ROADWAY DRAINAGE & MAINTENANCE

Street flooding has significant impacts on the city's transportation infrastructure. Road flooding slows traffic and increases the risk of accidents. Standing water on streets erodes road surfaces and exacerbates pothole formation. In the winter, water from flooded streets can freeze and form hazardous driving conditions. Especially at intersections, street flooding makes crossing streets and walking difficult for pedestrians and bicyclists. As residents of New York City have learned in recent years, even a short high intensity storm event can overwhelm the city infrastructure's capacity to handle the resulting flooding – causing widespread road and rail service interruptions.

One can point to unusual weather patterns for New York City's difficulty in accommodating high stormwater volumes, but ultimately much of New York's recent experiences with flooding are the result of the increased paving of the urban landscape which is now incapable of absorbing rainwater. Recent parking lot regulations developed by the DEP and DCP address flooding issues caused by parking lots, but cannot fully deal with problems caused by road design. This report highlights three water management technologies that have reduced roadway flooding and related traffic and transit delays in American cities and can help improve the quality of run-off flowing into New York's rivers and harbor.

Due to the nature of this material, examples of and opportunities for these technologies are presented together at the end of this section.

- Combined Roadway Drainage Systems
  - » Case Study 6: Portland's Green Streets Program
  - » Case Study 7: Seattle Natural Drainage Systems
- Pervious Paving Materials
  - » Case Study 8: Pervious Pavers & Porous Asphalt/Concrete
  - » Case Study 9: Reinforced Grass
- CatchTraps and Storm Drain Filters
  - » Case Study 10: DrainPac

The April and August 2007 rain storms flooded subway stations throughout the city, shutting down train service and creating dangerous conditions for passengers still in the system.
Credit: 2006 Chris J

COMBINED ROADWAY DRAINAGE SYSTEMS

Most roadway drainage strategies, when implemented in isolation, are ineffective. Rather, the most successful water management and roadway drainage strategies are a combination of design solutions that reduce the volume and slow down the rate at which rain water runs off roads and other paved surfaces, reducing the possibility that drains and sewers will flood. This report covers two cities, Portland, OR and Seattle, WA, that have effectively combined a variety of stormwater runoff management practices with highly successful results.

- Portland, Oregon's Green Streets Program
- Seattle, Washington's Natural Drainage Systems (Street-Edge Alternatives SEA-Streets, Green Grids and Cascades Programs)

Originally conceived of as ways to improve water quality, the drainage programs developed in Portland and Seattle have significantly reduced the amount of water run-off after rain storms and lowered the likelihood of street flooding. Both programs report run-off reductions of over 70% after major storms and have been widely praised both locally and in national planning literature.[1] Successful tests of these programs have been implemented in both medium and low density residential and commercial districts.

Background:

Historically, transportation planners and city or municipal governments have attempted to reduce street flooding by channeling rain water run-off into fixed capacity drains and pipes.[2] These methods pose problems, because as the amount of paved (non-porous) surface in a given area increases, the amount of water the pipes must handle also increases, resulting in overwhelmed pipes and subsequent flooding.

1 Vogel, Mary, "Moving Toward High-Performance Infrastructure;" Urban Land, October 2006, pp.75-9

2 City of Portland Bureau of Environmental Services, "Integrating Stormwater into the Built Environment," (http://www.portlandonline.com/shared/cfm/image.cfm?id=5355800; Accessed 11/26/2007

In many neighborhoods throughout New York City, rain storms frequently overwhelm existing sewers and drain pipes causing street flooding and ponding that makes streets dangerous and difficult for pedestrians and cars alike. Image source: NYC Dept. City Planning

Raised continuous curbs which separate paved areas from grass or tree pits often make matters worse by blocking water from reaching areas where it could infiltrate down. In addition, continuous curbs force rain water into channels which creates high velocity torrents of water that can damage infrastructure. Fixed capacity drains and pipes, when faced with high volumes of water carrying sediment and debris, can clog easily, further increasing the chance of flooding.

In contrast, water management practices such as those pioneered in Portland and Seattle attempt to decrease street flooding by increasing opportunities for the water to infiltrate into the ground rather than (or before) channeling it to the fixed capacity drains and pipes. Infiltration trenches, filter strips, vegetated swales and planter beds all work by retaining water; holding it either until it infiltrates naturally into the ground or by slowing down the water, releasing it to existing drains and sewer pipes at a slower, more manageable rate. For the most part, because they do not involve extensive pipe installation, such systems are easier to install as "retrofits" than traditional pipes and drains.

In general, environmental engineering on the street surface is always cheaper than drainage structures below ground.[3]

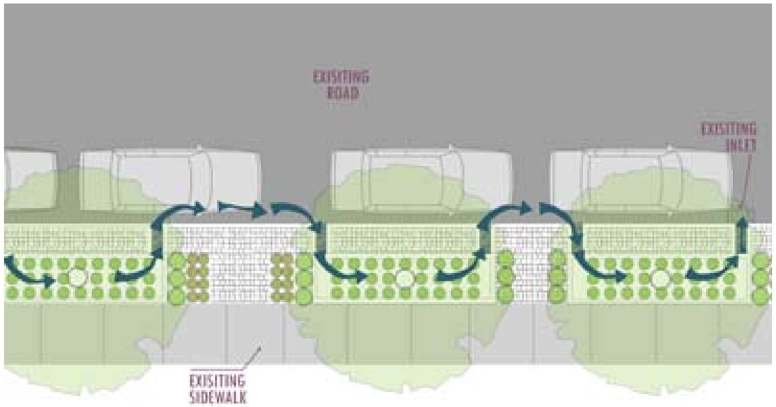
In New York City, modern water management practices are already gaining ground. Recent amendments to the New York City Zoning Resolution have been developed by the Department of City Planning in conjunction with the Department of Environmental Protection, the Department of Transportation and other city agencies, to increase the amount of pervious surface in the city and reduce water run-off. These include allowing pervious paving materials for commercial parking lots, a street tree and planting strip amendment and a planting requirement for front yards.[4] In addition, agencies like the NYC Department of Parks and Recreation already use highly durable pervious pavers on pedestrian walkways in New York City parks to reduce flooding. The New York City Council recently passed resolution Int. 0630-2007, requiring the city to produce a sustainable stromwater managment plan.[5]

3 Sustainable Drainage Website, "Benefits;"(http://www.sustainabledrainage.co.uk/benefits.html); Accessed 11/26/2007

4 New York City Department of City Planning Website, "Citywide Projects, Studies and Proposals," (http://www.nyc.gov/html/dcp/html/subcats/citywide.shtml); Accessed 2/6/08

5 New York City Council Website, "Legislation," (http://www.nyccouncil.info/html/legislation/legislation_details.cfm?ID=Int%200630-2007&TYPE=all&YEAR=2006&SPONSORS=YES&REPORTS=YES&HISTORY=YES); Accessed 2/6/08

Case Study 6: The Green Streets Program (Portland, OR)



Portland's Green Streets divert rain run-off into a series of linked porous planters before directing it to existing storm drains. Greens Streets can be introduced in highly-urban settings without requiring extensive sewer pipe excavation or construction. Image used with permission of City of Portland Bureau of Environmental Services.

Portland's Green Street pilot on SW 12th Avenue in downtown Portland demonstrates the applicability of modern water management programs to developed urban areas. Designed and maintained by the Portland Department of Transportation, the Portland Water Bureau and the Bureau of Environmental Services, the Green Streets Program has reduced on-street water run-off by up to 85% after major 25-year storm events.[6] The Green Street pilot absorbs the rain run-off from 8,000 square feet of paved roadway and sidewalk. It can handle 180,000 gallons of water in any single rain storm before directing water to the existing storm drain.[7]

Portland's Green Streets are retrofits of existing city blocks. The Green Street design diverts stormwater into a series of street

6 City of Portland Bureau of Environmental Services, "2006 Stormwater Management Facility Monitoring Report," City of Portland Bureau of Environmental Services, September 2006, p.6

7 City of Portland Bureau of Environmental Services, "SW 12th Avenue Green Street Fact Sheet," (http://www.portlandonline.com/bes/index.cfm?c=efdig&a=bcdhhg); Accessed 11/26/2007

level planters through small openings in the curb. If the storm produces more rain run-off than the first planter can hold, the excess water flows out of a curb cut on the downhill side of the planter, back into the street, and then is re-channeled into a second planter. Run-off that exceeds the capacity of the first and second planters flows into the third and so on. Only run-off from storms that produce more rain than can be handled by all four planters enters the traditional storm sewer.

Each planter (3 feet by 18 feet at the biggest) is designed to hold up to 6 inches of water and is lined with porous materials that allow the water to infiltrate into the ground at a rate of up to 4 inches per hour.[8] In addition, the planters are planted with native plants which can filter out sediments, limiting the amount of debris that can reach, and clog, the traditional storm drain. The plants are chosen for their ability to thrive in a variety of conditions, thus ensuring that the planters stay green and attractive.

The Green Street program uses indigenous plants in order to ensure that the planters remain green throughout the year. Image source: NYC Dept. City Planning

Portland's planners faced a number of urban design challenges in the implementation of the Green Streets. The full sidewalk width on SW 12th Avenue is 8' and they struggled to "[find] enough space for pedestrians, on-street parking, street trees, landscaping, street lighting, signage and stormwater planters" within that space.[9] The final design includes a 2'6" wide parking egress lane between the street and the stormwater planters. Water enters the planters through 12" curb cuts. An ADA accessible grate on top of the curb cut allows water to flow into the planter without disrupting the sidewalk surface. Smaller cuts in the planter wall allow water from the sidewalks to flow in as well. A full plan diagram is included in Appendix E.

The SW 12th Avenue Greet Street cost $33,000 including street and sidewalk improvements.[10]

In addition to SW 12th Avenue, the City of Portland has tested different elements of the Green Streets system at a number of other locations around the city. The Green Street project at SE Division Street, designed to manage water run-off from a large grocery store, its parking lot and the surrounding streets, combines 6 foot stormwater planters with bioswales. As with the SW 12th Avenue design, water run-off is collected in the "upstream" planter and channeled into subsequent planters as needed. The full system can remove approximately 1,000,000 gallons of stormwater from roadways and the sewer system annually.[11]

8 City of Portland Bureau of Environmental Services, "SW 12th Avenue Green Street Fact Sheet," (http://www.portlandonline.com/bes/index.cfm?c=efdig&a=bcdhhg); Accessed 11/26/2007

9 City of Portland Bureau of Environmental Services, "SW 12th Avenue Green Street Fact Sheet," (http://www.portlandonline.com/bes/index.cfm?c=efdig&a=bcdhhg); Accessed 11/26/2007

10 City of Portland Bureau of Environmental Services, "Green Streets Tour Map," (http://www.portlandonline.com/shared/cfm/image.cfm?id=96962); Accessed 11/26/2007, p.4

11 City of Portland Bureau of Environmental Services, "Sustainable Stormwater Management: Green Solutions;" (http://www.portlandonline.com/shared/cfm/image.cfm?id=123781); Accessed 11/26/2007

A narrow strip of porous pavers provides room for passengers to exit from their cars. The 12" wide, ADA accessible metal grate in the foreground covers the inlet by which rain run-off enters the planter. Image source: NYC Dept. City Planning

Other Green Streets designs in residential neighborhoods have included permeable pavement and pervious asphalt, especially in driveways, parking lots and parking strips. These paving materials allow water to infiltrate down through the paving and off the road surface. Like the planters and swales, designs that include permeable or pervious materials provide storm run-off with alternatives to existing storm drains, reducing the likelihood of street flooding.

Case Study 7: Natural Drainage Systems (Seattle, WA)

Seattle SEA Streets, built primarily in residential neighborhoods, reduce rain run-off and flooding with bio-swales and improved street design. Image source: NYC Dept. City Planning

Seattle's Street Edge Alternatives program (SEA-Streets) is a more radical approach to roadway drainage; in essence a re-envisioning of a residential block to reduce impervious surfaces and increase water infiltration.[12] Developed by planners from Seattle's Public Utilities (SPU) in conjunction with local community groups, SEA-Streets are partially maintained by homeowners on adjacent properties and by SPU.[13]

The SEA-Street program was first implemented in 2001 on a small two-block test site in northwest Seattle (NW 117th and NW 120th Street on 2nd Avenue), a low-density residential area that lacked sidewalks and drainage infrastructure like sewers and drains.[14] Ongoing monitoring by the city of Seattle and

12 Vogel, Mary, "Moving Toward High-Performance Infrastructure;" Urban Land, October 2006, p.77

13 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007, p.7

14 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007. This neighborhood would be equivalent, in terms of density and infrastructure, to parts of southeastern Queens and southern Staten Island.

researchers from the University of Washington has shown a 98% reduction in water run-off in the first year and a 99% reduction in run-off in the subsequent years.[15]

The SEA-Street design places bioswales, carefully planted ditches that can retain large volumes of water for short periods of time, along both sides of the 60 foot right of way.[16] These bioswales collect rain water run-off and, since they are porous, give it the opportunity to infiltrate down instead of sitting on the impervious road surface. The street bed itself was slightly canted to better direct rain water run-off into the swales. As in Portland, the SEA-Street bioswales were planted with native species specifically chosen for their ability to tolerate standing water and filter out pollutants. Thus, the bioswales also improve the quality of water that leaves the site as surface runoff.

The SEA-Street design also introduced slight curves to the street. These curves enhance the street aesthetics and also serve a drainage function, slowing down the velocity of rain water as it runs down the street and giving it more time to infiltrate into the ground.[17] In total, the SEA-Streets design reduced the amount of paved surface by 11% by narrowing the street to 14 feet in some places while including 18 foot "flares" at the corners.[18] Parking spaces and a sidewalk were also added. The modified street layout, approved by the Seattle Fire Department and Emergency Services, doubles as a traffic calming tool for the neighborhood.[19]

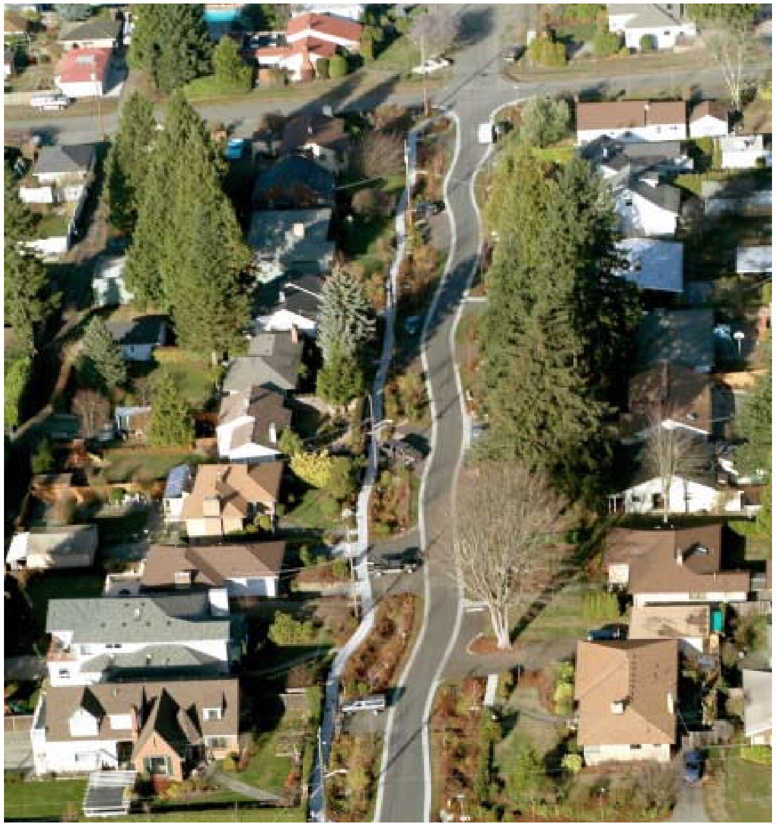
15 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007, p.8

16 ibid., p.6-8

17 Taus, Margaret, "Innovative Design Cuts Street Run-Off," Seattle Post Intelligencer, 20 November 2002 (http://seattlepi.nwsource.com/local/95881_model20.shtml); Accessed 12/11/07

18 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007, p.8

19 ibid. & Email Correspondence with Denise Andrews and Dick Lilly, Seattle Public Utilities, 6/13/2007



The SEA Street pilot (NW 117th and NW 120th Street on 2nd Avenue. The slight curves in the roadway slow the rain run-off as it flows down the street. The SEA Street design also serves as a traffic calming device and added sidewalks to a neighborhood that previously lacked them. Images used with permission of Seattle Public Utilities.

SEA-Streets cost about 25% less to build and maintain than conventional systems ($325,000 per 330 foot block as opposed to $425,000).[20] These costs are lower in part because reducing runoff at the source reduces the need to build additional costly pipes and holding tanks further down the system. Operations costs (ongoing maintenance and replanting) for the SEA-Streets are the responsibility of adjacent home owners. The initial SEA-

20 City of Seattle, Seattle Public Utilities, "Seattle Public Utilities; Natural Drainage System Program," (www.psat.wa.gov/.../II.%20Appendices/F.%20Natural%20Drainage%20System%20Costs.pdf; Accessed 11/26/2007

The bio-swales in Seattle's SEA Streets are planted and maintained by residents. Strong community participation from the outset is cited as an important element of the success of the program. Image used with permission of Seattle Public Utilities.

Street site was selected from a list potential sites, partially on the basis of strong community support and SPU planners cite constant community involvement as a key factor in the success of the SEA-Streets.[21]

Following their success with the initial SEA-Streets, the SPU planners have turned their attention to a variety of related Natural Drainage System projects including: streets with significant slopes (1-8%), known as the Cascade Program, and more densely developed areas, the Green Grids Program and High Point. Tests on the pilot Cascade Program, which employs a series of gated weirs and collected water from a 70 acre site, have shown a reduction of water run-off by between 48% and 74%.[22] Similar to the SEA-Streets, the cost (including survey, design, contract bid documents, construction and operations and maintenance associated with a 3 year plant establishment period) of the Cascade Program was substantially less than that of conventional drainage systems; $285,000/block as opposed to $520,000.[23]

The Broadview "Green Grids" pilot, which uses many of the techniques tested in the original SEA Street, covers an area of 15 city blocks or about 32 acres. It, along with subsequent Green Grids projects such as Pinehurst, has allowed planners to test their water management systems in larger, denser and topographically different areas.[24] The bio-swales in the Green Grid system absorb water run-off at up to 1.5 inches per hour.[25]

21 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007, p.7

22 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007

23 City of Seattle, Seattle Public Utilities, "Seattle Public Utilities; Natural Drainage System Program," (www.psat.wa.gov/.../II.%20Appendices/F.%20Natural%20Drainage%20System%20Costs.pdf0; Accessed 11/26/2007 & Email conversation with Tracy Tackett, Low Impact Development Program Manager, Seattle Public Utilities, 14, January, 2008

24 Seattle Public Utilities Website, "Broadview Green Grid Project;" (http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/Broadview_Green_Grid_Project/index.asp); Accessed 12/11/07

25 City of Seattle, "Seattle's Natural Drainage Systems;" The City of Seattle, Seattle Public Utilities, 2007, p.9

PERVIOUS PAVING MATERIALS

Pervious paving materials are a complementary technology that can—particularly when used in tandem with other modern drainage mechanisms—help to reduce street flooding by allowing water to infiltrate into the ground. Most commonly, pervious materials come either as:

- Pervious Pavers & Porous Asphalt/Concrete
- Reinforced Grass (also known as Plastic Geocells)

Background:

Alternative paving materials may be used in place of impervious materials (traditional concrete or asphalt) in order to reduce surface runoff and flooding. These materials allow water to infiltrate down reducing the amount of water on the surface and limiting the amount of water that would need to be removed via fixed capacity drains and pipes. While cobbles and brick are already somewhat pervious because of the cracks between each piece, many cities are beginning to experiment with new strategies that are sturdier and better mitigate storm sewer costs in the long term. New York City has amended the city's Zoning Resolution to allow the use of pervious materials in commercial parking lot designs.[26]

Parking lots, driveways and sidewalks are the most common places to install pervious paving materials because they contribute substantially to flooding problems but do not face the same intensity of wear and tear as high-volume streets or highways. In addition, these surfaces are relatively small and can be upgraded as part of a low-capital budget project. Alternative paving can also facilitate the biodegradation of oils from cars and allow tree roots to breathe.[27]

Pervious pavers, porous asphalt and concrete and reinforced grass are in widespread use all across North America, Europe and Asia. They complement other modern drainage systems by allowing water to pass through them thus reducing the burden on existing drainage systems.

26 New York City Department of City Planning, "Commercial and Community Facility Parking Lot Amendment," (http://www.nyc.gov/html/dcp/html/parking_lots/index.shtml0; Accessed 11/26/2007

27 Hun-Dorris, Tara, "Advances in Porous Pavement," Stormwater, March/April 2005 (http://www.erosioncontrol.com/sw_0503_advances.html); Accessed 11/26/2007

Case Study 8: Pervious Pavers & Porous Asphalt/Concrete

The Portland Bureau of Environmental Services is experimenting with pervious pavers and porous asphalt in residential neighborhoods. In this image, the pervious pavers serve a dual purpose, clearly marking the parking lane as well as reducing rain run-off and flooding. Image used with permission of City of Portland Bureau of Environmental Services.

The technologies for porous asphalt and concrete have been around for 30 years. However, difficulties in early projects have given them a poor reputation that they no longer warrant. In recent years the technology has modernized and greatly reduced the failure rates seen in the first applications.[28] Porous asphalt is now the paving surface of choice on interstate highways in Georgia and Oregon.[29] Transportation planners and environmental quality agencies in Portland are piloting programs

28 Building Design + Construction Website, "Porous Pavement: Slipping Through the Cracks," (http://www.bdcnetwork.com/article/CA6297622.html0; Accessed 11/26/2006

29 City of Portland Bureau of Environmental Services, "Pervious Pavement Projects: A New Approach to Stormwater Management," (http://www.portlandonline.com/BES/index.cfm?a=77074&c=45435#north); Accessed 11/26/2007

to introduce permeable pavers and porous asphalt on residential streets.[30] The city of Chicago is the in the process of repaving 2,000 miles of service alleys with permeable concrete.[31] These programs are intended to reduce the impervious surface area and decrease street flooding.

Porous asphalt and concrete differ from conventional asphalt and concrete because they are made without fine particulates which clog pores in the materials where water could otherwise pass through. As a result, water does not sit on the surface which leads to better traction and visibility for automobiles. Typically, 15% to 25% voids are achieved in the hardened concrete, and flow rates average around 48 in/hr.[32] Both porous asphalt and concrete require maintenance and need to be vacuumed or pressure-washed to ensure that the pores in the material do not get clogged. However, good design can reduce the frequency of vacuuming or washing required.[33]

Porous asphalt usually costs between $.50 and $1 per square foot, on par with conventional non-porous asphalt.[34] Pervious concrete tends to be more expensive – ranging from $2.00 to $6.50 per square foot of installed pavement where conventional non-pervious concrete ranges from $2.00 to $4.00 per square feet.[35] In Chicago, the permeable concrete used in the "Green Alley" program will cost $45 per cubic meter plus the cost of a stone filtration layer beneath the concrete. Chicago pays roughly $50 per cubic meter for conventional concrete making the two materials roughly the same in price. Janet Attarian, the Green Alley project director also notes that the cost of

30 City of Portland Bureau of Environmental Services, "Pervious Pavement Projects: A New Approach to Stormwater Management," (http://www.portlandonline.com/BES/index.cfm?a=77074&c=45435#north); Accessed 11/26/2007

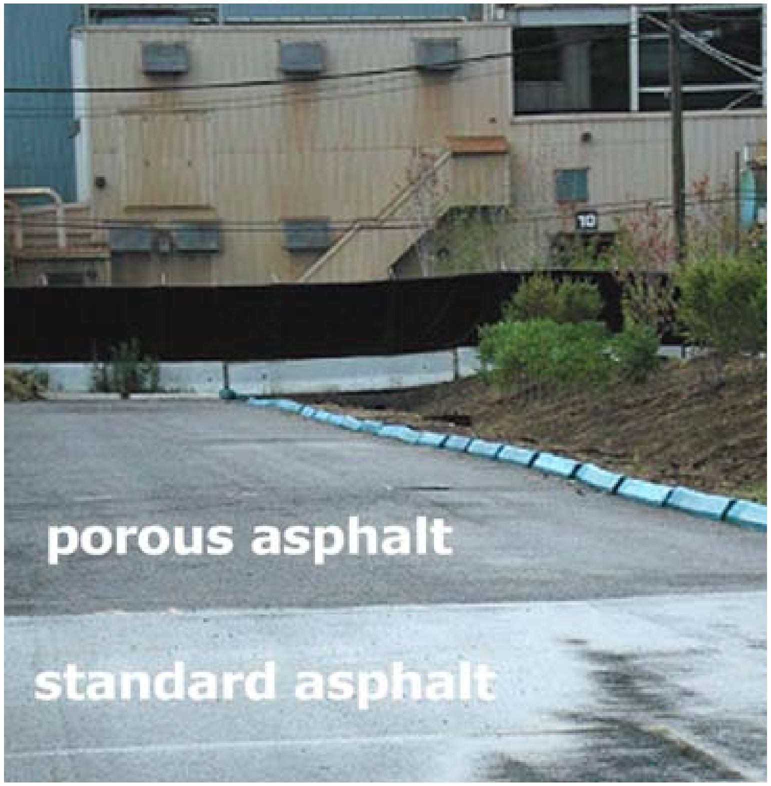
31 Saulny, Susan, "In Miles of Alley, Chicago Finds Its Next Environmental Frontier;" The New York Times, 26 November, 2007

32 Hun-Dorris, Tara, "Advances in Porous Pavement," Stormwater, March/April 2005 (http://www.erosioncontrol.com/sw_0503_advances.html); Accessed 11/26/2007

33 ibid.

34 Low Impact Development Center Inc. Website, (http://www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm); Accessed 12/6/2007

35 PaverSearch Website, "Permeable or Pervious Pavers Cost Comparion;" (http://www.paversearch.com/permeable-pavers-costs.htm); Accessed 11/26/2007



The use of porous asphalt can dramatically reduce the amount of water that remains on the road surface after a storm. This image taken shortly after an intense rainstorm shows essentially dry porous asphalt at the top and water sitting on conventional asphalt at the bottom. Image used with permission of Cahill Associates.

permeable concrete has dropped over $100 per square meter in the past year, as production companies increased production and facility with the material.[36] Chicago also anticipates that the cost of construction of the new alleys will be offset by reduced maintenance and drainage costs associated with conventional non-permeable concrete.[37] Permeable materials can minimize the need for additional stormwater drainage and treatment systems – effectively offsetting the overall cost to a city.[38]

36 Saulny, Susan, "In Miles of Alley, Chicago Finds Its Next Environmental Frontier;" The New York Times, 26 November, 2007

37 ibid.

38 WaterSheds Urban Stormwater Website, North Carolina State University, (http://www.water.ncsu.edu/watershedss/dss/wetland/aqlife/urbstorm.html#sr); Accessed 11/26/2007

Porous asphalt allows water to flow through it, minimizing the amount of water that remains on the surface. Image used with permission of TecEco Pty. Ltd.

Case Study 9: Reinforced Grass (Miami, FL; Houston, TX)

Reinforced grass, in place at Houston's Reliant Stadium and Miami's Orange Bowl, is used to reduce impervious surface cover and decrease parking lot flooding. Reinforced grass is structurally simple. Grass is planted inside short plastic cylinders or hexagons, called geocells. Once installed and allowed to grow in, areas covered with plastic geocells look like grassy fields, however, unlike natural fields, they provide structural support that can accommodate vehicles and prevent erosion. The cells provide protection for the topsoil, allowing cars to park on the grass without worry that their weight will compact it and prevent the grass from growing. During a 24 hour storm that yields 6 inches of rain, geocells developed by Grasspave2, one of the two major manufacturers, can absorb 97-100% of rainfall.[39]

In 1995, geocell-reinforced grass was applied to the Orange Bowl Stadium parking lot in Miami. The grass system was installed in three phases, for a total of 261,132 square feet of turf. 2,000 parking spaces are covered with Grasspave2, while the driving lanes were made of asphalt. The reinforced grass lot is capable of storing and cleaning up to 60,000 cubic feet of stormwater, capabilities that were put to the test in 2002 during massive flooding in the Miami area.[40] The Orange Bowl has not received any reports of cars getting stuck in mud on their reinforced grass parking lots.

In2002, following the Orange Bowl example, HOK Architects installed 317,000 square feet of plastic geocells at Reliant Stadium in Houston. This stadium, built to replace the Astrodome now boasts the largest application of engineered grass porous system to date.[41] The introduction of reinforced grass parking lots has also allowed the Stadium to host new summer events. At the old asphalt paved Astrodome, summer events were all but impossible due to the huge amount of heat absorbed and delivered by the blacktop. The new reinforced grass parking lots in contrast stay cool throughout the summer and the Stadium now hosts a range of summer events, festivals and the National Rodeo that would have been impossible before.[42]

The cost of grass reinforced with geocells can range from $1.50 to $5.75 per square foot of installed pavement.[43] They provide larger savings however, because in addition to mitigating flooding they also reduce the need to build other onsite stormwater treatment or storage facilities.

39 Invisible Structures Inc. Website, "GrassPave2," (http://invisiblestructures.com/GP2/grasspave.htm); Accessed 11/26/2007. The absorptive qualities of Grasspave2 vary by soil type.

40 Hun-Dorris, Tara, "Advances in Porous Pavement," Stormwater, March/April 2005 (http://www.erosioncontrol.com/sw_0503_advances.html); Accessed 11/26/2007

41 Invisible Structures, Inc. Website, Glist, Dustin, "The Double Life of Porous Pavesr—Curb Appeal with Function;" (http://www.landscapeonline.com/research/article/6558); Accessed 11/26/2007

42 Hun-Dorris, Tara, "Advances in Porous Pavement," Stormwater, March/April 2005 (http://www.erosioncontrol.com/sw_0503_advances.html); Accessed 11/26/2007

43 PaverSearch Website, "Permeable or Pervious Pavers Cost Comparion;" (http://www.paversearch.com/permeable-pavers-costs.htm); Accessed 11/26/2007

Reinforced grass pavers, shown here at the Reliant Stadium in Houston, TX, rely on a hidden structure of plastic cells in which grass is planted. The plastic cells keep the grass from being compacted, even when cars are parked on top. Image used with permission of Invisible Structures, Inc.

Orange Bowl - Reinforced Grass pavers, shown here at the Orange Bowl Stadium parking lot in Miami, FL, has dramatically increased the quality of the parking lot while also reducing the amount of water that storm drains and sewers must handle after rainstorms. Image used with permission of Invisible Structures, Inc.

CATCH BASIN INSERTS / STORM DRAIN FILTERS

In addition to drainage solutions that reshape the streetscape, inexpensive measures, like catch basin inserts and drain filters, can be installed in the interim to remove debris from drains. Such filters make storm drain cleaning easier and can reduce the likelihood that existing storm drains will clog, thus reducing the prevalence of roadway and subway flooding.

Background:

The average street is cluttered with leaves, trash, paper flyers and newspapers, sediment and other small objects. During rain storms, this debris is carried along with the water run off to storm drains. While the debris that remains at street level can typically be handled by routine street cleaning, debris that slips into the drain, below street level, is harder to reach and remove. The resulting clogged storm drains cause street flooding and create hazardous conditions for pedestrians, cyclists and drivers.

Case Study 10: DrainPac (Pacific Northwest, US)

PacTec Inc manufactures the DrainPac storm drain filter that can be placed inside existing curb inlets to capture debris, keeping it separate from the stormwater flow and ensuring effective operation of drains. Essentially hanging metal mesh baskets, the DrainPac filters are attached to the outside of the drain by chains and thus can be easily reached and cleaned. DrainPack filters were originally developed to address compliance issues associated with the Clean Water Act and offer a low-cost solution to localized flooding problems caused by clogged stormwater drains.

Each filter unit can hold up to 150 pounds of material – an adequate capacity for most all urban applications. They are also highly effective, able to collect 97 to 98 percent of the sediment in the water[44] Like all systems, maintenance is required to empty and re-set the filters. However, normal storms do not carry significant amounts of trash and debris to the filter, therefore maintenance is only required following heavy rains. In addition, drain inserts reduce the need for scheduling drain clean-outs by eliminating the amount of solids in drainage systems.[45]

The cost of the filters ranges from $130 to $400 depending on the size and filter design.[46]

PacTech's DrainPac storm drain filter catches debris entering the sewer system before it has a chance to clog the drain. Image used with permission of PacTech.

44 DrainPac Website, "Tahoe News," (http://www.drainpac.com/Tahoenews.htm); Accessed 11/26/2007
45 ibid.
46 DrainPac Website, "North Country News," (http://www.drainpac.com/Northcountynews.htm); Accessed 11/26/2007

EXAMPLES AND OPPORTUNITIES FOR ROADWAY DRAINAGE & MAINTENANCE:

Piloting modern water management practices meets 2030 PlaNYC goals and can help reduce flooding, related transportation congestion on our city's roads and some public health hazards.[47]

In looking to apply modern drainage systems in New York, flooding hot spots should be assessed using DEP, 311 and Community District Needs Assessment data. In particular, systems like Portland's Green streets would be applicable in higher density neighborhoods, while Seattle SEA-Streets would be more appropriate in lower density parts of Queens and Staten Island. Catch-traps and permeable pavement could be applied throughout the city.

47 In addition to transportation concerns, street flooding also poses severe environmental problems as excess storm runoff triggers the city's 460 combined sewer outfalls (CSOs). According to the USEPA and the Design Trust for Public Space, "combined sewer outfalls in New York City flood during half of all rainstorms, discharging approximately 27 billion gallons of wastewater in an average rainfall year." The water that is released into New York's waterways after storm events is contaminated by oil, chemicals, pesticides, and chemical fertilizers from roadways as well as raw sewage from the city's households and businesses (human wastewater) which contains bacteria and viruses. According to Riverkeeper, "on average CSO events occur about once per week (and as often as 70 times per year at some outfalls) and the average weekly polluted discharge is about 500 million gallons Citywide." Polluted waterways can make other city plans, like the construction of greenways and riverside parks, and the introduction of commuter and recreational boating, more difficult and dangerous.