II. EXISTING CONDITIONS AND PROBLEMS

Good water is the life-blood of natural systems. Three structural features of the twin lakes in Flushing Meadows negatively impact the quality and quantity of water:

1. **The area is ringed by roadways** that discharge pollutants into the lakes and cause significant habitat disruption.

2. **Large quantities of stormwater are diverted out** of the watershed, reducing the flow of the "life's blood" of all natural systems. Less water flowing in means a reduced flushing rate in terms of throughput, as well as less water to support plant communities.

3. **High nutrient content in the underlying sediments** from the historic salt marsh is compounded in Meadow Lake by the grassy water's edge, which attracts geese that deposit droppings, adding yet more nutrients to the water.

The ring of roadways: pollutant deposition & habitat disruption

The simple problem with Flushing Meadows-Corona Park is that it is cut off from the surrounding area by roadway infrastructure. As can be seen in the 1969 aerial photograph of the twin lakes in Flushing Meadows, major highways ring the entire circumference of the park. More than five miles of highway effectively surround the park with a nearly continuous "fence" of high-speed vehicles. This moving barrier deposits a continuous stream of hydrocarbons, nitrate, and metals on the roadway, portions of which are washed directly into the twin lakes.

Pollutants deposited per acre of major highway have been quantified. By these generally accepted measures, each acre of the Van Wyck and Grand Central can be estimated to annually discharge some 20 pounds each of hydrocarbons and nitrate, a half pound each of lead, zinc and copper, and two tons of suspended solids into receiving waters.

In total, the thirty-plus acres of roadway each year contribute a quarter ton of hydrocarbons and nitrogen, tens of pounds of heavy metals, and tens of tons of suspended solids. While precise solutions to these loads in terms of wetland uptake is premature without more accurate measures of wetlands and highway area and runoff, such quantities are certainly well within the range of wetland removal capacities reported in scientific and engineering literatures.[1]

Quantity of pollutants per roadway mile

mg/l	NOx	TKN	TP	Cu (µg/l)	Cd (µg/l)	Cr (µg/l)	Pb (µg/l)	Ni (µg/l)
max	13.37	2.45	1.54	53.5		20	56	17
	6.47	2.42	0.81	52		13	30	14
mean	2.25	1.42	0.43	24.2		8.1	21	8.1
kg/ha/yr								
german rd			1.6	0.62	0.04	0.06	1.33	
Charl NC			3.5	0.22	0.22	0.03	0.2	0.09

Wu,J.S., C.J. Allan, W.L.Saunders. J.B. Evett. 1998. Characterization and Pollutant Loading Estimation for Urban and Rural Highway Runoff. Journal of Environmental Engineering. Vol. 124 (7): 584-592.

Reintroduction of native animal and plant species through migration from one side of the highway to the other is severely limited by this high-speed traffic. While birds can fly across the road, there is often roadside evidence of others that do not make it. Toads, frogs, salamanders, turtles, snakes, squirrels, chipmunks, foxes, muskrat, and even smaller animals such as insects have limited opportunities to immigrate from surrounding landscapes, therefore isolating the park from nearby natural areas, in part, by eliminating migrants with a deadly barrier. By reintroducing these species into enhanced, engineered habitats, a diverse ecosystem can be re-established in Flushing Meadows-Corona Park.

1969 aerial photograph of Flushing Meadows showing the surrounding highways, which limit the natural reintroduction of native animal and plant species.

Disrupted hydrology: Stormwater shed, seeps, and puddles

The twin lakes are literally surrounded by impermeable infrastructure: expressways, parkways, boulevards, parking lots, railways, sidewalks, and paths. Each and all are paved or compacted and so made impermeable to precipitation, thus maximizing runoff. On the other hand, the existing open land, especially on the hills around the lakes, is most probably highly porous because of the high sand and gravel composition of the glacial subsoil, so water entering the unpaved areas probably migrates relatively quickly to groundwater that flows into the twin lakes.

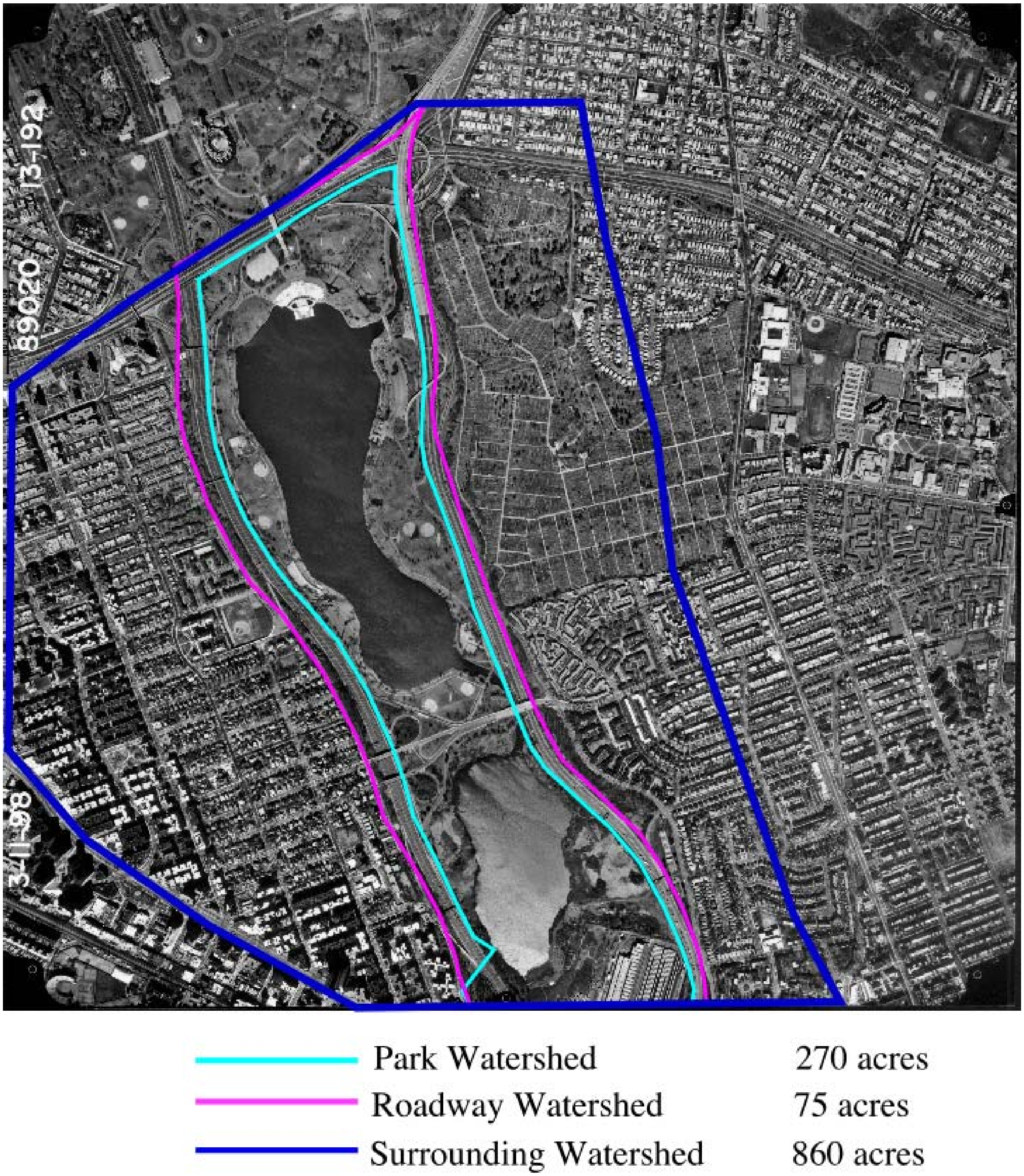
The terrace-like behavior of the infrastructure ringing the twin lakes can be seen adjacent to the highways, parking lots, and pathways, where seeps and upwelling of underground water sources are visible during wet periods or freeze-thaw cycles. The water blockage from these structures causes water to puddle and pool, increasing physical damage caused by freeze-thaw cycles and also increasing potential liability due to accident and injury. One manifestation of this ongoing problem may be seen in the seepages that emerge along the western edge of Meadow Lake following rain events, from the upslope water table that intersects the ground surface and runs across pathways and roads.

In a number of cases, failed pumps, or modified water tables emerge next to or over infrastructure, created more or less permanent wetland features – havens for mosquitoes in summer and ice hazards in winter.

Stormwater runoff and erosion

More than five miles of highway around the twin lakes and Flushing Meadows-Corona Park generate, from an inch of runoff, some two hundred thousand cubic feet of water. This runoff has created dozens of erosion gullies around both Willow and Meadow Lakes. The absence of fine-grained materials at the mouths of pipes and along roadway, parking lot and pathway edges indicates that runoff rates of a foot per second or greater has scoured away any clay, silts, and fine grained sands. This high velocity water carries fine sediments and nutrients into the lakes, at once disturbing the landscape and polluting the water with nitrate from acid precipitation, as well as metals, suspended solids, and hydrocarbons from the road surfaces.

Runoff discharge causes erosion gullies and creates mosquito breeding habitat.



The size of the watershed surrounding the twin lakes is a minimum of 1,200 acres, and probably closer to double that figure. Additional geographic analysis will be necessary to determine the precise boundaries.

Fragmented watershed: the diversion of stormwater

Less water flows through Flushing Meadows today than in the past. Ground water inputs have been compromised by the removal of vegetation and soil, and compaction. A major fraction of the four to six square mile watershed of the twin lakes has been built over, paved, and channeled into stormwater pipes. The immediate area of the park is between 200 and 300 acres, diminished from more than 2,000 acres of the historic watershed. While groundwater recharge from those upland areas is probably lower than the period preceding disturbance, it is still substantial because of the cemetery and other green space on the slopes around the lakes, which is not diverted by storm drains and related stormwater infrastructure.

According to the 1990 Department of Parks & Recreation study, approximately 70 million cubic meters of groundwater flows into the twin lakes each year, or over 100 million cubic feet per annum. While we do not, at present, have precise determinations of watershed scale, were it four square miles, this would mean that, on average, each square foot of landscape is capturing between one and two cubic feet of water. This is higher than expected, even with very efficient infiltration, so it is likely that the effective watershed is substantially larger, probably closer to six or even eight square miles. If the majority of runoff from this large watershed was redirected to creeks and wetlands around the restored edges of twin lakes, water quality of the lakes and Flushing Bay could be improved.

Low flushing rate

Since inputs must equal outputs, one approach to characterize water flow is to measure how much water flows out of the lakes, and then to use this quantity to infer what must enter the lakes from the watershed. In the NYCDPR Lake Restoration and Management Plan, the output at the tide gates has been reported to be 130 million cubic feet of water per year[2]. If the watershed is six square miles, the annual infiltration rate would have to be about two thirds of a cubic foot of water (0.65) for each square foot of land surface each year. This relationship is shown in the table below, which gives the water holding capacities of each lake:

	Willow Lake	Meadow Lake	Total
Mean Depth (feet)	4.3	4.9	
Area (acres)	46.9	93.4	140.4
Volume (cubic feet)	8,722,515	20,022,940	28,745,455.2
Groundwater input flow (cu. ft./year)	37,786,467	70,982,054	108,768,521
Groundwater+ surface input flow (cu. ft./year)	45,000,000	85,000,000	
Flush rate groundwater only (yrs.)	0.23	0.28	
Flush rate groundwater + surface (yrs.)	0.19	0.15	

As can be seen in the table, the holding time, or hydraulic residence, time is equal to the volume (8.7 million cubic feet) divided by the flow rate (45 million cubic feet per year), yielding a residence time of .19 years in Willow Lake. One way to think of this is that if no water were to enter the lake from its surroundings, Willow Lake would empty in 70 days. For Meadow Lake, the timeframe is approximately 55 days. In both cases, the relatively long residence time provides ample opportunity for phosphorus to enter the water column from sediment. The only way to increase flushing rates is to increase water inputs by redirecting stormwater within the watershed to enhanced wetland features, plant communities, and soil buffers around Flushing Meadows.

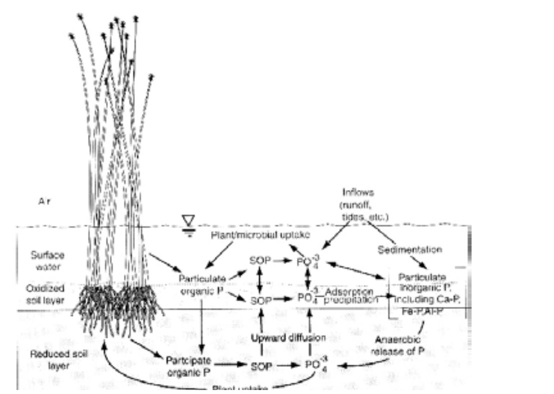
Pollutants and eutrophication

Two primary pollutants in the twin lakes cause "eutrophication" – the superabundant nutrient levels which lead to uncontrolled algal production followed by massive dieoffs from the subsequent depletion of oxygen:

1. **Phosphorus**, captured through thousands of years of sediment deposition in the former tidal marsh, is released under anoxic conditions (where oxygen is not present). Overproduction of algae removes oxygen from the lake bottom, establishing the anoxic conditions which make phosphate soluble, which in turn cause an increase in phosphorus release leading to more algal production.

2. **Nitrogen,** in the form of NO_3 and related compounds, is constantly emitted from internal combustion engines. It falls as particulates and in rain and snow on the land and flows into streams, ponds, lakes and rivers. It also leaches into the groundwater from highly fertilized residential lawns and cemeteries. Nitrate, NO_3, is a nutrient that, in superabundance, becomes a serious pollutant that causes water bodies to become "pea green" and overgrown with weedy species of algae.

   At a critical stage, phosphorus and nitrogen together produce extraordinary numbers of algal cells. This contributes to their own demise, since at night, when they cannot produce it, their own requirement for oxygen is not met by their surroundings. The death of algal cells from these and other causes leads to a burst of growth of the bacteria that use them as food, further depleting oxygen in the lake, and, periodically, leading to large fish kills, which may be directly caused by high concentrations of the fish toxin ammonia.



The phosphorous cycle (above) produces superabundance of algae when concentrations are high, leading to the production of ammonia, which kills fish in large numbers. The nitrogen cycle (below) contributes to the problem as well.

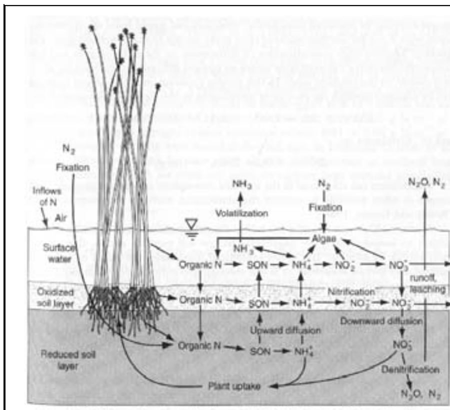
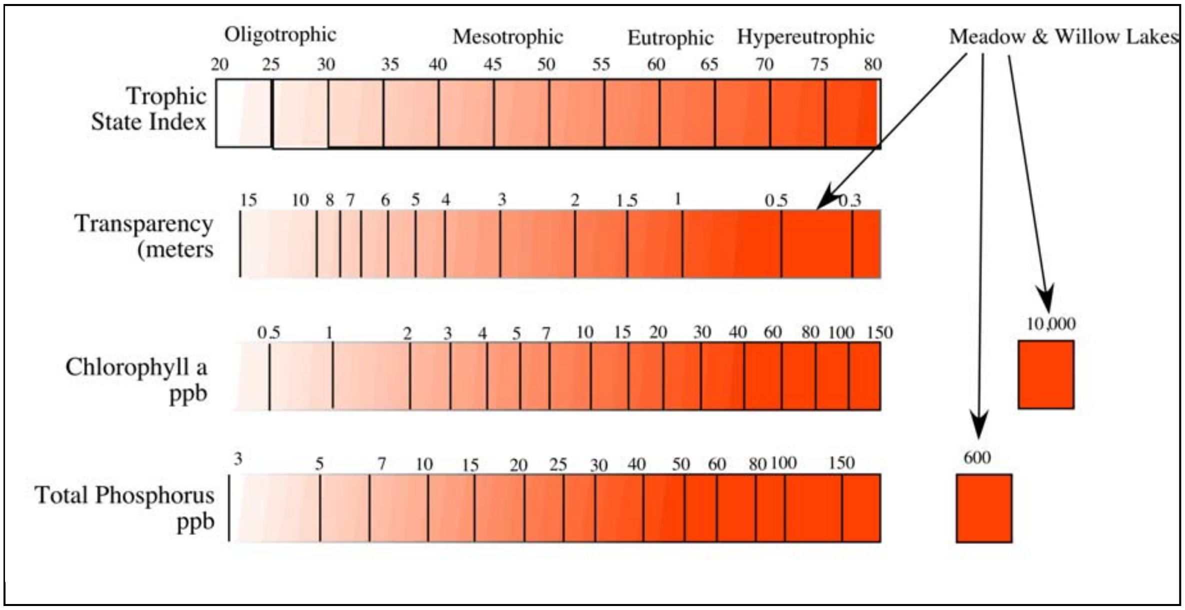


Figure 6-11 Nitrogen transformations in wetlands. SON indicates soluble organic nitrogen.

Simplified wetland nitrogen cycle. From Wetlands, by W.C. Mitsch & J.G. Gosselink, 3rd ed. p 171.

This cycle of phosphorus and nitrogen addition results in increased algal growth, decreased oxygen levels, algal death, fish kills, and further decreases in oxygen, which appears to be at work in both Willow and Meadow Lakes.



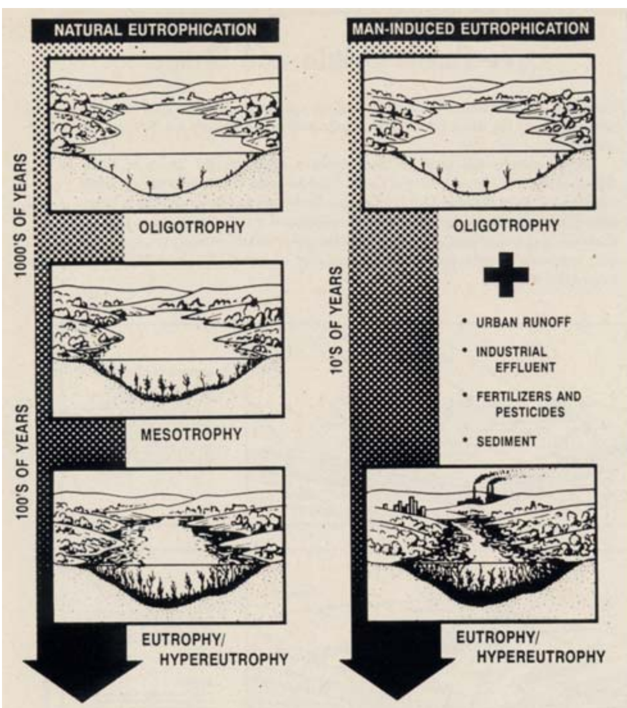


Figure 2-12.— *(left column)* The progression of natural lake aging or eutrophication through nutrient-poor (oligotrophy) to nutrient-rich (eutrophy) sites. Hypereutrophy represents extreme productivity characterized by algal blooms or dense macrophyte populations (or both) plus a high level of sedimentation. The diagram depicts the natural process of gradual nutrient enrichment and basin filling over a long period of time (e.g., thousands of years).

(right column) Man-induced or cultural eutrophication in which lake aging is greatly accelerated (e.g., tens of years) by increased inputs of nutrients and sediments into a lake, as a result of watershed disturbance by humans.

The Trophic State Index (top) is a measure of the "health" of lakes. As can be seen, measures of Meadow and Willow Lakes, reported in the Lawler, Matusky & Skelly Report, indicate values far into the hypereutrophic, or polluted, zone (from Carlson's Trophic State Index, modified from the Lake and Reservoir Restoration Guidance Manual, 1990). This manifests itself as the "pea soup" often seen in Meadow Lake (above).

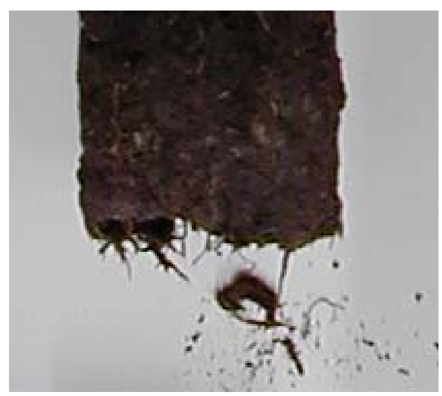
The EPA Manual (left) illustrates how human intervention speeds up the natural eutrophication process.

High nutrient sediments

Landfill and lake building on the original marsh area changed patterns of sediment deposition. By eliminating marsh habitat and tidal flows, the creation of the twin lakes at Flushing Meadows reversed physical and biogeochemical processes, removing oxygen and releasing nutrients instead of storing them.

When marshes are growing and developing, capturing sediments and adding biomass each year over the area of their distribution, nutrients are captured and stored. In plant biomass and in the oxidized area around the roots of marsh plants, phosphorus is taken up as a plant nutrient, and captured in oxidized iron, aluminum, or peat layers. With each large storm that causes upslope erosion, with each spring thaw, sediments are captured and phosphorus is stored by marsh plants. With each year of growth and autumn dieback, layers of peat, mats of intertwined plant roots and biomass at various stages of breakdown, intermingle with these sediments, creating an increasingly thick layer of rich sedimentary material. The presence of mussels and oysters can add to this storage capacity, by filtering up to millions of gallons of water per acre each day, and depositing their nutrient-rich wastes in the accumulating mass of peat and sediment.

Cutting off sediment sources by encasing creeks, diverting stormwater through pipes, and removing most of the tidal input with the tide gate used to create the lakes, has dramatically decreased sediment input rates. This has left nutrient-rich sediments exposed at the bottom of the lakes. Without the former exposure at low tide, and without the marsh grasses to move oxygen into these sediments, they have become anaerobic, as bacteria use up available oxygen. When oxygen disappears, phosphate is released into the water, providing nutrients for algae that create thick, green "blooms." This source of nutrients, where cores have been taken of the lake bottom, appears to be about two meters thick.



Cores taken in Willow Lake by the Gaia Institute indicate the presence of partly degraded plant material and fibers, which can be seen in the photos above and at left. The fibers, broken down plant parts and sediments comprise a deep peat layer, which may be as deep as two meters.

As long as these sediments remain, it is likely that the twin lakes will remain eutrophic, providing an abundant supply of the phosphorous that supports algae growth. When the algae become superabundant, as they appear to do each year, they die and provide biomass that is utilized by bacteria, depleting oxygen and releasing ammonia that is toxic to fish. This process is the probable cause of the yearly fish kills at Willow and Meadow Lakes. It is likely to continue as long as the sediments contribute nutrients to the water column.

Uniform lake edges and shoreline

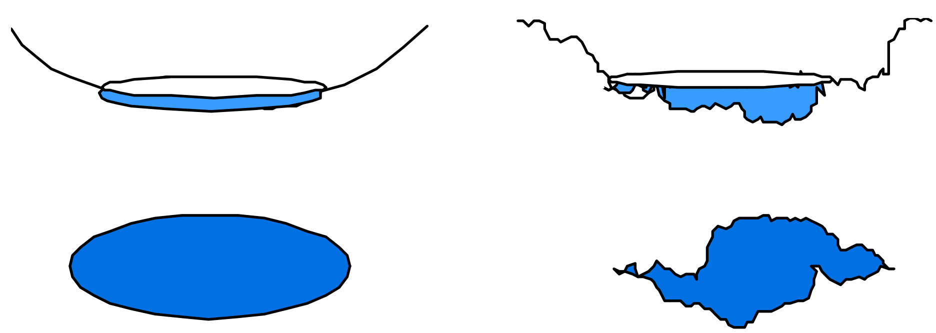
Habitat is enriched where different kinds of structures intersect. For example, increased biodiversity and/or ecological productivity may be expected where the landscape rises or falls sharply, where creeks or streams enter or leave larger bodies of water, or where bedrock or sediment types change abruptly, providing different chemical, physical, and mass and energy flow conditions.

Lake edges around Willow and Meadow Lakes are generally uniform in section. The bowl-like contour of the immediate watershed of the park and lake bottom shows relatively little change in relief – the topography of the basin is smooth and flat. In plan view, an analogous problem exists – the lake edge is comprised of smooth curves, with few peninsulas or promontories.

These two concepts are illustrated below: The left side shows relative uniformity in section and in plan, while the right side indicates more “fractalized” shapes, with changes in elevation, depth, and variegated edges.

Typical profile of twin lakes — *Cross-section*

Typical profile of natural lakes — *Cross-section*



Plan — *Plan*

The top graphic shows the watershed geometry features and lake in section, while the bottom graphic indicates the plan view of lake shoreline, with greatly increased habitat diversity on the right side of the graphic.

Habitat for invasive weeds and "weedy animals"

Uniform habitats, such as farm fields, lawns, and the straight edges of infrastructure often provide opportunities for one or a few organisms to dominate. Existing conditions around Willow Lake fit this description, since the lake edge is largely filled with the common reed *Phragmites*, to the exclusion of most other plants.

In a similar manner, the smooth banks, grassy landscape, and lack of shrub cover or dense edge vegetation makes for easy "goose walks," or an ideal habitat that attracts these animals to congregate at the water's edge. Their presence creates a nuisance in terms of droppings on lawns and walkways, added eutrophication from nitrogen and phosphorus, and increased fecal coliform bacterial counts in the lakes.

The reach of lawn-turf grass cover down to the water's edge provides an entry and invitation to geese. Tens to hundreds of these can distribute droppings over an extensive landscape – adding yet more nutrients to an already overloaded system.

Low quality soils: ash fill

While a few large willows and sweet gums populate the edges of the twin lakes, trees and shrubs are in a minority in terms of coverage compared to grasses and herbaceous plants in Flushing Meadows. This is partly caused by the fact that trees were not planted widely in the original landscaping for the Worlds Fair. It also reflects the likelihood that there was no substantial native seed source on-site or in the imported soils and landfill used to cover the historic marsh.

Grassy edges are readily eroded (above right). One scenario is that Nor'easters drive waves across the lake, which then undermine the shallow-rooted turf. Another is that sheet flow from lawns and walkways scour the edges while raindrops erode bare soil.

A rip-rapped or rock-lined shoreline (at right) protects against wave-driven erosion and provides some aquatic habitat, but is unproductive ecologically.

The low quality of the landfill materials is also indicated by the relative sparseness of the vegetation in many places, especially on the ash fill at the south end of Willow Lake. Vegetation is also spare in terms of species composition, with much of the edge of Willow Lake filled with a monoculture of the common reed *Phragmites*, and other areas of fill dominated by ragweed. Beyond the human health impacts of hay fever and asthma, ragweed dominance is indicative of a lack of competition from other plants and nutrient-poor soil.

The configuration of the lake edges and the low quality of the fill around the twin lakes is the cause of three ecologically detrimental effects:

1. **The low water holding capacity of the landfill material** has led to a poorly developed soil horizon, which means many kinds of plants cannot survive in these areas. By contrast, organic soil, which develops because of plant growth, captures and holds water.

2. **The lack of organics in the soil together with compaction** has led to low biodiversity and poorly developed root systems of plants. The resulting lack of soil structure has led to erosion, especially on the western sides of Willow and Meadow Lakes.

3. **The near-complete dominance of common reed** has led to the elimination of any opportunity for growth and development of diverse plant communities. This is especially true for Willow Lake, where nutrients from sediments and runoff are relatively high and water is abundant in low areas around the edges.

The lack of native plant communities leads inevitably to an additional problem – a lack of native seed sources. At the same time, the open, sparsely vegetated areas facilitate the dominance of the wind blown seeds of the non-native, invasive ragweed.

Open environments and edges have been readily invaded by porcelain berry, multiflora rose and hops, as well as the aggressive native grass, *Phragmites*, the common reed. While the southern edge of Willow Lake looks green, the invasive vine porcelain berry is at work killing the half-century-old trees on the site between Willow and Meadow Lakes, adjacent to Jewel Avenue.

While it appears green, the invasive vine porcelain berry is in the process of covering and killing the trees pictured above, adjacent to Willow Lake.

Low biodiversity

The numbers of different plant, animal and fish species present in and around the twin lakes today are significantly lower than healthy environments of comparable size. The bad news for Flushing Meadows comes in two forms:

- Ecosystem services, the capacities of natural systems to clean air and water, are not well distributed around Flushing Meadows to protect environmental quality and human health.
- Biodiversity is not a prevailing feature of Flushing Meadows.

The number of species in an area are, in general, maintained by immigration and extinction[4]. Populations of a species in a given area may disappear, but if "immigrants" in the form of individuals, seeds, or spores move in from neighboring areas, populations are restored and biodiversity maintained. The ring of roadways prevents this process from occurring naturally. Furthermore, the structure of the lake edges and bottom makes it difficult if not impossible for many species to take hold.

Fish biomass in the Twin Lakes is probably dominated by the non-native carp or goldfish, pictured above. Clean water plus the presence of predators such as the large mouth bass and eastern chain pickerel could help regulate carp populations, and increase biodiversity and overall productivity of the lakes.

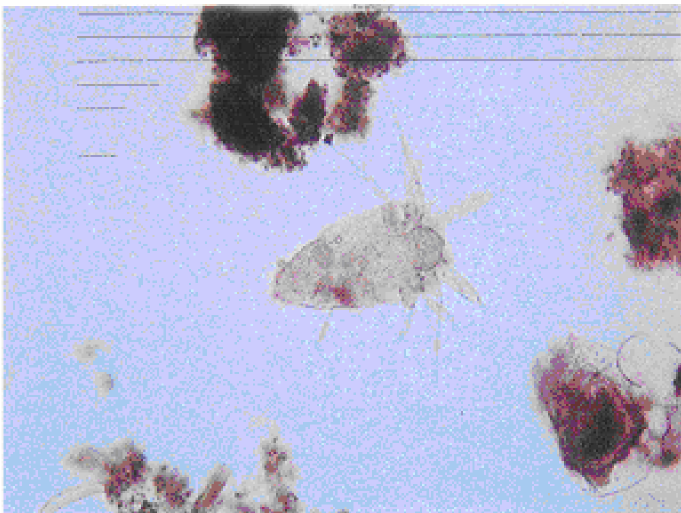
Fish: Surveys by the NYC Department of Parks show that only six different species of fish survive in the lakes today. These include pumpkinseed and bluegill sunfish, carp, white perch, Atlantic silverside, and banded killifish[5]. Comparatively sized water bodies in this area can have more than twice this number.

Plants: Similarly, only about 37 species of different plants have been identified in an area that should support anywhere from 300 to 400. For example, the eastern expanse of open space adjacent to Willow Lake is quite beautiful, but totally lacking in diversity. Grasses are sparsely colonized with sapling trees ten to twenty years of age. A few groups of non-native willows occur along the lake edges.

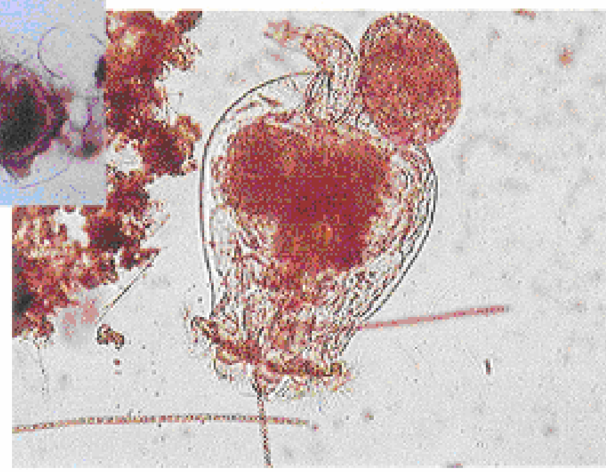
The bridge to the nature trails around Willow Lake have been closed by a chain link fence, providing no open view of the reaches of Flushing Meadows. The overgrown ball fields (visible in the 1969 aerial photograph, which can be seen on page 16) support few plant species. The extensive *Phragmites* community can be seen in the distance.

Birds: While bird census activity has been more intense at Jamaica Bay, Pelham Bay Park, and Central Park in New York City, in the list covering the years preceding February 1984, parks naturalists counted 160 species in the area, with 21 of these nesting or assumed to be nesting. In the period ending in April 1984, 318 species of bird were sighted at Jamaica Bay, with approximately 67 of these nesting in the area.[6] Thus about twice as many birds were seen in and around Jamaica Bay, with about three times as many nesting in the more diverse habitat of Gateway National Recreation Area, which includes trees, shrubs and meadow, in addition to *Phragmites.*

A Plankton Sample of Willow Lake

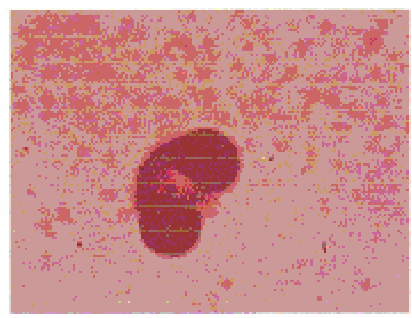


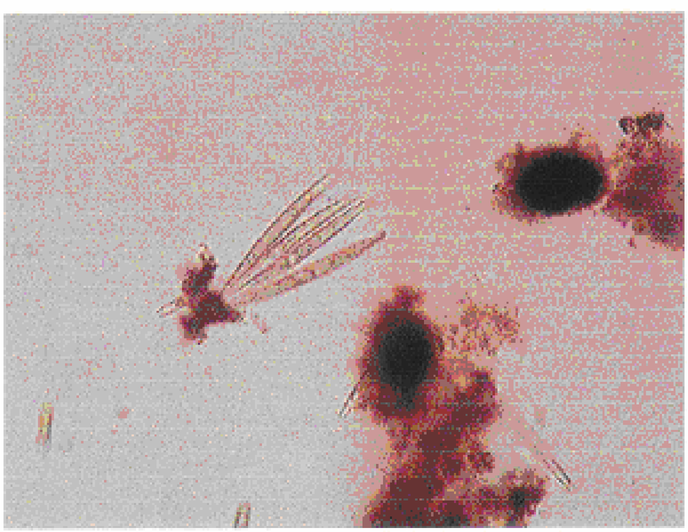
The rotifer pictured below feeds on bacteria and other single celled organisms. The presence and abundance of specific rotifer types can be used to characterize water quality.



The copepod pictured above is a member of the zooplankton, small animals that live in the water column, feeding on yet smaller organisms, and food for larger invertebrates and small fish. Abundance, distribution, and diversity of copepods depends on the kinds of habitat present, available food sources, and predation by dominant predators.

Creating different habitat types while conserving those already present in the lakes should increase the biodiversity of plankton as well as larger plants and animals.





Diatoms, pictured at left, are one of the most important algal groups in the primary productivity of the biosphere. The glassy, silica shells of these organisms can be seen in sediments from hundreds of millions of years ago. These shells or tests may be useful in characterizing changes in Meadow and Willow Lakes, and the history of the sediments beneath them. The pollen grain pictured above can also provide an indication of the ecological history of Flushing Meadow.

[1] Kadlek, R.H., & R.L. Knight:. 1996. Treatment Wetlands, CRC Press, Lewis Publishers, Boca Raton, FL.
[2] Flushing Meadows-Corona Park Lake Restoration and Management Plan. Prepared for NYC Department of Parks & Recreation, Olmstead Center, Flushing Meadows-Corona Park, Flushing, NY 11368. Prepared by Abel, Bainnson & Butz & Coastal Environmental Services, Inc. April 1990 Flushing Meadows-Corona Park Lake Restoration and Management Plan, cited above.
[4] MacArthur, R.H. & E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press
[5] Flushing Meadows-Corona Park Lake Restoration and Management Plan, cited above. Figure 6.7.
[6] These figures were taken from the Pamphlet from Gateway: “Birds of the Jamaica Bay Wildlife Refuge,” Compiled by Thomas H. Davis, U.S. Department of the Interior. National Park Service. Gateway National Recreation Area.