamsburg, the construction activity would be very disruptive to the primary mission of the Foundation. A final alternative would be to convert from a water-cooled system to another system. The Foundation indicates that they would be unlikely to make this switch because of the noise and visual degradation and, instead, they would forgo cooling in the summer. This approach might require them to close some buildings in the summer and could cause damage to various antiques within their buildings.

Conclusions: *Groundwater is the only source of geothermal cooling water for Colonial Williamsburg. If Colonial Williamsburg's permit is reduced below the amount necessary for cooling buildings in the central historic area, the most likely alternative would be to stop cooling some buildings in summer, which could limit guest access and potentially cause damage to some antiques.*

5. Groundwater Management Strategies

DEQ's groundwater permitting system is currently the state's primary groundwater management tool in the EVGWMA. Section 5 of this report discusses potential impacts on individual groundwater users of DEQ actions to reduce groundwater use through this current system of groundwater permitting. Other management approaches that complement or add to the current permitting approach may offer some promise to reduce costs of meeting state groundwater management goals. This section provides a conceptual level description of management options that the state may consider in the future.

These different options may produce changes in behavior and outcomes that can be described according four general criteria: cost effectiveness, incentives for innovation in water use reduction and supply management, administrative costs, and adaptive capacity. Cost effectiveness is defined as the potential for individual users to reduce the financial outlays for complying with and maintaining state groundwater management goals, using well established and existing approaches. Second, groundwater management alternatives might create incentives to develop and implement different approaches to water use and supply. Management options with strong incentives to reduce overall water use or to increase or better utilize existing sources of supply over time can lower costs and groundwater use over time. Third, administrative costs that include planning, coordination, regulatory, and other administrative activities required to implement new groundwater management actions must be acknowledged. All factors equal, management options with lower administrative cost are preferred. Finally, management options will be evaluated on the ability for users and DEQ to cost effectively revise plans based on new information. Water supply management requires long term planning, but is subject to considerable uncertainties (uncertainties about future water use, physical conditions such as aquifer response and climate change, economic conditions). Management options that facilitate identification and response to new conditions would produce lower costs over time.

The four criteria are not mutually exclusive. In fact, the criteria may overlap—for example, adaptability may contribute to innovation incentives. But these criteria can be seen as useful concepts for understanding the different outcomes that might be achieved under groundwater management alternatives. The list that follows was based on input received from representatives of permitted groundwater users and examples from other states. It should be noted that no single management strategy discussed below is superior across all four criteria (e.g. each management option is not without tradeoffs). The list below is not comprehensive, but it is illustrative of the types of options that the state could consider. Some of the options may be consistent with current statutes and regulations and others will require changes to existing statutory authority or regulation.

5.1 Permit Timing

Currently, the timing of individual permit renewals is determined by the 10-year permit cycle and the year that the permit holder originally obtained their permit. Renewal cycles for permit holders in close proximity are not generally coordinated and are likely to occur years apart.

Permit timing could be coordinated among groups of groundwater users to allow and encourage users to cooperate with other users during permit issuance. For example, there are a number of large and small groundwater users and wastewater discharges in the area around Franklin, Virginia, including the Franklin Paper Mill, the Ashland chemical plant, and the city of Franklin water system. This area may be the densest cluster of groundwater use in the EVGWMA and has experienced substantial aquifer declines before the paper mill temporarily shut down. If permits for each groundwater user in the area could be coordinated so that they are renewed simultaneously, the permit applicants would have a better opportunity to identify joint projects that could reduce total groundwater use among them.

The regional coordination of permits could go even further to include wastewater discharge permits under the Virginia Pollution Discharge Elimination System and implementation of local and Chesapeake Bay TMDLs. Coordination of both water supply and wastewater discharge will broaden the opportunities for water sharing and wastewater reuse. As mentioned earlier, the West Point Mill is investigating the possibility of using treated wastewater from the West Point treatment plant, as well as the possibility of providing treated wastewater to a nearby wood products manufacturer (which holds its own groundwater withdrawal permit). Representatives from the mill suggested that coordinated permit cycles might increase the opportunities and incentives for such cooperation and integration. For example, if West Point and Veneer (the wood manufacturer) were in the process of renewing their permits simultaneously, DEQ could promote some water sharing between the two as part of the permit review process.

Wastewater reuse and water sharing will not always be cost effective, but opportunities for identifying and investigating them will be greater if multiple parties are conducting technical work on different regulatory requirements simultaneously. In addition, regionally coordinated permits could allow DEQ to set regional groundwater withdrawal goals and work with applicants to identify strategies for meeting these goals. Coordinating permits among several permit users, however, would require some additional administrative costs for DEQ and permittees.

Changes to coordinate the timing of permit issuance might also be accompanied by an increase in the duration of permits. This combination might create opportunities and incentives for more cost effective groundwater allocation. Groundwater withdrawal discharge permits are currently issued for ten years. The useful life of civil infrastructure and industrial facilities often exceeds 50 years. Further, financing for public and private investments can extend 20 to 30 years. Many permit holders expressed concern about the long-term uncertainty associated with groundwater permits and the risk associated with making such long-term investments for projects that are dependent on water. The potential for functional investments in water treatment infrastructure to be partially or completely unusable due to a regulatory change (stranded asset) is a concern voiced by several users. Several CWSs have invested in treatment and other projects that are dependent on groundwater resources. Examples include NNWW's 1990 investment in the Lee Hall reverse osmosis plant for treating brackish groundwater and Suffolk's 2008 investment in an electrodialysis reversal plant for the same purpose. Similarly, International Paper and its partner, ST Tissue, have made investments to retrofit the Franklin Paper Mill to begin producing different paper products in response to shifting market conditions. Unanticipated changes in groundwater permit levels could increase the potential for misallocations in water infrastructure investments.

If DEQ moves forward with actions to reduce groundwater use within the existing permit program, longer term permits might offer a way to increase the potential for cost effective investments. Private companies, CWSs and other organizations will be better able to plan and make these investments if they have greater long-term certainty about groundwater permits (and potentially other permits). As part of its groundwater management program, the State of Georgia allowed for permits that last as long as 50 years. However, representatives from the state reported that long-term permits have not been used widely.

Lengthening permit terms, however, is not without drawbacks. Longer term permits can limit the state's ability to respond to new information about aquifer conditions and the consequences of changes in physical groundwater conditions on third parties. Longer permits would also require amendments to state groundwater laws and regulations (a new administrative cost)

5.2 Group Permitting Systems

The primary challenge confronting state groundwater management goals is reducing and maintaining future access and use of the Coastal Plain groundwater resource. A major challenge is to limit access and use of the groundwater resource in the face population growth and new economic development opportunities.

Reducing regional groundwater use to meet state management goals could be accomplished by reducing use among those users who can do so at the lowest cost. Once goals are achieved, the groundwater management system will require a mechanism to accommodate new groundwater withdrawal requests without imposing large costs or economic impacts in the region. In short groundwater management in the state will be confronted with the increasing challenge of reallocating access and use of a limited groundwater resource among multiple competing uses.

Under the existing groundwater permitting approach, DEQ has the primary responsibility of maintaining groundwater withdrawals among permitted users within overall aquifer targets. As new requests for groundwater withdrawals emerge (for example development of a new CWS or new commercial or industrial development), DEQ will need to either deny the groundwater permit, permit the new request and exceed aquifer targets, or reduce permitted withdrawals of other users. In this system, it may be difficult or costly for DEQ to determine where the most cost-effective opportunities for reduction exist because existing users have incentives to overstate water needs and costs in ways that protect their groundwater access. Furthermore, groundwater users with existing permits may have disincentives to reduce groundwater use once a permit is issued. Permittees who could reduce groundwater use during the permit term stand to "lose" the benefits of their groundwater conservation actions when the permit is renewed with lower groundwater withdrawal limits.

These challenges from the current permitting system may be addressed with what can be termed a "group permit system". Group systems share two common features: identification of regional, state-determined caps on permitted groundwater withdrawals and the assignment of some management responsibility for meeting the caps to the users themselves.

Such a system could assign a group permit to users in a specified area for a specific groundwater volume and time of use (ex. pumping only allowed during drought). The group permit also would specify individual allocations to each user covered under the general permit. Allocations could be specified as a total quantity of water (MGD) or as shares to the overall cap. Time of use might also be specified that would allow users the flexibility to determine how much water is used over time (e.g. as a drought management strategy). The users might then be responsible for devising and implementing a system of reallocating allocations under the group permit. Similar schemes have been used with considerable success for managing effluent discharges under the CWA, including in Virginia (Pomeroy, Evans, and Leeth 2005; Shabman and Stephenson 2007). Such a system would cap total groundwater access to existing users. New users would be required to secure groundwater allocations within the group permit before being allowed to pump.

Regional groundwater permit trading systems are another way to manage groundwater use and access. Groundwater permit trading systems directly assign groundwater allocations (the authorization to withdrawal a specific quantity or share of water) to individual groundwater users. New users could be required to purchase allocations from existing permit holders prior to being allowed to access groundwater. Rules would also be developed to authorize and regulate the transfer of allocation between users. Such programs have been implemented in a number of riparian right states (see Box 6-1).

Depending on the program rules, assignment of allocations to individual users could create incentives for users to reduce individual groundwater withdrawals since users would directly benefit from groundwater conserving actions. Unused groundwater allocations could be sold to others or perhaps banked for future use. Groundwater trading systems and group permitting systems, however, would require significant set up and implementation costs. New statutory authorization may be required depending on program design. In Virginia such systems may also need to be designed to overcome thin markets since groundwater use is currently dominated by relatively small number of significant users. The possible exercise of market power by a few key dischargers could undermine program cost effectiveness. Expanding the reach of the cap would also require expansion of metering requirements. To be successful, such programs would also require stability and security in the allocation of groundwater withdrawal. Groundwater users would need confidence in the groundwater allocation and transfer system in order to effectively participate.

Box 6.1: Groundwater Allocation and Trading

Several regional groundwater allocation and trading system have been implemented in states with riparian groundwater rights. The Upper Republican Natural Resource District (URNRD) in Nebraska issues groundwater allocations among landowners across three counties. The URNRD has used a trading scheme and other groundwater allocation mechanisms to manage groundwater in the area for many years (Juchems et al., 2013).

The URNRD has monitored all wells using meters since 1978 and established aggregate 5-year irrigation allocations for each well (Juchems, 2013). Allocations are based on the number of acres within an irrigated tract. These allocations are correlative rights which means that all rights have equal priority and are decreased proportionally in the event of a shortage. There are several mechanisms that allow landowners flexibility in redistributing allocations. Owners of multiple wells can pool their allocations across wells. In addition, unused allocations can be carried forward to the next 5-year period, or can be sold. The carry-forward and pooling policies were established in 1978 (Stephenson, 1996). These policies are intended to allow flexibility within the allocation system, and the carry-forward policy encourages irrigators to reduce their water use below the allocation. Sales of allocation rights must be approved by the URNRD board. The board's review will consider the water level at the buyer's location, and may impose a transfer tax, where a portion of the amount offered by the seller is given to the URNRD and retired (Cummings et al., 2001).

From 2006-2011, there were 524 operators in the URNRD managing a total of 3,179 fields (Juchems et al., 2013). Forty-nine operators participated in formal trades, involving 100 separate fields. The transaction costs associated with these trades include time and money for finding a trading partner and obtaining approval from the URNRD board, since there is no available trading platform to help identify potential trading partners. An analysis of URNRD data for 2006-2011 showed that larger operations (determined by the number of fields) were more likely to participate in the formal trading process. The current trading process does not allow for leases (i.e., annual use trades), which could increase participation.

North Carolina has also utilized various types of transfers and water banking to facilitate transition away from groundwater use (particularly in targeted aquifers). In early 2000, North Carolina initiated a process to aggressively reduce groundwater withdrawals in a fifteen county area called the Central Coastal Plain Capacity Use Area (CUA). In the CUA, users withdrawing over 100,000 gallons per day must have a permit (North Carolina Division of Water Resources 2007). The state established an initial groundwater base use rate for permitted users and then established reduction requirements across three different phases. In Phase I (2002-2008) users were required to reduce groundwater use 10% and 25% below the approved base rate (depending on location in the CUA). Phase II (2008-2013) required reductions between 20-50% and Phase III (2014-2018) will require 30-75%. To date groundwater withdrawals from the Cretaceous aquifer have been reduced from 40 mgd to less than 20 mgd.

As of 2011, the total cost to achieve these reductions is approximately $340 million (about $17 million per MGD of savings). Reducing withdrawals from the Cretaceous aquifer required both substantial investments in alternative surface and groundwater sources as well as extensive investments in new distribution and treatment systems. While the costs are high, several features of the program helped facilitate the source water transition. First, withdrawal limits were defined at the outset of the program, facilitating local water supply planning and coordination. Second, permittees were granted a variety of water transfer provisions. Permitted users may sell or transfer portions of their permitted withdrawal (North Carolina Division of Water Resources 2001). Both buyers and sellers must request a permit modification (or a new permit for buyers who are new users) for their new withdrawal amounts. The state also created the “Cretaceous aquifer bank account” allowing permittees to receive credit for, or bank, reductions in groundwater use below approved use rates. While banked water may be withdrawn for compliance purposes both during and after the phase in periods, water may only be banked (deposited) during the phase-in periods (through 2018). Banked water also may be transferred between accounts. Water banking provided strong incentives for permittees to bring alternative sources online early. Since the bank’s inception, permittees have saved a total of 37 billion gallons for future use.

5.3 State Support for Source Water Development

New water supplies will eventually be needed in the EVGWMA and new supply will likely be needed sooner if the state moves forward with actions to reduce groundwater use. This report describes many ways to augment water supply including development of new surface water storage, wastewater reuse, desalination and regional water sharing (which would require some new infrastructure). The State could explore options that would reduce the administrative costs and increase incentives to develop such water supply alternatives.

Section 4 discussed the regulatory difficulties for recent surface water project proposals in Virginia, especially King William Reservoir. In the end the Corps of Engineers and EPA concluded that the adverse environmental effects of the proposed project were unacceptable. The multi-layered system of separate regulatory decisions contributed to the controversial, lengthy, and costly permitting process for a project that was not ultimately built. Because of the King William Reservoir experience, most water users contacted for this investigation suggested that they are very reluctant to pursue surface water supply in the future. In contrast to the King William Reservoir case, Henrico, Cumberland, and Powhatan Counties recently completed regulatory approvals for Cobbs Creek Reservoir. At the very early stages of the Cobbs Creek proposal the counties invited DEQ to help shape the proposal so that it would be more consistent with state and federal environmental regulations and goals. This involvement by DEQ helped contribute to Cobbs Creek being approved with minimal controversy. Similar DEQ support and coordination could help CWSs and other groundwater users secure alternative water supplies in the future, which would make it easier for the region to reduce reliance on Coastal Plain aquifers.

DEQ and other agency involvement to help streamline regulatory processes would be beneficial for surface water as well as other potential water supply projects. Wastewater reuse would require various regulatory approvals under NPDES, TMDL, public health and other regulatory programs. Better coordinating these reviews may offer opportunities to help prevent costly delays in pursuing such projects.

The state has very limited experience addressing aquifer storage and recharge. The use of wastewater for indirect potable uses is also still rare. The limited experience with both artificial aquifer recharge and wastewater reuse may present opportunities for various affected parties and DEQ to identify promising source water supply alternatives and to clarify or amend regulatory requirements to lower administrative costs (Mission H_20, 2014).

5.4 Programs to Address the Self-Supplied Sector

Unpermitted self-supplied users accounts for roughly 30% of overall groundwater use (Pope et al., 2008). Given the nature of these users, the state and local governments have limited evidence on how the number of active wells and household withdrawals are changing for the domestic self-supplied sector. Several municipal utilities contacted for this report provided anecdotal evidence of growth in the unpermitted self-supplied sector withdrawals. For example, the Western Tidewater Water Authority noted seeing a trend towards individual wells for residential irrigation, especially in more affluent parts of the Suffolk. JCSA reports that they have seen approximately 50 new wells per year. In addition, little is known about how per capita household water use is changing for domestic well owners.

Growth in the self-supplied sector is likely to continue and can erode reductions achieved in permitted use. This potential growth will be driven by continued population growth in rural areas and incentives created by the relative cost of developing a well versus connecting to a CWS. Water and sewer connection fees vary by the size of the meter required. In the Hampton Roads region, water connection fees for a ¾-inch meter, which is a typical size for single family home, range from $230 to $8,000, and fees for a two-inch meter, which would likely supply multiple homes or a commercial establishment with larger water use, range from $1,220 to $38,150.[22] Sewer connection fees range from $450 to $11,455 for a ¾-inch connection or $450 to $74,340 for a two inch connection. In comparison, the Virginia Water Well Association estimates that the cost of drilling a domestic well in the Virginia Coastal Plain ranges from $13-$14 per foot, and typically 170-180 feet must be drilled for potable water. Thus, typical costs for drilling a well are $2,210-2,520. Depending on the meter size that would be required for a CWS connection, it may be less expensive for homeowners or businesses to drill a well. In both Chesapeake Utilities' and JCSA's service areas, the connection fee for a ¾-inch line exceeds $4,800, substantially more than costs for installing a well.

In addition, homeowners and businesses would also consider the water service rates for the local utility (see Exhibit 3-8Exhibit 3-8). Monthly costs for water from a CWS could exceed $100 per household (see Exhibit 3-9). Once a home or business has a well, operational costs are minimal (usually just a small amount of electricity to run pumps). Unlike municipal utilities, individuals on domestic self-supplied wells face very few financial incentives to conserve water. New limits on domestic groundwater use could lead to new incremental costs for CWSs to secure additional water or implement conservation programs. Such new costs for CWSs are likely to lead to further increases in prices, which have been consistently climbing in the region. Therefore it is very possible that differences between municipal water rates and self-supplied costs will widen and this could increase total withdrawals within the unregulated self-supplied sector.

The state could pursue a number of options to limit the growth and expansion in self-supplied groundwater wells. One strategy for the unregulated self-supplied sector would be to constrain the construction of new wells and/or to create incentives or requirements for connecting to public water systems. For instance, the state could require or create incentives for connecting to local utility water systems. This strategy could be implemented in multiple ways. The state could require homeowners to connect to a CWS or prohibit well drilling in areas already served by a CWS. Another approach would be to extend regulatory authority to a larger number of groundwater users, including small users that are

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[22] Based on a review of rates described on municipal utilities' websites.

currently unregulated, and imposing new limits and/or permit fees. Households connected to municipal water supply would face more financial incentives to reduce household water use and invest in water conservation appliances. Many such options, however, could face substantial administrative barriers and costs.

Local-level examples of such restrictions exist in the Virginia Coastal Plain. The City of Suffolk's zoning rules require that any major new development (over 5 lots) be within the urban district and must connect to the central system. Developers are also obligated to extend the water line to the new development. Local communities cannot have their own water system. Existing users within a certain distance from an existing line must become connected. Similarly, in James City County, new homes must connect to JCSA's system for indoor water use if they are within a certain distance of a water line. In addition, James City County prohibits use of public system water or self-supplied groundwater (unless it is drawn from the surficial aquifer) for outdoor irrigation of common areas in residential or commercial development; instead, property owners must use locally impounded surface water (e.g., stormwater retention basins).

The state could also investigate the option of requiring new construction within the EVGWMA to install appliances that meet stringent water conservation standards. The federal Energy Policy Act of 2005 updated water use standards for plumbing fixtures. Other federal standards exist for residential dishwashers. More stringent requirements (particularly on appliances like washing machines) could be imposed in specific areas with water supply problems (such as the EVGWMA or localities served primarily by groundwater). Such a requirement would impose some additional costs on new home buyers in the form of higher upfront appliance costs but these costs are relatively small when considering lower operating costs. Virginia uses similar programs in other areas. For instance, in areas of the state that do not meet federal air quality standards, the state limits the type of products sold that produce volatile organic compounds (VOCs) (9 VAC 5-20-206).

The state may also wish to explore ways to create or strengthen voluntary programs and financial incentives to reduce household groundwater use or to convert to a CWS system. Public education and marketing efforts could target rural water users on water conservation behavior and investment. Since these users are not served by a CWS and county governments have limited resources and incentives to reduce household water use, rural populations relying on self-supplied groundwater may be an under-served population regarding the benefits (private and public) water conservation investments. Financial incentives for domestic self-supplied users are discussed in the next section.

5.5 State Financing for Reducing Groundwater Use

State financial support for water conservation or source water conversion may also have potential to reduce the overall cost to the state, as well as create groundwater conservation incentives. The state could make a number of targeted investments including financial support for regional coordination and new financial incentive programs to adopt cost effective groundwater conservation measures.

As noted earlier in this report, the transition to a more limited groundwater future may be facilitated with enhanced regional coordination. The EVGWMA currently benefits from significant surface water storage and interbasin transfers. The region also benefits from strong involvement and support in water supply planning by the regional planning districts and nonprofit groups. Finally, groundwater use tends to be concentrated in a relatively small geographic area, facilitating cost-effective treatment and distribution of water. Regional scale investments in source water development will be more cost effective than similar local or individual efforts due to the substantial economies of scale associated with water resource capital investments. One challenge standing in the way of realizing these benefits could be coordination costs among multiple municipal and industrial water users. Such coordination costs would include development/refinement of regional water planning models (simulation and/or optimization), collection and dissemination of technical information water infrastructure and costs, and alternative development and negotiation among separate users/jurisdictions. Individual users may be initially reluctant to financially contribute to such an effort due to uncertainty of success and the limited ability to induce others to contribute. State leadership and financial support to regional water supply coordination and planning efforts could facilitate and support development of cost effective regional solutions to reduced access to groundwater.

State financial support could also be used to achieve cost effective reductions for unpermitted groundwater users. Thousands of homeowners with self-supplied groundwater wells face limited financial incentives to invest in water conservation technologies or water reducing behaviors. As shown above, well operating costs are less than the cost to use water in most municipal system. The difference changes the household returns on investments in ultra-high efficiency appliances like front-loading washers and provides few incentives to limit outdoor water use. The state could consider a suite of individual and local incentives to encourage reductions in groundwater use from the self-supplied sector. Financial inducements might include rebate programs on specific types of household appliances or local development grants for water conservation programs or implementing outdoor water use regulations. Virginia already offers tax credits for energy efficient household investments as well as a limited sales tax “holiday” for water efficient bathroom fixtures and toilets (Virginia Department of Taxation 2014). Such programs may be more effective if the size and type of incentives could be expanded and the scope of applicable investments broadened (for example, to include qualifying dishwashers and washing machines).

Similar tax incentives or new grant programs might also be used to facilitate water conserving investments by large industrial or municipal groundwater users. These programs might be justified on cost grounds because such demand side management programs are likely a relatively low cost way to reduce groundwater withdrawals and for creating incentives for conservation where few currently exist. There are multiple ways in which such grant programs could be created and administered to encourage water conservation or source water conversion, including competitive grant processes that reward low cost permanent reductions in groundwater use.

5.6 Support Studies on Water Use Trends

Uncertainty in future water use is one factor that may drive CWSs toward conservative estimates of the amount of water they will need in the future. As discussed earlier in this report, water use has been declining nationally and in the EVGWMA region. While local water supply planning activities has greatly improved our understanding of the current use and water supply capacities in the state, the underlying causes of declining water use that have recently emerged during the planning process are not well understood (nationally or in Virginia). There are many questions that remain unanswered. Are homeowners using less water for outdoor irrigation? If so, to what extent is this trend driven by permanent changes in landscaping? Was there a surge in uptake of water efficient appliances and plumbing fixtures? To what degree is the housing stock in eastern Virginia saturated with front-loading clothes washers, low flow toilets and the like? To what extent have declines in municipal per capita water use been reflected in domestic household water use for self-supplied well users? Have businesses and industries reduced the water intensity of their operations and, if so, how?

Having better information about the factors responsible for changes in water use could help water supply planners make better estimates of the potential range of future water use and the cost effectiveness of management actions. Many water supply managers suspect that water use has declined because homeowners made temporary reductions in outdoor water use in response to the down economy and that water use may quickly rebound as consumers gain more confidence in the economy. Other localities are finding that water use declines are driven more by long-term structural, technological and cultural factors, and less by short-term behavior responses to price or income (Frost, 2012). Much of the necessary data are likely available (e.g., detailed billing data) but some new data and new analyses will be required (particularly for domestic self-supplied groundwater use). Household surveys, water use audits (Rockaway, 2011), and analysis of aerial imagery to study private landscaping can help state and local water supply managers to better plan for and capitalize on changes in water use patterns.

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Appendix 1 Historic and projected future population in the Hampton Roads Region

All historical population data in this appendix are from the Weldon Cooper Center, except for Smithfield. Smithfield's historical populations are U.S. Census counts obtained from American FactFinder[23] (for 2000 and 2010) and from Chapter 3 of Smithfield's 1999 comprehensive plan[24] (for 1970-1990). Population projections are from the Cooper Center and HRPDC, as described in Section 2.

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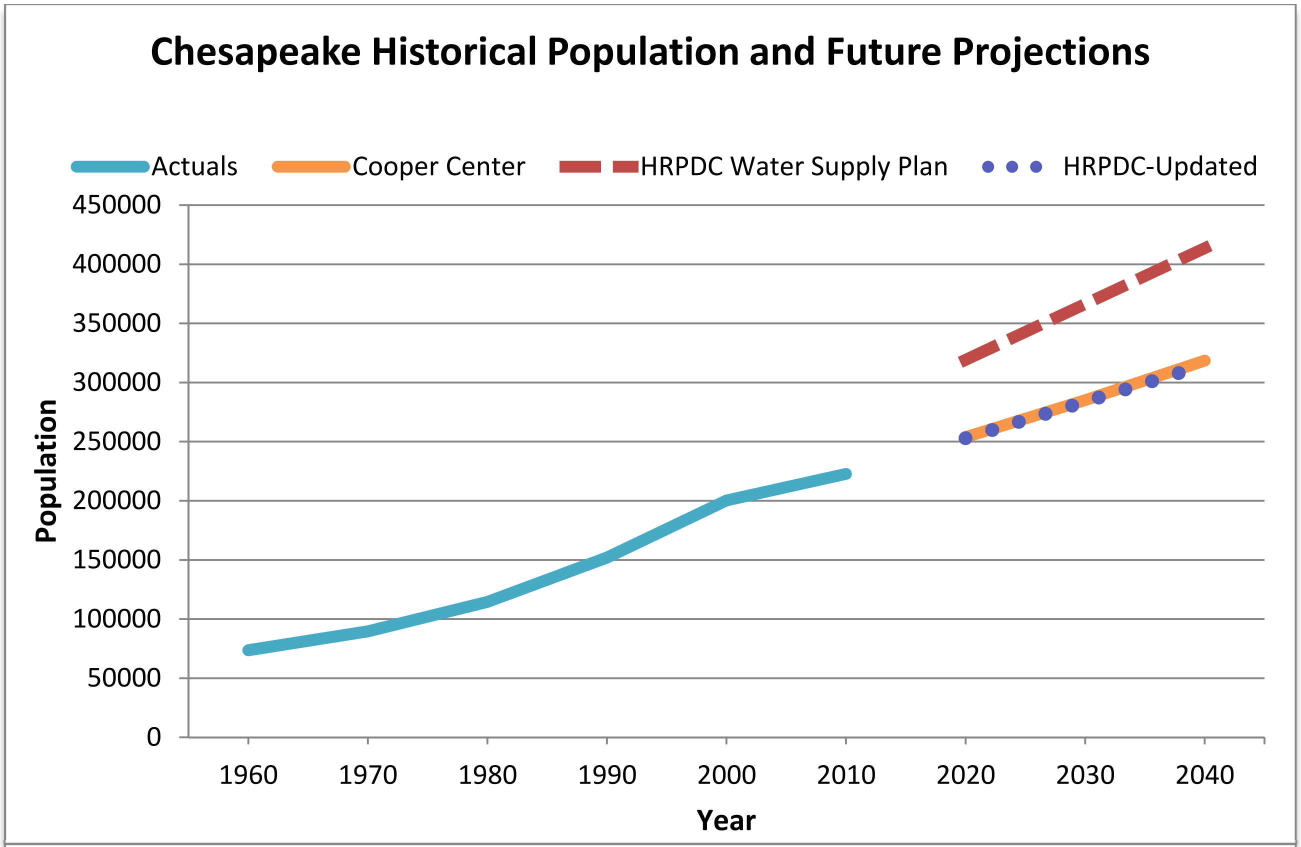
[23] Available at: http://factfinder2.census.gov/

[24] Available at: https://www2.smithfieldva.gov/cpart3.pdf


Chesapeake Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
450000
400000
350000
300000
250000
200000
150000
100000
50000
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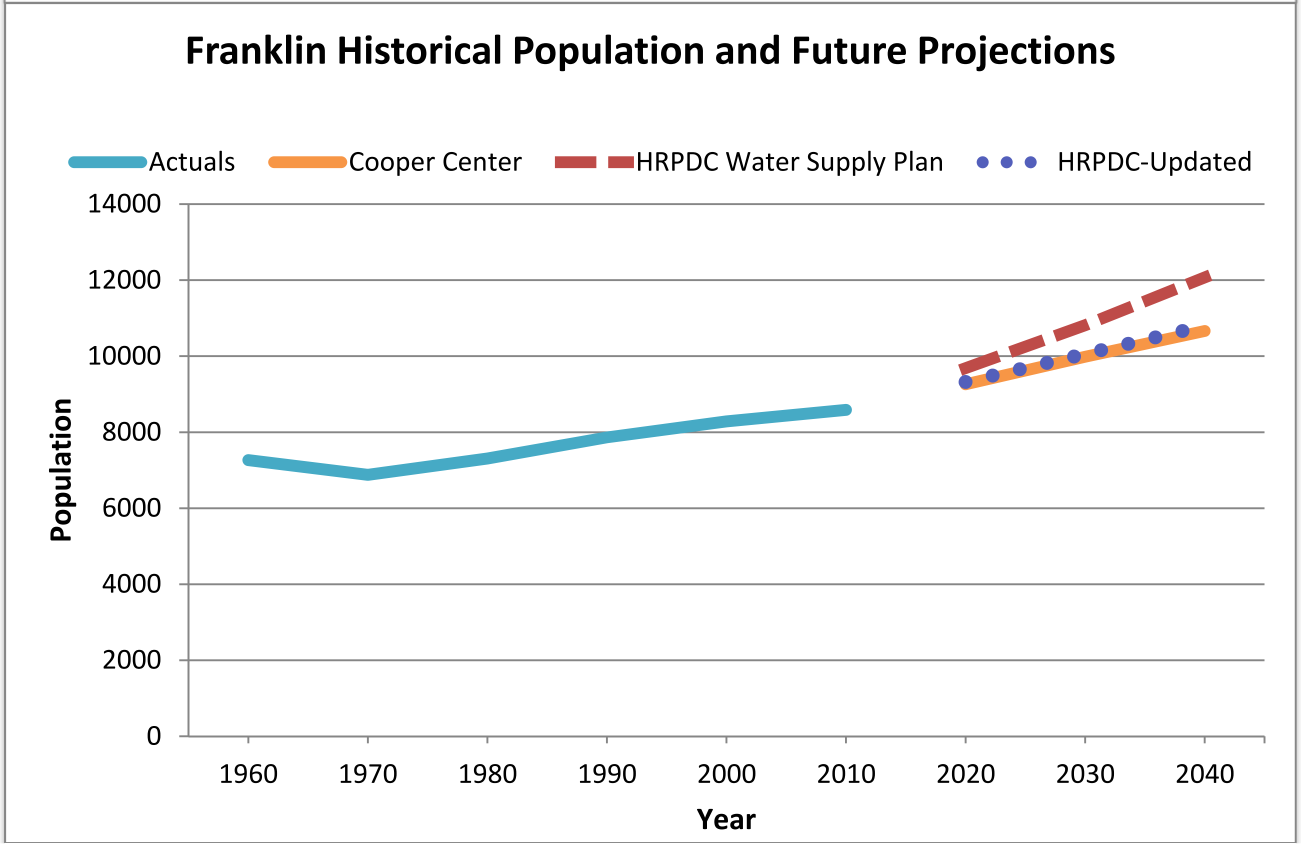
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year


Franklin Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
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12000
10000
8000
6000
4000
2000
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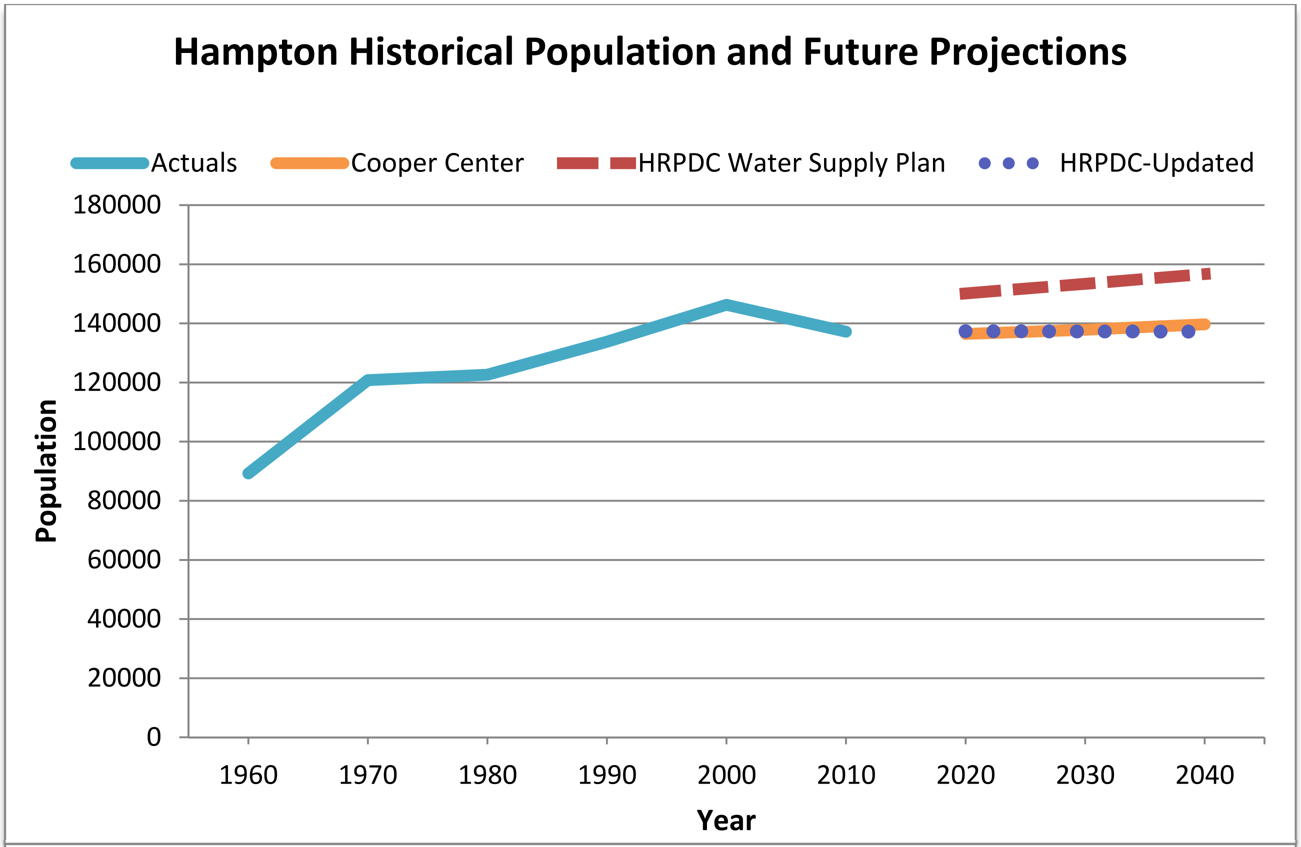
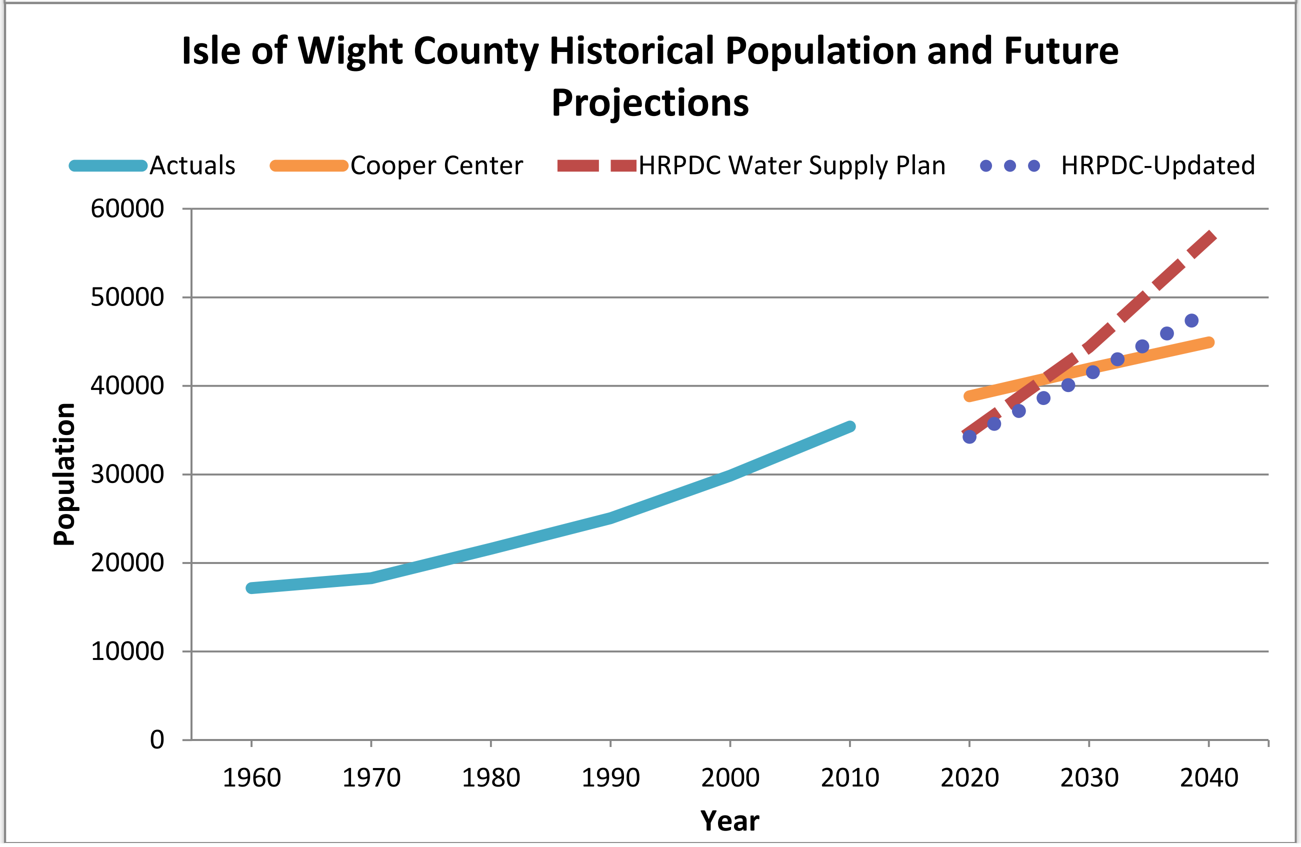
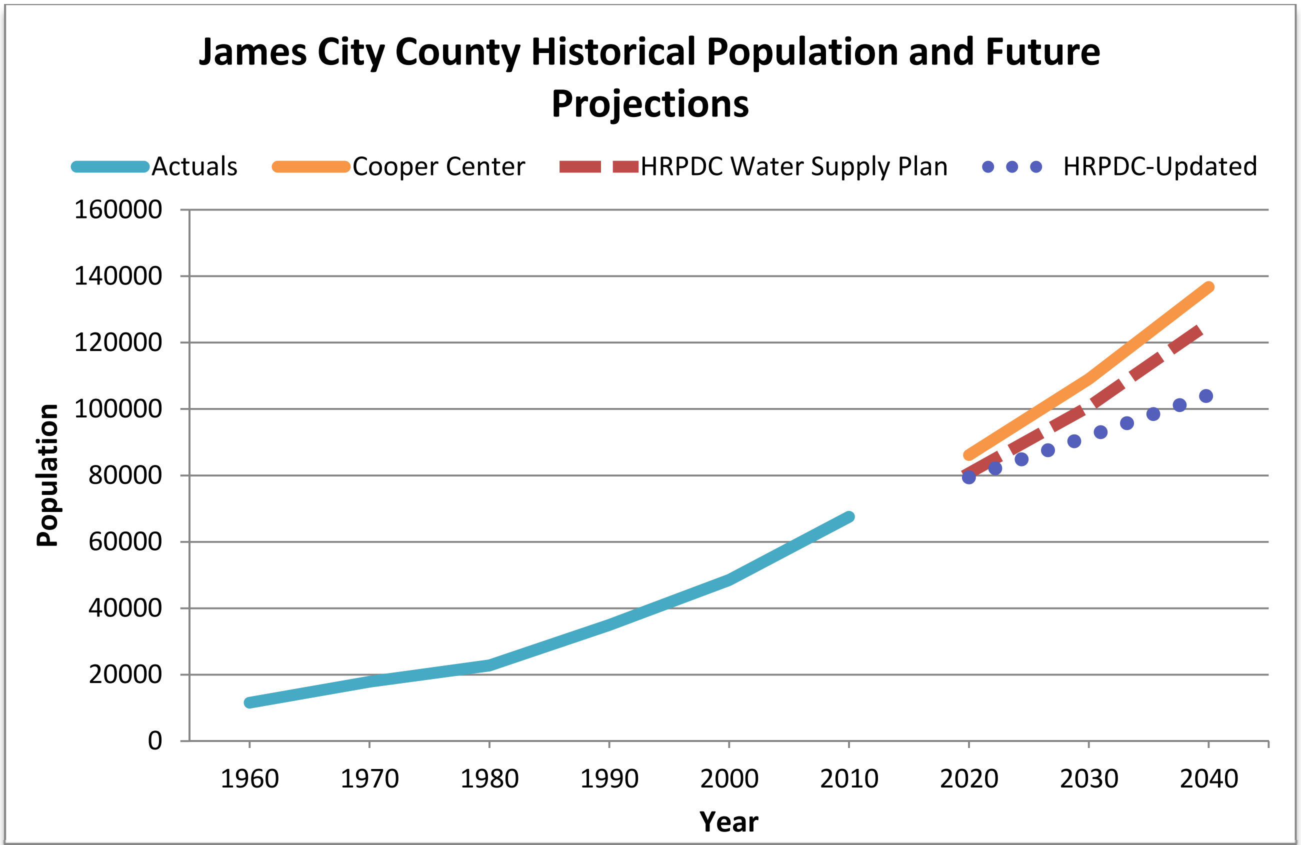
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year


Hampton Historical Population and Future Projections


Isle of Wight County Historical Population and Future Projections


James City County Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
160000
140000
120000
100000
80000
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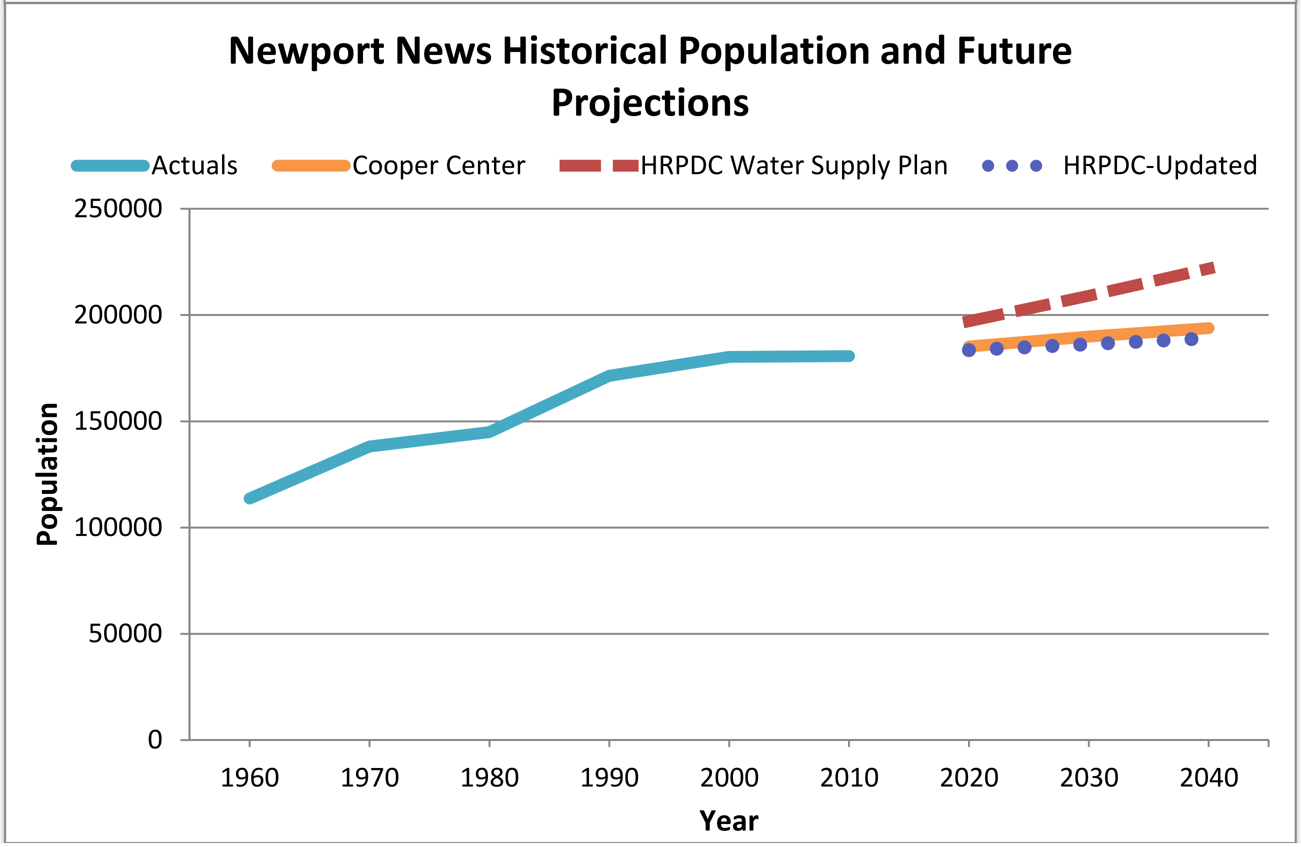
2000
2010
2020
2030
2040
Year


Newport News Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
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200000
150000
100000
50000
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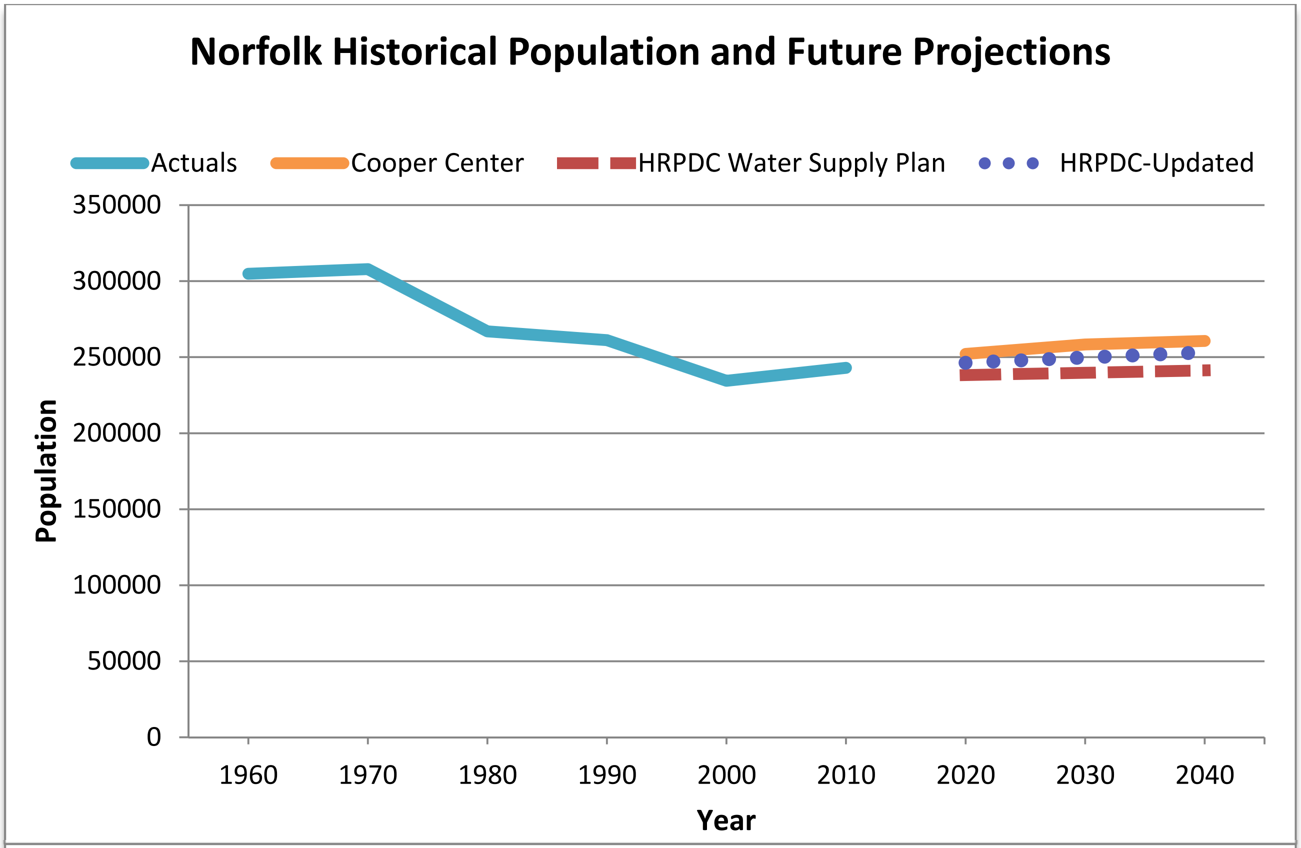
2010
2020
2030
2040
Year


Norfolk Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
350000
300000
250000
200000
150000
100000
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Population
1960
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1980
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2030
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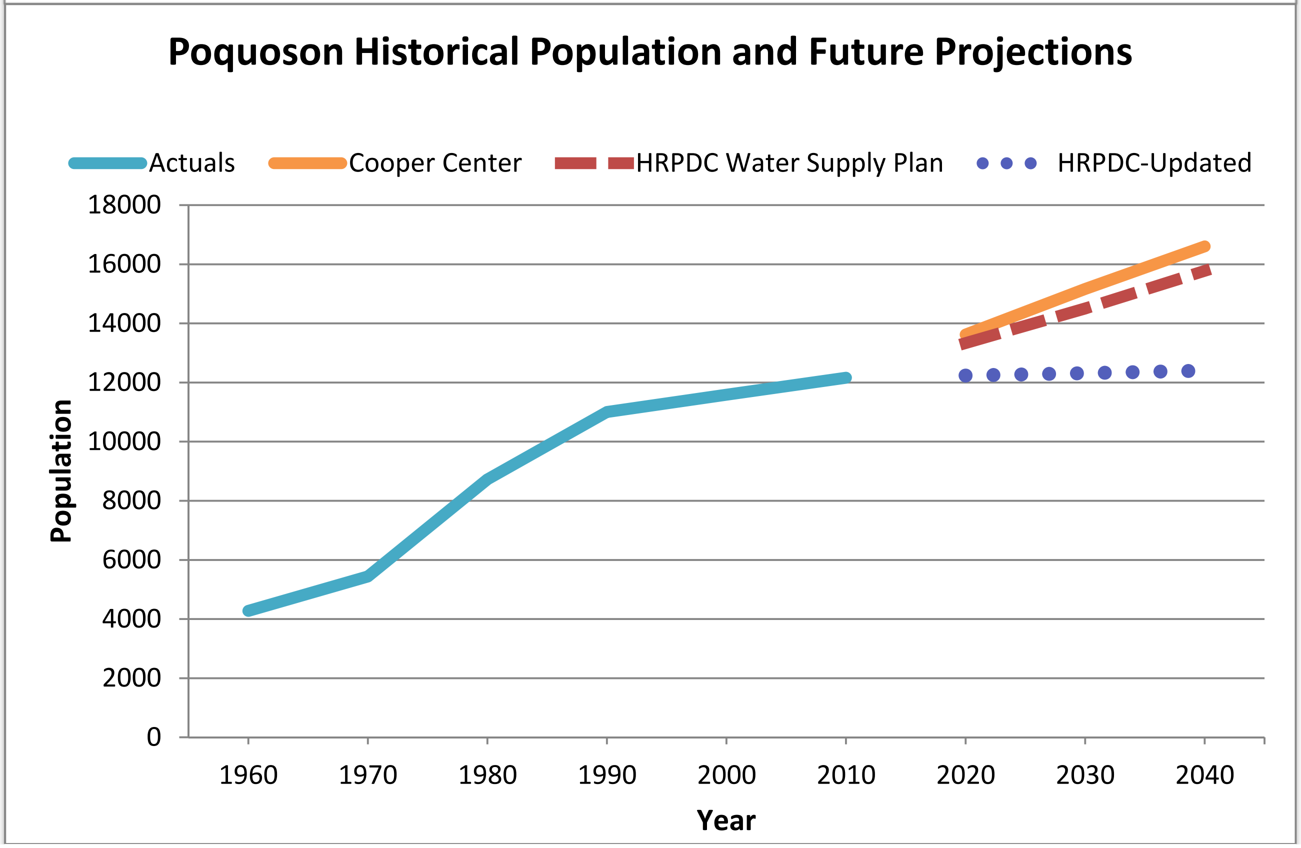
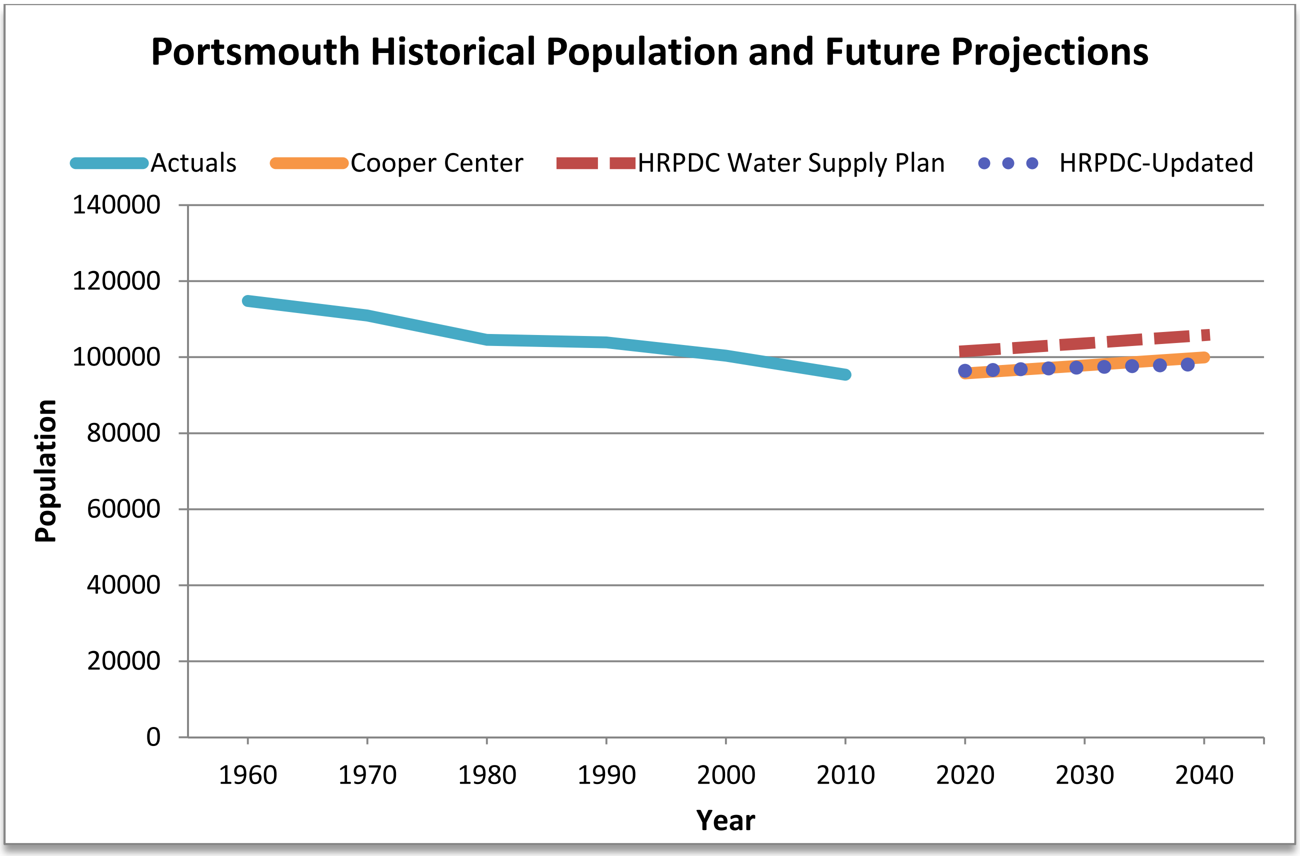
Year


Poquoson Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Population
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year


Portsmouth Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
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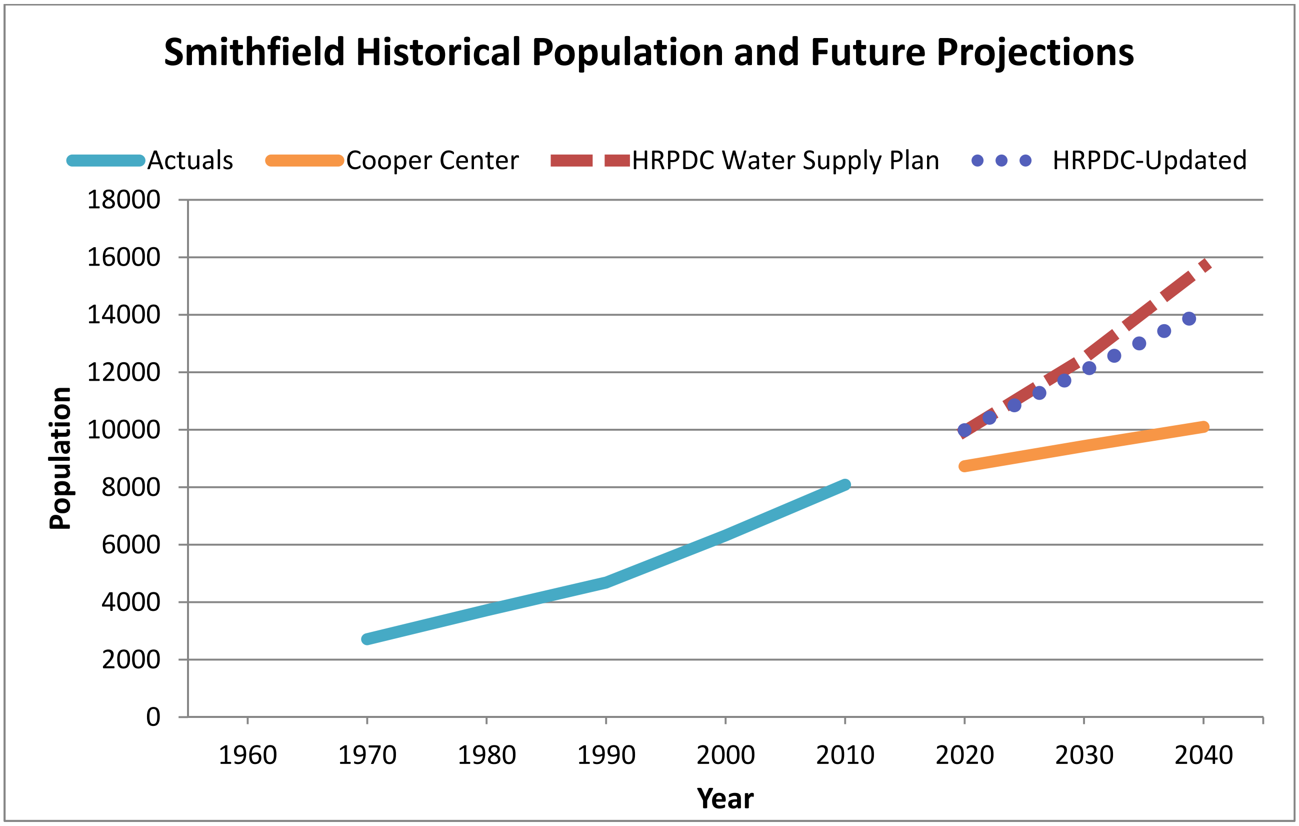
80000
60000
40000
20000
0
Population
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year


Smithfield Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
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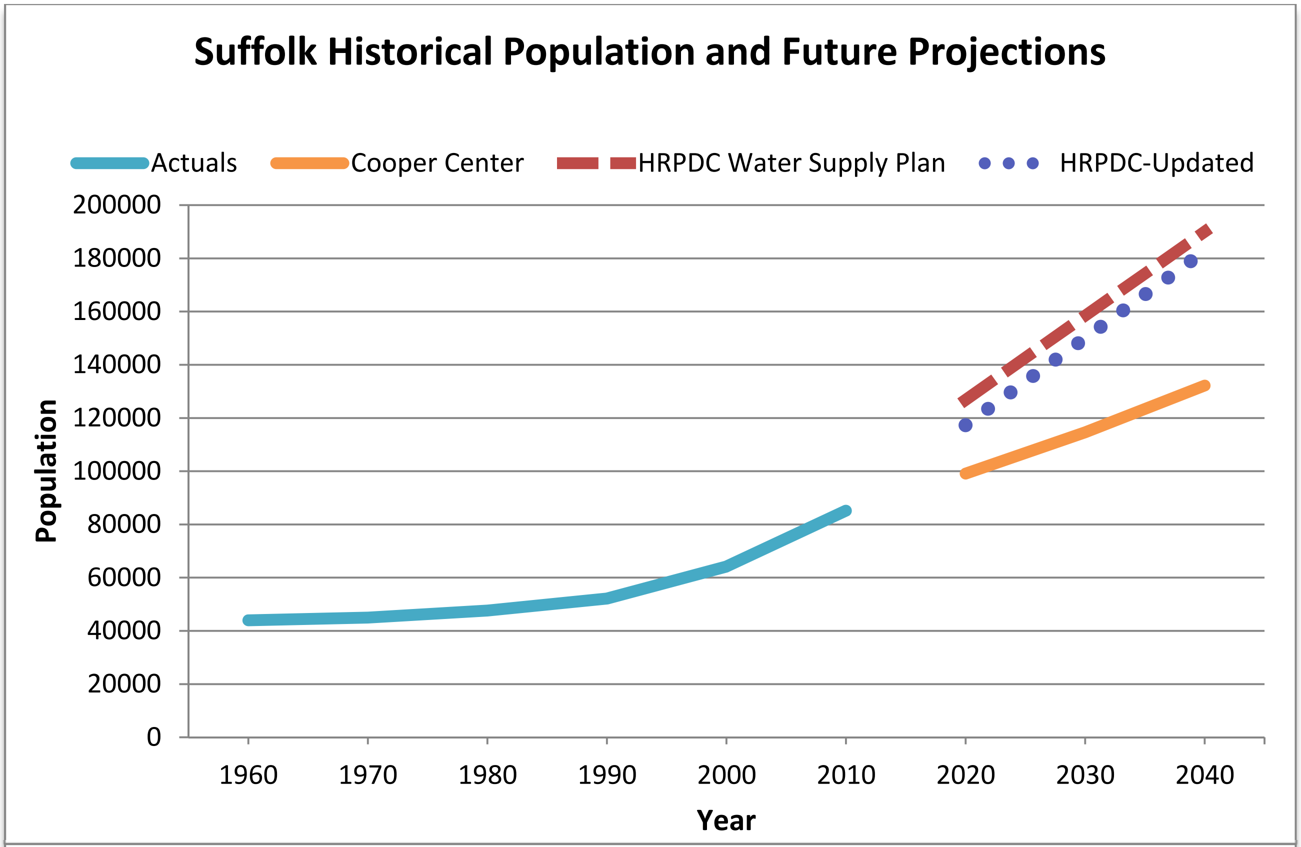
16000
14000
12000
10000
8000
6000
4000
2000
0
Population
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year


Suffolk Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
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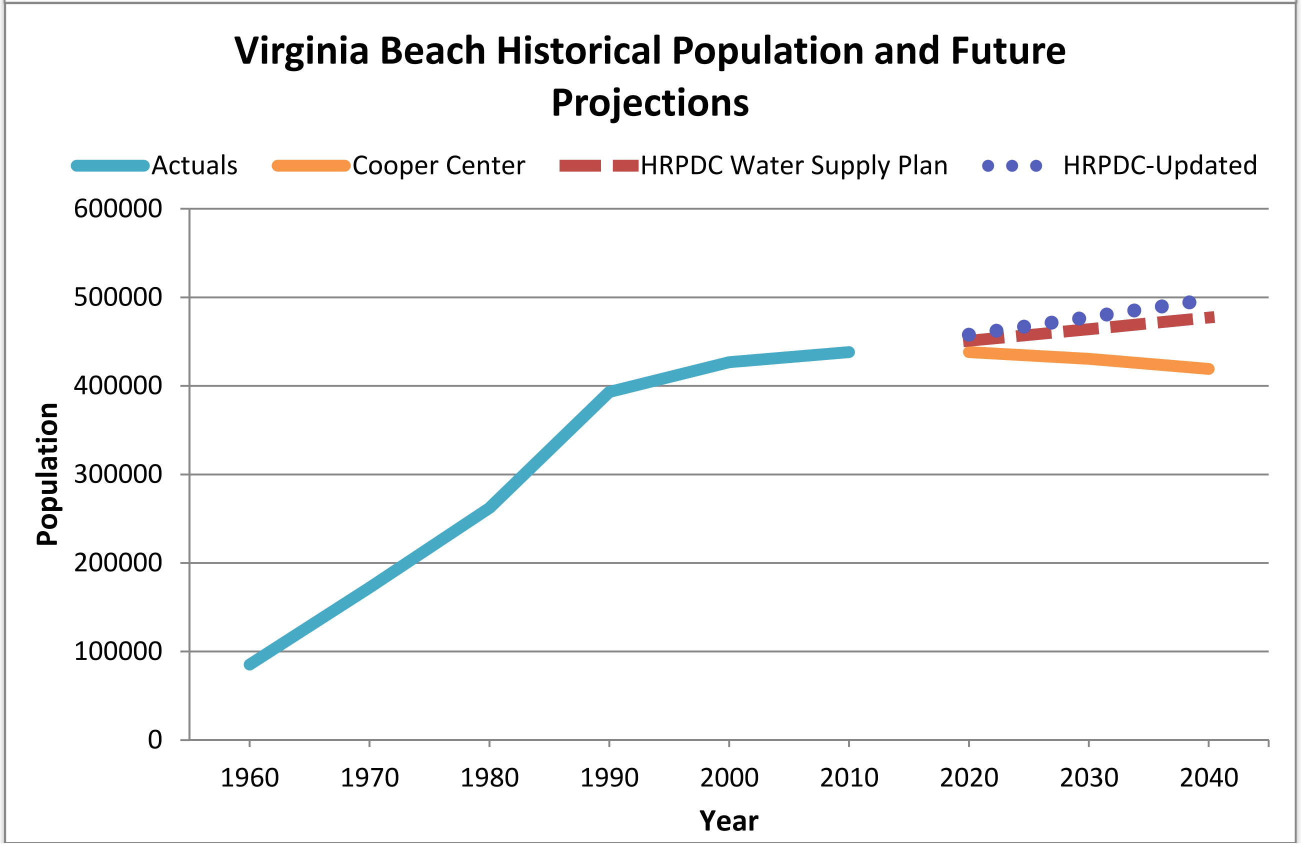
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year


Virginia Beach Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
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1990
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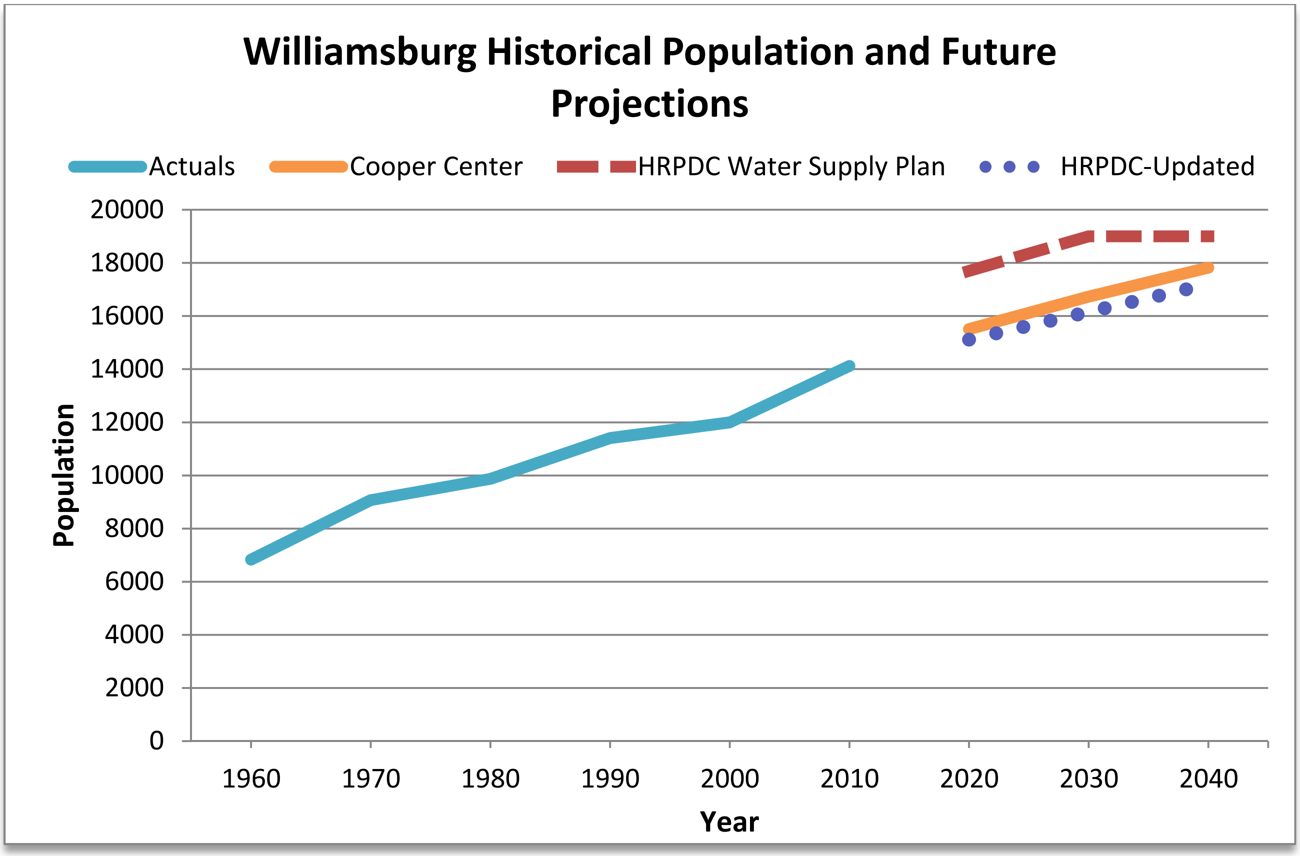
2020
2030
2040
Year


Williamsburg Historical Population and Future Projections
Actuals
Cooper Center
HRPDC Water Supply Plan
HRPDC-Updated
Population
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16000
14000
12000
10000
8000
6000
4000
2000
0
1960
1970
1980
1990
2000
2010
2020
2030
2040
Year

Appendix 2 Summary Tables of Wastewater Reuse Examples in the U.S.

Location and Project Name	Size, MGD	Capital Cost		Annual O&M Cost ($/kgal capacity)		Uses					Source
		2013 Dollars	Unit	2013 Dollars	Unit	Potable	Surface water augmentation	ASR	Irrigation	Industrial	
Pensacola, Florida Central Water Reclamation Facility	22.5	316									Westech, undated; ECUA, 2011
Yorktown Refinery, Virginia	0.5	3.85	million dollars	0.12 to 0.13	per year					☑	Water Reuse Association, 2004
Durango Hills, Las Vegas, NV	10	4.78	per kgal capacity per year	0.77	per kgal				☑		NRC, 2012
Desert Breeze, Las Vegas, NV	5	6.48	per kgal capacity per year	0.4	per kgal				☑		NRC, 2012
Trinity River Authority, TX	16.4	1.29	per kgal capacity per year	0.06	per kgal		☑		☑		NRC, 2012
Denver, CO	30	15.34	per kgal capacity per year	1.2	per kgal				☑		NRC, 2012
West Basin, CA	40	21.2	per kgal capacity per year	1.15	per kgal				☑	☑	NRC, 2012
Tuscon, AZ	30	0	per kgal capacity per year	0.57	per kgal				☑		NRC, 2012
Inland Emplire, CA	40	11.05	per kgal capacity per year	1.33	per kgal				☑	☑	NRC, 2012

Location and Project Name	Size, MGD	Capital Cost		Annual O&M Cost ($/kgal capacity)		Uses					Source
		2013 Dollars	Unit	2013 Dollars	Unit	Potable	Surface water augmentation	ASR	Irrigation	Industrial	
Orange Co. GWRS, CA	70	560.69	million dollars	1.31	per kgal	☑		☑			EPA, 2012; NRC, 2012
El Paso, TX	10	26.52	per kgal capacity per year	0.37	per kgal	☑					NRC, 2012
Casey WRF/Huie Wetlands, Clayton Co., GA	24	4.43	per kgal capacity per year	0.4	per kgal	☑					NRC, 2012
Shoal Creek/Panhandle, Clayton Co., GA	4.4	6.25	per kgal capacity per year	0.35	per kgal	☑					NRC, 2012
West Basin, CA	12.5	34.73	per kgal capacity per year	2.69	per kgal	☑					NRC, 2012
Inland Emplire, CA	20	12.73	per kgal capacity per year	1.33	per kgal	☑					NRC, 2012
NAWRF, Gwinnett County, GA	20	318.8	million dollars	n/a		☑					Hartley, 2005
Sierra Vista, AZ	4	7.81	million dollars	n/a			☑	☑			EPA, 2012
San Ramon, CA	6	90.26	million dollars	n/a					☑		EPA, 2012
Elsinore Valley, CA	6	4.81	million dollars	n/a			☑				EPA, 2012
Orlando E. Regional, FL	40	56.21	million dollars	n/a			☑		☑	☑	EPA, 2012
Marco Island, FL	5	1.67	million dollars	n/a					☑		EPA, 2012

Location and Project Name	Size, MGD	Capital Cost		Annual O&M Cost ($/kgal capacity)		Uses					Source
		2013 Dollars	Unit	2013 Dollars	Unit	Potable	Surface water augmentation	ASR	Irrigation	Industrial	
TECO/SWFWMD, FL	5	75.67	million dollars	n/a						☑	EPA, 2012
Gillette Stadium, MA	0.25	19.27	million dollars	n/a				☑		☑	EPA, 2012
Mill Run, PA	0.01	19.52	million dollars	n/a					☑	☑	EPA, 2012
San Antonio, TX	233	129.07	million dollars	n/a					☑	☑	EPA, 2012
Cary, NC	5	11.45	million dollars	n/a					☑	☑	EPA, 2012
Big Spring, TX	13	18.27	million dollars	n/a			☑				EPA, 2012
Millard H. Robbins, Jr. Regional Water Reclamation Facility, VA	54	170	million dollars	.36	per kgal	☑					Schimmoller and Kealy 2014