

## Surface Water Quality Regulation as a Driver for Groundwater Recharge: The Case of Virginia's Sustainable Water Initiative for Tomorrow

NELL GREEN NYLEN<sup>1</sup>

<sup>1</sup>Center for Law, Energy & the Environment, University of California, Berkeley, School of Law, CA, USA  
Email: [ngreennylen@berkeley.edu](mailto:ngreennylen@berkeley.edu)

**ABSTRACT** Water scarcity commonly motivates managed aquifer recharge projects, but other factors can motivate recharge efforts, including in relatively water-rich areas. Surface water quality regulation has been a major driving force behind a large-scale recharge project in development in Virginia's Coastal Plain region, where nutrient pollution from agricultural and urban sources has degraded the Chesapeake Bay's ecosystems, leading state and federal regulators to require dischargers to reduce their nutrient contributions to the watershed over time. Hampton Roads Sanitation District is pursuing the Sustainable Water Initiative for Tomorrow, an innovative, multi-benefit initiative designed to address both nutrient pollution in the Chesapeake Bay watershed and regional groundwater overdraft in the Coastal Plain. When fully implemented, the initiative is expected to recharge approximately 100 million gallons per day of drinking-water quality, treated municipal wastewater into the Potomac Aquifer System through injection facilities located at five of the District's wastewater treatment plants. As a result, the District expects to reduce its nutrient discharges from those plants by approximately 90%, enabling it to meet its own mandated nutrient limits while also generating nutrient credits that it can trade to other dischargers. Modeling suggests that the initiative will increase regional water pressure within the confined aquifer system, helping to combat groundwater overdraft and its negative impacts, including aquifer compaction and related land subsidence, falling water levels in wells, and saltwater intrusion. This case study provides insights into the influence of institutional context on managed aquifer recharge and on multi-benefit water resource projects more generally. **KEYWORDS** groundwater, recharge, water quality, regulation, wastewater, multi-benefit, nutrient pollution, water

### INTRODUCTION

Institutional context is an understudied but important aspect of managed aquifer recharge (MAR). This case study is part of a broader research effort designed to address knowledge gaps about how institutional context—including the regulatory environment, the goals and capacities of key stakeholders and decision makers, and the relationships between them—affects the motivations for pursuing MAR and, ultimately, where and how MAR is implemented.

One factor that differentiates this case from the others in this special section is an unconventional motivation for pursuing MAR. Recharge efforts are often motivated by water scarcity and a desire to enhance the sustainability and resilience of human water supplies. However, other

factors can play important roles in motivating MAR, including in relatively water-rich areas. This case study examines the development and phased implementation of a large-scale advanced wastewater treatment and recharge project in Eastern Virginia for which surface water quality regulation is a major driving force.

Hampton Roads Sanitation District (HRSD) is pursuing the Sustainable Water Initiative for Tomorrow (SWIFT) in response to a confluence of complementary needs and opportunities. First, SWIFT addresses the need to reduce nutrient pollution in the Chesapeake Bay watershed, as required under the federal Clean Water Act. HRSD is able to meet current limits on the amount of nutrients it can discharge in the watershed. However,

**TABLE 1.** SWIFT Case Study Overview.

Location	Hampton Roads Sanitation District, Virginia
Groundwater challenges	Declining water pressure within the aquifer, hydraulic gradient reversal, land subsidence, and saltwater intrusion
Motivating factors for MAR	Meeting current and future wastewater effluent limitations for nutrients, insulation from uncertainty surrounding future surface water quality standards, and regional groundwater overdraft
Goal of MAR project	Recharge approximately 100 million gallons per day (MGD)
Recharge method	Injection wells
Water source	SWIFT Water (municipal wastewater receiving advanced treatment to meet drinking water standards)
Key actor(s)	HRSD; EPA, Region 3; Virginia Department of Environmental Quality; Virginia Department of Health; Potomac Aquifer Recharge Oversight Committee
Nonregulatory challenges	Technical—Ensuring chemical compatibility of recharge water with native groundwater and aquifer materials, establishing appropriate control points, understanding spatial and temporal differences in groundwater flow, and avoiding corrosion or clogging of treatment and injection equipment Institutional—Expanding areas of expertise to enable successful implementation, public/stakeholder engagement, and creation of oversight body Funding—Uncertainty about whether EPA will approve reprioritization of funding under consent decree
Regulatory issues	Lack of direct state regulatory authority over underground injection combined with strong state interest in protecting groundwater quality, monitoring requirements, contingency planning needed for potential problems, uncertainty about whether EPA will approve consent decree amendments, and regulatory implications of reducing nutrient discharges below mandatory limits
Milestones	2014—Feasibility analysis and preplanning begin 2016—Room-scale pilots of treatment process options take place 2017—HRSD submits Integrated Plan to EPA 2018—One-MGD demonstration facility (SWIFT Research Center) begins operating 2019—Legislature establishes Potomac Aquifer Recharge Oversight Committee
Current status	Demonstration facility and planning for full-scale implementation
Cost	US\$1.1 billion estimated for full-scale construction; US\$21–US\$43 million estimated for full-scale annual operating costs

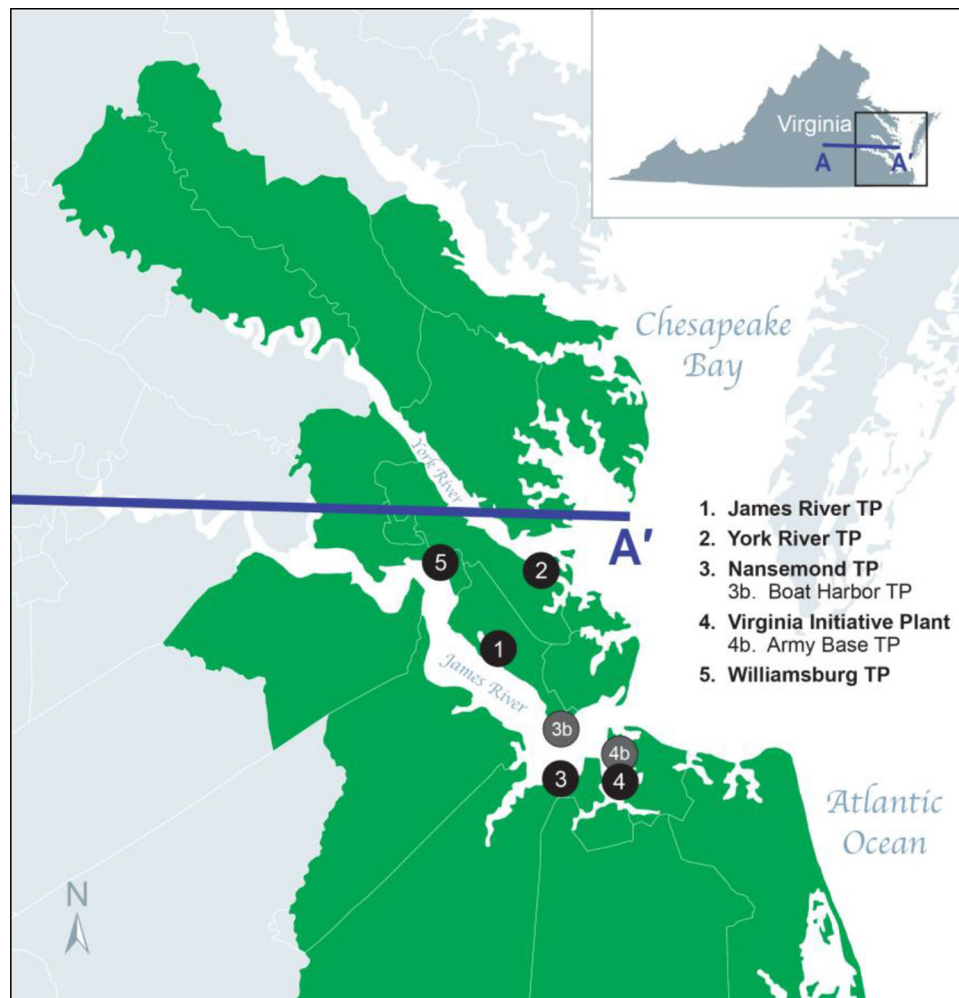
Note: EPA = U.S. Environmental Protection Agency; HRSD = Hampton Roads Sanitation District; MAR = managed aquifer recharge; MGD = million gallons per day; SWIFT = Sustainable Water Initiative for Tomorrow.

concerns that regulators might impose increasingly more stringent discharge limits in the future led HRSD to explore the possibility of preemptively treating its wastewater to drinking water standards, so it can avoid a cycle of investing in long-term assets that could quickly become outdated if effluent limits for nutrients or other pollutants are ratcheted down in the coming years. The other major driving force behind SWIFT is the need to address groundwater overdraft in Virginia's Coastal Plain, where groundwater withdrawals outstrip natural recharge rates, causing negative impacts such as declining well water levels, land subsidence, and saltwater intrusion.

Through SWIFT, HRSD will convert wastewater into a high-quality resource and use it to replenish the Potomac Aquifer System. At full-scale implementation, HRSD expects to be recharging a total of 100 million gallons per day

(MGD) of SWIFT water at five wastewater treatment plants in the Chesapeake Bay watershed. By greatly reducing the nutrient loads these plants discharge to area surface waters, SWIFT will enable HRSD not only to meet its own mandated nutrient limits, now and in the future, but also to generate nutrient credits that it can trade to other dischargers. The initiative also includes technical and institutional features meant to protect groundwater quality and ensure compliance with the federal Safe Drinking Water Act. Table 1 provides an overview of the SWIFT case study.

This case study can inform future efforts to incorporate MAR into multi-benefit solutions to complex water management challenges. While it is geared toward practitioners, other audiences may also find it useful. To increase accessibility for a broader range of readers, Key Terms and Acronyms are defined following the Conclusion.



**FIGURE 1.** Hampton Roads Sanitation District's (HRSD's) service area, showing the locations of five wastewater treatment plants with planned Sustainable Water Initiative for Tomorrow (SWIFT) treatment/recharge facilities (labeled 1–5) and two wastewater treatment plants that will not have SWIFT facilities of their own but will contribute wastewater to nearby SWIFT facilities (labeled 3b and 4b). The line A–A' shows the location of the cross section in figure 2. This figure is based on the HRSD Service Area map provided at <https://www.hrsd.com/about-us> (accessed 13 July 2019).

## CASE EXAMINATION

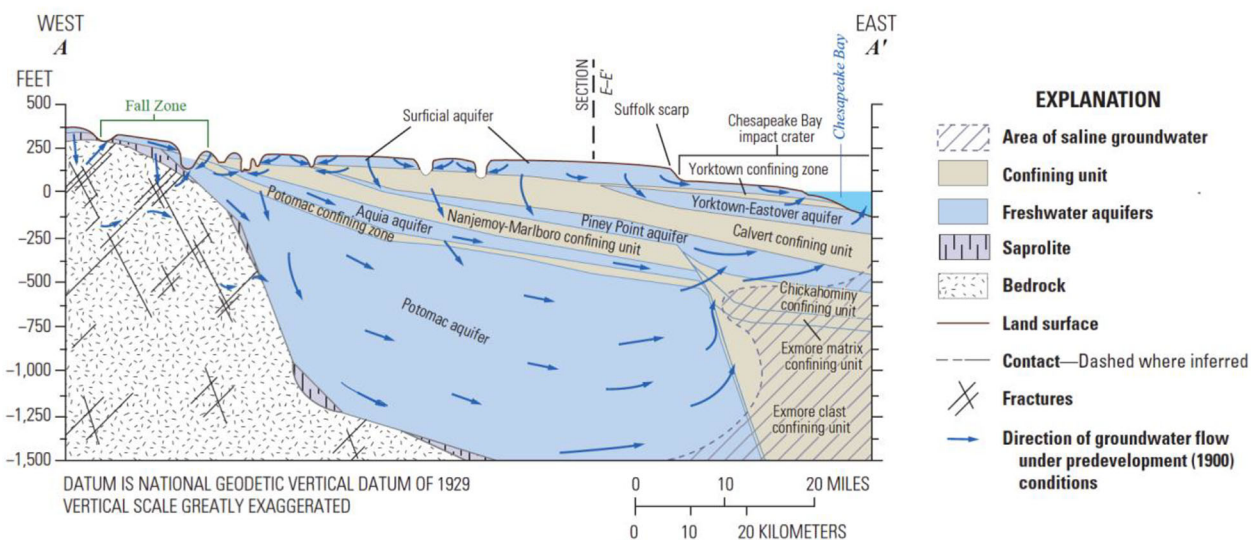
### Methods

This case study was developed through a combination of document analysis and interviews with key participants. A more detailed description of the methods for this and the other case studies in this special section can be found in Miller et al. [1]. Each of the case studies in the collection examines a different physical and institutional design for MAR. Case studies were developed through an analysis of documents and expert interviews. Documents reviewed include reports from agencies implementing the MAR projects, permits and reports from regulatory agencies, state laws and regulations, academic literature and technical reports, and news articles. Semistructured interviews were conducted with key individuals involved in the

development of each project including government officials, regulators, and project implementers. Interviewees provided firsthand knowledge of information not included in written documentation on the project, including details on process for development and challenges in implementing the project.

### Geographic Context

HRSD is a public agency that provides regional sanitary sewer conveyance and wastewater treatment for approximately 1.7 million people in 18 counties and cities in Virginia's Coastal Plain. Its service area spans much of the eastern part of the state of Virginia (figure 1). HRSD operates nine major wastewater treatment plants and seven smaller plants with a combined capacity of 249 MGD



**FIGURE 2.** Cross section through the Virginia Coastal Plain along the line A-A' shown in figure 1. *Source:* Masterson et al. [10]

that collectively treat an average of 150 MGD [2]. Much of HRSD's service area is located within the Chesapeake Bay watershed, a 64,000 square-mile area that includes parts of six states and the District of Columbia [3].

Nutrient pollution from agricultural and urban sources has degraded the Chesapeake Bay's ecosystems, negatively impacting fisheries and human health [4] and leading state and federal regulators to require significant dischargers to reduce their nutrient discharges over time.

The Coastal Plain receives, on average, more than 40 in. of precipitation per year [5] and experiences warm, humid summers and moderate winters [6, 7]. Surface water is abundant and accounts for approximately 90% of reported water withdrawals statewide (excluding withdrawals for power generation) [8].

Despite the abundance of surface water, groundwater is heavily used in Virginia's Coastal Plain. The gently sloping terrain of the Coastal Plain is underlain by a wedge of sediments that dips and thickens toward the east [9] (figure 2). This wedge includes the primary source of groundwater for the region, the hydrogeologic unit known as the Potomac Aquifer System [9–11]. Natural recharge occurs primarily along the far western edge of the Coastal Plain, where the aquifer is unconfined and surface water can directly infiltrate the system. By contrast, across most of the Coastal Plain, the Potomac Aquifer System is confined beneath less-permeable sediments that impede surface infiltration and pressurize the aquifer.

#### *HRSD and Surface Water Quality Regulation*

Like other publicly owned treatment works that discharge effluent to U.S. waters, HRSD's wastewater treatment plants must comply with permits issued under the federal Clean Water Act's National Pollutant Discharge Elimination System<sup>1</sup> [12]. The U.S. Environmental Protection Agency (EPA) has delegated primary permitting responsibilities to many states, including Virginia [13], where the Virginia Department of Environmental Quality (VDEQ) implements the program.

To begin to address nutrient pollution in the Chesapeake Bay watershed, Virginia's State Water Control Board assigned nutrient allocations to dischargers<sup>2</sup> starting in 2005. Then, in 2010, EPA went further, adopting the Chesapeake Bay Total Maximum Daily Load (TMDL), which established more restrictive limits on discharges of nitrogen, phosphorus, and sediment in the watershed [3, 14]. VDEQ is implementing the TMDL in part through a watershed-based general permit<sup>3</sup> that includes specific pollutant allocations (known as waste load allocations) for HRSD's wastewater treatment plants and for other significant Virginia dischargers.<sup>4</sup> Permittees can generate nutrient credits by discharging less than their assigned waste load allocation and may trade these credits

1. 33 U.S.C. §§ 1311, 1342, 1362.

2. 9 Va. Admin. Code §§ 25-40-10 to 25-40-70, 25-720-30.

3. Code of Virginia § 62.1-44.19:14; 9 Va. Admin. Code §§ 25-820-10 through 25-820-80.

4. 9 Va. Admin. Code §§ 25-820-70, 25-720-60(C), 25-720-120(C).

to other permittees under certain circumstances.<sup>5</sup> Dischargers were required to meet interim allocations by 2017 and must meet their final allocations under the TMDL by 2025 [15].

HRSD is currently meeting its aggregate nutrient load allocations for discharges to the James and York River basins through nutrient removal technologies it has phased in at plants in those basins over the last 12 years [16]. However, these allocations were based on the design flows of the treatment plants, and current average annual flows are much lower [16]. In the future, HRSD's nutrient allocations will likely be ratcheted down again, although it is not clear when or by how much.

HRSD also has commitments under an EPA consent decree to address Clean Water Act violations related to wet weather sanitary sewer overflows [17]. The decree requires HRSD to make significant financial investments over the coming years in order to reduce the incidence of overflows and the amount of pollutants, including nutrients, they contribute to Virginia surface waters.

#### *Regional Groundwater Overdraft and State Groundwater Regulation*

Groundwater extraction in Virginia's Coastal Plain has increased steadily over the last century, outpacing natural recharge and causing well water levels to drop more than 200 ft in some parts of the Potomac Aquifer System [9]. As a result, sediments in this confined coastal aquifer system are undergoing compaction that reduces the space available for groundwater storage and causes land subsidence that is compounding<sup>6</sup> the effects of global sea-level rise [18]. Pumping has changed groundwater flow patterns in the region in complex ways that increase the likelihood that saltwater intrusion will affect production wells [19].<sup>7</sup> Currently, water users extract groundwater from the Potomac Aquifer System at a rate of more than 100 MGD [20].

In response to concerns about groundwater quality, access, and long-term sustainability in the Virginia Coastal Plain<sup>8</sup> [21], the State Water Control Board has designated

two Groundwater Management Areas, which VDEQ administers [8]. In these areas, water users must have a permit to extract 300,000 or more gallons of groundwater per month.<sup>9</sup> As of November 2019, there were 330 active groundwater withdrawal permits for these large water users [22]. The vast majority<sup>10</sup> of the groundwater withdrawn by permittees is for industrial or public water supply uses [8]. Other groundwater users do not need permits. However, anyone extracting more than 10,000 gallons per day in any single month must report their withdrawals annually.<sup>11</sup> Little is known about unreported groundwater withdrawals, but an estimated 275,000–300,000 households rely on private domestic wells in the Eastern Virginia Groundwater Management Area alone [8].

To begin to address groundwater overdraft, VDEQ negotiated permit reductions for the 14 permittees that are collectively responsible for approximately 80% of permitted groundwater withdrawals in the Eastern Virginia Groundwater Management Area [8, 23]. Additionally, those who apply for a permit for new or increased withdrawals must now analyze and mitigate the impacts of those withdrawals.<sup>12</sup> However, further action is needed.

#### *Regulation of Underground Injection in Virginia*

MAR can be accomplished by a variety of means in unconfined aquifers, but recharging a confined aquifer generally requires an injection well that penetrates the aquifer's confining layer. Recharge through injection wells is regulated under the federal Safe Drinking Water Act's Underground Injection Control (UIC) program. Recharge wells are considered Class V wells.<sup>13</sup> Those wishing to use a Class V well must submit certain information to the UIC program and comply with requirements designed to protect underground sources of drinking water.<sup>14</sup> A permit is necessary if injection would "allow the movement of fluid containing any contaminant into" an underground source of drinking water, "if the presence of that contaminant may cause a violation of the primary drinking water standards . . . , other health based standards, or may otherwise adversely affect the health of persons."<sup>15</sup> While many states

5. 9 Va. Admin. Code § 25-820-70(IJ).

6. When compaction occurs at depth, it causes the land surface to sink, so that the same amount of global sea-level rise results in a higher relative local sea level that increases both long-term coastal inundation and temporary flooding during high tides and storms.

7. Subsidence exacerbates this risk by changing the pressure gradient between seawater and freshwater.

8. Code of Virginia § 62.1-257; 9 Va. Admin. Code § 25-600-20.

9. Code of Virginia §§ 62.1-258, 62.1-259.

10. ~52% and ~40% by volume, respectively, in 2017.

11. 9 Va. Admin. Code § 25-200-30.

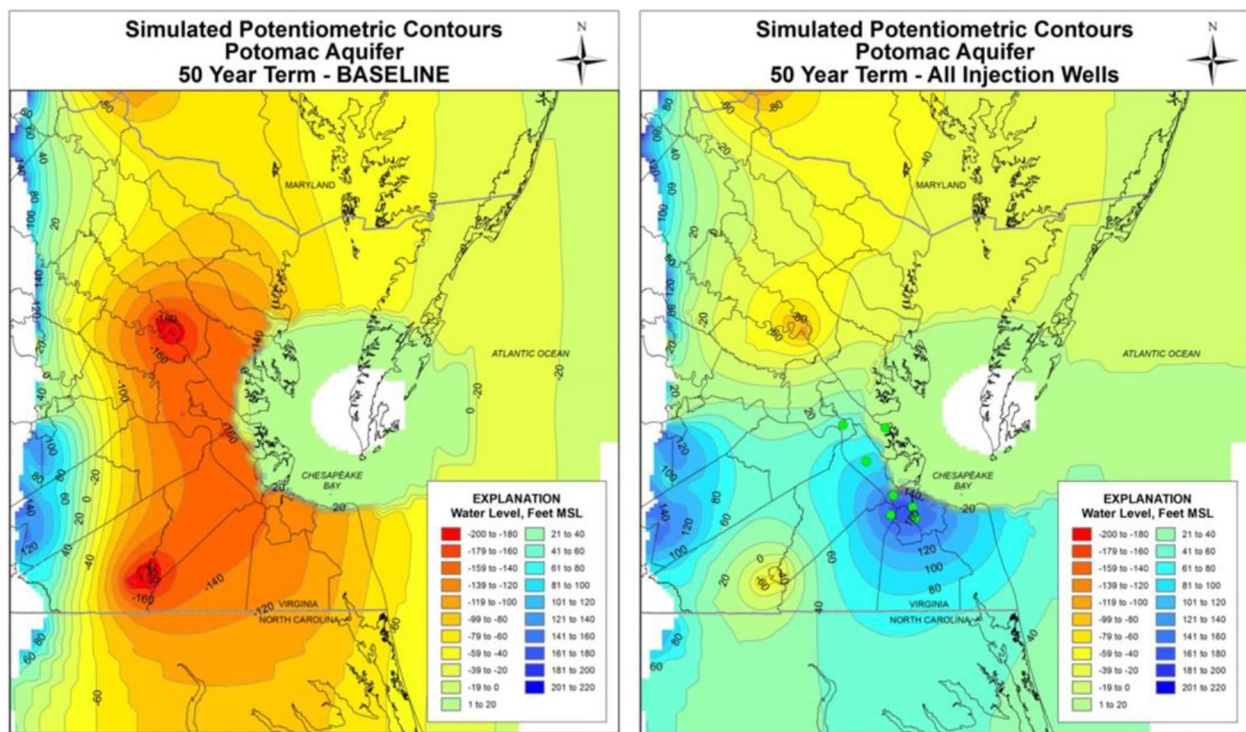
12. 9 Va. Admin. Code § 25-610-94(2).

13. 40 C.F.R. §§ 144.80(c), 144.81(6), (7), (10).

14. 40 C.F.R. §§ 144.82, 144.83.

15. 40 C.F.R. §§ 144.82(a), 144.84(b)(1).





**FIGURE 3.** Modeled future Potomac Aquifer well levels without the Sustainable Water Initiative for Tomorrow (SWIFT) (left) and assuming SWIFT facilities at seven of Hampton Roads Sanitation District's wastewater treatment plants injecting approximately 120 million gallons per day (right). *Source:* C.B. Bott and J. Heisig-Mitchell. HRSD's Vision for Managed Aquifer Recharge in Eastern Virginia, 17 May 2017 (Slide 18). Available: [https://www.chesapeakebay.net/channel\\_files/25148/trading\\_wg\\_presentation\\_051717\\_towg.pdf](https://www.chesapeakebay.net/channel_files/25148/trading_wg_presentation_051717_towg.pdf). Accessed 4 December 2019.

implement their own UIC programs, EPA Region 3 implements the UIC program in Virginia [24].

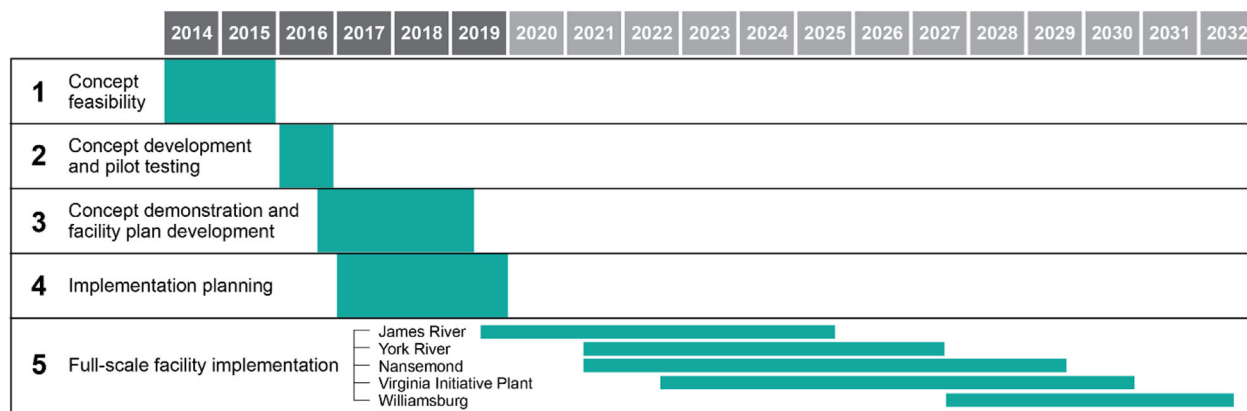
#### *Origin and Development of SWIFT*

HRSD began exploring the possibility of preemptively treating its wastewater effluent to drinking water standards to insulate itself from uncertainty surrounding future water quality standards, including its nutrient waste load allocations under the Chesapeake Bay TMDL [25, 26].

At the same time, HRSD recognized the potential for using high-quality effluent to replenish the over-tapped Potomac Aquifer System. During late 2014 and early 2015, analysis using VDEQ's groundwater model [25] suggested that injecting a combined 120 MGD of water at seven of HRSD's wastewater treatment plants would increase water pressure within much of the aquifer (figure 3) at an estimated cost of approximately US\$1 billion. This recharge would help stave off coastal saltwater intrusion; reduce future compaction, subsidence, and related relative sea-level rise; and, in theory, sustainably support existing and projected groundwater

withdrawals in the region. With the feasibility study in hand, HRSD reached out to the governor, the Secretary of Natural Resources, VDEQ, the Virginia Department of Health (VDH), the U.S. Geological Survey (USGS), the Hampton Roads Planning District Commission, and others with a potential stake in the multi-benefit project to gather input and seek support for moving forward. HRSD would eventually name the project SWIFT [27].

After initial research to examine treatment options, HRSD ran side-by-side, small-scale pilots at its York River Wastewater Treatment Plant in Seaford, Virginia, in 2016 [28]. The pilots subjected plant effluent to two different treatment processes: (1) a membrane-based reverse osmosis process and (2) a carbon-based advanced treatment process [28]. Testing demonstrated that both processes produced effluent that meets all primary (human-health-based) drinking water standards [28]. HRSD decided to use the carbon-based process because it has several advantages over reverse osmosis, including using less energy, generating less waste, and creating effluent that is projected to be more



**FIGURE 4.** Time line of Sustainable Water Initiative for Tomorrow development and its projected full-scale implementation.

chemically compatible [29–32] with native groundwater and aquifer materials.

HRSD is now using a US\$25 million design-build, proof-of-concept facility—the SWIFT Research Center—to demonstrate “at a meaningful scale” that the advanced treatment process it has chosen can meet primary drinking water standards and is chemically compatible with the native groundwater and sediments of the aquifer [33]. The Research Center is located at HRSD’s Nansemond Wastewater Treatment Plant in Suffolk, Virginia, and is capable of treating and injecting approximately 1 MGD [28]. In May 2018, the facility began injecting SWIFT Water into the Potomac Aquifer System [34].

In parallel with continuing to learn from the SWIFT Research Center, HRSD is laying the groundwork for full-scale implementation (figure 4). HRSD plans to construct SWIFT facilities at five of its wastewater treatment plants: James River, York River, Nansemond, Virginia Initiative, and Williamsburg [35]. However, as figure 1 shows, two additional plants will be involved. HRSD is planning a new pump station and force main to convey untreated wastewater flows from its Boat Harbor plant to the Nansemond plant [36]. It is planning a second pump station and force main to convey secondary-treated effluent from its Army Base plant to a combined SWIFT facility at the Virginia Initiative plant [37]. The decision to consolidate SWIFT treatment and recharge facilities in this way was made based on physical limitations at the Boat Harbor and Army Base plants and projected cost savings associated with consolidation [36, 37].

HRSD hopes to secure all required approvals for and begin construction of the first full-scale SWIFT facility in 2020, with all five facilities up and running by 2032 [35,

38]. Designs for the facilities, and associated monitoring, will be based on knowledge gained from operating the SWIFT Research Center and the site-specific conditions at each location [39]. At full implementation, HRSD expects to recharge approximately 100 MGD [39].

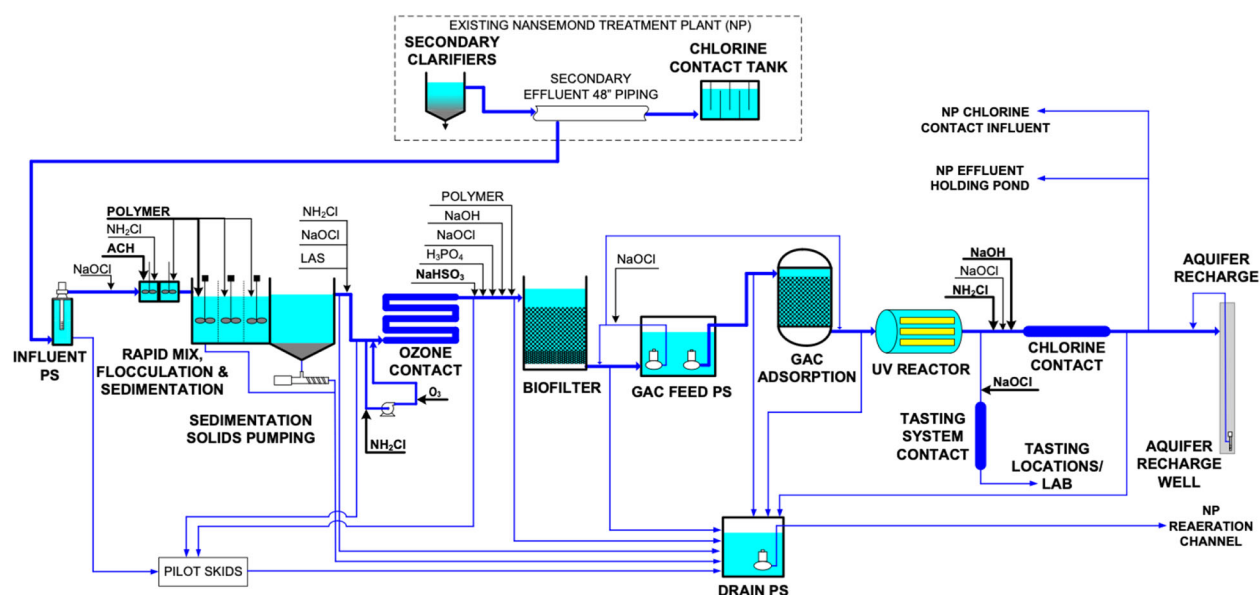
#### *Managed Aquifer Recharge Through SWIFT*

MAR projects involve many important, and often inter-related, considerations. These include designing an effective recharge process, establishing appropriate water accounting and monitoring protocols, determining how (and by whom) recharged water will be recovered, identifying the institutional arrangements needed to implement the project, and procuring sufficient funding.

**THE RECHARGE PROCESS.** Before wastewater gets to a full-scale SWIFT facility, it will be collected in HRSD’s sanitary sewer system, conveyed to one of its wastewater treatment plants, and subjected to at least secondary treatment. Within the SWIFT facility, this secondary effluent will receive further treatment before it is injected into the aquifer.

At the SWIFT Research Center, secondary effluent from HRSD’s Nansemond plant goes through a treatment train that includes coagulation, flocculation, sedimentation, ozonation, biological filtration, granular activated carbon, and ultraviolet disinfection [39] (figure 5). When advanced treatment is complete, the “SWIFT Water” is injected into a 1,410-ft-deep, 12-in-diameter recharge well with 11 separate screened intervals that intersect different parts of the Potomac Aquifer System [39].

The SWIFT Research Center is helping HRSD to gain critical operational experience, build knowledge, and



**FIGURE 5.** Sustainable Water Initiative for Tomorrow Research Center process flow diagram. From Hampton Roads Sanitation District (2019).

identify and address potential issues with the scaled-up treatment process, injection infrastructure and processes, and groundwater quality and flow monitoring. For example, in the Center's first few months of operation, HRSD discovered that an estimated 4.8 million gallons of recharged water exceeded the maximum contaminant level for nitrite because the biological filters in the treatment system were not yet fully functional [40–43]. Staff established new procedures for identifying and addressing contaminant exceedances and installed a continuous nitrite-monitoring analyzer as a critical control point [42, 43]. To ensure that it cleared (fully removed) the high-nitrite water, HRSD pumped about 20 million gallons of water out of the aquifer system before resuming normal recharge operations [40]. Similarly, in late 2018, HRSD suspended Research Center operations to address corrosion on equipment, including the Center's stainless steel flocculation and sedimentation tanks [39, 44]. HRSD has noted that it plans to use concrete tanks for full-scale SWIFT facilities to avoid corrosion problems [45]. Following warranty repairs, the Research Center was restarted in early April 2019, with injection beginning again later that month [46].

**RECHARGE WATER ACCOUNTING AND MONITORING.** HRSD is keeping close track of the water it recharges at the SWIFT Research Center, any water it pumps back

out, and the impacts associated with recharge. By May 2019, the Center had successfully recharged a (net) total of 100 million gallons of SWIFT Water [38]. Although this represents a small fraction of the recharge planned at full implementation, USGS researchers were able to see “a signal of expansion of the aquifer by a third of a millimeter over the course of two months” in an area that had been experiencing estimated compaction rates of 1.5–3.7 mm per year [47].

Four down-gradient monitoring wells are helping to track the progress and impacts of water recharged at the Research Center [28]. Three conventional monitoring wells—screened in the upper, middle, and lower portions of the aquifer—are located 400–500 ft from the injection well [39]. Additionally, a special monitoring well 50 ft from the injection well uses a special sampling system<sup>16</sup> to collect groundwater samples corresponding to each of the injection well's screens [39]. Early monitoring results<sup>17</sup> suggest that the movement of recharged water varies significantly over time and across space [39].

To track any water quality changes that occur, HRSD will monitor the recharge front as it migrates outward from each SWIFT facility. Water recharged at the SWIFT Research Center is not expected to reach the closest private well for about 50 years. If a contamination

16. The sampling system uses Flexible Liner Underground Technology.

17. Based on chloride concentrations and specific conductivity.



problem begins to develop, there should be ample time to detect it and mount an appropriate response that prevents harm to groundwater users, such as reversing the direction of the recharge pumps to remove the affected water.<sup>18</sup>

**RECOVERY.** HRSD does not plan to recover (withdraw) the water it recharges for its own use. Instead, the water will be available to Potomac Aquifer System users, subject to permitting or other regulation under state law.

**INSTITUTIONAL ARRANGEMENTS.** The SWIFT Research Center is currently operating without a permit for underground injection.<sup>19</sup> However, the full-scale SWIFT facilities will likely require UIC permits. HRSD will need to demonstrate that its injection activities will not adversely impact the aquifer as a source of drinking water.

Because the state has not accepted delegation of the UIC program from EPA, VDEQ and VDH lacked direct regulatory authority over HRSD's ability to pursue SWIFT in the first instance [33]. Recognizing the strong state interest in ensuring safe drinking water, HRSD has worked with these agencies, other entities, and outside experts to enable robust state oversight. It has held workshops, performed outreach, and maintained lines of communication with VDH and VDEQ at both the executive and technical levels throughout the SWIFT planning process [33, 48]. EPA Region 3 has solicited input from both agencies regarding proposed regulatory limits for water quality parameters [33].

Legislation passed in February 2019 memorializes this state oversight role. Virginia Senate Bill 1414 was modeled after an oversight program developed for an indirect potable reuse project<sup>20</sup> [49]. The legislation creates a 10-member advisory board—the Potomac Aquifer Recharge Oversight Committee—and a new monitoring laboratory, codirected by two university faculty members, to independently monitor SWIFT's effects.<sup>21</sup> The Oversight Committee includes eight voting members (the State Health Commissioner, the Director of VDEQ, the Executive Director of the Hampton Roads Planning District Commission, both laboratory Co-Directors, the Director

of the Occoquan Watershed Monitoring Laboratory, and two Virginia citizens appointed by the Governor) and two nonvoting members (the EPA Region 3 Administrator and the Director of the USGS's Virginia and West Virginia Water Science Center).<sup>22</sup> The legislation also explicitly authorizes the state to direct HRSD to stop injection activities or make needed changes if it fails to comply with EPA permits or authorizations.<sup>23</sup>

**COSTS AND FINANCING.** Full SWIFT implementation will involve an estimated US\$1.1 billion in capital spending [50], and early estimates of SWIFT's operating costs range from US\$21 to US\$43 million per year [51].

HRSD's governing commission independently sets user fees, the agency's primary source of revenue [52]. It issues bonds and uses cash on hand to finance capital projects [53], as well as pursuing available grant opportunities [52].

HRSD hopes to meet SWIFT's capital costs without altering its 10-year financial forecast by reprioritizing planned capital improvements [17, 54, 55]. To meet existing commitments, including nutrient requirements under the Chesapeake Bay TMDL and improvements required under its EPA consent decree [55, 56], HRSD had already developed a financial plan that includes a new rate structure to support about US\$2.5 billion in capital improvements over the next 10 years [56]. Based on SWIFT's projected water quality benefits, in September 2017, HRSD submitted an Integrated Plan<sup>24</sup> [57] for carrying out its responsibilities under the consent decree that would frontload SWIFT implementation and delay some required overflow reduction work [55]. However, EPA has not yet approved the plan, leading HRSD to consider petitioning the court to modify the consent decree to allow it [54].

#### *SWIFT Incentives and Benefits*

Many factors have motivated SWIFT or contributed to its success to date. Among the factors that may be relevant for other MAR projects are the potential for surface water quality regulation to serve as a motivator; the potential for recharge to provide specific regional benefits; the expected scale of those benefits and the potential for taking advantage of economies of scale; ongoing information gathering and analysis; the ability to self-fund; the potential for

18. In the unlikely event a severe, delayed-onset water quality problem develops and cannot be addressed in other ways, Hampton Roads Sanitation District could pay to extend public water service to households and businesses with affected wells.

19. This is known as "authorization by rule."

20. 9 Va. Admin. Code § 25-410-40.

21. Code of Virginia §§ 62.1-272 to 62.1-275.

22. Code of Virginia §§ 62.1-272.

23. Code of Virginia §§ 62.1-275.

24. 33 U.S.C. §§ 1319(h), 1342(s).

generating revenue or other secondary value; and building support through outreach and engagement to the public, regulators, and other critical stakeholders.

**SURFACE WATER QUALITY REGULATION AS A MOTIVATOR.** Although water scarcity is often the primary motivator for reusing treated wastewater in the western United States, SWIFT offers a good example of another driver that can come into play even in water-rich areas: surface water quality regulation. The prospect of increasingly stringent nutrient limitations for HRSD's discharges in the Chesapeake Bay watershed led it to explore the idea of treating its wastewater to drinking water standards to avoid a cycle of investment in long-term assets that could quickly become outdated if effluent limitations for nutrients (or other pollutants) are ratcheted down in the coming years. This high-volume, high-quality water makes the large-scale recharge operation that is central to SWIFT technically possible. Furthermore, HRSD's planned spending under its consent decree, and the possibility of reprioritizing a significant portion of that spending in the near term, provides a potentially straightforward path for funding SWIFT.

**REGIONAL GROUNDWATER BENEFITS.** Rather than discharging highly treated water into the already surface-water-rich lower reaches of the Chesapeake Bay watershed, where it would have little water supply benefit, or attempting to create stable demand for direct reuse of SWIFT Water, HRSD realized it could instead address a critical regional need. Replenishing the Potomac Aquifer System will have short- and long-term benefits for groundwater users and communities across Eastern Virginia.

**HRSD'S SIZE AND GEOGRAPHY AND SWIFT'S SCALE.** HRSD's large throughput and geographic footprint will enable it to treat and recharge large volumes of water each day at multiple locations with high recharge potential. These features increase the likelihood that SWIFT will significantly improve regional aquifer conditions. Additionally, although site-specific analysis and design will be necessary for each SWIFT facility, the economies of scale associated with planning and constructing multiple facilities will likely be significant.

**ONGOING INFORMATION GATHERING, MONITORING, AND ANALYSIS.** To date, information gathering, monitoring, and analysis have helped demonstrate the likely and

actual impacts of SWIFT. Continuing to track the quantity of water recharged, the recharged water's progress, effects on groundwater quality, changes in subsidence, and other parameters will be crucial for measuring SWIFT's performance relative to expectations, identifying where adjustments are needed, and protecting groundwater users from unintended consequences.

**HRSD'S INDEPENDENT RATE-SETTING AUTHORITY AND LARGE RATEPAYER BASE.** HRSD has the benefit of independently setting its rates for wastewater service and is able to spread costs across its large ratepayer base to achieve its goals. Other wastewater service providers may need approval for rate changes, and smaller providers cannot spread costs as widely. Entities with these constraints could have a harder time funding an ambitious project like SWIFT.

**THE GENERATION OF NUTRIENT CREDITS.** HRSD expects SWIFT not only to meet HRSD's nutrient reduction responsibilities but also to generate nutrient credits it can trade to municipal stormwater dischargers to help achieve the Chesapeake Bay TMDL more quickly and cost effectively [58, 59]. SWIFT will significantly reduce HRSD's nutrient discharges to the Chesapeake Bay watershed, eliminating an estimated 90% of the nutrient load from each SWIFT-equipped wastewater treatment plant [33]. Estimates suggest SWIFT could generate enough credits to enable 11 counties and cities in the area to save up to US\$2 billion on improvements that would otherwise be needed to meet their mandated nutrient reductions [47, 60].<sup>25</sup> HRSD has already made agreements with all 11 municipalities [47]. These arrangements have the potential to further the surface water quality and public health goals of VDEQ, EPA, and VDH while helping to minimize the costs of complying with the Chesapeake Bay TMDL for the municipalities and the people they serve. Because the primary beneficiaries of the proposed trades will be HRSD ratepayers, who are funding SWIFT (and, therefore, funding credit generation) through their user fees, and who live in those municipalities, HRSD will provide nutrient credits under these agreements at no charge. However, it will also look for opportunities—that do not directly affect

25. These counties and cities have municipal separate storm sewer system (MS4) discharge permits that require them to make nutrient reductions.

its ratepayers—to trade credits to other interested parties at market prices, which would provide the district with an additional source of revenue to help offset SWIFT’s costs. Regardless, the expected availability of credits and the savings they represent for potential trading partners and the communities they serve provide economic incentives for increased regional support for SWIFT.

**EXTENSIVE OUTREACH AND ENGAGEMENT.** From the beginning, HRSD has made concerted, extensive efforts to engage with EPA, VDEQ, VDH, area municipalities, nonprofit organizations, and other stakeholders to understand their goals, ideas, and concerns. The SWIFT Research Center has also expanded opportunities for direct public engagement and education through, for example, frequent tours by school and community groups. Collectively, these efforts have helped build broad support for SWIFT and made the project better.

## CONCLUSION

This case study examines HRSD’s experience to date pursuing SWIFT, an innovative initiative designed to address both nutrient pollution in the Chesapeake Bay watershed and groundwater overdraft in Virginia’s Coastal Plain region. When SWIFT is fully implemented, HRSD expects to recharge a total of 100 MGD of high-quality water into the Potomac Aquifer System at five of its wastewater treatment plants. If the initiative goes as planned, it will substantially reduce HRSD’s wastewater discharges and nutrient contributions to the watershed, generating nutrient credits it can trade to other dischargers.

Surface water quality regulation has been a key driver for SWIFT. Without this incentive, HRSD would have little motivation to pursue recharge and the broad public benefits—for both surface water quality and regional aquifer conditions—it is likely to bring.

Although HRSD is the primary proponent of and manager for SWIFT, it is a truly multi-benefit initiative that takes advantage of a confluence of needs and opportunities and carries multiple risks. As a result, an array of public and private entities have a significant stake in SWIFT’s success. The reduced nutrient loading enabled by SWIFT will further the surface water quality goals and public health missions of VDEQ, VDH, and EPA and improve conditions for surface water recreation, public water systems that use surface water, and Chesapeake Bay fisheries. The nutrient credits SWIFT is expected to

generate will help cities and counties meet required nutrient reductions more cost effectively, reducing the financial burden on their residents. Groundwater users of all types stand to benefit from more reliable and sustainable access to groundwater. Finally, SWIFT has the potential to reduce future subsidence and related relative sea-level rise across the Virginia Coastal Plain, benefiting everyone in the region but especially those living or working in low-lying coastal areas. All of these stakeholders have an interest in robust oversight, monitoring, contingency planning, performance evaluation, and adjustment to ensure SWIFT’s success and to identify and appropriately address any problems that arise.

Perhaps SWIFT’s most distinctive feature is HRSD’s recognition of and proactive approach to addressing a particular type of regulatory risk—specifically, a lack of direct state regulatory authority over underground injection coupled with a strong state interest in groundwater quality and the state’s responsibility and broad general authority to protect public health. HRSD has not only made sure key state agencies (VDEQ and VDH), other important stakeholders, and experts have seats at the table during SWIFT development and implementation, it has gone a step further, pursuing legislation to formalize a robust state oversight role. Similarly, HRSD has identified contingencies for addressing low-probability (but high-consequence) drinking water contamination, should it arise.

Notably, some of the factors that have, so far, made SWIFT possible could pose future challenges. First, despite SWIFT’s explicitly multi-benefit nature, HRSD has been its primary decision maker and proponent to date. Yet HRSD’s decisions need to account for the benefits SWIFT might bring, and the burdens SWIFT might impose, on a range of other parties with sometimes divergent interests and needs. To gain and maintain their support, HRSD has needed to frame SWIFT in terms of these distinct potential benefits and to ensure that SWIFT is technically constructed and validated to actually produce them. The newly formed Potomac Aquifer Recharge Oversight Committee is likely to change this dynamic by distributing formal responsibility for SWIFT among more actors. Second, HRSD is proposing to pay for SWIFT in large part by reprioritizing funding that was originally intended for other capital improvement projects required under its consent decree. If EPA does not approve this proposal, HRSD may need to find alternative sources of funding. This would, at a minimum,

complicate and delay SWIFT implementation. But it might not pose an insurmountable barrier if other stakeholders that stand to benefit from SWIFT are willing to pitch in.

This case study provides a window into how institutional context can affect MAR, including MAR projects for which surface water quality regulation is an important driver. These insights may also be relevant for multi-benefit water resource projects, which can involve similar considerations and motivations, more broadly.

## KEY TERMS AND ACRONYMS

(CWA) *Clean Water Act*—An act passed by the U.S. Congress in 1972 to control water pollution. It prohibits discharges of pollutants from a point source into “waters of the United States” without a permit (see NPDES below).

*Confined aquifer*—A water-bearing hydrogeologic unit that is overlain by a less-permeable “confining” layer.

*Consent decree*—A court order reflecting settlement terms that parties to a lawsuit have agreed to, which is entered as a judgment of the court. Regulators sometimes use consent decrees to require entities that have violated regulatory requirements to address the underlying problems that led to the violations.

*Design flow*—The volume of wastewater a wastewater treatment plant is designed to treat over a specific unit of time.

*Eastern Virginia Groundwater Management Area*—One of two Groundwater Management Areas currently designated in the state of Virginia.

(EPA) *Environmental Protection Agency*—The federal agency responsible for implementing federal water quality regulation, including the Clean Water Act and the Safe Drinking Water Act.

*EPA Region 3*—The EPA office responsible for implementing federal environmental laws in the Mid-Atlantic region, serving Delaware, the District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia, and seven federally recognized tribes.

*Force main*—A pressurized pipe used in conjunction with a pump to convey wastewater from one location to another.

(HRSD) *Hampton Roads Sanitation District*—A wastewater utility that provides regional sanitary sewer conveyance and wastewater treatment for much of Virginia’s Coastal Plain.

*Land subsidence*—The gradual settling or sudden sinking of the land surface as a result of the removal or

displacement of subsurface materials (e.g., the compaction of aquifer materials as a result of groundwater withdrawals).

(MAR) *Managed aquifer recharge*—A project that intentionally introduces water (usually excess surface water) into an aquifer.

(MGD) *Million gallons per day*—A measure of flow. In this case, the volume of water (in millions of gallons) that passes through a wastewater treatment plant or is recharged in a unit of time (1 day).

(NPDES) *National Pollutant Discharge Elimination System*—The permitting program for pollutant discharges under the federal Clean Water Act.

*Nutrient credit*—An unused authorization to discharge a certain amount of nitrogen or phosphorus into a particular watershed that may be traded.

*Potomac Aquifer System*—The primary source of groundwater used in Virginia’s Coastal Plain, currently understood to be a single hydrogeologic unit consisting of a three-dimensional network of anastomosing coarser-grained (generally more permeable) river channel deposits and finer-grained (generally less permeable) overbank deposits.

(POTW) *Publicly owned treatment works*—A wastewater treatment works owned by a state or municipality, including all devices and systems used to store, treat, or recycle municipal sewage or liquid industrial wastes as well as the sewers and pipes used to convey wastewater to a POTW treatment plant.

*Reuse*—Putting treated wastewater to some useful purpose. Reuse can be direct (such as using treated wastewater immediately for landscape irrigation) or indirect (e.g., storing treated wastewater underground for a period of time before withdrawing it for subsequent use).

*Sanitary sewer*—A pipe or conduit that carries wastewater from residential, commercial, and industrial sources to a wastewater treatment plant (collectively known as a *sanitary sewer collection system*).

(SSO) *Sanitary sewer overflow*—Untreated or partially treated sewage that escapes from a sanitary sewer collection system.

*Safe Drinking Water Act*—An act passed by the U.S. Congress in 1974 to ensure safe drinking water. It requires EPA to set federal drinking water standards that all water providers must meet and prohibits underground injection that could endanger drinking water sources (see UIC Program below).



*Saltwater intrusion*—Landward movement of the interface between freshwater and saltwater in a coastal aquifer (or upward movement of salty pore water from deeper sediments) commonly caused by groundwater pumping.

*Secondary effluent*—Wastewater that has undergone primary treatment (physical separation, by screening and settling, of solids) and *secondary treatment* (generally, biological removal of most dissolved and suspended organic compounds).

*State Water Control Board*—The governor-appointed board responsible for administering state water control law in Virginia. It adopts regulations and considers special orders resolving violations in certain circumstances but has delegated day-to-day administration to VDEQ.

(SWIFT) *Sustainable Water Initiative for Tomorrow*—The name of Hampton Roads Sanitation District's wastewater treatment and recharge program that is the subject of this case study.

*SWIFT Water*—Municipal wastewater that has undergone advanced treatment in a SWIFT facility to meet drinking water standards.

(TMDL) *Total Maximum Daily Load*—The total amount of a pollutant that may be discharged to a waterbody with impaired water quality under the federal Clean Water Act.

(UIC Program) *Underground Injection Control Program*—The program that regulates underground injection wells to protect drinking water aquifers under the federal Safe Drinking Water Act.

(USGS) *U.S. Geological Survey*—A federal agency responsible for providing reliable scientific information, including information about water resources.

(VDEQ) *Virginia Department of Environmental Quality*—The state agency responsible for implementing the federal Clean Water Act's NPDES program and overseeing groundwater management in Virginia. It administers regulations approved by the State Water Control Board.

(VDH) *Virginia Department of Health*—The state agency responsible for protecting public health in Virginia.

(WLA) *Waste load allocation*—The proportion of the Total Maximum Daily Load for a particular waterbody that is allocated to a specific point source of pollutant discharges, such as a certain wastewater treatment plant.

(SSOs) *Wet weather sanitary sewer overflows*—SSOs that occur as a result of inflow or infiltration of water into the sanitary sewer system during or after a storm event.

## ACKNOWLEDGMENTS

Michael Kiparsky helped interview key actors in SWIFT's development. Michael Kiparsky, Anita Milman, Kathleen Miller, Dwayne Amos (Hazen and Sawyer), Marcia Degen (VDH), Jamie Heisig-Mitchell (HRSD), Ted Henifin (HRSD), Scott Kudlas (VDEQ), and John Tracy (Texas Water Resources Institute) provided comments on a draft of this case study. Their thoughtful feedback informed the final version.

## COMPETING INTERESTS

The author has declared that no competing interests exist.

## FUNDING

Funding for this research project was provided by Nestlé Waters North America. Additional funding was provided by National Science Foundation Grant 28139880-50542-C to the ReNUWIt Engineering Research Center. This case study builds on research funded by U.S. Environmental Protection Agency Grant EPA91601-0001 through Paradigm Environmental, Inc.

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