CLEAR

Christiana Land, Ecosystem, and Aquatic Restoration[1]

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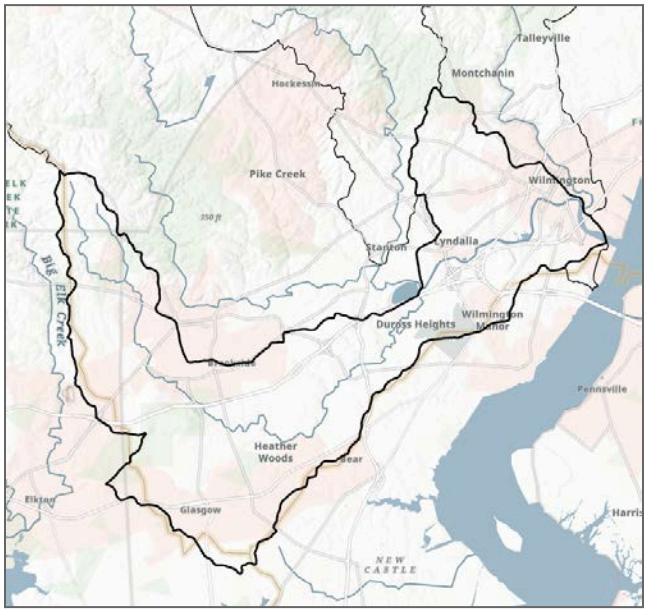

[1] This student paper was prepared in 2026 in partial completion of the requirements for UAPP 411/611, a course in the Joseph R. Biden School of Public Administration and Policy at the University of Delaware. The research, analysis, water problem identification, and recommendations contained in this paper are the work of the student team who authored the document and do not represent the official or unofficial views of the School of Public Policy or of the University of Delaware. Without the specific permission of its authors, this paper may not be used or cited for any purpose. The authors relied in many instances on externally supplied data and make no independent representations as to the accuracy of the data.

Mission Statement

The goal of CLEAR is to assess ongoing damage to the Christina River Watershed and provide targeted recommendations for remediation that build upon existing cleanup efforts. This report offers guidance at the local and state level on actions that can help restore the watershed and its surrounding ecosystems. The proposed recommendations are designed to be implemented over a 15-year period, with full completion expected by 2041.

Background

Geographical Context

The Christina River Watershed is located primarily in New Castle County, Delaware, and extends into portions of Maryland and Pennsylvania. As the major cities and towns have grown in Delaware, the watershed has become an increasingly important feature of the region's landscape (DNREC, 2014). The landscape of the watershed is a mix of agricultural, urban, and suburban land uses (Delaware River Watershed Initiative) and is part of the larger Christina Basin which spans approximately 78 square miles (Christina Conservancy, 2019). The watershed is fed by the Red Clay Creek, White Clay Creek, and the Brandywine River, and ultimately drains into the Delaware River (DNS, 2007).

Physical Characteristics of the River

The main stem of the watershed, the Christina River, is approximately 35 miles (56 km) long. Its headwaters begin in Maryland before the river flows into Newark, Delaware (Christina Conservancy, 2019). The lower portion of the river, just south of Christiana, Delaware, is tidal due to the water being pushed upstream from the Delaware River.

Within the Atlantic Coastal Plain portion of the watershed, the landscape features steep, incised stream channels. In addition, parts of the main river have been channelized to support cargo traffic in Wilmington, Delaware.

Photo #1. Upper Christina River on Rittenhouse Trail. Photo taken on April 17th, 2026

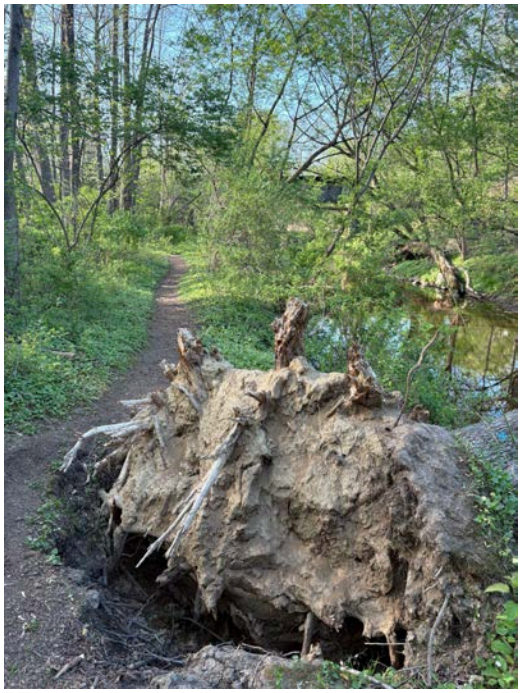

Photo #2. Upper Christina River on Rittenhouse Trail. Photo of bank erosion taken April 17th, 2026.

Water Quality and Composition

Water quality in the Christina River is affected by several stressors, including wetland loss from development, land conversion, and the legacy impacts of historical PCB discharges (McGuire, 2025). Local agencies have determined that the river is impaired due to levels of nutrients and chemical pollutants recorded above the Total Maximum Daily Load (TMDL) set by the State of Delaware (DNS, 2007). The Delaware Department of Natural Resources and Environmental Control (DNREC) is currently implementing a plan to address historic PCB pollution in the Christina River through their Christina-Brandywine River Remediation Restoration Resilience (DNREC) project and the Watershed Approach to Toxics Assessment and Restoration Program (WATAR). These projects involve soil assessment and remediation due to concerns about past contamination in vulnerable communities along the Christina and Brandywine Rivers.

Biological Diversity

Despite urbanization, the Christina River watershed supports a range of ecologically significant habitats and species, even though their conditions are somewhat degraded. One habitat present in the Christina River Watershed is tidal wetlands. Tidal wetlands are biologically rich habitats and are a critical resource for migrating shorebirds and wintering waterfowl, while serving as nurseries for commercial fish and shellfish species. Another type of habitat present is freshwater wetlands which provides wildlife and plant habitat for a number of species. One significant ecological feature of the watershed is the Delmarva Bay. Delmarva Bays are isolated, shallow, seasonally flooded depressions that support rare plants and animals such as the eastern tiger salamander (Stimpson, 2018). Approximately 73 acres of Delmarva Bays remain in the Christina River watershed. However, invasive species represent a threat to native biodiversity

across all wetland types. As of 2014, a report compiled by DNREC and the Partnership for the Delaware Estuary noted that invasive plant species were found in 95% of the riverine wetlands in the watershed, with 48% of riverine wetlands dominated by invasive plant cover (DNREC, 2014). Common reed was the most prevalent invasive plant in tidal wetlands, though purple loosestrife, narrowleaf cattail, and mile-a-minute weed also contributed to the invasive plant cover, with an estimated 34% of the tidal wetland acreage in the watershed covered by invasive plants (Jennette et al, 2014).

Human Connections

The Christina River runs through downtown Wilmington and is the site of the Port of Wilmington. A high percentage of developed land cover exists within the Delaware boundary of the Christina River watershed. The Christina River Watershed provides more than 75% of the water supply for residents and businesses in New Castle County, Delaware. (Christina Conservancy, 2019). The Christina River watershed has been shaped by centuries of human activity, beginning with European settlement in 1638 and accelerating through the Industrial Revolution and modern development. One of the biggest impacts in recent history to the river and surrounding tidal marshes occurred with the construction of Interstate 95 in the 1960s. During construction over 400 hectares (1,000 acres) of tidal marsh were destroyed (Jennette et al, 2014). The Christina River watershed is currently among the most urbanized in Delaware, with 59% of land use being characterized as "urban" (Christina Conservancy, 2019). Figure #1 shows the land-cover and land-use for the watershed. In addition to wetland degradation, environmental contamination is a significant issue in the Christina River watershed. Four Superfund sites are located in the watershed and dozens of Brownfield sites are in Wilmington. Some Brownfield

Sites within the Christina River Watershed include the Dupont Haskell Labs (U.S. EPA, 2024), Chrysler Assembly Plant, State Funded Brownfield (BrightFields, Inc., 2014), Newark South Well Field - West (U.S. EPA, 2017), Churchman's Marsh (DNREC), New Castle Army Airfield (DNREC), and the E.I Dupont Newport Landfill (DNREC).

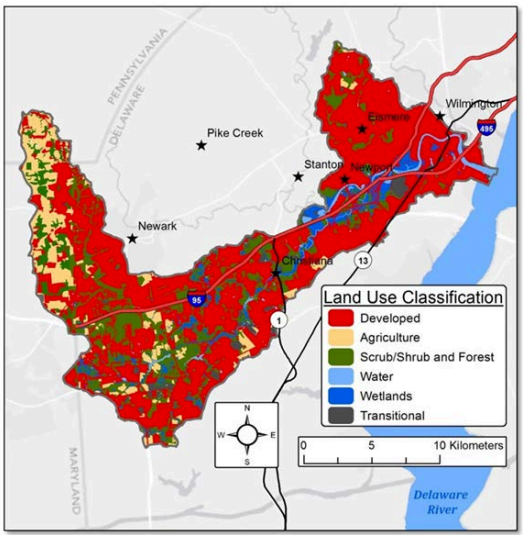

Figure #1. Land cover of the Christina River watershed based on 2005 (PA), 2007 (DE) and 2010 (MD) Land-use/Land-cover datasets. (Jennette et al, 2014).

Economic Considerations

The Christina River watershed is a significant economic and ecological asset in Delaware and the surrounding region. According to the University of Delaware Water Resources Center (WRC, 2013), the water, natural resources, and ecosystems of the Christina River watershed contribute between $98 million and $3.4 billion annually to the Pennsylvania, Delaware, and Maryland economies encompassing water quality, water supply, fish and wildlife, recreation, agriculture, forests, and public parks (Baumbach et al, 2013). Natural resources within the Christina River watershed also directly and indirectly support over 19,000 jobs generating more than $40 million in annual wages. Recreational fishing represents a significant share of this

value. Delaware's resident population in 2023 was approximately 182,321 (Christina Conservancy, 2019). Applying a per-capita fishing value of $32 per person yields an estimated annual recreational fishing value of approximately $33 million for the watershed's Delaware population (WRC, 2013). This figure aligns with the broader regional picture: the U.S. Fish and Wildlife Service found the annual economic value of recreational fishing, hunting, birding, and wildlife-associated activities was $269 million in Delaware alone in 2006 dollars (WRC, 2013), which is about $472 today (MN FED Inflation Calculator).

Streamflow in the Christina River also represents a quantifiable water supply asset. The primary USGS stream gauge monitoring the lower portion of the free-flowing Christina River is Station 01478000, located on the right bank approximately 0.5 miles southeast of Coochs Bridge and 22.6 miles upstream from the river's mouth, with a period of record extending from April 1943 to the present (USGS). The year-over-year average streamflow at this gauge is 27 cubic feet per second (cfs) (SNOFLO). Converting to million gallons per day (MGD) using the standard factor of 0.6463 MGD per cfs yields approximately 17.45 MGD. Valuing this flow at $1,000 per million gallons, a common benchmark for municipal water supply, and multiplying by 365 days per year produces an estimated annual water supply value of roughly $6.37 million per year from this gauge location alone. When accounting for the full Christina Basin including navigation benefits at the Port of Wilmington, the Basin contributes $4.5 billion annually to regional economies (WRC, 2013). However, these projected streamflow and water supply values are only one component of a much broader economic picture.

Problems

Problems	Description	Causes
P1: High Enterococcus Bacteria Concentration	Concentration of enterococcus bacteria frequently exceeds safe limits for recreation in the Christina River Watershed. EPA mandates that a single sample of river water must not exceed 100 colony forming units (cfu) per 100 mL.	Common sources of bacteria in surface water: ● Leaking septic systems ● Pet waste ● Suburban/Urban Runoff ● Combined sewer overflows
P2: Increasing Habitat Loss	Endangered and threatened species that inhabit the Christina River watershed are facing ongoing habitat decline.	Common causes of degradation: ● Increased rate and volume of stormwater runoff ● Increasing percentage of impervious cover due to development changes ● Habitat fragmentation ● Riparian buffer erosion
P3: Declining Public Awareness of Restoration	Comprehensive assessments of the Christina River Watershed have not been conducted in the past decade, leaving some uncertainty about its overall health and the level of public awareness.	Common causes of declining awareness: ● Competing environmental or social issues ● Information is niche and may need to be presented differently to different audiences

Policies and Governing Bodies

Multiple agencies at the local, state, and federal levels share responsibility for water allocation and conservation in the Christina River Watershed. At the federal level, the U.S Environmental Protection Agency (EPA) oversees the National Pollutant Discharge Elimination System (NPDES, 2025). This program monitors point-source pollution entering protected waterways, including the Christina River, and issues permits that limit the type and concentration of pollutants that can be discharged. Interstate partnerships are essential for maintaining the health of the watershed. The Delaware River Basin Commission (DRBC) and the Christina Basin

Clean Water Partnership are two organizations that collaborate to implement pollution control strategies. In 2008, they determined the limits for the TMDLs for the Christina River (WRC, 2019).

For the state of Delaware exclusively, DNREC manages both non-point source and legacy pollution in the river. Locally, in Newark, DE, The University of Delaware Water Resources Center and the Christina Conservancy provide guidance and support for addressing river impairments.

Problem 1: High Concentrations of Enterococcus Bacteria

The Christina River is identified as an impaired waterway. A river or waterway is considered impaired when pollution levels are high enough to harm wildlife or significantly alter the ecosystem (CA OEHHA). One of the primary reasons the Christina River is classified this way is the elevated levels of enterococcus bacteria recorded in the water (Kauffman, 2003). While not all enterococcus bacteria are harmful to human health, some - particularly fecal strains - can pose serious risks. Consuming fish from waters with high levels of fecal bacteria can be dangerous for both humans and animals. Elevated bacteria levels can also limit recreational use, such as swimming or boating due to increased health risks. Additionally, the presence of fecal contamination often indicates broader water quality issues, including runoff from sewage or agricultural sources (U.S. EPA, 2025).

For this report, we investigated recent spikes in the level of enterococcus bacteria recorded in the Christina River. The table below (Table #1) represents these spikes and were recorded at the Nottingham Road water quality station.

Table #1. Recent spikes in Enterococcus in the Christina River (2020 - 2025) Water quality station at Nottingham Rd. (Station ID 106191) and NOAA Precipitation Totals for 24 hrs West Grove, PA (Station West Grove 2.6 W, PA US1PACH0023)

Date	Value (cfu/100ml)	WQS	Precipitation (72 hrs record in inches) - Station ID - West Grove	Enterococcus per inch of rain ((cfu/100ml)/inches)
October 4, 2022	4,840	180	2.75	688 cfu/100 ml/inch of rain
April 2, 2024	5,790	180	3.02	1,977 cfu/100 ml/ inch of rain
July 2, 2024	3,110	180	2.76	1,127 cfu/100 ml/ inch of rain

High enterococcus levels happen right after heavy rainfall events. Though this enterococcus data is reported at a monitoring station located at the border of Maryland and Delaware, the water being tested is from Maryland and Pennsylvania. Based on our land use map in the Christina River watershed (Figure #1) the catchment area in Maryland and Pennsylvania is primarily agricultural and developed areas. A large portion of the creek in Maryland and PA runs through the Fairhill State Natural Resource Area, housing developments, and Chisel Creek Golf Club.

Goal 1: Reduce enterococcus spikes by 1,000 cfu/100 ml per year, at the Nottingham Rd Station, through property owner education.

Septic systems are a common way for land owners to manage wastewater onsite not connected to municipal wastewater systems (U.S. EPA, 2025). Information from Zillow was pulled on the waste water treatment being used in housing developments north of Nottingham Rd. Water quality station. These developments primarily use on site septic systems for wastewater management. The Chisel Creek Golf Club closed in 2020 has a 3,000 gallon septic tank on site (Maye, 2020). The level of maintenance is unknown currently of this septic tank. The new owners of this property, the maintenance of the septic tank on site, and the gulf courses

use of fertilizers may be contributing to high enterococcal levels in the upper Christina. The Fairhill Natural Resources Area may contribute to high enterococcal levels north of the Nottingham Rd. water quality station. Their general property maintenance information is not publicly available. The Natural Resource Area may use fertilizers on their property contributing to the enterococcal levels in the upper Christina.

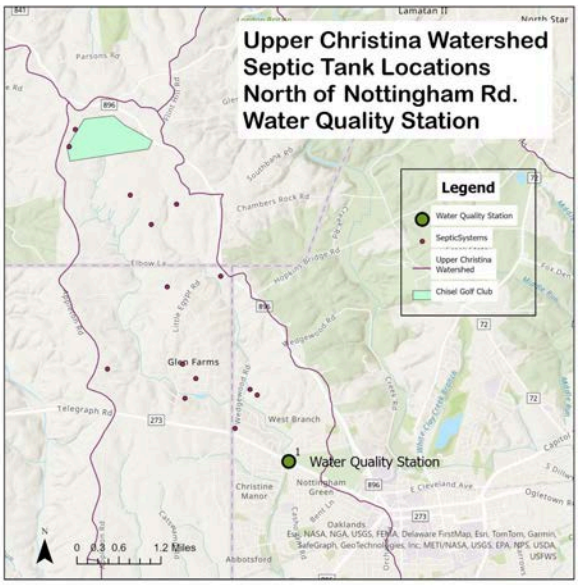

Figure #2. Septic Systems above the Nottingham Rd Water Quality Station in the Upper Christina Watershed

Septic systems that are properly installed, sited, and maintained can protect public health, preserve valuable water resources, and maintain economic vitality. Poorly maintained septic systems can cause groundwater contamination, spread disease to humans and animals and improperly treated sewage poses risk of contaminating nearby surface waters (U.S. EPA, 2025). Educational materials on septic system maintenance like those provided by the EPA can be distributed to homes, businesses, and natural areas surrounding the upper portion of the Christina River Watershed to reduce enterococcal bacteria entering the watershed (U.S. EPA, 2025).

Problem 2: Habitat Loss from Degradation of Riparian Buffers and Wetlands

Thirty-nine percent of non-tidal streams in the Piedmont Basin (which includes the Christina River Basin) have poor habitat due to increased frequency and rate of runoff from urban and suburban development (Kauffman, 2003). Development in the area continues to rise and peaked at 25% impervious cover in 2010 (Pizzuto, J.E., 2023). Research indicates that stream conditions can become severely degraded when as little as 10% of a watershed is covered by impervious surfaces (We Conserve PA Library). Impervious surfaces cause rapid overland water flow. Natural permeable areas, such as riparian buffers, help slow and distribute this runoff. These buffers act as natural sponges, absorbing water and trapping sediment that would otherwise flow directly into rivers. Without them, the quick moving runoff picks up pollutants and particulate matter on its way to the river. Over time, this accelerates streambank erosion, degrades water quality downstream, and reduces habitat diversity, making it more difficult for aquatic species to survive (Penn State, 2025). A hallmark species of the region, the northern bog turtle, is considered endangered and the populations have been affected by riparian and wetland degradation (U.S. FWS).

Goal 2: Reduce Impervious Cover by Revegetating 20 acres or Adding 50 new Smartyards

We propose two major steps to reduce stormwater and runoff and preserve natural habitats for local endangered and threatened species. First, revegetate riparian buffer zones and barren soils, with a focus on habitats for the northern bog turtle along the Christina River. Figure #3 shows the distribution of bog turtle populations. This revegetation effort should prioritize native species such as the common yarrow, river birch, and white pine (Brandywine Conservancy, 2016). These plants improve water quality and enhance wildlife habitat. They are

especially effective when planted on south-facing slopes, which are more prone to erosion due to higher sun exposure and drought conditions (DNREC, 2026). Plant root systems stabilize soil by binding aggregates, which helps prevent topsoil erosion and reduces the transport of nutrients like nitrogen and phosphorus into waterways (Firoozi, A.A., 2024). The revegetation process typically takes 10 to 25 years to fully establish, with most maintenance occurring the first five years (Groh, T.A. et al., 2020). In Delaware, the average cost to restore and preserve one acre of wetlands is approximately $2,230 in today's dollars (Hansen, 2015). Although the exact acreage of northern bog turtle habitat in Delaware is uncertain, even restoring an estimated 20 acres could meaningfully improve watershed conditions and habitat quality (Macdonald, 2022).

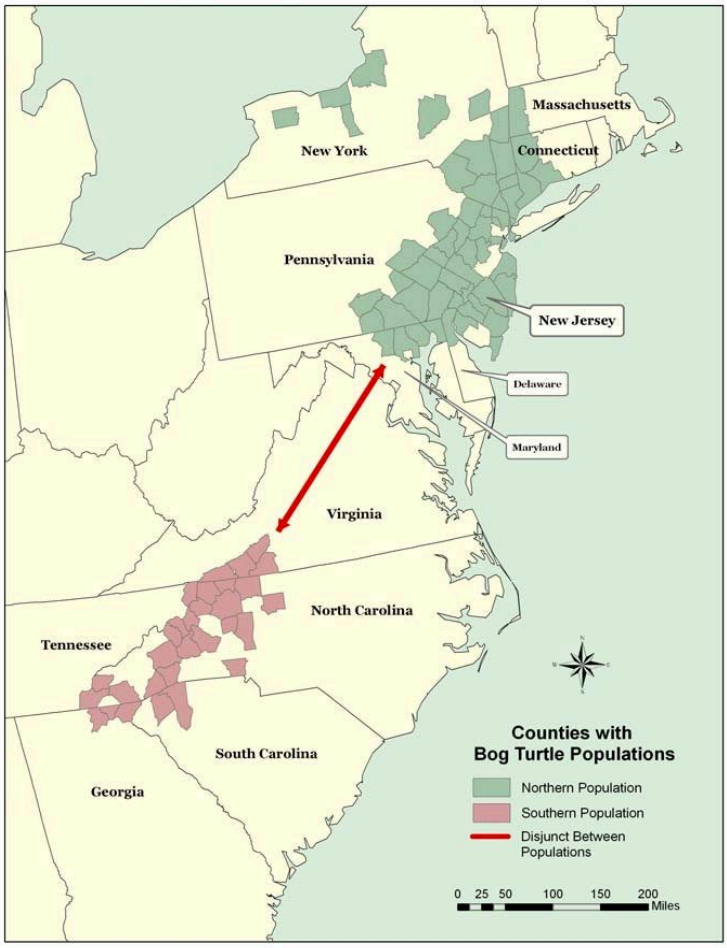

Figure #3: Geographic Distribution of the Bog Turtle (Walton, 2006)

Our second recommendation is to reintroduce the Smartyards Landscaping program in the Christina Basin. The program was launched by the Delaware Nature Society (DNS) in 2003 as a part of the Christina Basin Clean Water Strategy. It supported homeowners by helping them design and install rain gardens on their property. Each participant received $500 in supplies and materials, along with educational resources and hands-on guidance from the organization. The program was funded through the Christina Basin Target Watershed Grant and resulted in the installation of 150 Smartyards across the basin (V'Combe, 2008).

Rain gardens play an important role in reducing stormwater runoff and supporting local wildlife (V'Combe, 2008). They work by capturing precipitation and allowing it to slowly infiltrate the ground, which helps recharge unconfined aquifers. Recommended plan species for rain gardens in Delaware include Virginia sweetspire, buttonbush, marsh marigold, blackhaw, and many others (Jenkins and Barton, 2020).

Photo #3: Example Rain Garden with Native Plants and Soil Media (UM, 2023)

We specifically recommend reinstating a partnership between the DNS and residents in the Christina River Watershed to relaunch the Smartyards program. The goal would be to add an additional 50 Smartyards over the 10-year timeframe outlined in the mission statement of this report. Along with these new installations, a program reevaluation would benefit the DNS by allowing them to assess the long-term impacts of the initiative since its completion in 2008. Including the capital costs for providing landscaping support to homeowners, the total estimated cost to implement the expanded program today would be approximately $154,763 (V'Combe, 2008).

Problem 3: Declining Public Interest in Christina River Watershed

Awareness of the environmental issues affecting the Christina River Watershed has declined over the past 10-15 years. While the mid-to-late-2010s saw a strong period of research activity, grant-funded initiatives, and coordinated restoration planning, this momentum has slowed in recent years. For example, a 2023 conference on Wilmington River restoration primarily focused on existing efforts to address point-source pollution, and no new comprehensive watershed-scale reports or initiatives were presented or implemented (DNREC, 2023).

This decline in activity has contributed to reduced public engagement and visibility. With fewer comprehensive reports being published and fewer restoration programs actively promoted, the watershed has become less prominent in public discourse and local media coverage. This trend is further supported by Google Trends data, which shows a steady decrease in search interest for terms such as ‘Christina River", "Christina River Delaware”, and “Christina River Conservation” since 2005.

Goal 3: Raise Awareness of Christina River Watershed through education and branded merchandise to secure restoration funding within 5 years.

To strengthen public interest and awareness of the Christina River Watershed, we recommend exploring the feasibility of establishing an environmental education center within Christiana Mall. Located in a high-traffic area, this center would reach a broad audience and feature interactive exhibits on local ecology, water quality, and habitat restoration. It could also function as a hub for guided walks through Churchman's Marsh which is right up the street from the mall off Churchman's Road.

A small retail space within the center could offer branded educational merchandise such as reusable water bottles, apparel, and learning materials. These items would generate ongoing revenue and we estimate that after 5 years, they could help to fund the projected 10-year plans outlined in Problems #1 and #2. In addition to funding support, the merchandise would reinforce watershed awareness beyond the center itself, extending its educational impact into the broader community.

This concept is similar to the Van Scott Nature Reserve Education Center, which proposed implementing an environmental education program in 2020. However, it is unclear whether the full education center was ultimately completed (Delaware Highlands Conservancy, 2020). Their education center was also set to offer nature walks and other conservation education. Our recommendation differs in that we do not propose developing an entirely new standalone facility. Instead, we suggest adapting this idea by using available vacant space within Christiana Mall as a centralized and accessible hub for watershed education, public engagement, and funding generation.

Conclusions

Overall, the Christina River Watershed faces interconnected challenges of water quality degradation, habitat loss, and declining public awareness that reinforce one another and limit long-term recovery. However, these issues also present clear opportunities for coordinated intervention through targeted restoration projects, expanded community engagement, and sustained environmental education. The recommendations outlined in this report range from septic system education and riparian buffer restoration to the reintroduction of homeowner-based programs like Smartyards and the development of a public education center in the Christiana Mall. All recommendations work together to address both the ecological and social dimensions of watershed health.

By improving water quality, restoring critical habitats, and rebuilding public connection to the watershed. These strategies aim to create measurable environmental improvements while also strengthening community stewardship. In particular, liking restoration efforts with education and revenue-generating outreach provides a pathway for long-term funding stability beyond traditional grant cycles. Together, these combined efforts support the broader goal of returning the Christina River Watershed to a healthier, more resilient system that can sustain both biodiversity and human use well into the future.

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