# Stormwater Capture Parks along the Henry Hudson Parkway: Developing Endor Garden as a Watershed Model

**The purpose of this proposal is to describe a model framework for the Henry Hudson Parkway Scenic Byway coupling parkland creation with overpass infrastructure along the Henry Hudson Right-of-Way in the Bronx. This program was developed by the Gaia Institute in partnership with the Riverdale Nature Preservancy, funded by the J.M. Kaplan Fund.**

*View from the Fieldston Road Overpass of the Henry Hudson Parkway in the Bronx* *photo by John Benfatti*

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**Parkland Adjacent to the Fieldston Road Overpass of the Henry Hudson Parkway**

**Terraced planting enables the once bare slope to capture water in soil, and support a dense, multi-layered, vegetated buffer.**

**When the New York City Department of Parks and Recreation collaborated on a design for four GreenStreet beds on the Fieldston Road Overpass, vibrant plantings increased soil and vegetated cover adjacent to the paved surfaces. These dense, verdant landscapes have transformed a previously sterile public space into an inviting esplanade.**

**Entrance to Endor Community Garden pictured below.**

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# SCOPE AND PURPOSE

The Riverdale Nature Preservancy has been awarded a grant to investigate how parklands and green buffers adjacent to the Henry Hudson Parkway (NY 9A) could be improved to increase aesthetic value, capture stormwater, and decrease environmental degradation from erosion and non-point pollution. Should the Henry Hudson become the first "Scenic Byway" in New York City, such status would make funds available for beautifying and functionally improving parklands and green buffers within the Parkway corridor or right-of-way. Properly designed, such efforts would greatly improve the visual experience of motorists and residents, while at the same time improving environmental conditions and increasing biodiversity of the surrounding area. Specifically, these modifications would help to:

- divert stormwater from combined sewers, by capturing runoff generated from neighboring streets and roadways into surrounding surface soil infiltration zones
- minimize erosion of topsoil, through terracing and other landscape features to slow and hold runoff
- improve air quality, by promoting the development of 'natural filters' including trees and other vegetation
- increase biodiversity and enhance vegetation cover in existing parkland and neighboring property, by restoring soils and using stormwater to remediate ecosystems that presently don't '*hold water'*

The purpose of this report is to identify opportunities to better integrate the infrastructure and parkland of the Henry Hudson Parkway into surrounding neighborhoods and landscape. We focus this report on a span of the Parkway located in the Fieldston area of the Bronx. Existing conditions are compared to the original New York City Department of Parks and Recreation drawings dated October 1, 1937. Conceptual design drawings are presented that illustrate how this particular span of parkway could be improved by hydrologically coupling impervious surfaces with redesigned green buffer infiltration zones. In addition to these environmental considerations, a discussion is provided of the significant economic benefits that could be realized through this initiative in the form of reduced storm sewer and treatment facility infrastructure costs for New York City, and increased real estate values for adjacent property owners. Finally, the implications of the proposed improvements to the Fieldston span for other sections of the Parkway are discussed.

## Introduction and Site Description

### *General Description of the Henry Hudson Parkway*

The Henry Hudson Parkway extends 11.1-mile from West 72nd Street in Manhattan across the Harlem River to the Bronx-Westchester border. Designed and constructed in the 1930s at the height of the American Parkway Movement, the bridge over the Harlem River with its magnificent, unimpeded vistas on the Hudson and the Palisades opened to toll-paying motorists on October 12, 1937. In 1938, the National Park Service identified eight factors that differentiated parkways from ordinary highways:

1) designated for noncommercial, recreational use
2) avoided unsightly buildings and other unattractive roadside developments
3) were built within a much wider right-of-way to provide an insulating strip of parkland between the roadway and the abutting private property
4) eliminated frontage and access rights and preserved the natural scenic value of the landscape they passed through
5) preferably took a new location, bypassing existing built-up communities and avoiding congestion
6) aimed to make accessible the best scenery in the country it traversed, hence the shortest or most direct route was not necessarily a primary consideration
7) eliminated major grade crossings
8) had entrance and exit points spaced at distant intervals to reduce interruptions to the main traffic stream

While these criteria apply to parkways generally, each and all well characterize the Henry Hudson Parkway.[1]

### *Natural Landscape Destruction and Inadequate Attempts at Slope Protection*

The construction of NY-9A required severe alteration of the city's natural coastline and most rugged topography, the Manhattan and Riverdale Ridges.[2] As NYC Parks Commissioner during the construction years, Robert Moses' vision for the Henry Hudson Parkway (or as it was originally called, "the West Side Improvement") included an uninterrupted, "great highway that went uptown along the water," connecting the City to Westchester, and a great park on landfill on what he considered a 6.5 mile muddy "wasteland" along the Hudson River. To save money on land acquisition, the parkway was run straight through both Fort Tyron and Inwood Hill parks, two of the last remaining pieces of virgin woodland in Manhattan. In the Bronx, hundreds of trees were destroyed as the 140 foot wide parkway was built on top of what was the two-lane, tree-lined "Spuyten Duyvil Parkway" and Riverdale Avenue. As it passed through Van Cortlandt Park, it destroyed one of the last fresh water marshes of substantial size in New York City.[3]

At the request of the Riverdale Nature Preservancy, Bronx historian Lloyd Ultan investigated the history of the parkway in the Riverdale area. In his researches, he found that, in order to situate the Henry Hudson right-of-way in Van Cortlandt Park without destroying the Parade Ground and

to connect with the Saw Mill River Parkway in Westchester, Moses ran the parkway north along Riverdale Avenue as far as 253rd St. then veered sharply east. This is the only span of the parkway right-of-way where Moses did not make use of an existing road but condemned substantial amounts of existing private property. The extensive parkland created in the process is identified on maps as Henry Hackett Park, and includes the Fieldston area considered in this study. Although much of this land was rocky and wooded, one mansion and several small cottages were destroyed to make way for the new parkway. W 253rd Street, a narrow winding lane laid out by Frederick Law Olmsted, was preserved as the service road so that its English Tudor homes and landscape could provide a scenic view from the Parkway.

New trees were planted for slope protection along the Parkway right of way. A drawing prepared by the New York City Parks Department in 1937 shows the trees planted along the Fieldston span. Some sixty-six years later, these trees have matured, and a few others have taken root. In some places a thin understory has developed, while in others high velocity runoff from upslope impervious areas has eroded and removed the topsoil, leaving rocky subsoils which support virtually no understory vegetation.

***General Description of Study Area***

The focus of this report consists of an approximately half-mile span of parkland bounded by the Parkway lanes to the north, West 253rd Street to the south, Fieldston Road to the west, and Broadway to the east. *(See Figure 1.)* The Henry Hudson Parkway here runs east-west before entering Van Cortlandt Park, with the northbound exit ramp sloping down to Broadway. Abutting steep slopes provide no room for a shoulder in this length of the Parkway. West 253rd Street running parallel and just to the south connects Fieldston with Old Post Road. Also constrained by slope and bedrock, this narrow two way street is only 25 feet wide, lacking sidewalks on either side. Illegal dumping has led to the accumulation of abandoned cars, toilet bowls, broken glass, rusted metal, and construction debris (especially concrete and asphalt) strewn amongst the spare tree cover and parkland understory between West 253rd Street and parkway lanes to the north. Adjacent parkland was previously separated from this road by a retaining wall, but the original stone work has since degraded and eroded away, replaced, in some areas, with standard metal guardrail. On the south side of West 253rd Street, the 19.5-acre campus of the Riverdale Country School includes buildings, sports fields, lawns and parking areas. Hard gneisses of the Manhattan Formation create exposed rock escarpments throughout this landscape, creating steep slopes at the road edges, which lack the protection of curbs or sidewalks, thus creating an extremely dangerous situation for Riverdale Country School students and other pedestrians on West 253rd Street.

The western end of this park contains a woodland garden and habitat trail, called “Endor”. Volunteers under the auspices of the New York City Parks Department GreenStreets Program, Bronx Green-Up, and Green Thumb are presently restoring the area, frequently utilized by many elderly people and children from the nearby apartment buildings and Russian Residence. An unfinished trail constructed by Wave Hill Forestry interns follows established desire lines in an attempt to connect the park to Old Post Road, a common destination for walkers. This construction was attempted in order to provide pedestrians with an alternative to walking in the dangerous roadway.

## MATERIALS AND METHODS

A number of data sources contributed to the preparation of this report including:

Sheet 10 of the "Henry Hudson Parkway Slope Protection" drawings prepared by the New York City Department of Parks and Recreation, dated October 1, 1937;

"Existing Sewers Section 24," a map prepared by the City of New York, dated May 21, 1934, depicting combined sewer infrastructure and planned Parkway alignment in the vicinity of the study area;

Current topographic plot elevations for the area were obtained in GIS format from the New York City Department of Parks and Recreation; and, two site investigation and field documentation visits were conducted with representatives of the Riverdale Nature Preservancy in August, 2002.

## REVIEW OF EXISTING CONDITIONS

### Vegetation

Following Parkway construction, the Slope Protection Plan of 1937 indicates where saplings and shrubs were planted amongst the few remaining mature trees in the park located to the south of the northbound lanes of the Parkway. Approximately 110 trees were installed south of the Parkway and north of West 253rd Street. These plantings included the following species:

1) *Cornus florida*
2) *Quercus coccinea*
3) *Quercus palustris*
4) *Quercus velutina*
5) *Tsuga Canadensis*
6) *Betula lenta*

The following shrubs were installed in designated beds in quantities of 50 to 650 at a time:

1) *Viburnum acerifolium*
2) *Cornus paniculata*
3) *Ampelopsis quinquefolia*
4) *Viburnum prunifolium*
5) *Celastrus orbiculafus*

No plantings were made at that time in Endor Park near Fieldston Road. Old-time residents recall that this area was instead furnished with benches and a horseshoe court, the remnants of which can still be seen today.

Shrubs but no trees were planted in the semi-circular area between the northbound parkway and the exit ramp to Broadway, including the following species:

1) *Rosa humilis*

2) *Rosa nifida*
3) *Aronia melan*

Currently, the entire parkland area located south of the Parkway and just north of W 253 Street between Fieldston Road and Old Post Road is wooded. Bruce Kershner, director of the New York Old Forest Survey, inventoried trees in this area in September of 2002. He identified several old growth trees (oaks, and also American beeches, distinguished by their soaring, branchless trunks and smooth grey bark); several 100-200 year old estate trees (e.g., copper beeches); and numerous exotic species about 65 years old that were popular in park planting at the time: *Pawlonia*, *Magnolia*, etc. There are also some fallen hemlocks of the same age, presumably planted for screening, having since succumbed to wooly adelgid and/or death due to low soil moisture and atmospheric humidity levels which presently characterize the microclimate of the site.

Besides these trees, understory growth in the project area is minimal, especially where high velocity runoff from impermeable areas upslope have been discharged into the woodland, eroding and removing topsoil. It is of interest in this regard that a wooded area not shown in the 1937 plan has developed in the area inside the Parkway jug handle, close to Broadway, perhaps because of deeper, undisturbed soils.

**Topography**

Parkway traffic lanes slope downward from an elevation of approximately 115 feet just east of the Fieldston Road overpass, to an elevation of approximately 60 feet where the parkway lanes cross over Broadway and enter Van Cortlandt Park. The northbound exit ramp slopes downward to Broadway, which itself is at an elevation of approximately 42 feet. West 253rd Street also slopes downward to the east. The Fieldston Road intersection is at an elevation of approximately 144 feet, while the intersection of West 253rd and Old Post Road is at 65 feet above sea level. The landscape rises to the southwest of the study area, reaching elevations of near 250 feet along Goodridge Avenue.

The park slopes downhill from West 253rd Street to the Parkway traffic lanes. While the slope is moderate in the middle of the park, the rock drops off steeply and suddenly at the western and eastern ends of the span immediately adjacent to the Parkway. Here the slope is so severe that, for safety reasons, the New York City Department of Transportation does not allow its own workers or volunteers to remove the trash accumulated over several decades near the roadway edge.

**Drainage conditions**

New York City Sewer maps dated May 21, 1934 indicate that the two main combined sewer lines in the area also slope downward to the east. One branch runs underneath the Parkway lanes and another underneath West 253rd Street. Some of the residential neighborhood areas located further upland to the south and west appear from these maps not to have been served by these sewer lines.

Runoff from the Henry Hudson Parkway enters catch basins on the road surface, which conveys it to the combined sewer line running under the roadway. With no catchbasins along West 253rd Street, roadway runoff flows to the east over the surface where it is eventually directed by various impediments into the lower lying parkland, or into the combined sewer catchbasin at the intersection of West 253rd Street with Old Post Road.

A significant additional volume of stormwater runoff is discharged to West 253rd street from the impervious areas on the 19.5-acre Riverdale Country School campus, located on the hill to the south. The high velocity runoff from the campus has caused serious erosion in the park, as shown in the photos provided in Figure 1. Three active erosion areas have been identified:

1. **Directly across West 253rd Street from the Riverdale Country School Driveway:** Runoff from the western portion of the Riverdale Country School campus is directed through a series of rip-rap channels, pipes, and other conduits to the parking lot and driveway entrance onto West 253rd Street, just south of Fieldston Road. During rainfall events, runoff moves at high velocity down the driveway, across West 253rd Street, and into the adjacent parkland. Stormwater from the span of West 253rd Street extending up to Fieldston Avenue also enters the park at this location. A large eroded gully has developed where this flow leaves the pavement and begins to move downhill (see photos in Figure 1). A riprap channel built in the park in an effort to protect the slope from the destructive runoff actually exacerbates the problem by channeling the high velocity stormwater further downhill. Consequently, there is virtually no vegetation in this area of the park.

2. **Opposite 219 W. 253rd Street:** A second series of drains and pipes transports runoff from the central portion of the Riverdale Country School campus into West 253rd Street via a concrete shoot adjacent to a building at 219 West 253rd Street. This discharge is directed into a rip-rap ditch parallel to the street, where it combines with runoff from W 253rd Street. During storm events, velocities in this ditch must be substantially greater than one foot per second, since it contains no fines, little sand, and no vegetation. Scouring is beginning to undermine the roadway asphalt in some areas. About 40 feet further down the street, rocks and a tree divert the flow across the roadway surface and into the park, leading to a large erosion gully downslope. Except for a few trees, with some root exposure, vegetation in this portion of the park is minimal. Down gradient, this runoff is burying the trunk of a copper beech tree, estimated to be 150+ years old, and is likely to kill the tree, by girdling root, which tends to occur, where soil piles up above the soil-line around the trunk.

3. **Opposite the driveway near Old Post Road:** A second driveway of the Riverdale Country School campus transports runoff generated upslope, together with stormwater discharged from various downspouts, and runoff from nearby rock outcroppings, to W 253rd Street near Old Post Road. Here stormwater from the campus combines with street surface runoff, entering the park with increased force. Some vegetation is still in place here, but topsoil loss is evident over significant portions of the site.

## EVALUATION OF EXISTING CONDITIONS

Trees planted in the study area in the 1930's have matured. By itself, however, tree cover is not effective in controlling erosion. Shrubs planted seven decades ago have not expanded coverage. Without a healthy, dense vegetation cover, the sloping parkland remains highly susceptible to erosion. Factors which may have suppressed understory development through the years include: the erosion of topsoil, the loss of in-situ water holding capacity resulting from the loss of topsoil and diminished groundwater recharge, an impoverished on-site seed bank, and the lack of immigration of native plants from adjacent ecosystems which have also decreased in biodiversity. These conditions made it difficult for a stable understory of herbaceous and shrub vegetation to develop on the sloping parkland. What remains is not a self-sustaining ecological system but, in fact, the opposite, since further erosion of soil and nutrients further degrades the capacity of the soil to support plants, leading to further erosion, etc.. The system is therefore likely to continue to degrade over time.

Severe erosion has thus resulted where vegetation, soils, and other landscape features fail to intercept, slow down, and infiltrate runoff, allowing it to gather volume and force, as it finds its way downhill to the catchbasins along the Henry Hudson Parkway and at the intersection of West 253rd Street and Old Post Road. During intense storm events, the wastewater treatment plants at the end of the combined sewers exceed capacity, and discharge all excess and untreated stormwater and wastewater into the Harlem River.

## PROPOSAL

### Design Overview

It is here proposed that parkland soils adjacent to the Henry Hudson Parkway can be utilized as a cost-effective means of stormwater capture and treatment. As the prior analysis illustrates, the behavior of presently degraded natural systems are part of the erosion problem, but by ecologically engineering terraced plantings and soil beds, infiltration zones can be restored and enhanced on the sloping terrain. In so doing, the biodiversity and ecological productivity of the park vegetation can be increased, while at the same time eliminating or greatly limiting stormwater discharge from this length of 253rd Street into combined sewers.

The design approach presented here relies on the well grounded, and long term use of how low-cost berms and terraces. These utilize freeboard height to scale water holding capacity to incorporate precipitation from each subsection of a watershed. The simplified strategy operative here is to keep water on the land for periods long enough for infiltration to occur. Moist soils and infiltration then together help to stabilize existing slopes by supporting the growth and development of plant and soil systems, essential for short and long term erosion protection. This same terracing can also serve as a base for a pedestrian trail and public access, thus serving the multiple goals of park use. The overall objectives of the proposed design are therefore the following:

1) To infiltrate *three inches* of runoff from West 253rd Street, roughly equivalent to the amount generated by a *two-year storm*, entirely within the existing wooded areas in the adjacent parkland in under *18* hours
2) To infiltrate *six inches* of runoff from West 253rd Street, roughly equivalent to the amount generated by a *100-year storm*, entirely within the existing wooded areas in the adjacent parkland in under *48 hours*
3) To stabilize the existing slopes within the park
4) To provide a safe pedestrian trail from Fieldston Road to Old Post Road
5) To enhance ecological productivity and maximize biodiversity within the existing parkland.
6) To restore the natural sound and visual buffer of the parkway provided by deep soils and dense understory plantings.

In order to be workable on the limited foot print of the slope available, this design assumes that stormwater generated on the Riverdale Country School campus will be eliminated through onsite stormwater capture and treatment based on similar principles to those used in the parkland. A second design scenario is provided below, however, which estimates the total impervious area that could be accommodated by maximizing the infiltration potential of the park. Because the road surface of the Henry Hudson is at a lower elevation than the parkland, it is not considered in this analysis. Vegetated areas located within the exit jug handle should be considered for infiltration of runoff from the Parkway lanes in a subsequent study.

**Background**

Urban stormwater runoff from streets, lawns, parking lots, and rooftops contains a spectrum of contaminants including nitrogen, phosphorus, suspended solids, hydrocarbons, pathogens, and heavy metals. All of these contaminants are attenuated in soil systems, which processes are enhanced by promoting contact between stormwater and biogeochemically active soil surfaces, since removal efficiencies proportional to the amount of contact.[4] Mechanisms for pollutant removal include filtration, biogeochemical decomposition, sorption and precipitation. Each and all occur as stormwater infiltrates into soils in vegetated areas. The use of naturally vegetated or ecologically engineered infiltration galleries, as opposed to standard environmentally engineered trenches, basins, or other structural systems, is advantageous since high infiltration rates are maintained in these areas by the ongoing earth moving and burrowing activities of roots and invertebrates. Additional benefits include appropriate scaling using ecologically based technologies with lower construction costs. By diverting runoff from impervious surfaces into terraced infiltration galleries distributed as multiple barriers along a series of downgradient contours throughout a given watershed, water is kept out of storm sewers and is fed into the landscape, increasing ecological productivity and replenishing local groundwater. At the same time, green buffers decrease the urban heat-island through the integrated coupling of shading, reradiation, and evapotranspiration carried out by plant leaves. Because of their large surface areas, trees contribute to other aspects of environmental quality: dissipating the force of rain, filtering pollutants from the air, reducing wind speed, absorbing sound, stabilizing soils, and providing habitat for birds, mammals and insects.[5]

**The Design**

The total surface area of West 253rd Street between Fieldston and Old Post Roads is approximately 0.6 acre. A two-year storm, yielding three inches of precipitation, results in the generation of approximately 50,000 gallons of water from the street surface alone. In the current configuration, this water, along with runoff entering the park from upslope, is collected in catchbasins and discharged into the combined sewer. Stormwater passing through the park presently carries topsoil, leaves and other humic matter away with it, removing biomass and minerals essential for the development of a sustainable understory. Erosion also undermines the built environment, compromising the structural integrity of W 253rd Street. To make matters still worse, this landscape impact is then translated into water quality problems when sediment, suspended solids, and pollutant loads are transferred to the sewer lines and receiving waters around the Bronx and the City.

The design proposed couples impervious sections of West 253rd Street with sections of parkland, which have been redesigned for water infiltration. As shown in Figure 2, contouring of the street surface is used to direct runoff generated from Catchment Area "A" to Infiltration Zone "A." Runoff generated from Catchment Area "B" is diverted to Infiltration Zone "B," and so on. Where possible, the street surface is pitched to the south, so that runoff enters first a curbside infiltration gallery on the 'uphill' side of the roadway (See Section 1). Excess runoff then passes under the roadway through a small culvert, over a small energy-dissipating apron, and into a bermed-off, terraced infiltration gallery located within the park. Where no room is available to construct the curbside infiltration gallery on the south side of the street, it is built on the north side, immediately adjacent to the parkland (See Section 2). Infiltration zones within the park have been sized such that three inches of runoff from the coupled impermeable catchment will

not exceed maximum depths of 1.5 feet, and will entirely infiltrate into the park soils within 18 hours. These low depths and short detention times help to ensure that water does not remain ponded and stagnant on the slope, creating undesirable mosquito breeding habitat and stressing vegetation by creating sustained anaerobic soil environments. Given the porosity and permeability of onsite soils, an infiltration rate of one inch per hour has been assumed (soils found in similar environments in Westchester County, such as Charlton and Paxton soils, often have permeabilities of 2-6 inches per hour[6]). The perimeter berms have been designed with top elevations which, while below the lowest elevation of the pertinent roadway catchment to ensure that street flooding does not occur, are also three feet above the bottom of the infiltration areas. This provides for the storage of six inches of runoff from all impervious areas and results in zero discharge from the area, even during a 100-year, catastrophic storm event.

Berms are low cost features and easy to install. Compacted clay, woodchips, and compost can be used to achieve the desired elevation using a small bobcat tractor, and manual tampers. In steeper areas, where the 3:1 side slopes of earthen berms are difficult to achieve, rock gabions encased in non-woven geotextiles, or packed with rock and soil, can be used to accomplish the same objective. In both cases, the purpose of the berm is to decrease the velocity of overland flow, trapping sediments and water on the slope and, in so doing, promoting infiltration. Water table recharge promotes understory growth, and can sustain plant communities through periods of drought. While the existing steep, unstable, eroded slopes and road edges have made the completion of a safe pedestrian trail impossible, the proposed berms can be used as the base for a continuous trail connecting Old Post to Fieldston Road, also shown in Figure 2.

**Maximum Infiltration Potential of Parkland**

Using the two design criteria described above, i.e., three inches and six inches of runoff, respectively, a second catchment scheme was developed to maximize the infiltration potential of the parkland. The goal of this design exercise was to determine the maximum volume of stormwater that could be infiltrated into the existing park soils given the space available. This design is shown in Figure 3. Again assuming an infiltration rate of one inch per hour with infiltration zones circumscribed by three-foot berms, and inundated to depths of less than 1.5 feet during a two-year storm event, a total volume of 95,000 gallons of water could be infiltrated on the slope in under 24 hours. If, as described above, 50,000 gallons of water are generated from three inches of runoff from West 253rd Street alone, this calculation indicates that the park is capable of infiltrating approximately 40,000 gallons of additional runoff from upslope sources. This is an amount equivalent to three inches of runoff from approximately 0.5 acres of impermeable surface. As mentioned previously, the entire area of the Riverdale Country School campus is 19.5 acres. It was not possible to calculate here the precise percentage of this area that drains towards West 253rd Street. However, inspection of the extent of the network of channels, gulley, shoots, and impervious areas indicated in Figure 1 suggest that significantly more than 0.5 acres of the campus drain directly into the project area. It would thus be necessary to eliminate this upslope discharge through on-site stormwater management within the confines of the school property if zero or minimal discharge of stormwater to combined sewers is to be achieved along this span of the Henry Hudson Parkway. Given the expansive open space available within the upslope property, it is likely that this goal could readily be achieved given interest and a cooperative framework on the part of Riverdale Country School.

## CONCLUSIONS

The attempt to replace forest destroyed as a result of the construction of the Henry Hudson Parkway has not succeeded structurally or functionally. Adjacent to 253rd Street, relatively few new trees have taken root. Without significant site restoration and ecological engineering, it is unlikely that new trees will germinate and grow to replace existing stands planted in the 1930's as these die off. The likely outcome of a 'no-action plan', patterns of which can already be seen, involves the eventual colonization of the site with a monoculture of Norway maples. Such stands cover the understory in dense shade, adding the stress of lack of sufficient sunlight to the already eroded slopes, further inhibiting water holding capacity and the recruitment of understory shrubs and herbaceous plants. Full coverage by Norway maples result in a more or less open forest floor, providing minimal screening of noise and sound, and, because off reduced leaf surface area near the ground, such forest structure is likely to have reduced air pollutant abatement capacity.

If the problem described here is not addressed, runoff generated upslope will continue to erode topsoil, and inhibit understory development in the Henry Hudson Parkland, while loading combined sewers with non-point source pollutants. As regulations limiting CSO discharge to surface waters come online, the City will be required to address this problem directly. A mitigation approach involving the construction of end-of-pipe infrastructure to capture and treat stormwater in excess of current treatment plant capacities is costly, both economically and ecologically. On the other hand, rebuilding natural systems to capture and treat non-point pollutants on the landscape diminishes combined sewer discharge and at the same time offers a fiscally, functionally, and aesthetically attractive alternative to 'no action' or end-of-pipe solutions.

As demonstrated in this proposal, ecological engineering can be used to integrate stormwater within the roadside landscape by directly addressing the sub-basin water budget for specific quantities of runoff using hydrologically informed design criteria. Here, the redesign of a specific buffer zone around the Henry Hudson Parkway and West 253rd Street corridor can be used to incorporate stormwater, thereby substantially diminishing roadway runoff. These same stormwater capture enhancements also achieve significant improvements in environmental quality. If upwards of 90,000 gallons of stormwater can be infiltrated in a narrow vegetated area along one side of a half-mile span of Parkway, then at least 4 million gallons of water could potentially be diverted from combined sewers and surface water discharge were similar designs developed along both sides of the full 11.5 mile Henry Hudson Parkway. The capture of three inches of runoff from the highway surface in terraced soils along this length could more than double this figure. This ecologically based, zero-discharge approach would provide testable steps toward improving surface water quality, enhancing ecological productivity, and eliminate the need for the construction of capital intensive, end-of-the-pipe treatment infrastructure. By dint of location, geological and landscape context, the Henry Hudson may also provide a timely example of how Parkway's around the City and State of New York be used to simultaneously improve aesthetic, transportation and environmental quality goals.

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**Endnotes:**

[1] As cited in Expansion of the National Park Service in the 1930's: Administrative History. Chapter Four: New Initiatives in the Field of Recreation and Recreational Area Development. Accessed online, August, 2002. (www.cr.nps.gov/history/onlinebooks/unrau-williss/adhi4i.htm)

[2] Fort Tryon and Chapel Farm are the two highest points in the counties of New York and the Bronx, respectfully.

[3] Caro, Robert A., The Power Broker. Vintage Books: New York, 1975. p 525-526.

[4] Todd, DK (1980) Groundwater Hydrology 2nd Edition. John Wiley & Sons: New York. 538 pp.

[5] Technical Note #15 1(1): 30-31 in Schueler, TR and HK Holland, eds. (2000) The Practice of Watershed Protection. Center for Watershed Protection, Maryland. 741 pp.

[6] Soil Survey of Putnam and Westchester Counties, New York. September, 1994. USDA, Soil Conservation Service.