ATLANTA'S RESILIENT GREEN INFRASTRUCTURE WITH PERMEABLE INTERLOCKING CONCRETE PAVEMENT

"Permeable interlocking concrete pavers are a very effective solution for stormwater management, especially in highly urban areas with combined sewers that need capacity relief."

—Todd Hill, PE, Interim Deputy Commissioner,
City of Atlanta Department of Watershed Management

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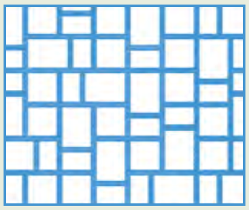
Atlanta Green Infrastructure Initiative: The Largest PICP project in America



4 miles of PICP streets
= **1.5 million** concrete pavers

In July 2012, a series of storms caused combined sanitary and storm sewer overflows in southeast Atlanta, making a flooded mess of streets and homes. The flooding occurred at the nexus of impervious pavement drained mostly by sewers overflowing with runoff and sewage from downtown Atlanta. The downstream recipients were the Peoplestown, Mechanicsville and Summerhill neighborhoods. They received sanitary sewage exacerbated by stormwater runoff from a 1,500-acre (607 ha) highly urbanized, mostly impervious drainage area.

These particular storms were a game-changer for Atlanta. After visiting the flooded neighborhoods, Mayor Kasim Reed committed to finding a long-term solution. Thus began the Southeast Atlanta Green Infrastructure Initiative that created resilient infrastructure by converting the street system to carry and infiltrate drainage rather than generate runoff and send it further downstream. This initiative led to the largest permeable interlocking concrete pavement (PICP) road project in North America with more than four miles (6.4 km).

First Responders

With a mandate from the Mayor's Office to solve flooding problems, the Department of Watershed Management rose to the challenge. "We went out into the field with our contractors to conduct assessments and returned with conceptual sketches to implement these projects quickly," said Todd Hill, Interim Deputy Commissioner, Office of Watershed Protection from the Department of Watershed Management. "We then developed a phased approach."

The bottom line, comprehensive flood abatement solution meant managing about 24 million gallons (106 million liters) of runoff choking combined sewers. Addressed in phases, the first response was a 30-day program to clean all catch basin inlets, raising curbs, installing bioswales and rain gardens on city property. These efforts resulted in 350,000 gallons (1.3 million liters) of sewer capacity relief. "Not a lot, but a start," Mr. Hill said.

Phase two involved constructing a 5.8 million gallon (22 million liter) underground storage vault to hold storm and sanitary sewer outflow. The massive vault saw installation underneath a parking lot at Turner Field during the four months' offseason for the Atlanta Braves baseball team.

This phase included converting several flood-prone streets to PICP. These are shown in Figure 1. In March 2015, construction began on the PICP street replacements that took almost a year and a half to complete. With 2 to 4 ft (0.6 to 1.2 m) thick, open-graded aggregate subbase reservoirs, the streets stored just over four million gallons (15.1 million liters). An unexpected benefit from the PICP was infiltrating about a fourth of this volume into underlying clay soils. This volume disappeared thanks to working with Mother Nature.

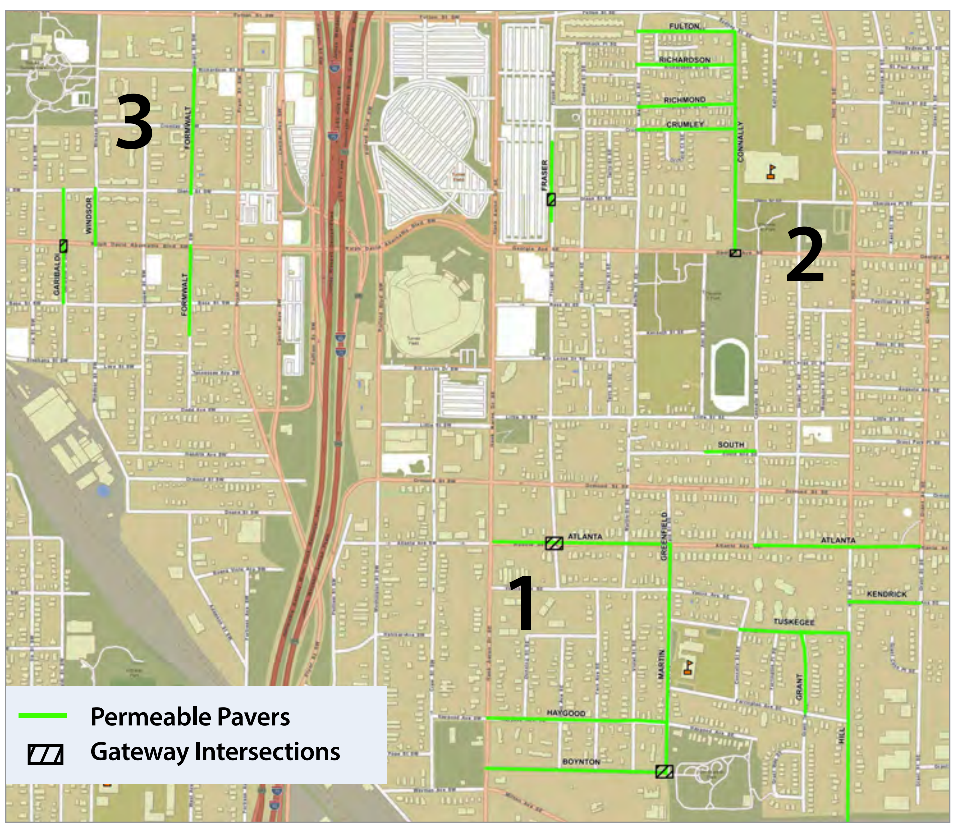


Figure 1. Four miles of PICP streets in southeast Atlanta neighborhoods: 1 = Peoplestown; 2 = Summerhill; 3 = Mechanicsville.

At this writing, phase three is currently underway. It mitigates two million gallons (7.5 million liters) through sewer capacity relief ponds at a community park in Peoplestown. Most of the homes that once stood on this block have been removed.

Resilient Street Design Yields an Economical Return

At the outset of planning their roadway renovations, Mr. Hill and his team asked, "What will get us the biggest bang for our buck?" Considering PICP they agreed, "If we're going to do a paver project, we're going big,'" Mr. Hill said. And that's just what they did. Looking back, the pavers with thick aggregate storage reservoirs were less expensive than the underground water storage vaults.

With a budget of $15.8 million that initially included $1.1 million in allowances for restoring utility lines, the Department of Watershed Management began excavation and installation of PICP on the first of many streets upstream from the flood-prone areas. Volume reduction and sewer capacity relief goals were met with PICPs thanks to thick aggregate reservoirs beneath them. "We selected residential streets that contributed to the flooding of our combined sewer system," said Mr. Hill. Collectively, the four miles (6.4 km) of permeable paver roads provided about four million gallons (15.1 million liters) of capacity relief.

The original plan had six miles (9.6 km) of roadways slated to receive PICP. Once crews started peeling back the old streets, they unearthed some unforeseen complications. On some of the larger stretches, crews uncovered old streetcar lines alongside utility lines encased in two feet of concrete. "The timeline to even remove a few feet at a time was going to be so outrageous that it would blow our schedule, blow the budget, and make it impossible for residents to access their homes, so we had to make a decision to remove that portion," Mr. Hill said.

According to Mr. Hill, their desire was to install as much PICP as possible and not deplete the budget on extra labor costs for removing century-old urban archeology. This pragmatic approach brought the project to completion on time and under budget. But there were still other challenges to overcome during construction.

Unforeseen Infrastructure Renovation

With some street sections nearly 100 years old, the first surprise encountered by construction crews was a layer of old concrete below the asphalt roads that required additional demolition time.

Once the old pavements and bases were removed, a new set of challenges emerged. "We had utilities showing up that shouldn't have been there, and some at depths that weren't shown on any plans," Mr. Hill said (see Figure 2). Brick manholes were especially difficult to work around and many were replaced (see Figure 3). Water mains and old pipes ruptured during excavation and required repair. Of the $1.1 million originally earmarked for utility replacement and repairs, unforeseen infrastructure brought the total closer to $3 million by project completion.

Figure 2. Excavation included removal of abandoned utility lines.

Figure 3. Reconstructing a brick manhole.

While achieving relief to flooded sewers and neighborhoods was the main objective, the decision to use PICP also contributed to increased property values for some communities, and led to new development investments.

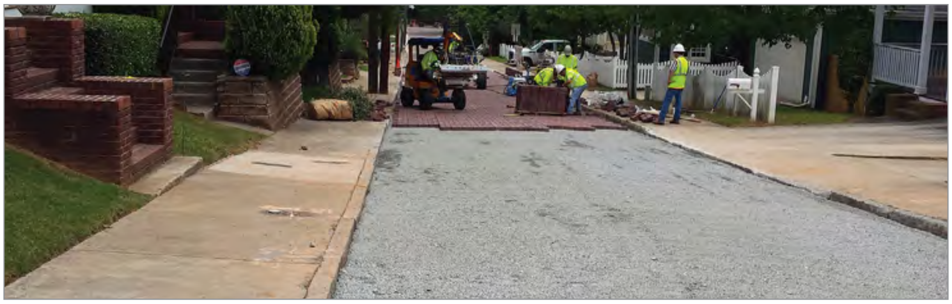


Figure 4. The screeded bedding layer ready to receive the concrete pavers.

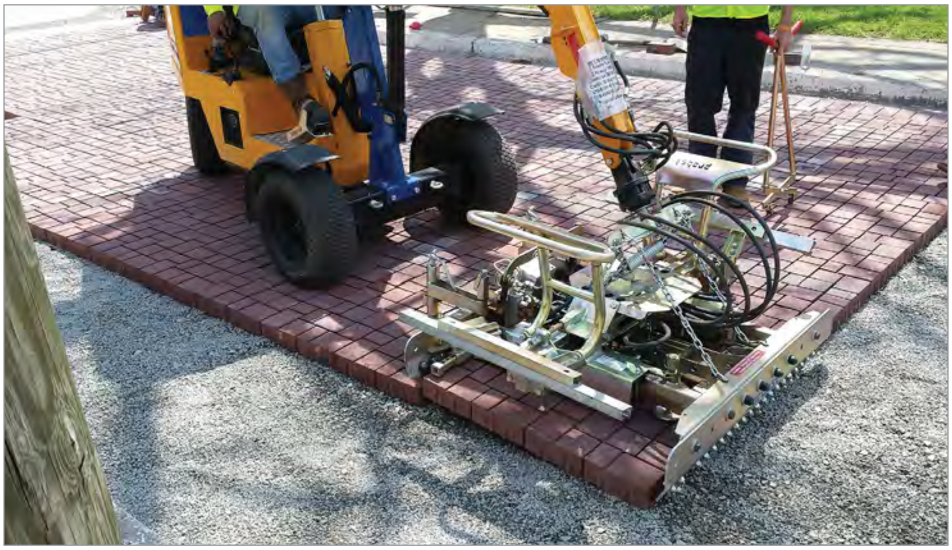


Figure 5. Machine-installed concrete pavers place them in their final laying pattern.

Another construction concern was the close proximity of older homes to some streets. Crews excavated two to four feet (0.6 to 1.2 m) for the aggregate subbase layer and installed impermeable liners against the sidewalks to prevent lateral migration of stormwater toward these homes and their basements. Figure 7 illustrates an example of installed impermeable liners.

The pavers were placed on a screeded, 2 in. (50 mm) thick bedding layer of ASTM No. 89 aggregate. Figure 4 illustrates this bedding layer which rests on a 4 in. (100 mm) thick layer of No. 57 aggregate. This base 'chokes' or prevents the bedding layer from entering the thick ASTM No. 2 aggregate subbase reservoir.

Due to their layout and age, street widths and curbs varied as much as a foot (0.3 m) from one block to the next, adding a substantial amount of cutting time for the concrete edge pavers. Despite this challenge, machine-installed concrete pavers manufactured and placed in their final laying pattern helped maintain an average rate of about 5,000 sf (464 m^2) per day with no time required for concrete to cure. Figure 5 illustrates a machine placing the concrete pavers on a screeded bedding layer. The pavers were compacted, joints filled with ASTM No. 89 aggregate, swept clean and compacted again.

Managing road closures and rerouting traffic, including public transit buses, also posed a significant challenge. "During the construction phase, there was a bit of inconvenience, to put it mildly," said Cameo Garrett, External Communications Manager for the Department of Watershed Management. "It was very important that, as things changed during construction, we continuously provided information and updates to the affected communities."

The original construction time estimates anticipated that residents would lose access to their driveways for only a few days. But with unforeseen utility repairs needed, the average road closures stretched to 1½ weeks. "Coordinated community outreach and engagement was a necessity for a project of this magnitude," said Cory Rayburn, Watershed Manager II for the Department of Watershed Management. "The contractor, along with the City's Communications staff, went out of their way to address the needs of the residents who were directly affected."

Capacity Relief

"Permeable interlocking concrete pavers are a very effective solution for stormwater management, especially in highly urban areas with combined sewers that require capacity relief," Mr. Hill said. "We have been surprised by and pleased with the amount of infiltration into the ground. We were estimating much less." Many of the sloped streets used check dams within their subbases to encourage infiltration. Figures 6 and 7 illustrate how the dams detain water for flow control and infiltration into the soil subgrade. With the check dams and deep aggregate subbases, the streets store runoff from a four-hour, 25-year storm yielding 3.68 in. (3 mm) of rainfall.

While achieving relief to flooded sewers and neighborhoods was the main objective accomplished by this project, the decision to use PICP also contributed to increased property values for some communities, and led to new development investments. "Based on feedback we have received from members of the community, the houses on the PICP streets are more sought after than on other streets in these neighborhoods," Mr. Hill said. "The residents who live in those areas really love the pavers and think they're very beautiful," Ms. Garrett said. Figure 8 demonstrates increased neighborhood character from the PICP street.

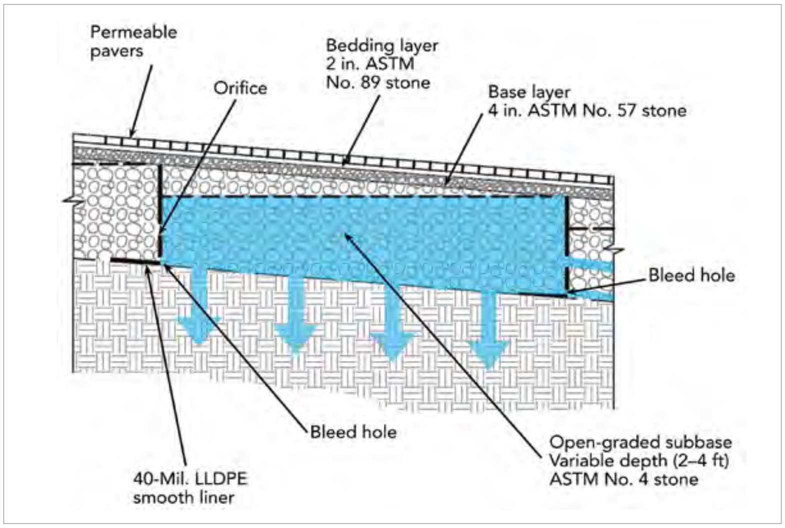


Figure 6. Sloped soil subgrades meant use of regularly spaced check dams made with an impermeable liner with drain hole penetrations.

Figure 7. A check dam in place ready to receive supporting aggregate.

Figure 8. By improving neighborhood character and eliminating flooding, property values rose.

"Our council member for this district is very pleased with the project, and other council members and residents have asked if they can have pavers in their districts for their stormwater management," Mr. Hill said. While the project drew attention of some jealous neighbors, it has expanded nationally as well as in the region. Just to the north of Atlanta, the City of Roswell installed its first permeable paver roadway last year after staff visited the Atlanta project during construction.

An Ounce of Prevention Yields…

The Atlanta Department of Watershed Management focuses efforts on educating contractors who will be working on or around their permeable pavement to prevent damage before it occurs. Nonetheless, some accidents happen from uninformed users who might assume that spills head to catch basins, then forget about the pollution. In one instance, a concrete mixing bucket was washed into the gutter and ran down one of the paver roadways. The runoff clogged the paver joints as well as the aggregate subbase, resulting in a $6,000 repair bill. In other instances, construction sites adjacent to the PICP roads needed to carefully contain sediment so it didn't run into the street.

"It's going to take education to ensure that anyone digging into these paver roadways has either gone through training or read the maintenance manual," Mr. Rayburn said. The maintenance manual provided by the design-build contractor was revised by the Department of Watershed Management, and the first training course was with the Department of Public Works. "As of now, the protocol is to call our construction inspectors, the ones who were onsite during the paver installations, to monitor any tie-in construction involving water or sewer lines," Mr. Rayburn said.

The city has a three-year contract with the project's design-build contractor to provide maintenance for the PICP. "Once that period is up, it will take a coordinated effort between the Public Works Department and the Watershed Department to ensure these paver roads are protected and that preventive maintenance is engrained in our daily processes," Mr. Rayburn said.

Figures 9 and 10. After completion in 2015, a 3-year maintenance contract ensures care for high use areas such as intersections and utility access. The City takes over maintenance at the end of this contract.

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>
> *—Cory Rayburn, Watershed Manager II, Atlanta Department of Watershed Management*

The Triple Bottom Line from Resilient Green Infrastructure

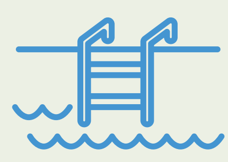
For any municipality contemplating PICP streets, Mr. Hill advises, "Spend a lot of time planning the process, and assess the condition of all existing utilities, so that rehabilitation can be included in the construction contract." Particularly with older urban streets, there may be layers of unknown mysteries beneath the surface. "Have a full-blown SUE [Subsurface Utility Exploration] done for every road to identify some of the harder-to-locate utilities before starting work," Mr. Rayburn said. The SUE helps the design-builder come up with a more comprehensive design prior to excavation or construction, saving time and minimizing surprises.

"We are very grateful that our administration was so farsighted with regard to sustainability and provided the support to allow us to install this project that contributes to making Atlanta a leader in sustainability. They provided the necessary support to make this project a reality," Mr. Hill said. "We worked closely with our Public Works Department to increase understanding of these types of practices and develop standard details to simplify design," Mr. Rayburn said. "There are numerous case studies that highlight the benefits of using green infrastructure, not just to improve water quality or provide capacity relief, but to also deliver social and economic development benefits."

In Atlanta's case, the green infrastructure initiative had a direct impact on new investment. "The Historic 4th Ward watershed project near Ponce City Market helped spur a huge amount of economic growth while addressing flooding issues within a combined sewer area," Mr. Rayburn said. "Whereas traditional gray infrastructure, such as tunnels and vaults, has been used historically to address flooding and sewer capacity issues, we're now looking at a combination of gray and green infrastructure to solve these problems while providing something the community can be proud of."

The Size of the Challenge

4 million gallons of PICP storage capacity = the water in **about 6 Olympic size pools**



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