Transportable Rain Gardens in the United States of America

5,678 Words

Introduction and Literature Review

The United States of America is a large and diverse nation, both geographically and culturally, spanning from the Atlantic Ocean to the Pacific, showcasing a variety of landscapes that include fertile farmlands, expansive plains, majestic mountains, and vibrant cities. The country functions as a federal republic, characterized by a governmental structure that balances national authority with state sovereignty. Renowned for its economic strength, the United States is a global leader in technology, industry, and agriculture, exporting goods and ideas around the world. Its cultural diversity, which has developed over centuries of immigration, continues to shape the nation's identity and its influence on the global stage.

As of 2022, the estimated population of the United States is approximately 333 million inhabitants. A significant portion of the population—around 80%—resides in urban areas, while roughly 20% live in rural regions. The U.S. functions as a federal republic with a presidential system, organized into three branches—executive, legislative, and judicial—within a constitutional framework. National leadership comprises the President and a bicameral Congress (House and Senate), with states retaining substantial authority within the federal structure (Rural Data Explorer, 2023).

In terms of land use, approximately 97% of the total U.S. land area is classified as "rural," highlighting a stark contrast between geographic coverage and population distribution. The nation is home to just over 2 million farms, encompassing about 900 million acres, with the average farm size estimated at around 441–444 acres (Who is Rural America?, 2025) (Rural Data Explorer, 2023).

In 2023, an estimated 13.5% of U.S. households—approximately 18 million households—experienced food insecurity at some point during the year, with 5.1% facing "very

low food security," characterized by disrupted eating patterns and reduced food intake. Disparities between rural and urban food insecurity indicate that, in 2023, rates in rural areas rose to 15.4%, compared to the national average of 13.5%. However, other studies suggest that food insecurity rates in rural households are comparable to, or only slightly above, those in urban areas (e.g., 15.4% in rural areas versus 15.9% in principal urban centers). Notably, children in rural areas are disproportionately affected: 84% of counties with the highest rates of childhood food insecurity are located in rural regions. Additionally, although short-term food insecurity was marginally higher among urban families (6.2%) compared to rural families (4.6%) among adults in 2021, rates among low-income families were similar (Food Security in the U.S., 2025) (Northwest Harvard, 2025) (Rural Data Explorer, 2023).

Agriculture remains a cornerstone of the U.S. economy and land use. Major agricultural regions include the Corn Belt (noted for corn and soybeans), the Wheat Belt, and California's Central Valley, recognized for its production of fruits, vegetables, and nuts. The Southern states have historically produced cotton, tobacco, and rice, while Florida is a prominent producer of citrus fruits, particularly oranges. The United States stands as a net agricultural exporter, with exports valued at approximately $176 billion in 2024, although agricultural imports slightly exceeded exports at $213 billion (Food Security in the U.S., 2025).

The structure of farmland has experienced increasing consolidation: although large farms constitute only 4% of all farms, they control about two-thirds of total agricultural land. Furthermore, the largest farms (defined as those with sales of $5 million or more) comprise less than 1% of total operations, yet are responsible for 42% of total agricultural sales. Government subsidies, totaling $10.4 billion, predominantly benefit these large agricultural operations ('America is a factory farming nation': key takeaways from US agriculture census, 2024).

Infrastructure and access to resources vary by region. Although rural areas account for approximately 71% of U.S. land, they contain a smaller share of the population, reflecting notable density disparities. Rural areas also experience lower broadband access, with adoption rates ranging from 65% in larger rural towns to as low as 53% in the smallest communities, in contrast to higher rates in urban regions. Moreover, rural areas encounter challenges related to food access, with an estimated 20% categorized as food deserts, impacting approximately 2.4 million individuals residing far from supermarkets (Who is Rural America?, 2025) (Food Security in the U.S., 2025).

In rural America, per capita income averages around $49,900, and poverty rates hover at approximately 15.4%, both of which lag behind national averages: the overall national per capita income is $64,143, and the national poverty rate is lower. Employment in rural areas is diverse, with only 7% of jobs in farming, compared to 18% in government, 13% in manufacturing, and 11% in healthcare. Median household income in rural settings is generally lower than in urban areas, although housing costs are also lower, leading to a higher percentage of rural households that own their homes outright (Who is Rural America?, 2025) (Food Security in the U.S., 2025).

Dietary patterns among families in rural areas vary by region but typically include staples such as grains, protein sources, and fruits and vegetables, influenced by availability and economic means. Access to healthcare in rural regions often depends on a network comprising Critical Access Hospitals, rural clinics, and Federally Qualified Health Centers. A factor that is notably influential in dietary failure is the impact of clean water. From drinking to being used to grow crops, water is the single most important resource in food security. One major setback when attempting to sustain clean drinking water from groundwater is Nitrogen Pollution (CDC Morbidity and Mortality Weekly Report, 2022).

Nitrogen pollution poses an extremely significant threat to the groundwater quality of Long Island, New York. The people of Long Island have utilized their groundwater over the last few centuries for many different reasons. The aquifers are estimated to contain around 90 trillion gallons of fresh water for all of Long Island (NSWCA). These usages include drinking, showering, cooking, and other domestic needs people fulfill with water. According to the U.S. Geological Society's National Water-Use Information Program (NWUIP), from 2005 to 2010, the annual withdrawal of groundwater from the public supply averaged approximately 380 million gallons per day for Nassau and Suffolk Counties together (Long Island Water Use, 2017). The reliance on Long Island's groundwater is evident in the major quantities withdrawn daily. Based on the U.S. Geological Survey (USGS), public water suppliers in both Nassau and Suffolk counties pumped an average of 375 million gallons daily in 2015 to meet residential and commercial demands (Our Long Island Aquifers: The Basics, 2015; Walter, 2024).

The primary aquifers, including the Upper Glacial, Magothy, and Lloyd, serve as the region's lifeline, but they are increasingly under pressure from overuse, but contamination has seemed to be a larger problem as of recent. Managing Long Island's groundwater is a forever growing challenge. The New York State Department of Environmental Conservation (NYSDEC) notes that contamination from pollutants such as nitrates, volatile organic compounds (VOCs), and saltwater intrusion threatens the quality of the aquifers. Local governments and water authorities have implemented programs to address these concerns, such as advanced water treatment facilities and public education campaigns (New York City- Nassau County Water Supply Interconnection, 2022).

In Suffolk County, a worrisome trend has been observed: while 83% of community supply wells had nitrogen concentrations less than or equal to 6 mg/L in 2013, an already

concerning amount, there has been an increase in nitrogen pollution in groundwater over the last decade, primarily due to the increased usage of fertilizers since. This emphasizes the overwhelming need for comprehensive data collection to assess the full impact of nitrogen inputs on Long Island (Executive Summary, 2015).

Green infrastructure is the primary source of combat against abundant macronutrient pollution across the United States, with numerous different designs and models being utilized to combat this issue. Rain Gardens have been utilized in the past to eradicate pollutants from our water in large settlements, as well as yielding a multitude of other capabilities. The science and benefits behind them have been coupled with the Richards Equation (Partial Differential Equation) to study recharge and infiltration rates in stormwater management (Dussaillant, 2004). The vast majority of research pertaining to Rain Gardens, however, have primarily been focused on understanding the absorption of multiple primary macronutrients such as nitrogen compounds and Phosphorus compounds in the fibrous root system of the plant involved, paired with the eutrophication cycle, permeability and porosity rates, etc (Kitajima, 2021).

Numerous studies also venture into runoff control, and how thousands of gallons of stormwater that are harmful in how they contribute to dangerous flooding can be controlled and monitored. Different soils can play into this field of runoff control, with research proclaiming that conditions in the soil such as conditioned waterworks sludge and crushed clinker ash. The overall theme on the basis of research on rain gardens is prevalent, and they are well utilized to find out a multifariousness of different problems pertaining to soil composition all the way to runoff percolation (Boughton, 2021).

Phytorepudiation in regards to nitrogen pollution is also a part of rain gardens that has been looked into. Studies diving into the deep consequences of flooding and sewage backup

being exposed to the environment are problems that have potential solutions in rain gardens. The natural filtration of the rain garden is extremely impactful in absorbing certain pollutants that it is exposed to in these highly contaminated waters (Ishimatsu, 2017).

Research concerning transportable rain gardens is essentially defunct, as most rain gardens are stationed on top of built in structures created particularly for them. Studies have attempted to produce transportable green infrastructure in the form of green roof trays that would serve to grow plants on the top of roofs in designed crates in the Great Plains. These trays would be designed to help control local watersheds to prevent flooding, and rather capture water for either human use or to be provided for the plants themselves to remain sustainable (Vogel, 2015). Other approaches to transportable green infrastructure use approaches like transportable tree beds to provide shelter for certain animal species, while simultaneously combatting the overload of carbon dioxide in places where it is exceedingly abundant (Dickinson, 2023).

Additionally, work has been done in New York City to look further into the broader implications for the future of green infrastructure, and whether or not transportability has potential to become readily available. Researchers looked into the political side effects of green infrastructure planning and analyzed local opinions on whether the idea of developments in this field would be necessary. The citizens outline the practicality of using natural resources in the fight against problems like water management, the heat-island effect, photochemical smog, and even air quality. The essence, however, is cities are not doing enough to fight off these climatic issues, and the implementation of transportability in green infrastructure could be a potential gateway to coming closer to the solution of these problems (Meerow, 2020).

In New York State, rain gardens have actively expanded their green infrastructure to manage stormwater and pursue environmental resilience. Since 2022, the city has committed to

more than doubling its green infrastructure program by constructing more than 11,000 additional curbside rain gardens, aiding the more than 4,000 already in place (Torres, 2023). The goal of this plan is to solve local flooding and reduce combined sewer overflows, improving the health of the city's waterways while also helping limit nitrogen pollution.

According to the New York Climate City Justice Office, the city plans to implement over 11,000 new curbside rain gardens, contributing to the greening of more than 1,500 acres and adding over 660,000 square feet of green space (Green Space, 2023).

Beyond New York City, other regions in the state are also adopting rain gardens as a sustainable stormwater management solution in a means to help reduce nitrogen pollution. For example, the Pass Arboretum in Syracuse features rain gardens that capture approximately 746,000 gallons of water annually. This exemplifies the broader application of this green infrastructure approach across New York State, which produces the same positive feedback on the awareness in combatting nitrogen pollution (Rain, rain go this way: Rain gardens catch runoff and pollutants, 2012).

Gap

Storm water runoff often contains nitrogen, which is commonly found in various fertilizers. The addition of nitrogen to storm water is dangerous due to the overwhelming abundance of nitrogen pollution in groundwater that can be attributed to toxicity and growth effects on plants and humans. As the polluted storm water runs into storm drains, the concentration of the ground water increases. Specifically, Long Island utilizes its groundwater for multiple various uses, but this project's aim is to provide solutions for food security. Although there are some studies which have been conducted regarding transportable green

infrastructure, such as green roof trays or transportable tree beds, there have been none completed on transportable rain gardens for the coverage of storm drains during rainfall events. This research aims to create a solution to filter polluted groundwater naturally to help combat against nitrogen pollution, while simultaneously analyzing the effectiveness of transportable green infrastructure such as a rain garden in Long Island, New York. This same effective technique can then be replicated in other regions across the United States of America, and ultimately across the world.

Methodology

Phase 1: Creation of the Skeleton

This project aims to design a transportable rain garden with a grass weed catcher at the bottom and sides to retain soil and plant roots, while filtering nitrogen from polluted groundwater, with support underneath to hold the structure while still allowing water to pass. The rain garden is envisioned as a modular, portable system for urban and suburban environments, like Long Island, where excess nitrogen runoff affects water quality. The system dimensions are 4 feet (length) × 2.5 feet (width) × 6 inches (depth), exactly the dimensions in terms of length and width of an average storm drain grate.

This skeleton for this project primarily was developed using computer-aided design (CAD), allowing for detailed before physical implementation. SketchUp was the ideal program of choice to build an online model and test the dimensions for the skeleton of the transportable rain garden to be built because it is user friendly and offers an accessible platform for design. First, a lightweight material that easily could be punctured had to be decided on. PVC piping with drilled holes were selected to be used to create a skeleton for the rain garden.

According to the calculations below (Equation 1), a volume of 1.02778 ft^3, or about 1 ft^3 of PVC piping was used to craft the dimensions of the rain garden and then left to hold the structure of the skeleton. This structure will then be wrapped around both the perimeter and underside with anti weed mesh to allow for water flow in all directions.

Once this process is complete, Long Island Hampton topsoil and Long Island Hampton compost was poured in a 1:3 ratio of compost to topsoil within the skeleton. This mixture was placed into about ¾ of the space inside the skeleton. The mixture (Equation 2) would account for a total volume of 2.97917 ft^3, or roughly 3 ft^3 of combined compost and topsoil. The compost (Equation 3) will account for a volume of 0.744792 ft^3 or approximated 0.7 ft^3, while the amount of topsoil (Equation 4) will account for a volume of 2.23428 ft^3, or about 2.2 ft^3.

Equation 1: ((4ft)(2.5ft)(.5ft)) - ((3.6667ft)(2.1667)(.5ft)) = 1.02778 $ft^3 \approx 1$ ft^3

Equation 1. This equation represents the 3 numbers in the first set of parentheses which contain the total area of the skeleton, minus the 3 numbers in the second set of parentheses which is the volume of space in the middle of the skeleton that would be hollowed out, resembling a crate. This volume is a part of Figure 1 depicted further on, which shows the skeletons, with the same dimensions as calculated in Equation 1.

Equation 2: (¾) ((3.6667ft)(2.1667)(.5ft)) = 2.97917ft³ ≈ 3 ft³

Equation 2. This equation represents the volume of the skeleton that had been removed in Equation 1, to allow for the creation of just the skeleton. This number would have to be multiplied by ¾ and added back into the original skeleton, resembling the second part of the rain garden system, which would be the composting and topsoil mixture for the plants to grow in. This volume is not a part of Figure 1 depicted further on, which shows the skeletons, with the same dimensions as calculated in Equation 1.

Equation 3: (2.97917)(¼) = 0.744792 ft³ ≈ 0.7 ft³

Equation 3. This equation represents the amount of volume calculated in total that would be compost in the mixture of compost and topsoil inside the skeleton of the rain garden using the same parameters from Equation 2. According to the 1:3 ratio of compost to topsoil, ¼ of the total volume of the mixture calculated in Equation 2 would be compost.

Equation 4: (2.97914)(¾) = 2.23428 ft³ ≈ 2.2 ft³

Equation 4. This equation represents the amount of volume calculated in total that would be topsoil in the mixture of compost and topsoil inside the skeleton of the rain garden using the same parameters from Equation 2. According to the 1:3 ratio of compost to topsoil, ¾ of the total volume of the mixture calculated in Equation 2 would be topsoil.

Phase 2: Proposed Gardening Implementation

The majority of this hypothetical implementation would take place outside of the ideal growing season in New York. Therefore, the actual plant growth and rain collection could not be completed. The following are the proposed steps to ideally finalize the production of a transportable rain garden based on prior research and literature, as well as guidance and consultation from local engineers and gardeners.

The planting process will begin once the mixture has been placed in the completed skeleton. Due to the limited amount of space available for weeds to grow, it was necessary to choose plants whose weeds do not surpass six inches and still absorb good nitrogen content, like staying native to Long Island. This is because the brand of compost and topsoil has a pH content most similar to natural soil in the wilderness of Long Island, meaning that if a plant could grow in the soil of the wilderness in Long Island, it could grow in the rain garden. The type of plant that would fit this category would be an upland plant, as they absorb and are in between 40% to 60% of the nitrogen in the groundwater available to them, and are abundant across Long Island. Good native examples of upland plants that could be utilized to be input into this rain garden are Blue Flag Iris (*Iris versicolor*), Soft Rush (*Juncus effusus*), and Marsh Marigold (*Caltha palustris*). These plants all fall under the specifications needed for this process. When planting, a random seed would spread throughout the soil in the rain garden. After waiting for approximately a month for the new plants to assimilate to the soil, they would be all be fully grown under the proper gardening care, such as watering, sunlight, nutrients, etc (Rain garden plants: Iris versicolor and Iris virginica, 2017; Rushes, 2015).

According to USGS, a 4-foot by 2.5-foot rain garden would only accumulate 1 gallon of water under light rain. Assuming that this rain garden will not just be placed in any random area

and that it would be placed under the slope of a road, constantly channeling water towards it, a good approximation for the amount of water that could be expected would be anywhere from around hundreds of thousands, to even millions of gallons under light rainfall (0.05 inches - 0.2 inches). moderate (0.2 inches - 0.5 inches) and heavy rainfall (0.5 inches - 3 inches), for this small of a rain garden, would not be ideal as it would flood, so it would not be exposed to such conditions. The reason it likely would not be fully functional for all types of rain events, like downpours, storm surges, tropical storms, and more because the size of the rain garden is smaller in comparison to large scale rain gardens located in New York City. A solution, if in the event one of these events were to occur, would be to simply remove the rain garden from the storm grate, and store it indoors until the event has passed. As for light rain, the permeability and porosity of the soil would have to be tested, especially in terms of the ratio that it is in. Using this permeability and porosity, it could be determined how much water would be the maximum threshold before flooding would occur and, therefore, how long it would take for the rain guard to be at maximum capacity regarding the timing of exposure to rain. Due to time constraints, however, these tests couldn't be run, so the further research and conclusion will better show this process.

Assuming that the garden will be sectioned into thirds, the amount of plants in each third must be known to calculate volume absorbed and concentration. There are approximately 3 to 5 flowers per each stalk of Blue Flag Iris, and it could confidently be said that there will be at least three stalks of Blue Flag Iris as it would need a 10-inch by 10-inch area to grow healthily with ample space for runoff to pass through as well as roots and leaves to spread to spread. For the Soft Rush, one stalk of the plant's spread would be on a space of 10-inch by 20-inch area. This one stalk would bear anywhere from 50-150 flowers. For Marsh Marigold, 12-inch by 12-inch

area, allowing for at least two stalks and with around 1-25 flowers per stalk. The total water should be approximately 1 gallon per watering, as more than a gallon at a time would result in the potential of flooding of the rain garden (Rain garden plants: Iris versicolor and Iris virginica, 2017; Rushes, 2015).

Once done, the amount of nitrogen content in rainwater that is then transformed into runoff on streets could be roughly estimated using nitrogen testing kits. Using this nitrogen content, could then calculate the amount that would be absorbed by the plants in the rain garden using their approximate nitrogen uptake number. This would then yield an approximation of how much nitrogen would be cleaned up from the runoff, which could then be deemed as either efficient or inefficient.

Model/Art

A model rain garden was built to give a visual demonstration of how the rain garden would operate. This model was built out of the following materials: PVC pipe, PVC elbows, masking tape, PVC glue, silicon glue, metal banding and plates, anti-weed catching mesh, and household supplies (drill, PVC hacksaw, silicon gun, markers). The dimensions of this model would be cut in half, so instead of the model being 4 feet by 2.5 feet by 0.5 feet, it would be 2 feet by 1.25 feet by 0.25 feet. This is because the model would then imitate half the dimensions of an average storm drain.

The first step in making this model consisted of cutting three 10 foot by 1 inch PVC pipes into fifteen 2 foot by 1 inch lengths. These PVC pipes then had to be sanded with appropriate PVC grade sanding material to smoothen out edges and surfaces. After this step, 2 inch lines were drawn from the ends of the piping, and holes were drawn perpendicularly to the surface.

From these 2 holes, an extra 5 holes were drilled in a parallel line, with them all being equidistant from each other. These holes were drilled straight through the pipe, allowing for water to seep through the top of the piping, and then leak out through the hole on the bottom. The next step was inspired by the French drains system, as it was created so that the water would build up between the valleys created by the pipes being side to side. As a result, holes were drilled in between the spaces of the 7 holes drilled on the top, on both sides, to allow water to seep through the sides. Once these steps were completed, there were a total of 11 pipes consisting of holes that were to be compiled together. The 2 pipes on the outside perimeter would need to be put to the side, as they would need 2 PVC elbows on each side and 1 PVC "T" connector in order to extend the height to 3 inches high, with the addition of extra PVC. The other 9 PVC Pipes would be glued together, in a side to side fashion connected by silicon glue. The other 2 pipes would then have their PVC elbows and "T's" facing upward along with the holes. These structures would then be cemented together using PVC glue, ensuring that the structure could be held together as one.

Once this step was completed, pieces of PVC pipe measuring 1 ¾ inches by 1 inch were cut so they could be cemented into the opposite side of the elbows and "T's" in order to extend height for the anti-weed mesh to be wrapped around, acting as pillars. These PVC pipes would be placed, and then the 6 pillars would be installed at the corners of the base and the middle of the length. Once finished, it would all be silicon glued along the outside perimeter of the structure with the other 9 pipes. For extra reinforcement, 2 hose clamps would be tied around both sides of the model rain garden for extra reinforcement to ensure stability and structure. Once this step took place, 3 pieces of anti-weed mesh with a length of 78 inches by 5 inches each would be wrapped around the perimeter of the rain garden, and then taped down to ensure there

would be minimal movement at the very least, and no removal of mesh. After this, the structure itself would then be taped, and the same process would be done with 3 pieces of anti-weed mesh with a length of 15 inches by 24 inches so that the bottom of the rain garden could be covered. Once this step was completed, the visual model was completed.

Figure 1. A head-on view of the skeleton of the Rain Garden, depicting the structure and design visually. The black wrap-around is anti-weed mesh, to allow for infiltration of water. The finished rain garden would contain the soil mixture and plants inside the skeleton.

Figure 2. A top view of the skeleton of the rain garden, showcasing the PVC glue (purple streaks) and the two metal hose clamps running parallel across the skeleton.

Results

In order to deem the rain garden successful, the amount of nitrogen removal from polluted groundwater would have to be calculated and analyzed to identify the effectiveness and practicality of building these rain gardens using strictly the information posted in phase 1. In order to calculate the total amount of nitrogen removal from the groundwater, first the total amount of groundwater that passes through the rain garden would have to be calculated. This number can be approximated based on the "Rational Method," which calculates the peak runoff rate or the total collection of water (Q) by multiplying the runoff coefficient (C) by the rainfall intensity (I) and the drainage area (A): $Q = C * I * A$.

The average rainfall in Old Westbury is 108.5 mm or roughly 4.27 inches per month. According to the Old Westbury Rainfall Forecast, between 2020-2025, Old Westbury averaged 0.1 inches per rainfall. Assuming that one inch of rainfall accounts for nearly 17.4 million gallons (USGS), and that there is an average of 1 inches per rainfall in Old Westbury, a reasonable estimate for the amount of gallons that find its way into storm drains in Old Westbury could be 1.74 million gallons per rainfall.

It can be assumed that the runoff rates for structures are as follow: roof/concrete: 0.95, asphalt: 0.85, porous asphalt/concrete or permeable pavers: 0.70, green roof with four or more inches of growing media: 0.70, gravel parking lot: 0.65, undeveloped areas: 0.30, grass areas: 0.20, rain gardens, vegetated swales, and other surface green infrastructure practices: 0.20. Based on more GIS Maps of Old Westbury and their infrastructure, the following estimations can be drawn from the amount of infrastructure area in Old Westbury, and the composition of land it takes up. In order to further simplify these values, however, these structures were grouped together to better estimate a broad overview of the runoff coefficient. These values would be determined: roofs, driveways, and roads = 15% of the area with an average runoff coefficient of 0.85; lawns, fields, and greenery = 70% of the area with an average runoff coefficient of 0.20; wooded areas = 10% of the area with an average runoff coefficient of 0.30; institutional and commercial areas = 5% of the area with an average runoff coefficient of 0.70. Using these values, the runoff coefficient will be determined (Equation 5).

Table 1. Chart showing the average percent of area estimation derived from various different GIS maps of Old Westbury, and runoff coefficients provided by SWMM5. The same values are plugged into the equation below the chart (Equation 5).

	Roofs, Driveways, and Roads	Lawns, Fields, and Greenery	Wooded Areas	Institutional and Commercial Areas	Total
Average Percent of Area Estimation	15%	70%	10%	5%	100%
Runoff Coefficient	.85	.20	.30	.70	.33

Equation 5: ((0.15)(.85)) + ((0.70)(0.20)) + ((0.10)(0.30)) + ((0.05)(0.70)) / 1 = 0.3325 ≈ 0.33

Equation 5. This equation represents the average runoff coefficient for Old Westbury by multiplying the average percent of area estimation and runoff coefficients for each of the four different types of surfaces. Once multiplied together, all four values were added together yielding a runoff coefficient of 0.33.

The assumed runoff coefficient for Old Westbury would be approximately 0.33. Using this runoff coefficient (C), as well as the rainfall intensity (I) known to be approximately 0.1 inch per rainfall, all that is left is to find the drainage area (A). This can be done by measuring the average area of a single storm drain, which tends to be 3.5 feet by 1.5 feet. This would mean the area is 5.25 ft^2. According to a GIS New York State Governmental Storm Drain Map, there are

647 recorded storm drains in the area of Old Westbury. This value would then be multiplied by the 647 storm drains resulting in 3,396.75 ft² or 0.07 acres. Now, the rational method formula can be used to determine the peak runoff rate (Equation 6).

Equation 6: (0.33)(0.1)(0.07) = 0.00231

Equation 6. This equation represents the peak runoff rate or the total collection of water (0.00231) by multiplying the runoff coefficient (0.33) by the rainfall intensity (0.1) and the drainage area (0.07). The peak runoff rate of 0.00231 is the estimated constant of total water that makes contact with the rain garden every time it rains.

In order to find the total amount of water that comes in contact with the rain garden, the total amount of rain collected from the event has to be multiplied by the peak run off rate. Assuming this value is the average rainfall at 0.1 inches, which yields 1.74 million gallons, this would mean only approximately 4,019 of the 1,740,000 gallons make it into the storm drain. According to available data from the EPA (Environmental Protection Agency), the average nitrogen pollution per liter of runoff is around 2.5 milligrams per liter (mg/L) which is equal to approximately 9.46353 milligrams per gallon. For 4019 gallons, this would equate to nearly 38,033.9270 milligrams of pure nitrogen pollution being run through and cleaned by the rain gardens.

Discussion and Future Research

In total, in one event of rainfall in Old Westbury, close to 38,000 milligrams of nitrogen would be collected and cleaned from our ground water. To grasp the perspective of whether this extent of nitrogen actually makes a difference, effects of nitrogen need to be compared and contrasted with the result of the study.

According to the U.S. EPA, exposure to approximately 10 milligrams per liter of nitrate in drinking water for humans is enough to be associated with methemoglobinemia in infants and children, as well as numerous other harmful symptoms alongside it. On average, slightly less than 1 milligram per liter of nitrite in drinking water corresponds to an interference with oxygen transport in the blood. The severity of nitrite compared to nitrate is due to the toxicity ranking of nitrite being higher. Other forms of nitrogen also have harmful impacts on humans, as approximately 1 milligram per liter of ammonia in drinking water noticeably affects the taste and odor of the water, with higher levels of around 3 milligrams per liter linked to high levels of contamination (Ammonia, 2000).

As for plants, different levels of effects have different outcomes on various species of flora and their specific range of tolerance. Generally, anywhere between 30-50 milligrams per liter of nitrate in groundwater can lead to excessive vegetative growth. This yields a negative impact on production of crops and hurts the value, especially in markets for fruit and vegetables. Additionally, concentrated ammonium is harmful for plants as well, with 90 to 100 milligrams per liter of ammonium in groundwater proven to produce toxicity effects on plant roots, especially those that are in poorly aerated or acidic soils (Nitrates, 2024).

When qualifying whether the rain garden effectively contributes to reducing nitrogen pollution, it is important to take into consideration its purpose. According to the results, it would

merely be a first stage in helping filter out nitrogen from sewage, helping water process plants as an effective primary purification of contaminated runoff. Considering the ease of creation coupled with the independence and self maintenance, as well as the importance of the results, the finished rain garden would undoubtedly be highly effective if deployed in the field.

For future study, the prototype would have to be tested and utilized in a formal experiment, measuring the total amount of nitrogen in the water beforehand, and then exposing the full amount of water to the rain garden, collecting the filtered water after. This collected water would then have to be tested for the amount of nitrogen, and scaled up to the amount of nitrogen removed when 4019 gallons are exposed. If the results are near the theoretical calculations, the rain garden could be regarded as effective.

Further research with transportable rain gardens could be conducted on phosphorus pollution as opposed to nitrogen pollution, another abundant macronutrient in the ground, like nitrogen, primarily collected by fertilizers in runoff. There would be minor complications in testing for the change in phosphorus pollution rather than nitrogen pollution, because both have similar particulate size, point source, and health damages. Different soil compositions, hydrology, and spatial feasibility are all possible fields to effectively learn how gardens with varying conditions can strip nitrogen from groundwater in less-urbanized areas. A long term study could track changes in nitrogen levels at various sites with and without rain garden implementation. Nutrient removal efficiency in different stormwater management systems has been examined, providing a foundation over extended periods of time (Collins, 2010; Dietz, 2007).

Alternatively, given that rain gardens can be constructed in classrooms as part of woodworking or engineering courses, the impact of incorporating green infrastructure projects

into school curricula is significant. Future research could examine how environmental education influences students' long-term engagement with sustainability efforts (Leibowitz, 2014).

Limitations

As stated in the methodology, the majority of this project took place in the late fall and winter months which is outside of the growing season in New York. Therefore, the actual plant growth and rain collection could not be completed. Instead, data for mathematical calculations was generated from average rainfall numbers from government websites. This led to potential inaccuracies, with a likely margin of error as some assumed areas of surfaces in Old Westbury being approximated, and the runoff coefficients being averaged with potential discrepancies in material composition.

Other potential limiting factors could be the lack of accuracy in water quality specific to the region of Old Westbury. The rate used was a state average for New York, but due to the environment of Long Island, with the abundance of surrounding water and profuse population, it is likely that the milligram per liter rate for nitrogen pollution may be off when compared to the state average. This would result in a different amount of total nitrogen being filtered out from the rain garden, which could help increase the effectivity or, on the contrary, decrease the effectivity of the rain garden.

The final main limiting factor that may impact results would be the exact location of the storm drains. Due to the sheer amount of storm drains in Old Westbury, it was unreasonable to delve into the unique case of location for each individual storm drain. In essence, the distance away from each storm drain could result in different amounts of runoff collection. In addition, the slope of the ground has an effect on the direct amount of water being exposed to the rain

garden, with steeper slopes likely contributing to more nitrogen exposure. Both these specifications had to be unaccounted for due to time constraints and lack of resources for measurements and accurate location.

Conclusion

The protection as well as the management of Long Island groundwater resources are extremely important not only for ensuring that the region's water quality and public health over the next few hundreds of years do not deteriorate, but also to maintain food and water security. Current research provides numerous reasons as to why nitrogen pollution remains to be a massive threat, certain methods and precautions can be taken in attempts to minimize the effects of nitrogen pollution on society. The usage of green infrastructure, such as the transportable rain gardens in this research, are one small step that can be taken to reduce the problem in the long run.

Although rain gardens may have a significant impact in areas such as Manhattan in New York City, they are not seen in suburban areas such as Old Westbury. There is a high ceiling as to just how much nitrogen can be stripped away from the groundwater if certain rain gardens are to be implemented. These simple structures are easy enough to be built in classrooms as part of a woodworking class or even an engineering class. The community benefits also shine as it raises awareness for native plant species around Long Island, therefore helping spread not only beauty, but awareness for local flowers and plants. Realistically, the same can be said for other areas in America. The revolution of green infrastructure is one that can be a useful solution to rural, suburban, and urban areas, further reinforcing food security and water conservation.

Ultimately, investing in green infrastructure represents an extremely proactive approach to helping preserve the groundwater of both Long Island and the United States of America. By people building more transportable rain gardens, a massive reduction in nitrogen pollution will be seen over long periods of time, therefore yielding more access to clean water further supporting food security.

References

AMMONIA. (2000, January). Oregon Department of Human Services. Retrieved April 30, 2025, from https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/DRINKINGWATER/MONITORING/Documents/health/ammonia.pdf

The Best of The Rest. (n.d.). Long Island Pine Barrens. Retrieved April 30, 2025, from https://www.pinebarrens.org/the-best-of-the-rest/

Boughton, C. (2021). Effects of and potential interventions to combat climate change impacts on groundwater resources in Long Island and Shelter Island. *Consilience*, (24), 1-11.

Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., Gragson, T. L., ... & Whitmer, A. C. (2011). An integrated conceptual framework for long‐term social–ecological research. *Frontiers in Ecology and the Environment*, *9*(6), 351-357.

Dickinson, S., Dimond, K., & Li, S. (2023). Green waste to green architecture: optimizing urban tree systems for renewable construction material supply chains. *Socio-Ecological Practice Research*, *5*(3), 263-273.

Dietz, M. E. (2007). Low impact development practices: A review of current research and recommendations for future directions. *Water, air, and soil pollution*, *186*, 351-363.

Dussaillant, A. R., Wu, C. H., & Potter, K. W. (2004). Richards equation model of a rain garden. *Journal of Hydrologic Engineering*, *9*(3), 219-225

Estimated Nitrate Concentrations in Groundwater Used for Drinking. (n.d.). United States Environmental Protection Agency. Retrieved April 30, 2025, from https://www.epa.gov/nutrientpollution/estimated-nitrate-concentrations-groundwater-used

-drinking#:~:text=2010).,which%20is%20from%20groundwater%20wells).&text=Values%20are%20rounded%20to%20the,(10%20mg/l).

Estimated Nitrate Concentrations in Groundwater Used for Drinking. (2024, December 2). United States Environmental Protection Agency. Retrieved April 30, 2025, from https://www.epa.gov/nutrientpollution/estimated-nitrate-concentrations-groundwater-used-drinking#:~:text=2010).,which%20is%20from%20groundwater%20wells).&text=Values%20are%20rounded%20to%20the,(10%20mg/l).

Executive Summary. (2015, March). Suffolk County Government. Retrieved April 30, 2025, from https://www.suffolkcountyny.gov/Portals/0/FormsDocs/Health/EnvironmentalQuality/ComprehensiveWaterResourceManagementPlan/Executive_Summary.pdf

Food Security in the U.S. - Key Statistics & Graphics. (2025, January 8). Economic Research Service U.S. DEPARTMENT OF AGRICULTURE. Retrieved August 31, 2025, from https://ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics

Green Space. (2023). NYC Mayor's Office of Climate & Environmental Justice. Retrieved April 30, 2025, from https://climate.cityofnewyork.us/subtopics/green-space/

Ishimatsu, K., Ito, K., Mitani, Y., Tanaka, Y., Sugahara, T., & Naka, Y. (2017). Use of rain gardens for stormwater management in urban design and planning. *Landscape and Ecological Engineering*, *13*, 205-212

Julien, J., Gardner, N., Tucker-Ray, S., & Stewart, S., III. (2025, March 20). *Who is Rural America?* McKinsey Institute for Economic Mobility. Retrieved August 31, 2025, from https://www.mckinsey.com/institute-for-economic-mobility/our-insights/who-is-rural-america

Juncus effusus. (n.d.). New Moon Nursery. Retrieved April 30, 2025, from https://newmoonnursery.com/nursery-plants/juncus-effusus/#:~:text=This%20rush%20is%203%2D4,soils%20with%20fluctuating%20water%20levels.

Key Facts & Statistics. (n.d.). Northwest Harvard. Retrieved August 31, 2025, from https://www.northwestharvest.org/resources/key-facts-statistics/

Kitajima, N. (2021). Experimentally based designing of rainwater runoff control for implementing of Rain Garden. フジタ技術研究報告= *Fujita technical research report*, (57), 71-76.

Leibowitz, B. (2014). Conducive environments for the promotion of quality teaching in higher education in South Africa. *Critical Studies in Teaching and Learning (CriSTaL)*, *2*(1), 49-73.

Long Island Nitrogen Action Plan (LINAP). (n.d.). Department of Environmental Conservation. Retrieved April 30, 2025, from https://dec.ny.gov/nature/waterbodies/oceans-estuaries/linap

Long Island Water Use. (2017, May 11). USGS. Retrieved April 30, 2025, from https://www.usgs.gov/centers/new-york-water-science-center/science/long-island-water-use

Meerow, S. (2020). The politics of multifunctional green infrastructure planning in New York City. *Cities*, *100*, 102621.

National Stormwater Calculator. (2024, August 22). United States Environmental Protection Agency. Retrieved February 3, 2025, from https://www.epa.gov/water-research/national-stormwater-calculator

New York City- Nassau County Water Supply Interconnection. (2022, August). New York State Department of Help. Retrieved April 30, 2025, from https://www.health.ny.gov/environmental/water/drinking/docs/nyc_nassau_county_feasibility_study.pdf

Nitrates. (2024). European Commission. Retrieved April 30, 2025, from https://environment.ec.europa.eu/topics/water/nitrates_en

Nitrogen Control Program for Long Island Sound. (n.d.). Connecticut Department of Energy & Environmental Protection. https://portal.ct.gov/deep/municipal-wastewater/nitrogen-control-program-for-long-island-sound

Nitrogen Pollution in Long Island Sound. (n.d.). NEIWPCC. Retrieved April 30, 2025, from https://neiwpcc.org/our-programs/pollution-control/lis-tmdl/

Old Westbury Rainfall Forecast. (n.d.). WillyWeather. Retrieved April 30, 2025, from https://rainfall.willyweather.com/ny/nassau-county/old-westbury.html

Our Long Island Aquifers: The Basics. (2015). NSWCA. Retrieved April 30, 2025, from https://www.nswcawater.org/water_facts/our-long-island-aquifers-the-basics/

Percentage of Adults Aged ≥18 Years Living in Families That Were Food-Insecure in the Past 30 Days,† by Family Income§ and Urbanicity¶ — National Health Interview Survey, United States, 2021**. (2022, December 2). CDC Morbidity and Mortality Weekly Report (MMWR). Retrieved August 31, 2025, from https://www.cdc.gov/mmwr/volumes/71/wr/mm7148a6.htm

Rain Garden Plants: Iris versocolor and Iris virginica. (2017, January 26). Clemson Cooperative Extension Home & Garden Information Center. Retrieved April 30, 2025, from

https://hgic.clemson.edu/factsheet/rain-garden-plants-iris-versicolor-and-iris-virginica/#:~:text=Showy%2C%20masses%20(3%20to%205,negatively%20impacted%20long%2Dterm..

Rain, rain go this way: Rain gardens catch runoff and pollutants. (2012, August 25). Syracuse. Retrieved April 30, 2025, from https://www.syracuse.com/cny/2012/08/rain_rain_go_this_way_rain_gardens_catch_runoff_and_pollutants.html

Reed, B. (Ed.). (2024, February 15). *America is a factory farming nation': key takeaways from US agriculture census*. The Guardian. Retrieved August 31, 2025, from https://www.theguardian.com/environment/2024/feb/15/us-agriculture-census-farming

Rural Data Explorer. (2023). Rural Health Information Hub. Retrieved August 31, 2025, from https://www.ruralhealthinfo.org/data-explorer

Rushes. (2015). MISSOURI DEPARTMENT OF CONSERVATION. Retrieved February 3, 2025, from https://mdc.mo.gov/discover-nature/field-guide/rushes#:~:text=Soft%20rush%20can%20have%2050,with%20true%20sepals%20and%20petals.

Stormwater Infrastructure Mapping Inventory and Assessment. (2020, April). NYS, Department of State Division of Coastal Resources South Shore Estuary Reserve Council. Retrieved February 3, 2025, from https://dos.ny.gov/system/files/documents/2020/04/coastal-resiliency-and-water-quality-on-long-island.pdf

Technologist, A. (2017, October). *Runoff Coefficients for InfoSWMM, InfoSWMM SA, ICM and XPSWMM*. SWMM5, ICM SWMM, ICM InfoWorks, InfoSWMM, InfoSewer. Retrieved

April 30, 2025, from https://swmm5.org/2017/10/12/runoff-coefficients-for-infoswmm-infoswmm-sa-icm-and-xpswmm/

Vogel, J. R., Moore, T. L., Coffman, R. R., Rodie, S. N., Hutchinson, S. L., McDonough, K. R., ... & McMaine, J. T. (2015). Critical review of technical questions facing low impact development and green infrastructure: A perspective from the Great Plains. *Water Environment Research*, *87*(9), 849-862.

Walter, D.A., Jahn, K.L., Masterson, J.P., Dressler, S.E., Finkelstein, J.S., and Monti, J., Jr., 2024, Simulation of groundwater flow in the Long Island, New York regional aquifer system for pumping and recharge conditions from 1900 to 2019: U.S. Geological Survey Scientific Investigations Report 2024–5044, 113 p., https://doi.org/10.3133/sir20245044.