Supporting the Use of Green Infrastructure (GI) in the Lower Galveston Bay Watershed



Exploration Green Stormwater Wetlands, Houston, TX

Prepared for:

Galveston Bay Estuary Program

Texas Commission on Environmental Quality

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# List of Acronyms

BIG Bacteria Implementation Group

BMPs best management practices

cfu colony forming units

*E. coli* *Escherichia coli*

EIH Environmental Institute of Houston

EPA Environmental Protection Agency

Excel Microsoft Excel

GBEP Galveston Bay Estuary Program

GI green infrastructure

HARC Houston Advanced Research Center

HCFCD Harris County Flood Control District

H-GAC Houston-Galveston Area Council

L liter

LID low impact development

mg milligram

mL milliliter

SAS Statistical Analysis Systems (now just SAS)

TCEQ Texas Commission on Environmental Quality

TSS total suspended solids

TX AgriLife Texas A&M AgriLife Extension

TKN total Kjeldahl nitrogen

WBPs Watershed-based Plans

# Executive Summary

Completed green infrastructure (GI) studies have suggested GI effectiveness at removing pollution, including metals, nutrients, sediments, and pathogens. However, no thorough review of local and regional *in situ* GI efficacy has been completed. This report is an attempt at bringing GI performance data from local, regional, and national sources together to see what story it can tell us.

The Houston-Galveston Area Council (H-GAC) is a voluntary association of local governments, representing thirteen counties within the Gulf Coast Planning Region and serves as the Metropolitan Planning Organization for the eight-county Houston-Galveston area. The agency provides technical assistance supporting community planning, environmental planning, and water management initiatives in rural, suburban, and urban areas. H-GAC sees GI as an important planning tool as the region continues to develop and redevelop, helping address stormwater quality and quantity; offsetting impervious cover thru greenspace and natural capital; and providing a potential return on investment via infrastructure cost saving and increased lot yields[[1]](#footnote-2).

GI can assist in controlling stormwater on a developed site by maintaining or restoring natural hydrology, supporting infiltration and evapotranspiration (evaporation and transpiration by plants), and increased retention time. Water quality can then be enhanced by the settling of sediments and heavy metals, nutrient uptake by biological components, solar breakdown of bacteria, and natural and mechanical filtration. Developers can often save on construction costs through less reliance on gray infrastructure such as asphalt, concrete, drainage piping, and land set aside for detention basins. GI practices as quality-of-life, are often aesthetically pleasing and work with natural landscapes and incorporate native planting materials, helping developments to blend in with the natural environment. The practices help to promote higher quality-of-life often using recreational trails and bike paths placed within the GI feature.

The results from this report’s analyses highlight the overall positive impacts of GI practices on water quality improvement. However, limited GI performance data was encountered which restricted overall conclusions supporting the use of GI. It is recommended that additional performance data is still needed to better validate these observations and to provide more robust insights for effective decision-making. That said all GI practices reviewed in this report demonstrated the ability to reduce water quality parameters.

Introduction

H-GAC is a voluntary association of local governments, representing thirteen counties within the Gulf Coast Planning Region and serves as the Metropolitan Planning Organization for the eight-county Houston-Galveston area. The agency provides technical assistance supporting community planning, environmental planning, and water management initiatives in rural, suburban, and urban areas. H-GAC sees green infrastructure (GI) as an important planning tool as the region continues to develop and redevelop, helping address stormwater quality and quantity; offsetting impervious cover thru greenspace and natural capital; and providing a potential return on investment via infrastructure cost saving and increased lot yields[[2]](#footnote-3).

H-GAC with local partners, collects and assesses data to evaluate the region’s water quality and develops and implements plans with local stakeholders to address water quality and other environmental issues. Water quality for the region has notably improved since implementation of the Clean Water Act in the 1970s[[3]](#footnote-4); however, a sizable number of the waterways in Houston-Galveston region still fail to meet state water quality standards and/or screening criteria for one or more parameters[[4]](#footnote-5). Watershed-based planning efforts have identified stormwater run-off pollution as a major contributor to poor water quality. H-GAC supports local watershed-based plans (WBPs)[[5]](#footnote-6) and implementation efforts like the Bacteria Implementation Group (BIG)[[6]](#footnote-7).

The Houston-Galveston region includes the third most populous county, Harris County, and fourth most populous city, Houston, in the United States. H-GAC forecasts a strong economy and robust growth to lead to the addition of 500 square miles of developed area, including 9.5 million parking spaces, 7.0 million square feet of non-residential and 3.5 billion square feet of residential roofs in the Houston-Galveston region over the next 25 years[[7]](#footnote-8). This increase in impervious surface area and associated alteration of natural hydrology can significantly increase runoff volumes and pollutant loadings, potentially causing additional negative impacts to local waterways, Galveston Bay, and the Gulf of Mexico.

While GI is not a practice for all situations and results if implemented can vary, H-GAC believes that GI practices are valuable, viable, and if implemented widely will:

1. Assist the region better manage stormwater volumes;
2. Protect and improve the long-term health of the region’s waterbodies;
3. Support local community goals for open space, greenspace, and quality-of-life; and
4. Serve to lower developer costs, support higher property values, and meet local and state stormwater and water quality requirements.

## What is Green Infrastructure?

GI presents a practical solution to WBP. Stormwater management practices that attempt to mimic predevelopment hydrology will be referred to as ‘green infrastructure’ or GI (Figure 1) throughout this report. These types of practices have also been identified as ‘low impact development,’ ‘stormwater best management practices or BMPs,’ and ‘nature-based solutions,’ amongst others. Terminology is challenging in that these practices are most often engineered and can include both gray ‘human sourced’ and natural ‘earthen and vegetative’ infrastructure. GI can be incorporated into larger stormwater management volume control efforts found in both dry and wet detention, bypass conveyances, and channel modifications.

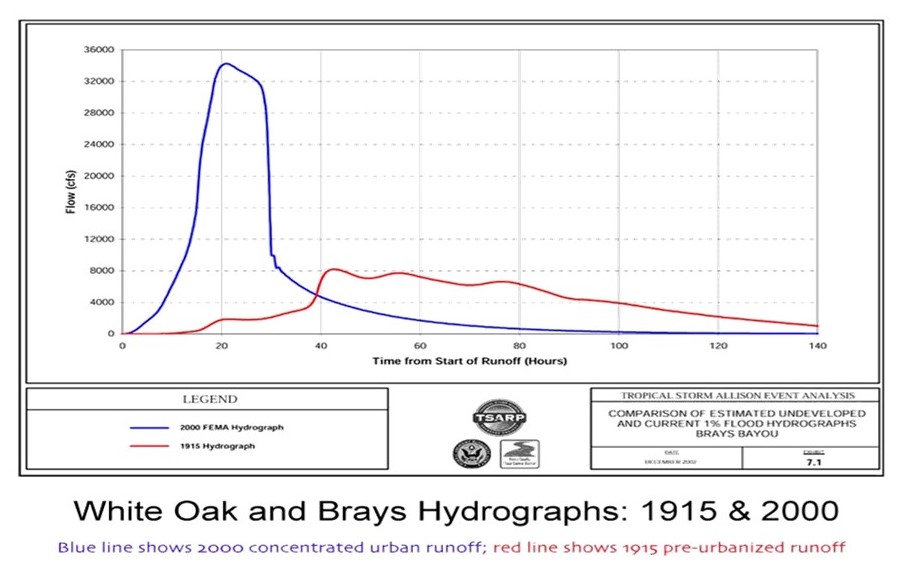


Figure 1. Hydrographs for pre-urbanized development and post urban development[[8]](#footnote-9)

GI can assist in controlling stormwater on a developed site by maintaining or restoring natural hydrology, supporting infiltration and evapotranspiration (evaporation and transpiration by plants), and increased retention time. Water quality can then be enhanced by the settling of sediments and heavy metals, nutrient uptake by biological components, solar breakdown of bacteria, and natural and mechanical filtration.

Completed GI studies have suggested GI effectiveness at removing pollution, including metals, nutrients, sediments, and pathogens. However, no thorough review of local and regional *in situ* GI efficacy has been completed. This report is an attempt at bringing GI performance data from local, regional, and national sources together to see what story it can tell us.

The BIG, a voluntary stakeholder group implementing a bacteria reduction plan in the Houston region, has noted improving conditions in area waterways, where the City of Houston, Harris County and Harris County Flood Control District (HCFCD) have implemented bacteria reduction measures, including GI. However, the BIG has found it a challenge to link water quality improvements with changes these organizations made to their development ordinances, codes, and practices allowing for GI. They support the use of GI where appropriate. In addition, GI can be used to address regulatory issues, such as Texas Pollution Discharge Elimination System permits, which encourage local municipalities and governments to manage pollutants within their districts to address impaired waters[[9]](#footnote-10). The BIG has pushed for an evaluation of GI efficacy to assist in encouraging its use.

As the regional planning entity for the upper Texas Gulf Coast, H-GAC is the nexus for multiple sustainability planning initiatives. H-GAC coordinates the region’s interest in building more resilient communities. GI tools and practices will help realize several strategies identified in H-GAC’s *Our Great Region 2040[[10]](#footnote-11),* a regional sustainability plan completed in 2014 with support from the U.S. Department of Housing and Urban Development. For example, one of that plan’s priority strategies is to “conserve natural assets through the multi-benefit of green infrastructure projects and designing with nature, such as GI and expanding Our region’s network of open space and trails along waterways.”

H-GAC supports the use of GI practices in all 13 counties in the Houston-Galveston region because they present sustainable cost-effective strategies[[11]](#footnote-12). Developers can often save on construction costs through less reliance on gray infrastructure such as asphalt, concrete, drainage piping, and land set aside for detention basins. Long-term maintenance costs often have been found to cost less or be on par with traditional stormwater and water quality conveyances. Housing lots adjacent to a GI feature can often sell for a premium over traditional lots. GI offers developers a reimbursement incentive as the state will allow for some GI costs to be recouped through the issuance of municipal utility bonds like reimbursements for other stormwater features.

Local governments encouraging the use of GI should see benefits from GI as supportive of the communities’ quality-of-life by attracting and supporting healthier living which in turn makes the community more attractive to relocating businesses. GI practices as quality-of-life, are often aesthetically pleasing and work with natural landscapes and incorporate green space through native planting materials, helping developments to blend in with the natural environment. As previously mentioned, these practices help to promote higher quality-of-life often using recreational trails and bike paths placed within the GI feature. GI presents opportunities for connectivity to adjacent communities and local waterways.

## Supporting the Use of Green Infrastructure (GI) in the Lower Galveston Bay Watershed

This project aimed to develop a recommended GI practice list for local governments, developers, decision makers, non-profits, and other organizations. Over the last 20 years, at least 86 GI installations have been completed by various organizations within the Houston-Galveston region (Figure 2). It is hoped that a prioritized list which contemplates water quality performance, along with other considerations (i.e., initial cost, long-term maintenance, stormwater control, community benefits, habitat, etc.), will encourage local governments, developers and other interested parties, and enhance the promulgation of GI in the region.

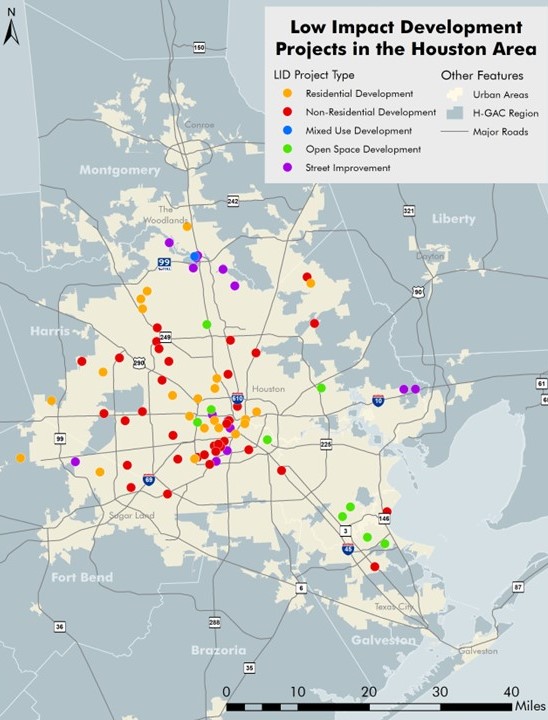


Figure 2. LID projects in the Greater Houston Region[[12]](#footnote-13)

GI practices have been installed in the region to assist with stormwater management and improve water quality, along with other benefits. Many of these practices have included water quality performance monitoring on pathogen bacteria, nutrients, sediment, etc. In some instances, that information has been shared with local agencies and funding partners. However, this data has never been combined to assess and rank these GI practices together, with the goal of recommending those practices that would be best suited to the Houston-Galveston region.

H-GAC completed the *Designing for Impact, a Regional Guide for Low Impact Development*[[13]](#footnote-14) under a grant from the Gulf of Mexico Program that explained the need for GI practice use. The guide did not, however, directly use local data in making the case for the examples provided. The guide relied on professional judgement in which practices were highlighted. Additionally, more GI practices have since been installed and performance evaluated. Therefore, an expansive look at this data was warranted.

Both the *Galveston Bay Plan, 2nd Edition[[14]](#footnote-15)* and the BIG’s Implementation Plan[[15]](#footnote-16) recommend evaluating GI to further evidence the need for these practices. This project acts on those recommendations to make local and regional data more readily accessible to resource agencies and more importantly, local decision makers.

## 

## GI Design Primer

What do GI practices look like? There are a variety of GI practice designs that have been studied. The designs span from mechanical filtration to natural filtration and from engineered soils to established natural wetland soils. Below is a list of common practices, however this is not a thoroughly exhaustive list (Figures 3 and 4).[[16]](#footnote-17)

Detention – a dry basin that is used to temporarily hold stormwater. Treatment exists in removing suspended sediments.

Retention – a basin that maintains a permanent pool of water, while temporarily retaining stormwater. Treatment removes suspended sediments, solar radiation, and evaporation.

Mechanical – engineered practices that are almost entirely manufactured. The treatment is more targeted and involves mechanical filtration media.

Vegetative Strip or Grass Swale – an open conveyance containing grass or other vegetation. Some sedimentation and plant uptake are features.

Green Roof – consists of an engineered surface made of soil media, a drainage layer and an impermeable membrane. Evaporation and transpiration are key treatment features.

Bioretention – sometimes considered rain gardens, planter boxes or bioswales, these layered engineered systems consist of engineered soils, mulch, and rock held in smaller basins. These are designed to hold water for a specific timeframe, before releasing via an underground pipe. These practices are planted and allow for sedimentation and plant uptake.

Permeable Pavement – grass, rock, pavers, concrete and/or asphalt used as surface road and parking lot construction. The materials are porous and include a water storage layer underneath. Sediments and other pollutants can be filtered out.

Stormwater wetland – a manufactured wetland designed to treat stormwater combining the features of a retention pond with wetland plants. Plants are used to uptake nutrients and transpire water.

Floating wetland – a manufactured wetland island using manufactured floating structures with engineered growing media. Treatment is through plant roots which uptake nutrients. A newer practice that is potentially a good retrofit for retention basins, where including stormwater wetlands may not be possible or as an augmentation within a stormwater wetland.

Rainwater harvesting – a rain barrel, cistern, or underground storage used to capture rainwater. Their treatment feature is to prevent, or limit run off. Water is then used in irrigation or another secondary purpose.

Treatment train – two or more practices place in line to combine water quality and design benefits, expanding GI use within different areas of a development.

Figure 3. GI Practice Types



Figure 4. Example of a treatment train

Project Methodology

## Sources of GI Data

H-GAC performed a nested approach, preferentially using local existing data (i.e., Environmental Institute of Houston (EIH), HCFCD Regional Best Management Practice Database (BMPbase)[[17]](#footnote-18), and others and augmenting this data with state and national data (i.e., International Stormwater Best Management Practice (ISBMP) Database[[18]](#footnote-19) , to identify and recommend, in collaboration with water professionals, a GI list that accounts for local conditions in the Houston-Galveston region (e.g., soils and precipitation).

This project did not monitor or sample existing GI sites or create new environmental data. Rather, this project acquired and assessed available and existing GI datasets and summary data from local, state, and national-level projects. H-GAC assembled a work group of water professionals from the region with local GI knowledge to assist in identifying and acquiring the data. The following tasks were carried out:

1. Convened and organized a project committee (e.g., EIH, Houston Advanced Research Center (HARC), TX AgriLife, HCFCD, Harris County, and City of Houston);
2. Compiled available local GI data, catalogued by practice(s);
3. Completed analysis of GI data and/or utilize existing summary analysis;
4. Compared analysis with state and national examples from areas of common soil types, precipitation, and/or other pertinent factors determined by the project committee; and
5. Sought to identify and recommend GI practices.

## International Stormwater Best Management Practice Database

The [International Stormwater Best Management Practice Database](https://bmpdatabase.org/) represents a consolidation of over 25 years of data from and information about stormwater management field studies, web tools, performance summaries, and monitoring guidance. BMP data hosted on the site is sourced worldwide from locations throughout North America and other continents such as Asia, Australia, and Europe. The objective driving the establishment of the ISBMP Database included:

* The development of standardized protocols for BMP studies, and
* Organizing data from both historical and ongoing BMP studies in a standard format.

Methods from the ISBMP [2009 Monitoring Guidance](https://bmpdatabase.org/s/2009MonitoringManualSingleFile.pdf) are used widely to track performance of stormwater BMPs[[19]](#footnote-20).

Due to the broad geographical scope of the database, data from a selection of 42 sites from throughout the southeastern United States were extracted into the H-GAC database to reflect the topographical and climatological conditions most relevant more closely to the H-GAC region. To achieve this, a subset of the ISBMP Database showing only sites from the continental United States was extracted. From this subset, only sites from United States Environmental Protection Agency (EPA) Rain Zones 2, 3, 4, and 5 (Figure 5[[20]](#footnote-21)) were considered for inclusion in the H-GAC dataset. All data from Harris County, Texas was removed from the remaining data as data from the HCFCD would be integrated directly in the next phase of database development. Finally, only sites with corresponding water quality data were selected for inclusion in the H-GAC database for use in the efficacy analysis.

A map of the united states

Description automatically generated

Figure 5. EPA rain zones

The oldest ISBMP timepoint in the H-GAC database is from 1992 and the most recent is from 2013. The 42 sites included typically supported two monitoring stations each to capture data from the inflow and outflow of each BMP. Where multiple BMPs were implemented at a site, the number of monitoring stations was greater. In total, 103 monitoring stations were included in the dataset. BMP types in the final dataset include Bioretention, Detention Basins, Grass Strips, Green Roofs, Manufactured Devices, Media Filters, Permeable Pavement, Porous Pavement, and Retention Ponds. Bioretention and Manufactured Devices were the most common BMPs with each type representing roughly 30% of the dataset respectively. The 42 ISBMP Database sites assessed in this analysis are represented in Table 1.

Table 1. ISBMP Database sites assessed

| **ISBMP Test Site** | **Location** | **BMP Type** | **Monitoring Station Count** | **Start Date** | **End Date** | **Events** |
| --- | --- | --- | --- | --- | --- | --- |
| Louisburg bioretention-L1 | Louisburg, NC | Bioretention | 2 | 5/30/2004 | 11/23/2004 | 24 |
| NCSU Wilmington | Wilmington, NC | Retention Pond | 11 | 1/17/2008 | 2/9/2010 | 200 |
| I-95 Plaza StormFilter | Newark, DE | Manufactured Device | 2 | 4/1/2005 | 11/15/2007 | 22 |
| SC\_StructBMP4 | Yemassee, SC | Manufactured Device | 2 | 8/27/2005 | 9/19/2006 | 24 |
| SC\_StructBMP1&2 | Beaufort, SC | Manufactured Device | 4 | 4/7/2005 | 11/7/2006 | 50 |
| SMNW EXT DRY DET | Shawnee, KS | Detention Basin | 1 | 5/19/2011 | 9/28/2013 | 24 |
| Charlottesville HS Biofilter | Charlottesville, VA | Bioretention | 2 | 7/10/2010 | 11/16/2010 | 26 |
| DeBary Detention with Filtration Pond | DeBary, FL | Retention Pond | 4 | 5/28/1992 | 11/30/1992 | 125 |
| OP Soccer Complex | Overland Park, KS | Manufactured Device | 2 | 6/27/2011 | 11/7/2011 | 9 |
| I-95 Plaza AbTech Ultra-Urban Filter w/ Smart Sponge Plus Antimicrobial Additive | Newark, DE | Manufactured Device | 2 | 12/13/2006 | 4/20/2009 | 22 |
| Westfield Level Spreader | Charlotte, NC | Grass Strip | 2 | 2/23/2006 | 1/5/2007 | 22 |
| OP Recycling Center | Overland Park, KS | Bioretention | 2 | 7/16/2010 | 9/19/2013 | 65 |
| Cub Run Rec Center | Chantilly, VA | Bioretention | 4 | 9/25/2008 | 3/28/2010 | 37 |
| SC\_StructBMP3 | Beaufort, SC | Manufactured Device | 2 | 4/7/2005 | 9/19/2006 | 24 |
| Greensboro bioretention-G1 | Greensboro, NC | Bioretention | 2 | 7/12/2003 | 9/6/2004 | 34 |
| I-95 Plaza UltraDrainguard Filter | Newark, DE | Manufactured Device | 2 | 12/13/2006 | 4/20/2009 | 40 |
| HC | Shawnee, KS | Manufactured Device | 2 | 3/29/2007 | 6/30/2007 | 8 |
| SJC - Ext Dry | Shawnee, KS | Detention Basin | 2 | 7/7/2011 | 4/23/2013 | 10 |
| Providence | Merrifield, VA | Control | 2 | 6/3/2005 | 3/12/2010 | 15 |
| I-95 Plaza HydroKleen Filter | Newark, DE | Manufactured Device | 2 | 4/8/2006 | 4/28/2008 | 40 |
| I-95 Plaza Delaware Sand Filter | Newark, DE | Media Filter | 2 | 4/1/2005 | 5/12/2008 | 42 |
| I-95 Plaza BaySaver | Newark, DE | Manufactured Device | 2 | 11/16/2005 | 11/13/2008 | 40 |
| Highland View | Overland Park, KS | Media Filter | 2 | 9/12/2008 | 11/7/2011 | 75 |
| NCDOT I-40 Site D | Faison, NC | Porous Pavement | 3 | 9/29/2008 | 5/24/2010 | 53 |
| Greensboro bioretention-G2 | Greensboro, NC | Bioretention | 2 | 7/13/2003 | 9/6/2004 | 34 |
| Herrity Green Roof | Fairfax, VA | Green Roof | 2 | 2/1/2008 | 4/8/2010 | 34 |
| Louisburg bioretention-L2 | Louisburg, NC | Bioretention | 2 | 5/30/2004 | 11/23/2004 | 25 |
| Mango Creek | Knightdale, NC | Bioretention | 5 | 11/2/2009 | 12/13/2010 | 146 |
| I-95 Plaza Bioretention Cell | Newark, DE | Bioretention | 2 | 4/1/2005 | 11/15/2007 | 47 |
| 87th Metcalf BMP | Overland Park, KS | Bioretention | 2 | 9/12/2008 | 9/15/2010 | 60 |
| SJC - Bio Ret 6 | Shawnee, KS | Bioretention | 2 | 6/11/2012 | 9/28/2013 | 58 |
| I-95 Plaza AbTech Ultra-Urban Filter w/Smart Sponge | Newark, DE | Manufactured Device | 2 | 12/13/2006 | 4/20/2009 | 45 |
| Bama Belle UFF | Tuscaloosa, AL | Manufactured Device | 2 | 7/16/2010 | 3/30/2013 | 99 |
| NCDOT I-40 Site C | Faison, NC | Permeable Pavement | 2 | 9/6/2008 | 5/24/2010 | 40 |
| BRC Site B | Nashville, NC | Bioretention | 2 | 4/20/2008 | 2/28/2009 | 38 |
| VC | Shawnee, KS | Manufactured Device | 2 | 5/2/2007 | 6/30/2007 | 8 |
| SMNW HANCOR | Shawnee, KS | Manufactured Device | 2 | 5/24/2011 | 9/28/2013 | 65 |
| SJC - Bio Ret 3B | Shawnee, KS | Bioretention | 2 | 5/24/2012 | 9/28/2013 | 48 |
| NCDOT I-40 Site A | Benson, NC | Permeable Pavement | 3 | 9/6/2008 | 5/24/2010 | 39 |
| BRC Site A | Nashville, NC | Bioretention | 2 | 4/20/2008 | 2/28/2009 | 38 |
| NCDOT I-40 Site B | Benson, NC | Permeable Pavement | 2 | 9/6/2008 | 5/24/2010 | 41 |
| I-95 Plaza Suntree Grate Inlet Skimmer | Newark, DE | Manufactured Device | 2 | 4/27/2007 | 4/20/2009 | 32 |

## Harris County Flood Control District Best Management Practice Database

Deemed the local dataset, HCFCD’s Regional BMP dataset was sourced from their online database. Within the online interactive mapping application[[21]](#footnote-22), a user has the flexibility to identify and download data from the agency’s numerous structural projects that aim to improve water quality while also fulfilling their primary goal – flood damage reduction.

HCFCD has more than 2,500 miles of bayous and streams within their district. With the county’s growing population of an estimated 4.7 million people (2020 census), flood reduction and water quality improvements are the top priority of the region. The HCFCD manages their stormwater monitoring program according to the methodology and guidance developed by the International Stormwater BMP Database along with sampling protocols developed by the Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring Procedures (SWQM). Although the program was developed in 2002, the monitoring began in 2003 on common structural features within the district’s channels and detention basins such as constructed wetlands, floatable collection devices, and riparian vegetated corridors. Data from these projects allow the HCFCD to continually update and improve designs for flood damage reduction projects and meet water quality objectives.

The Regional BMP database application allows a user to query, review, analyze, and display stormwater BMP effectiveness data. The database was considered a foundational data component in H-GAC’s GI analysis. Although the database was built to mimic the International Stormwater Database in the southeast Texas region, the data was integrated into H-GAC’s database through direct measures.

Download in the fall of 2022, eight major project locations (test sites) were downloaded and integrated into H-GAC’s database. These included stormwater BMP types of Dry Detention Basins, Wet Detention Basins, and Constructed Wetlands. Wet detention basins were the most numerous of the project BMP types. The data consisted of five locations described as ‘wet detention basins’, one location described as a ‘dry detention basin’, and two project locations as ‘wetlands’ and ‘riparian channels.’ The data included ranged from 2004 to 2013. Monitoring was only conducted during wet weather conditions to capture stormwater discharge. Twenty-five percent of the data was sourced from Test Site B504-03-00, which consists of two monitoring stations. The test site has only one outlet where storm water leaves the basin through a culvert network (Table 2). Most of HCFCD’s test sites consisted of a single inlet and single outlet configuration. In project locations where there were three monitoring stations, usually two of the stations were considered entry points for the stormwater (inlets) and one exit point (outlet). Table 2 provides site descriptions and a data summary of the district’s dataset.

Table 2. BMP sites taken from BMPbase

| HCFCD Test Site | BMP Type | Site Description | Monitoring Station Count | Date Range | Raw Sample Count (Water Quality Parameters) | Watershed |
| --- | --- | --- | --- | --- | --- | --- |
| B504-03-00 Dry Detention Basin | Dry Detention Basin | The facility was designed to control the 100-yr storm event and consists of a detention basin with three small pilot channels that direct water toward a central pilot channel running parallel to Clear Lake City Boulevard. Stormwater leaves the basin through a subsurface box culvert network that discharges to HCFCD Basin B504-02-00. | 2 | 2005-2013 | 642 | Armand Bayou |
| B512-01-00 Wet Detention Basin | Wet Detention Basin | The system consists of a two inlet and one outlet configuration. The basin consists of a detention basin with a permanent pool area interspersed with wetlands and habitat islands. The design maintains a permanent pool in the basin. The system has two inlets and one outlet. | 3 | 2010-2013 | 316 | Armand Bayou |
| E500-12-00 Wet Detention Basin | Wet Detention Basin | The system consists of a single inlet and outlet configuration. The detention basin is designed to control a 25-year storm event and consists of a detention basin with a permanent pool area interspersed with wetlands and habitat islands. The design maintains a water quality volume in the basin consisting of 1 foot depth over the basin area with a 72 hour drain time. | 3 (2 within project boundary and 1 immediately upstream of project boundary) | 2008-2013 | 213 | White Oak Bayou |
| E515-01-00 Wet Detention Basin | Wet Detention Basin | The system consists of a single inlet and outlet configuration. The detention basin is designed to control a 25-year storm event and consists of a detention basin with permanent pool areas interspersed with wetlands and habitat islands. The design maintains a water quality volume in the basin consisting of at least a 1 ft depth over the basin area with a slow drain time. | 2 | 2009-2013 | 208 | White Oak Bayou |
| P700-01-00 Wetlands Mitigation Bank | Constructed Wetlands | Several BMPs are located within the mitigation bank. The BMPs are referred to as the surge basin, treatment wetlands and habitat wetlands. | 3 | 2004-2007 | 280 | Greens Bayou |
| T101-00-00 Riparian Channel | Constructed Wetlands | The channel consists of a riparian corridor with wetland plants occupying the lowest elevation in the channel. | 2 | 2008-2012 | 172 | Barker Reservoir |
| T501-01-00 Wet Detention Basin | Wet Detention Basin | The system consists of a two inlet and one outlet configuration. The basin is designed to control a 25-year storm event and consists of a detention basin with a permanent pool area interspersed with wetlands and habitat islands. The design maintains a permanent pool in the basin. The system has two inlets and one outlet. Flow also enters the system through roadside ditches draining to concrete pipes at Porter Road. | 3 | 2008-2012 | 382 | Barker Reservoir |
| P518-02-00 Halls Bayou Regional Detention Basin | Wet Detention Basin | The HCFCD name for this facility is Halls Bayou Regional Detention Basin and it is located at Keith Weiss Park. The BMPs consists of four wetland basins separated by four riparian corridors (Structural). Sandstone weirs are incorporated into the riparian corridors to increase dissolved oxygen. The wetland basins receive flow from two local drainage areas and low flow from Halls Bayou. | 3 | 2013 | 12 | Greens Bayou |

## Journal Articles and Local Data

The third set of data came from a review of journal articles and local data. Project committee members were instrumental in locating local data that could only be found in white papers and reports submitted to state resource agencies. Table 3 contains the local, state, and national level data gathered for analysis in this project. The team does not presume to intend the data gathered present the totality of available data from journal articles and there are likely many other relevant sources that could have been added.

Several of the acquired documents include multiple practices studied by the team. In those cases, Table 3 reflects separate lines for each individual practice studied. In a few of the studies, GI practices were placed in series. This is often called a ‘treatment train.’ In those cases, there were inflow and outflows for each GI practice, where the outflow for one practice becomes the inflow for the downstream practice. In each of these cases, each practice was considered separate and retained, along with the entire treatment system.

A key point worth noting is the lack of the historic raw data record for each study. The sourced articles and white papers contained summary data and final analysis. This would prove limiting for the types of data analyses that were performed.

Table 3. Journal Articles and Local Data[[22]](#footnote-23)

| **Site Name/ Study Name** | **Treatment Type** | **Location** | **Lat** | **Long** | **Source** | **Date Sample** | **Sample Media** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Brays Bayou Stormwater Wetland | Wetland - Inlet | Houston, Harris County, TX | 29.726431 | -95.290819 | Inflow | Jan 2007-Mar 2008 | Stormwater Outfall |
| Brays Bayou Stormwater Wetland | Wetland - Outfall | Houston, Harris County, TX | 29.726431 | -95.290819 | Outflow | Jan 2007-Mar 2008 | Wetland Outfall |
| Birnamwood Dr. | Swale Inlet | Spring, Harris County, TX | 30.072319 | -95.374322 | Inflow | 06/2014-02/2017 | Surface Runoff/Flow |
| Birnamwood Dr. | Swale Outfall | Spring, Harris County, TX | 30.071542 | -95.382692 | Outflow/  Inflow | 06/2014-02/2017 | Surface Vegatative Swale |
| Birnamwood Dr. | Bioretention Inlet | Spring, Harris County, TX | 30.071542 | -95.382692 | Outflow/  Inflow | 06/2014-02/2017 | Surface Vegatative Swale |
| Birnamwood Dr. | Bioretention Outfall | Spring, Harris County, TX | 30.071175 | -95.382656 | Outflow | 06/2014-02/2017 | Bioretention Soil Media |
| Birnamwood Dr. | Treatment Train Inlet | Spring, Harris County, TX | 30.072319 | -95.374322 | Inflow | 06/2014-02/2017 | Surface Runoff/Flow |
| Birnamwood Dr. | Treatment Train Outfall | Spring, Harris County, TX | 30.071175 | -95.382656 | Outflow | 06/2014-02/2017 | Multimedia |
| Dallas Urban Center Stormwater BMPs | Pervious Pavement - Concrete Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Pervious Pavement |
| Dallas Urban Center Stormwater BMPs | Pervious Pavement - Expanded Shale Reinforced Grass Pavers Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Pervious Pavement |
| Dallas Urban Center Stormwater BMPs | Pervious Pavement - Interlocking Concrete Paver Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Pervious Pavement |
| Dallas Urban Center Stormwater BMPs | Pervious Pavement - Plastic Reinforced Gravel Pavers Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Pervious Pavement |
| Dallas Urban Center Stormwater BMPs | Impervious Asphalt - Control Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Pervious Pavement - Control |
| Dallas Urban Center Stormwater BMPs | Bioretention Inlet | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Inflow | 09/2013-01/2015 | Surface Runoff/Flow |
| Dallas Urban Center Stormwater BMPs | Bioretention Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 09/2013-01/2015 | Bioretention Soil Media |
| Dallas Urban Center Stormwater BMPs | Rainwater Harvesting Control | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 12/2012-08/2012 | Rainwater Harvesting - Control |
| Dallas Urban Center Stormwater BMPs | Rainwater Harvesting Homeowner Use | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 12/2012-08/2012 | Rainwater Harvesting |
| Dallas Urban Center Stormwater BMPs | Rainwater Harvesting Evapotranspiration Usage | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 12/2012-08/2012 | Rainwater Harvesting |
| Dallas Urban Center Stormwater BMPs | Rainwater Harvesting Soil Moisture Usage | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 12/2012-08/2012 | Rainwater Harvesting |
| Dallas Urban Center Stormwater BMPs | Green Roofs - Hydrotech System | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Green Roof Hydrotech System |
| Dallas Urban Center Stormwater BMPs | Green Roofs - Drainage Layer | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Green Roof Soil and Drainage |
| Dallas Urban Center Stormwater BMPs | Green Roofs - No Drainage Layer | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Green Roof Soil No Drainage |
| Dallas Urban Center Stormwater BMPs | Green Roofs - Control | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 03/2013-03/2015 | Green Roof - Control |
| Dallas Urban Center Stormwater BMPs | Detention Pond - Inlet 1 | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | L1 Inflow | 02/2015-06/2015 | Surface Runoff/Flow |
| Dallas Urban Center Stormwater BMPs | Detention Pond - Inlet 2 | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | L2 Inflow | 02/2015-06/2015 | Surface Runoff/Flow |
| Dallas Urban Center Stormwater BMPs | Detention Pond - Outfall | 17360 Coit Road, Dallas, Dallas County, TX | 32.987089 | -96.766842 | Outflow | 02/2015-06/2015 | Detention Pond Outflow |
| University of Texas Recreation Park MD Anderson Campus Wetland | Wetland - Inlet | 7510 Bertner Rd. Houston, Harris County, TX | 29.692917 | -95.397317 | Inflow | 09/2019-07/2020 | Stormwater Outfall |
| University of Texas Recreation Park MD Anderson Campus Wetland | Wetland - Outfall | 7510 Bertner Rd. Houston, Harris County, TX | 29.692917 | -95.397317 | Outflow | 09/2019-07/2020 | Wetland Outfall |
| Exploration Green Recreation Park Phase 1 Stormwater Wetland | Wetland - Inlet | Diana Ln, Houston, Harris County, TX | 29.563333 | -95.120589 | Inflow | 09/2019-07/2020 | Stormwater Outfall |
| Exploration Green Recreation Park Phase 1 Stormwater Wetland | Wetland - Outfall | Diana Ln, Houston, Harris County, TX | 29.563333 | -95.120589 | Outflow | 09/2019-07/2020 | Wetland Outfall |
| Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | Wetland - Inlet | 1800 Old Spanish Trail, Houston, Harris County, TX | 29.695631 | -95.400075 | Inflow | 09/2019-07/2020 | Stormwater Outfall |
| Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | Wetland - Outfall | 1800 Old Spanish Trail, Houston, Harris County, TX | 29.695631 | -95.400075 | Outflow | 09/2019-07/2020 | Wetland Outfall |
| EIH UHCL Wetland | Wetland - Inlet/Spigot Reclaim Water - S | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582961 | -95.100119 | Inflow | 04/2012-05/2012 | Reuse water from WWTF |
| EIH UHCL Wetland | Wetland - Outfall - 8 | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582828 | -95.101201 | Outflow | 04/2012-05/2012 | Outfall Primary Wetland |
| EIH UHCL Wetland | Wetland - Inlet - 8 | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582828 | -95.101201 | Inflow | 04/2012-05/2012 | Inflow Secondary Wetland |
| EIH UHCL Wetland | Wetland - Outfall - 10 | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582389 | -95.101622 | Outflow | 04/2012-05/2012 | Outfall Secondary Wetland |
| EIH UHCL Wetland | Wetland Detention - Inlet - 10 | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582389 | -95.101622 | Inflow | 04/2012-05/2012 | Inflow Wetland Detention |
| EIH UHCL Wetland | Wetland Detention - Outfall - 12 | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582495 | -95.101804 | Outflow | 04/2012-05/2012 | Outfall Wetland Detention |
| EIH UHCL Wetland | Wetland - Inlet/Spigot Reclaim Water - S | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582961 | -95.100119 | Inflow | 04/2012-05/2012 | Reuse water from WWTF |
| EIH UHCL Wetland | Wetland - Outfall - 12 | 2700 Bay Area Blvd, Houston, Harris County, TX | 29.582495 | -95.101804 | Outflow | 04/2012-05/2012 | Outfall Wetland Detention |
| Floating Wetland Retrofit North Carolina | Detention Pond | I-85 and US 15 Department of Transportation Pond, Durham, North Carolina | 36.024661 | -78.944225 | Pre-Retrofit | Nov. 2008-March 2010 | Pre-retrofit Inlet |
| Floating Wetland Retrofit North Carolina | Detention Pond | I-85 and US 15 Department of Transportation Pond, Durham, North Carolina | 36.024661 | -78.944225 | Pre-Retrofit | Nov. 2008-March 2010 | Pre-Retrofit Outlet |
| Floating Wetland Retrofit North Carolina | Floating Wetland - 9% coverage | I-85 and US 15 Department of Transportation Pond, Durham, North Carolina | 36.024661 | -78.944225 | Post-Retrofit | July 2010-Sept. 2011 | Post-retrofit Inlet |
| Floating Wetland Retrofit North Carolina | Floating Wetland - 9% coverage | I-85 and US 15 Department of Transportation Pond, Durham, North Carolina | 36.024661 | -78.944225 | Post-Retrofit | July 2010-Sept. 2011 | Post-Retrofit Outlet |
| Floating Wetland Retrofit North Carolina | Detention Pond | NC Museum OF Life Science Pond, Durham, North Carolina | 36.027058 | -78.900222 | Pre-Retrofit | Nov. 2008-March 2010 | Pre-retrofit Inlet |
| Floating Wetland Retrofit North Carolina | Detention Pond | NC Museum OF Life Science Pond, Durham, North Carolina | 36.027058 | -78.900222 | Pre-Retrofit | Nov. 2008-March 2010 | Pre-retrofit Outlet |
| Floating Wetland Retrofit North Carolina | Floating Wetland - 18% coverage | NC Museum OF Life Science Pond, Durham, North Carolina | 36.027058 | -78.900222 | Post-Retrofit | July 2010-Sept. 2011 | Post-retrofit Inlet |
| Floating Wetland Retrofit North Carolina | Floating Wetland - 18% coverage | NC Museum OF Life Science Pond, Durham, North Carolina | 36.027058 | -78.900222 | Post-Retrofit | July 2010-Sept. 2011 | Post-Retrofit Outlet |

# Data Preparation and Analysis

## H-GAC Database

To directly compare data from the ISBMP and HCFCD databases, the data were organized into a single database in Microsoft Excel (Excel). Starting with the selection of ISBMP data which represented the most comprehensive dataset of the aforementioned sources, a common format for site description information was developed based on the available information. The list of headers denoting the site description information to be included in the database are as follows:

* Original Database Site ID Number
* H-GAC Database Number (internal reference)
* BMP Design Type
* Site Name (descriptive)
* Monitoring Station Number
* Monitoring Station Name (descriptive)
* Event ID Number
* Date Sampled
* Time Sampled
* Sample Media
* Sample Type (e.g., grab, EMC-flow weighted)

Following these columns, water quality data headers including the parameter name and measurement unit were added based on the availability of data in the ISBMP subset. Broad categories and their corresponding constituents are shown in Table 4.

All corresponding data from the ISBMP database and HCFCD database collected at the same site, monitoring station, date, and timepoint were transposed from their host databases into the H-GAC dataset using the formats for site description and water quality parameters. Cells were filled based on the availability of data as not all sites had data for every parameter. In instances where no data for a specific parameter was recorded at a site, the cell was left blank.

Because the data collected from literature review was coarser in terms of the results only being available in summary form, publication data was organized in a separate Excel sheet from the combined ISBMP and HCFCD data. Comparable headers for site description and water quality parameters were used to capture this dataset with notes made to indicate what data had been averaged or represented as a median value.

Once organized into comprehensive databases, visualization of data gaps and assessment of robustness for statistical analysis was made easier.

The data analysis follows a standardized methodology to ensure consistency across multiple parameters. Initially, the dataset undergoes thorough preparation and cleaning, including importing data from Excel files and making necessary adjustments such as modifying column lengths, column names, and converting units where appropriate. Extraneous variables are eliminated, and textual descriptions are standardized for clarity and uniformity. Sorting the data enhances organization and facilitates subsequent analysis steps. Discussions were centered on selecting relevant variables for analysis, considering both the quantity of data available and the variables outlined in the project proposal. For instance, focusing on Total Suspended Solids (TSS) as a representative of metals bound with soluble solids demonstrates a strategic approach to maximizing available data. Variables such as Total Kjeldahl Nitrogen (TKN), Enterococci, *Escherichia coli* (*E. coli)*, Nitrite-Nitrate, Total Phosphate, TSS, Volumetric Flow, Nitrate, and Orthophosphate were analyzed comprehensively, providing a multifaceted view of water quality dynamics.

The inclusion of data from multiple sources with varying formats necessitated careful data cleaning to ensure consistency and integrity. Removing inconsistent entries, such as those denoted by “-999999”, was crucial for maintaining data integrity. Subsequently, the analysis focuses on computing via SAS (previously Statistical Analysis System) analytical software, summary statistics for various parameters, including mean, median, and count, to gain insights into their distribution and variability.

## Data Analysis

The effectiveness of GI in mitigating pollutant levels is then evaluated by calculating percentage reduction between mean inflow and mean outflow value for unique combinations of inflow and outflow based on sitename and GI practice across different parameters as shown in Figure 6. Indeed, the percent reduction method was found to be a common comparative method used in the GI literature[[23]](#footnote-24). This metric provides a quantitative measure of the impact of green infrastructure measures on improving water quality. Results are rounded for clarity and presented in a format conducive to informed decision-making. This comparative analysis served as the cornerstone for deriving insights into the effectiveness of different GI practices across various sites.

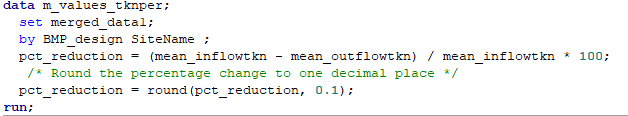


Figure 6. Screenshot of the percentage reduction calculation SAS code

Table 4. Parameters found in the ISBMP database

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Biological** | **Nutrients** | **Solids** | **Ambient** | **PAHs** | **Metals** | **Other** | **Precipitation** | **Flow** | **Cost** |
| Chlorophyll-*a*, mg/L | Total Kjeldahl Nitrogen, mg/L | Total Suspended Solids, mg/L | pH, SU | Acenaphthene, µg/L | Dissolved Cadmium, µg/L | Alkalinity, mg/L | Precipitation Event Duration, minutes | Total Volume, cubic meters | Cost, Year |
| Enterococcus, cfu/100mL | Dissolved Nitrogen, mg/L | Total Dissolved Solids, mg/L | Specific Conductance, µmhos/cm | Acenaphthylene, µg/L | Total Cadmium, µg/L | Total Organic Carbon, mg/L | Precipitation Depth, cm | Mean Flow Rate, cubic meters per second | Cost, Total, USD |
| *E. coli*, cfu/100mL | Total Nitrogen, mg/L | Total Solids, mg/L | Turbidity, NTU | Anthracene, µg/L | Dissolved Calcium, µg/L | Hardness, Carbonate, mg/L | Precipitation One Hour Peak Value, cm/hour |  | Cost, Average Annual Routine Maintenance, USD |
| Fecal Coliform, cfu/100mL | Ammonia Nitrogen, mg/L | Volatile Suspended Solids, mg/L | Water Temperature, °C | Benz[a]  anthracene, µg/L | Dissolved Chromium, µg/L | Chloride, mg/L |  |  | Cost, Average Rehabilitation, USD |
| Total Coliform, cfu/100mL | Ammonium Nitrogen, mg/L | Suspended Sediment Concentration, mg/L | Dissolved Oxygen, mg/L | Benzo(b)  fluoranthene, µg/L | Total Chromium, µg/L | Biological Oxygen Demand, mg/L |  |  | Cost, Excavation/Clearing, USD |
|  | Nitrite, mg/L |  |  | Benzo[a]  pyrene, µg/L | Dissolved Copper, µg/L | Chemical Oxygen Demand, mg/L |  |  | Cost, Structural Materials, USD |
|  | Nitrate, mg/L |  |  | Benzo[ghi]  perylene, µg/L | Total Copper, µg/L | Oil+Grease, mg/L |  |  | Cost, Install/Construct, USD |
|  | Nitrite+Nitrate, mg/L |  |  | Benzo[k]  fluoranthene, µg/L | Dissolved Iron, µg/L | Total Petroleum Hydrocarbons (Diesel), µg/L |  |  | Cost, Structural Controls, USD |
|  | Dissolved Organic Nitrogen, mg/L |  |  | Chrysene, µg/L | Total Iron, µg/L | Total Petroleum Hydrocarbons (Gasoline), µg/L |  |  | Cost, Vegetative Landscape, USD |
|  | Total Organic Nitrogen, mg/L |  |  | Fluoranthene, µg/L | Dissolved Lead, µg/L | Oxidation Reduction Potential, mV |  |  | Cost, Engineering Overhead, USD |
|  | Dissolved Phosphorous, mg/L |  |  | Fluorene, µg/L | Total Lead, µg/L |  |  |  |  |
|  | Total Phosphorous, mg/L |  |  | Naphthalene, µg/L | Dissolved Magnesium, µg/L |  |  |  |  |
|  | Suspended Phosphorous, mg/L |  |  | Nitrobenzene, µg/L | Dissolved Nickel, µg/L |  |  |  |  |
|  | Orthophosphate, mg/L |  |  | Phenanthrene, µg/L | Total Nickel, µg/L |  |  |  |  |
|  | Total Orthophosphate, mg/L |  |  | Pyrene, µg/L | Dissolved Zinc, µg/L |  |  |  |  |
|  | Particulate Organic Phosphorous, mg/L |  |  | Trihalomethanes, µg/L | Total Zinc, µg/L |  |  |  |  |

In addition to numerical summaries, visualizations such as box plots are generated to illustrate the distribution of percentage reduction across different parameters as shown in Figure 7. These visual aids enhance comprehension and facilitate the identification of trends and patterns in the data. Numerous discussions were held to determine the optimal data representation method, considering the limited dataset size. Iterations involving line graphs, log plots, multi-variable plots, scatter plots, and box plots were conducted, ultimately opting for vertical box plots due to their ability to maximize the utility of available datasets. Attempts to employ a variety of statistical tests, such as ANOVA testing, to determine conclusive relationships between GI practices were hindered by the limited size of the datasets.

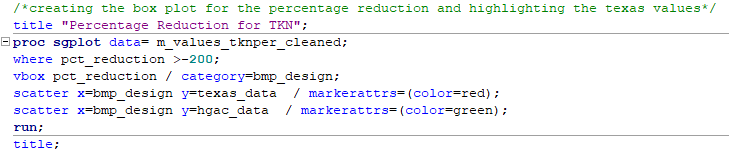


Figure 7. Screenshot of the creating vertical boxplot through SASs

Results

Despite the data limitations, the use of average, median, and box plots of GI practices yielded several findings and helped to shed light on the effectiveness of GI measures in improving water quality. Through data preparation, cleaning, analysis, and visualization, trends emerge across various parameters.

Most GI measures exhibit positive percentage reduction, indicative of water quality improvement. Notably, the Houston-Galveston region demonstrates particularly favorable results compared to other areas. That said, specific observations include negative percentage reduction values for certain GI measures in TKN, Enterococci, *E. coli*, Nitrite-Nitrate, Total Phosphate, TSS, Volumetric Flow, Nitrate, and Orthophosphate levels, underscoring the nuanced impact of different GI approaches on water quality parameters.

Figure 8 is an example of a graphical box plot. This box plot is of the percent reduction of TKN for those GI practices where TKN was collected. The average is shown as a diamond and the median as a line. Seventy-five percent of the data is represented by the box with the remaining 25% as the “tails” or “whiskers”. The level of a practice’s variability is shown by the range of the data and size of the box. Low variance would have a small box and tight tails, i.e., retention, while high variability can be seen with larger boxes and wide tails, i.e., detention (Figure 8). However, caution is warranted as many of the GI practices may have only a few individual projects represented (Table 5) and without the ability to complete a statistical test, any conclusions are not necessarily significant. Some graphs, depending on the parameter, may also distinguish the results if available for local GI percent reduction data, in green, and data from state-level practices, in red.

Before proceeding into individual GI performance, not all parameters along with their tables and graphs, will be highlighted in the sections to follow. However, all tables and graphs are provided in Appendix C. Appendix C includes graphs for the percent reduction of each parameter analyzed within individual GI practice types, providing a visual of the percent reduction from the performance table for each practice type.

## Nutrients

Key components of the analysis include evaluating nutrients such as TKN, nitrate + nitrate, nitrate, total phosphate, and orthophosphate. These were selected for analysis as their sample size was sufficient in the available datasets. Nutrients naturally occur in the environment but can be augmented by anthropogenic sources which can lead to an imbalance of nutrients and possible negative effects. If nutrients are excessive, the condition can accelerate growth of producers and may lead to deleterious effects to higher trophic levels due to poor water quality conditions.

Nitrogen is complex in nature; the removal process is even more complex as nitrogen can be reduced through sedimentation and bio assimilation or reduced through the denitrification cycle. Therefore, it would be advantageous if a BMP design couples the nutrient removal process with a design that also removes solids.

Many of the GI practices available in this analysis measured for dominant forms of nitrogen which includes TKN, nitrate + nitrite, and nitrate. Most BMP designs showed a positive influence in the reduction of these parameters.

### TKN

TKN is a measure of the amount of organic nitrogen. In the TKN assessment, bioretention and detention BMP designs indicated the highest ranges in percent reduction (Figure 8). Whereas treatment trains, swales, and retention show some of the least variability. As noted previously, there needs to be ample caution as Table 5 demonstrates, of the 45 projects listed, there are only two GI projects covering treatment trains and swales each, four represent detention basins, while there are 13 bioretention projects.



Figure 8. TKN Box Plot

Table 5. TKN Percent Reduction

| **BMP Design** | **Site Name** | **Lat** | **Long** | **Avg TKN Inflow**  **(mg/L)** | **No of Samples Inflow** | **Avg TKN Outflow (mg/L)** | **No of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 38.9720 | -94.6761 | 4.8181818 | 22 | 2.695 | 20 | 09/12/2008 | 09/15/2010 | 44.1 |
| Bioretention | BRC Site A | 35.9705 | -77.9340 | 0.7581667 | 18 | 0.5398421 | 19 | 04/12/2008 | 03/01/2009 | 28.8 |
| Bioretention | Birnamwood Dr. | 30.0723 | -95.3743 | 0.4597 | 1 | 0.3767 | 1 | 06/01/2014 | 02/01/2017 | 18.1 |
| Bioretention | Cub Run Rec Center | 38.8893 | -77.4670 | 4.8866125 | 16 | 0.935 | 10 | 09/25/2008 | 03/28/2010 | 80.9 |
| Bioretention | Greensboro bioretention-G1 | 36.1526 | -79.8716 | 2.6147368 | 19 | 4.6142857 | 14 | 07/01/2003 | 09/27/2004 | -76.5 |
| Bioretention | Greensboro bioretention-G2 | 36.1536 | -79.8716 | 1.3125 | 16 | 11.275 | 4 | 07/01/2003 | 09/27/2004 | -759 |
| Bioretention | I-95 Plaza Bioretention Cell | 39.6629 | -75.6903 | 5.719 | 10 | 2.7990909 | 11 | 04/01/2005 | 11/15/2007 | 51.1 |
| Bioretention | Louisburg bioretention-L1 | 36.1326 | -78.2221 | 1.4825 | 12 | 1.0558333 | 12 | 05/30/2004 | 12/23/2004 | 28.8 |
| Bioretention | Louisburg bioretention-L2 | 36.1336 | -78.2221 | 1.66 | 12 | 1 | 13 | 05/30/2004 | 12/23/2004 | 39.8 |
| Bioretention | Mango Creek | 35.7843 | -78.5134 | 0.5427667 | 30 | 0.6646 | 30 | 11/02/2009 | 12/02/2010 | -22.4 |
| Bioretention | OP Recycling Center | 38.9116 | -94.6798 | 11.832759 | 29 | 2.4925926 | 27 | 07/16/2010 | 09/19/2013 | 78.9 |
| Bioretention | SJC - Bio Ret 3B | 39.0243 | -94.7817 | 1.2365385 | 26 | 2.2590909 | 22 | 05/24/2012 | 09/28/2013 | -82.7 |
| Bioretention | SJC - Bio Ret 6 | 39.0233 | -94.7810 | 1.0409091 | 33 | 1.292 | 25 | 05/24/2012 | 09/28/2013 | -24.1 |
| Detention | B504-03-00 Dry Detention Basin | 29.7604 | -95.3698 | 2.8996875 | 32 | 4.789931 | 29 | 09/29/2005 | 02/06/2013 | -65.2 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 1.43 | 1 | 0.97 | 1 | 11/01/2008 | 03/01/2010 | 32.2 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 0.88 | 1 | 0.35 | 1 | 11/01/2008 | 03/01/2010 | 60.2 |
| Detention | SJC - Ext Dry | 39.0228 | -94.7818 | 1.1333333 | 3 | 1.6333333 | 6 | 07/07/2011 | 04/23/2013 | -44.1 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 3.32 | 1 | 0.37 | 1 | 07/01/2010 | 09/01/2011 | 88.9 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 0.84 | 1 | 0.55 | 1 | 07/01/2010 | 09/01/2011 | 34.5 |
| Grass Strip | Westfield Level Spreader | 35.1811 | -80.8488 | 128.37105 | 19 | 0.96 | 3 | 11/29/2005 | 01/05/2007 | 99.3 |
| Manufactured Device | HC | 39.6629 | -75.6903 | 1.825 | 4 | 1.95 | 4 | 03/29/2007 | 06/30/2007 | -6.8 |
| Manufactured Device | I-95 Plaza BaySaver | 39.6629 | -75.6903 | 10.622 | 10 | 7.497 | 10 | 11/16/2005 | 11/13/2008 | 29.4 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 39.6629 | -75.6903 | 11.056 | 10 | 11.424 | 10 | 04/08/2006 | 04/28/2008 | -3.3 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 39.6629 | -75.6903 | 5.5618182 | 11 | 2.539 | 10 | 12/13/2006 | 04/20/2009 | 54.3 |
| Manufactured Device | I-95 Plaza StormFilter | 39.6629 | -75.6903 | 7.5790909 | 11 | 7.1581818 | 11 | 04/01/2005 | 11/15/2007 | 5.6 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 39.6629 | -75.6903 | 5.4036364 | 11 | 1.161 | 10 | 04/27/2007 | 04/20/2009 | 78.5 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 39.6629 | -75.6903 | 11.179091 | 11 | 9.86 | 11 | 12/13/2006 | 04/20/2009 | 11.8 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 39.6629 | -75.6903 | 4.921 | 10 | 3.928 | 10 | 12/13/2006 | 04/20/2009 | 20.2 |
| Manufactured Device | OP Soccer Complex | 38.8820 | -94.7053 | 1.35 | 4 | 1.42 | 5 | 06/27/2011 | 11/07/2011 | -5.2 |
| Manufactured Device | SMNW HANCOR | 39.0057 | -94.7348 | 1.1216667 | 30 | 1.5867647 | 34 | 05/24/2011 | 09/28/2013 | -41.5 |
| Manufactured Device | VC | 39.0100 | -94.7363 | 2.525 | 4 | 2.25 | 4 | 05/02/2007 | 06/30/2007 | 10.9 |
| Media Filter | Highland View | 38.8556 | -94.6916 | 2.2035714 | 28 | 2.2448276 | 29 | 09/12/2008 | 11/07/2011 | -1.9 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 39.6629 | -75.6903 | 2.9054545 | 11 | 1.6995455 | 11 | 04/01/2005 | 05/12/2008 | 41.5 |
| Retention | B512-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 2.208 | 12 | 0.905 | 10 | 12/29/2010 | 02/06/2013 | 59 |
| Retention | E500-12-00 Wet Detention Basin | 29.7604 | -95.3698 | 2.4792 | 15 | 1.75 | 1 | 08/05/2008 | 01/10/2013 | 29.4 |
| Retention | E515-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 1.1672308 | 13 | 0.622375 | 8 | 07/20/2009 | 02/21/2013 | 46.7 |
| Retention | T501-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 3.9116 | 15 | 0.9453 | 10 | 01/18/2008 | 01/31/2012 | 75.8 |
| Stormwater Wetland | EIH UHCL Wetland | 29.5830 | -95.1001 | 2.23 | 1 | 3.23 | 1 | 04/01/2012 | 05/01/2012 | -44.8 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 29.7604 | -95.3698 | 1.3472 | 15 | 1.736 | 5 | 12/16/2004 | 03/13/2007 | -28.9 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 29.7604 | -95.3698 | 1.11 | 3 | 1.6114 | 5 | 01/18/2008 | 01/31/2012 | -45.2 |
| Stormwater Wetland Primary | EIH UHCL Wetland | 29.5830 | -95.1001 | 3.57 | 1 | 2.63 | 1 | 04/01/2012 | 05/01/2012 | 26.3 |
| Stormwater Wetland Secondary | EIH UHCL Wetland | 29.5840 | -95.1011 | 2.63 | 1 | 2.23 | 1 | 04/01/2012 | 05/01/2012 | 15.2 |
| Swale | Birnamwood Dr. | 30.0723 | -95.3743 | 0.5369 | 1 | 0.4597 | 1 | 06/01/2014 | 02/01/2017 | 14.4 |
| Swale | Mango Creek | 35.7843 | -78.5134 | 0.6284375 | 32 | 0.6074194 | 31 | 11/02/2009 | 12/13/2010 | 3.3 |
| Treatment Train | Birnamwood Dr. | 30.0723 | -95.3743 | 0.5369 | 1 | 0.3767 | 1 | 06/01/2014 | 02/01/2017 | 29.8 |
| Treatment Train | EIH UHCL Wetland | 29.5830 | -95.1001 | 3.57 | 1 | 3.23 | 1 | 04/01/2012 | 05/01/2012 | 9.5 |

Grass strips as a GI practice present another form of caution. Results suggest that this would be the best GI practice at 99.3 % reduction. However, having only one data point, does this example represent the tail, 25% of data or the box, 75% of data? So, what can be concluded from Figure 8? Most practices have a net positive relationship with a percent reduction of TKN greater than zero. The exceptions, when looking at the averages and medians, would appear to be detention and stormwater wetland. Possible reasons for this could include the organic biomass in a stormwater wetland, and maybe the organic reservoir in a detention basin that builds up waiting to be suspended during a storm event.

### Nitrate + Nitrite

Although showing a general trend for the reduction of nitrate + nitrite concentrations, the results among BMP designs were highly variable (Figure 9). In particular, the media filter design showed a complete increase in concentration with the median value around -80% (Table 6). However, it is important to note that the media filter design was limited to a sample size of two, though both indicating an increased concentration of the nitrate + nitrite parameter.



Figure 9. Nitrate + Nitrite Box Plot

Table 6. Nitrate + Nitrite Percent Reduction

| **BMP Design** | **Site Name** | **Lat** | **Long** | **Average Nitrate + Nitrite Inflow (mg/L)** | **No. of Samples Inflow** | **Average Nitrate + Nitrite Outflow (mg/L)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 38.9720 | -94.6761 | 0.8113636 | 22 | 4.497 | 20 | 09/12/2008 | 09/15/2010 | -454.3 |
| Bioretention | BRC Site A | 35.9705 | -77.9340 | 0.1932222 | 18 | 0.5968947 | 19 | 04/12/2008 | 03/01/2009 | -208.9 |
| Bioretention | BRC Site B | 35.9705 | -77.9340 | 0.174 | 4 | 1.1041053 | 19 | 04/12/2008 | 03/01/2009 | -534.5 |
| Bioretention | Birnamwood Dr. | 30.0723 | -95.3743 | 0.2435 | 1 | 0.3618 | 1 | 06/01/2014 | 02/01/2017 | -48.6 |
| Bioretention | Cub Run Rec Center | 38.8893 | -77.4670 | 0.6781688 | 16 | 0.273 | 10 | 09/25/2008 | 03/28/2010 | 59.7 |
| Bioretention | Greensboro bioretention-G1 | 36.1526 | -79.8716 | 0.209 | 20 | 0.27 | 14 | 07/01/2003 | 09/27/2004 | -29.2 |
| Bioretention | Greensboro bioretention-G2 | 36.1536 | -79.8716 | 0.334375 | 16 | 0.19625 | 4 | 07/01/2003 | 09/27/2004 | 41.3 |
| Bioretention | I-95 Plaza Bioretention Cell | 39.6629 | -75.6903 | 2.12 | 10 | 1.3022727 | 11 | 04/01/2005 | 11/15/2007 | 38.6 |
| Bioretention | Louisburg bioretention-L1 | 36.1326 | -78.2221 | 0.3583333 | 12 | 0.2825 | 12 | 05/30/2004 | 12/23/2004 | 21.2 |
| Bioretention | Louisburg bioretention-L2 | 36.1336 | -78.2221 | 0.53 | 12 | 0.2038462 | 13 | 05/30/2004 | 12/23/2004 | 61.5 |
| Bioretention | Mango Creek | 35.7843 | -78.5134 | 0.3356667 | 30 | 0.201 | 30 | 11/02/2009 | 12/02/2010 | 40.1 |
| Bioretention | OP Recycling Center | 38.9116 | -94.6798 | 0.6792308 | 26 | 1.2791667 | 24 | 07/16/2010 | 09/19/2013 | -88.3 |
| Bioretention | SJC - Bio Ret 3B | 39.0243 | -94.7817 | 0.62625 | 24 | 1.02 | 19 | 05/24/2012 | 09/28/2013 | -62.9 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 0.2 | 1 | 0.08 | 1 | 11/01/2008 | 03/01/2010 | 60 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 0.12 | 1 | 0.06 | 1 | 11/01/2008 | 03/01/2010 | 50 |
| Detention | SJC - Ext Dry | 39.0228 | -94.7818 | 0.57 | 3 | 0.575 | 6 | 07/07/2011 | 04/23/2013 | -0.9 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 0.17 | 1 | 0.06 | 1 | 07/01/2010 | 09/01/2011 | 64.7 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 0.34 | 1 | 0.06 | 1 | 07/01/2010 | 09/01/2011 | 82.4 |
| Grass Strip | Westfield Level Spreader | 35.1811 | -80.8488 | 6.0584211 | 19 | 0.3066667 | 3 | 11/29/2005 | 01/05/2007 | 94.9 |
| Manufactured Device | HC | 39.6629 | -75.6903 | 0.4733333 | 3 | 0.81 | 3 | 03/29/2007 | 06/30/2007 | -71.1 |
| Manufactured Device | I-95 Plaza BaySaver | 39.6629 | -75.6903 | 1.806 | 10 | 1.1475 | 10 | 11/16/2005 | 11/13/2008 | 36.5 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 39.6629 | -75.6903 | 1.978 | 10 | 1.6775 | 10 | 04/08/2006 | 04/28/2008 | 15.2 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 39.6629 | -75.6903 | 0.9118182 | 11 | 11.609 | 10 | 12/13/2006 | 04/20/2009 | -1173.2 |
| Manufactured Device | I-95 Plaza StormFilter | 39.6629 | -75.6903 | 1.6127273 | 11 | 1.9045455 | 11 | 04/01/2005 | 11/15/2007 | -18.1 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 39.6629 | -75.6903 | 1.3088636 | 11 | 0.49125 | 10 | 04/27/2007 | 04/20/2009 | 62.5 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 39.6629 | -75.6903 | 1.125 | 11 | 0.9968182 | 11 | 12/13/2006 | 04/20/2009 | 11.4 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 39.6629 | -75.6903 | 0.87 | 10 | 1.026 | 10 | 12/13/2006 | 04/20/2009 | -17.9 |
| Manufactured Device | OP Soccer Complex | 38.8820 | -94.7053 | 0.73 | 4 | 0.734 | 5 | 06/27/2011 | 11/07/2011 | -0.5 |
| Manufactured Device | SMNW HANCOR | 39.0057 | -94.7348 | 0.3314286 | 28 | 0.5429032 | 31 | 05/24/2011 | 09/28/2013 | -63.8 |
| Manufactured Device | VC | 39.0100 | -94.7363 | 0.43 | 3 | 0.3333333 | 3 | 05/02/2007 | 06/30/2007 | 22.5 |
| Media Filter | Highland View | 38.8556 | -94.6916 | 0.6221429 | 28 | 1.3617241 | 29 | 09/12/2008 | 11/07/2011 | -118.9 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 39.6629 | -75.6903 | 1.6409091 | 11 | 2.5627273 | 11 | 04/01/2005 | 05/12/2008 | -56.2 |
| Retention | B512-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 0.741 | 1 | 0.05 | 1 | 12/29/2010 | 02/06/2013 | 93.3 |
| Retention | DeBary Detention with Filtration Pond | 28.8763 | -81.2977 | 0.2291641 | 64 | 0.1180617 | 47 | 05/28/1992 | 11/30/1992 | 48.5 |
| Retention | E515-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 0.162 | 1 | 0.05 | 1 | 07/20/2009 | 02/21/2013 | 69.1 |
| Retention | T501-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 1.63 | 1 | 0.25 | 1 | 01/18/2008 | 01/31/2012 | 84.7 |
| Stormwater Wetland | EIH UHCL Wetland | 29.5830 | -95.1001 | 0.14 | 1 | 0.84 | 1 | 04/01/2012 | 05/01/2012 | -500 |
| Stormwater Wetland | Exploration Green Recreation Park Phase 1 Stormwater Wetland | 29.5633 | -95.1206 | 0.475 | 1 | 0.509 | 1 | 09/01/2019 | 07/01/2020 | -7.2 |
| Stormwater Wetland | Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | 29.6956 | -95.4001 | 2.51 | 1 | 0.642 | 1 | 09/01/2019 | 07/01/2020 | 74.4 |
| Stormwater Wetland | University of Texas Recreation Park MD Anderson Campus Wetland | 29.6929 | -95.3973 | 0.413 | 1 | 0.075 | 1 | 09/01/2019 | 07/01/2020 | 81.8 |
| Stormwater Wetland Primary | EIH UHCL Wetland | 29.5830 | -95.1001 | 13.16 | 1 | 0.67 | 1 | 04/01/2012 | 05/01/2012 | 94.9 |
| Stormwater Wetland Secondary | EIH UHCL Wetland | 29.5840 | -95.1011 | 0.67 | 1 | 0.14 | 1 | 04/01/2012 | 05/01/2012 | 79.1 |
| Swale | Birnamwood Dr. | 30.0723 | -95.3743 | 0.2142 | 1 | 0.2435 | 1 | 06/01/2014 | 02/01/2017 | -13.7 |
| Swale | Mango Creek | 35.7843 | -78.5134 | 0.4053125 | 32 | 0.3677419 | 31 | 11/02/2009 | 12/13/2010 | 9.3 |
| Treatment Train | Birnamwood Dr. | 30.0723 | -95.3743 | 0.2142 | 1 | 0.3618 | 1 | 06/01/2014 | 02/01/2017 | -68.9 |
| Treatment Train | EIH UHCL Wetland | 29.5830 | -95.1001 | 13.16 | 1 | 0.84 | 1 | 04/01/2012 | 05/01/2012 | 93.6 |

The treatment train design was also limited to a sample size of two; one project indicated a percent reduction of 93.6, while another project indicated a percent reduction of -68.9. Isolating the analysis at the various treatment processes within the train is highly encouraged to understand the impacts at each BMP design. A comprehensive approach at the treatment train level did not demonstrate anticipated performance results.

Other highly variable practices include bioretention and manufactured devices. Stormwater wetlands and detention basins appear to perform better at addressing inorganic forms of nitrogen when compared to TKN. With the exception of one project returning a net increase in the average Nitrate + Nitrite concentration, the other five stormwater wetlands projects averaged between 74% and 95% reduction. Other notables include floating wetlands and retention basins, which appear to be consistently good at reducing both inorganic (64%, -82%, 49%, -93%, respectively) and organic (35%, -90%, 29%, -76%, respectively) forms of nitrogen. The data for the floating wetland GI practice came from one study[[24]](#footnote-25). The journal article’s authors looked at the benefits of percent wetland coverage, 9% versus 18%. The authors also provided data for the detention basins collected prior to test modification. The later results were included with the detention basin data.

### Nitrate

An assessment for the reduction of nitrate was almost fully sourced from the journal article data (Table 7) and demonstrated a limited sample size. In two bioretention projects, the results were significantly different with one project showing a nitrate reduction of 69.6% and the other, an increase of -68.9% (Figure 10).



Figure 10. Nitrate Box Plot

Table 7. Nitrate Percent Reduction

| **BMP Design** | **Site Name** | **Average Nitrate Inflow  (mg/L)** | **No. of Samples Inflow** | **Average Nitrate Outflow  (mg/L)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | Birnamwood Dr. | 0.1991 | 1 | 0.3363 | 1 | . | . | -68.9 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 45,476 | 1 | 13,804 | 1 | . | . | 69.6 |
| Detention | B504-03-00 Dry Detention Basin | 0.6786645 | 31 | 0.3807552 | 29 | 09/29/2005 | 02/06/2013 | 43.9 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 91 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 1.8 | 1 | 3.85 | 1 | . | . | -113.9 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 1.8 | 1 | 6.67 | 1 | . | . | -270.6 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 1.8 | 1 | 8.76 | 1 | . | . | -386.7 |
| Manufactured Device | Bama Belle UFF | 0.5118367 | 49 | 0.345 | 50 | 07/16/2010 | 03/30/2013 | 32.6 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 81.68 | 1 | . | . | 56.5 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 53.57 | 1 | . | . | 71.5 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 84.58 | 1 | . | . | 55 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 125.98 | 1 | . | . | 33 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | 235.09 | 1 | 117.16 | 1 | . | . | 50.2 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | 235.09 | 1 | 120.35 | 1 | . | . | 48.8 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | 235.09 | 1 | 90.77 | 1 | . | . | 61.4 |
| Retention | B512-01-00 Wet Detention Basin | 5.7679091 | 11 | 0.12709 | 10 | 12/29/2010 | 02/06/2013 | 97.8 |
| Retention | E500-12-00 Wet Detention Basin | 0.4197333 | 15 | 0.311 | 1 | 08/05/2008 | 01/10/2013 | 25.9 |
| Retention | E515-01-00 Wet Detention Basin | 0.7529583 | 12 | 0.3798571 | 7 | 07/20/2009 | 02/21/2013 | 49.6 |
| Retention | T501-01-00 Wet Detention Basin | 0.7419286 | 14 | 0.78 | 9 | 01/18/2008 | 01/31/2012 | -5.1 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 0.6053 | 15 | 0.1 | 5 | 12/16/2004 | 03/13/2007 | 83.5 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 0.5993333 | 3 | 0.731 | 5 | 01/18/2008 | 01/31/2012 | -22 |
| Swale | Birnamwood Dr. | 0.2098 | 1 | 0.1991 | 1 | . | . | 5.1 |
| Treatment Train | Birnamwood Dr. | 0.2098 | 1 | 0.3363 | 1 | . | . | -60.3 |

Increases of the nutrient were also observed in green roof designs and the single treatment train design that collected nitrate data. Green roofs contributed over 100% increase, which is consistent with literature demonstrating that green roofs generally perform poorly in the first years of installation and tend to improve once vegetation stabilizes[[25]](#footnote-26). This is indicative of using engineered soil substrates where leaching out of nutrients is possible. This was similarly found in the bioretention practice in Birnamwood Dr.[[26]](#footnote-27). With this discussion of engineered soils and green roofs it is a good point to discuss the projects at the Dallas Urban Center[[27]](#footnote-28). Green roofs, permeable pavement, and rainwater harvesting tests were set up with a control and three – four test protocols. The authors used the control variable as the inflow concentration while the outflow concentration came from each test to determine the performance precent reduction. Green roofs and permeable pavement tested different material composites while the rainwater harvesting design utilized different methods of drawdown. Table 3 includes a column that describes the different methods or materials employed for green roofs, permeable pavement, and rainwater harvesting.

### Total Phosphate

Since phosphorous is a limiting nutrient in most freshwater systems, it was a key component in the analysis. The forms available and in sufficient quantities for analysis include total phosphate and orthophosphate. Phosphorous is generally highly particulate-bound due to its natural properties. It was anticipated that BMP types that target sediment and filtration removal processes would be the most favorable design. Indeed, media filter and manufactured device GI practice types appear to have effective reduction percentages for total phosphate (Figure 11). However, there were notable outliers with three of the 15 manufacturing devices averaging increases in total phosphate (Table 8). The media filter is difficult to learn from as one of the two practices averaged an increase of -306 %, while the other media filter reduced total phosphate by 56%. Here again small sample sizes limit observable conclusions. Retention and stormwater wetlands appear to be potential candidates for reducing total phosphate, though variability is a concern.



Figure 11. Total Phosphate Box Plot

Table 8. Total Phosphate Percent Reduction

| **BMP Design** | **Site Name** | **Average Total Phosphate Inflow (mg/L)** | **No. of Samples Inflow** | **Average Total Phosphate Outflow (mg/L)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 0.6063636 | 22 | 1.9505 | 20 | 09/12/2008 | 09/15/2010 | -221.7 |
| Bioretention | BRC Site A | 0.0727778 | 18 | 0.0727778 | 18 | 04/12/2008 | 03/01/2009 | 0 |
| Bioretention | BRC Site B | 0.0727778 | 18 | 0.0596316 | 19 | 04/12/2008 | 03/01/2009 | 18.1 |
| Bioretention | Charlottesville HS Biofilter | 0.2055556 | 9 | 0.1185714 | 7 | 07/10/2010 | 11/16/2010 | 42.3 |
| Bioretention | Cub Run Rec Center | 0.7884375 | 16 | 0.1265 | 10 | 09/25/2008 | 03/28/2010 | 84 |
| Bioretention | Greensboro bioretention-G1 | 0.2231579 | 19 | 0.7185714 | 14 | 07/01/2003 | 09/27/2004 | -222 |
| Bioretention | Greensboro bioretention-G2 | 0.208 | 15 | 9.1 | 4 | 07/01/2003 | 09/27/2004 | -4,275 |
| Bioretention | I-95 Plaza Bioretention Cell | 0.639 | 10 | 0.2918182 | 11 | 04/01/2005 | 11/15/2007 | 54.3 |
| Bioretention | Louisburg bioretention-L1 | 0.3275 | 12 | 0.2491667 | 12 | 05/30/2004 | 12/23/2004 | 23.9 |
| Bioretention | Louisburg bioretention-L2 | 0.15375 | 12 | 0.25 | 13 | 05/30/2004 | 12/23/2004 | -62.6 |
| Bioretention | Mango Creek | 0.115 | 30 | 0.2086667 | 30 | 11/02/2009 | 12/02/2010 | -81.4 |
| Bioretention | OP Recycling Center | 7.7737097 | 31 | 1.2182759 | 29 | 07/16/2010 | 09/19/2013 | 84.3 |
| Bioretention | SJC - Bio Ret 3B | 0.4223077 | 26 | 0.6440909 | 22 | 05/24/2012 | 09/28/2013 | -52.5 |
| Bioretention | SJC - Bio Ret 6 | 0.1843939 | 33 | 0.2788 | 25 | 05/24/2012 | 09/28/2013 | -51.2 |
| Detention | B504-03-00 Dry Detention Basin | 1.279 | 32 | 1.7173103 | 29 | 09/29/2005 | 02/06/2013 | -34.3 |
| Detention | SJC - Ext Dry | 0.1466667 | 3 | 0.2391667 | 6 | 07/07/2011 | 04/23/2013 | -63.1 |
| Grass Strip | Westfield Level Spreader | 2.9210526 | 19 | 0.9566667 | 3 | 11/29/2005 | 01/05/2007 | 67.2 |
| Manufactured Device | Bama Belle UFF | 2.0808163 | 49 | 0.9382 | 50 | 07/16/2010 | 03/30/2013 | 54.9 |
| Manufactured Device | HC | 0.17125 | 4 | 0.19125 | 4 | 03/29/2007 | 06/30/2007 | -11.7 |
| Manufactured Device | I-95 Plaza BaySaver | 1.183 | 10 | 0.666 | 10 | 11/16/2005 | 11/13/2008 | 43.7 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 1.461 | 10 | 1.368 | 10 | 04/08/2006 | 04/28/2008 | 6.4 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 0.9795455 | 11 | 0.3335 | 10 | 12/13/2006 | 04/20/2009 | 66 |
| Manufactured Device | I-95 Plaza StormFilter | 0.6481818 | 11 | 0.6481818 | 11 | 04/01/2005 | 11/15/2007 | 0 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 0.4113636 | 11 | 0.1095 | 10 | 04/27/2007 | 04/20/2009 | 73.4 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 1.3772727 | 11 | 1.0936364 | 11 | 12/13/2006 | 04/20/2009 | 20.6 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 0.3955 | 10 | 0.326 | 10 | 12/13/2006 | 04/20/2009 | 17.6 |
| Manufactured Device | OP Soccer Complex | 0.1475 | 4 | 0.238 | 5 | 06/27/2011 | 11/07/2011 | -61.4 |
| Manufactured Device | SC\_StructBMP1&2 | 0.5758824 | 17 | 0.4156471 | 17 | 04/07/2005 | 11/07/2006 | 27.8 |
| Manufactured Device | SC\_StructBMP3 | 0.2757273 | 11 | 0.2514167 | 12 | 04/07/2005 | 09/19/2006 | 8.8 |
| Manufactured Device | SC\_StructBMP4 | 1.19 | 12 | 0.7275 | 12 | 08/27/2005 | 09/19/2006 | 38.9 |
| Manufactured Device | SMNW HANCOR | 0.104 | 30 | 0.1498529 | 34 | 05/24/2011 | 09/28/2013 | -44.1 |
| Manufactured Device | VC | 0.3825 | 4 | 0.24125 | 4 | 05/02/2007 | 06/30/2007 | 36.9 |
| Media Filter | Highland View | 0.1516071 | 28 | 0.6148276 | 29 | 09/12/2008 | 11/07/2011 | -305.5 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 0.2586364 | 11 | 0.1140909 | 11 | 04/01/2005 | 05/12/2008 | 55.9 |
| Retention | B512-01-00 Wet Detention Basin | 4.0017667 | 12 | 0.2813 | 11 | 12/29/2010 | 02/06/2013 | 93 |
| Retention | DeBary Detention with Filtration Pond | 1.0218281 | 64 | 0.053 | 47 | 05/28/1992 | 11/30/1992 | 94.8 |
| Retention | E500-12-00 Wet Detention Basin | 1.6120667 | 15 | 1.69 | 1 | 08/05/2008 | 01/10/2013 | -4.8 |
| Retention | E515-01-00 Wet Detention Basin | 0.3632308 | 13 | 1.1610625 | 8 | 07/20/2009 | 02/21/2013 | -219.6 |
| Retention | T501-01-00 Wet Detention Basin | 1.9312 | 15 | 0.6946 | 10 | 01/18/2008 | 01/31/2012 | 64 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 1.379 | 15 | 0.349 | 5 | 12/16/2004 | 03/13/2007 | 74.7 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 1.4933333 | 3 | 1.8646 | 5 | 01/18/2008 | 01/31/2012 | -24.9 |
| Swale | Mango Creek | 0.160625 | 32 | 0.1554839 | 31 | 11/02/2009 | 12/13/2010 | 3.2 |

### Ortho Phosphate

A review of the ortho phosphate reduction capabilities of GI practices is overly positive. Variability is a concern, but except for permeable pavement and treatment train, most of the variability is contained on the side of reducing ortho phosphate (Figure 12). Looking at the variability, there are instances of extreme outliers (Table 9). Bioretention includes several examples of high increases in ortho phosphate, particularly one value of -4,671%. Permeable pavers also demonstrate increases in ortho phosphate. Finally, green roofs, as noted previously, can contribute nutrient loads, particularly early on while the media is newly installed. Green roofs performed poorly with ortho phosphate with percent reduction values of -269, -285, and   
-321 (Table 9).



Figure 12. Ortho Phosphate Box Plot

Table 9. Ortho Phosphate Percent Reduction

| **BMP Design** | **Site Name** | **Average Ortho Phosphate Inflow (mg/L)** | **No. of Samples Inflow** | **Average Ortho Phosphate Outflow (mg/L)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 35.014444 | 18 | 5.23625 | 16 | 09/12/2008 | 09/15/2010 | 85 |
| Bioretention | BRC Site A | 0.0270625 | 16 | 0.0292353 | 17 | 04/12/2008 | 03/01/2009 | -8 |
| Bioretention | BRC Site B | 0.0270625 | 16 | 0.0284706 | 17 | 04/12/2008 | 03/01/2009 | -5.2 |
| Bioretention | Birnamwood Dr. | 0.0639 | 1 | 0.0629 | 1 | . | . | 1.6 |
| Bioretention | Cub Run Rec Center | 0.1864133 | 15 | 1.1035 | 10 | 09/25/2008 | 03/28/2010 | -492 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 10351 | 1 | 565 | 1 | . | . | 94.5 |
| Bioretention | Greensboro bioretention-G1 | 0.0647368 | 19 | 0.6107143 | 14 | 07/01/2003 | 09/27/2004 | -843.4 |
| Bioretention | Greensboro bioretention-G2 | 0.171875 | 16 | 8.2 | 4 | 07/01/2003 | 09/27/2004 | -4,670.9 |
| Bioretention | I-95 Plaza Bioretention Cell | 0.4282 | 10 | 0.1718182 | 11 | 04/01/2005 | 11/15/2007 | 59.9 |
| Bioretention | Louisburg bioretention-L1 | 0.2016667 | 12 | 0.1716667 | 12 | 05/30/2004 | 12/23/2004 | 14.9 |
| Bioretention | Louisburg bioretention-L2 | 0.0141667 | 12 | 0.1823077 | 13 | 05/30/2004 | 12/23/2004 | -1,186.9 |
| Bioretention | OP Recycling Center | 0.0982609 | 23 | 0.3977273 | 22 | 07/16/2010 | 09/19/2013 | -304.8 |
| Bioretention | SJC - Bio Ret 3B | 0.0971429 | 21 | 0.4888235 | 17 | 05/24/2012 | 09/28/2013 | -403.2 |
| Detention | B504-03-00 Dry Detention Basin | 0.9821406 | 32 | 0.7430517 | 29 | 09/29/2005 | 02/06/2013 | 24.3 |
| Detention | Floating Wetland Retrofit North Carolina | 0.14 | 1 | 0.12 | 1 | . | . | 14.3 |
| Detention | Floating Wetland Retrofit North Carolina | 0.13 | 1 | 0.07 | 1 | . | . | 46.2 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 0.24 | 1 | 0.02 | 1 | . | . | 91.7 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 0.12 | 1 | 0.07 | 1 | . | . | 41.7 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 0.48 | 1 | 1.85 | 1 | . | . | -285.4 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 0.48 | 1 | 2.02 | 1 | . | . | -320.8 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 0.48 | 1 | 1.77 | 1 | . | . | -268.8 |
| Manufactured Device | Bama Belle UFF | 0.3811111 | 9 | 0.323 | 10 | 07/16/2010 | 03/30/2013 | 15.2 |
| Manufactured Device | HC | 0.025 | 3 | 0.0333333 | 3 | 03/29/2007 | 06/30/2007 | -33.3 |
| Manufactured Device | I-95 Plaza BaySaver | 0.39 | 10 | 0.1885 | 10 | 11/16/2005 | 11/13/2008 | 51.7 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 1.156 | 10 | 0.858 | 10 | 04/08/2006 | 04/28/2008 | 25.8 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 0.2463636 | 11 | 0.135 | 10 | 12/13/2006 | 04/20/2009 | 45.2 |
| Manufactured Device | I-95 Plaza StormFilter | 0.2445455 | 11 | 0.1777273 | 11 | 04/01/2005 | 11/15/2007 | 27.3 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 0.3418182 | 11 | 0.075 | 8 | 04/27/2007 | 04/20/2009 | 78.1 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 0.545 | 11 | 0.3454545 | 11 | 12/13/2006 | 04/20/2009 | 36.6 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 0.137 | 10 | 0.088 | 10 | 12/13/2006 | 04/20/2009 | 35.8 |
| Manufactured Device | OP Soccer Complex | 0.045 | 4 | 0.07 | 5 | 06/27/2011 | 11/07/2011 | -55.6 |
| Manufactured Device | SMNW HANCOR | 1.304 | 25 | 1.1728571 | 28 | 05/24/2011 | 09/28/2013 | 10.1 |
| Manufactured Device | VC | 0.1133333 | 3 | 0.07 | 3 | 05/02/2007 | 06/30/2007 | 38.2 |
| Media Filter | Highland View | 0.0460526 | 19 | 0.41325 | 20 | 09/12/2008 | 11/07/2011 | -797.3 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 0.1095455 | 11 | 0.0940909 | 11 | 04/01/2005 | 05/12/2008 | 14.1 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 0.24 | 1 | . | . | 60 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 17.16 | 1 | . | . | -2760 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 1.03 | 1 | . | . | -71.7 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 6.86 | 1 | . | . | -1,043.3 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | 94.26 | 1 | 20.07 | 1 | . | . | 78.7 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | 94.26 | 1 | 44.71 | 1 | . | . | 52.6 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | 94.26 | 1 | 5.05 | 1 | . | . | 94.6 |
| Retention | B512-01-00 Wet Detention Basin | 0.598675 | 12 | 0.3822727 | 11 | 12/29/2010 | 02/06/2013 | 36.1 |
| Retention | DeBary Detention with Filtration Pond | 0.0517228 | 57 | 0.0769149 | 47 | 05/28/1992 | 11/30/1992 | -48.7 |
| Retention | E515-01-00 Wet Detention Basin | 0.2920833 | 12 | 0.19225 | 8 | 07/20/2009 | 02/21/2013 | 34.2 |
| Retention | T501-01-00 Wet Detention Basin | 1.2722667 | 15 | 0.4356 | 10 | 01/18/2008 | 01/31/2012 | 65.8 |
| Stormwater Wetland | EIH UHCL Wetland | 0.22 | 1 | 0.37 | 1 | . | . | -68.2 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 1.6736667 | 15 | 0.2656 | 5 | 12/16/2004 | 03/13/2007 | 84.1 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 3.2966667 | 3 | 2.846 | 5 | 01/18/2008 | 01/31/2012 | 13.7 |
| Stormwater Wetland Primary | EIH UHCL Wetland | 2.64 | 1 | 0.38 | 1 | . | . | 85.6 |
| Stormwater Wetland Secondary | EIH UHCL Wetland | 0.38 | 1 | 0.22 | 1 | . | . | 42.1 |
| Swale | Birnamwood Dr. | 0.0429 | 1 | 0.0639 | 1 | . | . | -49 |
| Treatment Train | Birnamwood Dr. | 0.0429 | 1 | 0.0629 | 1 | . | . | -46.6 |
| Treatment Train | EIH UHCL Wetland | 2.64 | 1 | 0.37 | 1 | . | . | 86 |

## Pathogens

The authors previously noted that the Houston region’s largest water quality impairment is related to pathogens and their health risk to humans via contact recreation. GI practices that demonstrate reductive capacity would seemingly be a benefit for this region. Two bacteria indicator species, Enterococci and *E. coli,* aretraditional indictive measures of pathogen presence in waters.

Enterococci is used in marine and brackish waters. A review of available studies returned few examples of GI practices studied, and as such are not reviewed here. Box plot graphs and the percentage reduction table for the few studies identified can be found in Appendix C.

GI practices studied to evaluate the *E. coli* removal effectiveness was more fulsome and robust. Nine GI practice types were available for review. The results are more varied among the nine types (Figure 13). Bioretention and stormwater wetlands demonstrated the greatest variability. In the case of stormwater wetlands, a couple of reduction values were removed from the graph   
(-2,273% and -645.1%) where two of the six stormwater wetlands performed poorly (Table 10). Their removal was to make the graph more readable. Appendix C contains a separate graph with the extreme values included. This was also done for similar cases with the other parameters.



Figure 13. E. coli Box Plot

Table 10. E.coli Percent Reduction

| **BMP Design** | **Site Name** | **Average *E. coli* Inflow (cfu/100mL)** | **No. of Samples Inflow** | **Average *E. coli* Outflow (cfu/100mL)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | Birnamwood Dr. | 3,154.5 | 1 | 4,729.1 | 1 | . | . | -49.9 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 31,855,184 | 1 | 11,489,962 | 1 | . | . | 63.9 |
| Detention | B504-03-00 Dry Detention Basin | 34,981.737 | 19 | 5,990.7368 | 19 | 09/29/2005 | 02/06/2013 | 82.9 |
| Grass Strip | Westfield Level Spreader | 2,200.4833 | 6 | 2,400 | 1 | 11/29/2005 | 01/05/2007 | -9.1 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 104 | 1 | 346 | 1 | . | . | -232.7 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 104 | 1 | 1,149 | 1 | . | . | -1,004.8 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 104 | 1 | 715 | 1 | . | . | -587.5 |
| Manufactured Device | Bama Belle UFF | 6,063.8936 | 47 | 3,432.2766 | 47 | 07/16/2010 | 03/30/2013 | 43.4 |
| Manufactured Device | SC\_StructBMP1&2 | 5,953.7273 | 11 | 7,408.0833 | 12 | 04/07/2005 | 11/07/2006 | -24.4 |
| Manufactured Device | SC\_StructBMP3 | 5,801.8182 | 11 | 4,824.5455 | 11 | 04/07/2005 | 09/19/2006 | 16.8 |
| Manufactured Device | SC\_StructBMP4 | 8,572.2727 | 11 | 4,139 | 11 | 08/27/2005 | 09/19/2006 | 51.7 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 20,600 | 1 | 18,500 | 1 | . | . | 10.2 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 20,600 | 1 | 10,597 | 1 | . | . | 48.6 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 20,600 | 1 | 8,842 | 1 | . | . | 57.1 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 20,600 | 1 | 1,121 | 1 | . | . | 94.6 |
| Retention | B512-01-00 Wet Detention Basin | 39,035.889 | 9 | 1,296.875 | 8 | 12/29/2010 | 02/06/2013 | 96.7 |
| Retention | E500-12-00 Wet Detention Basin | 52,011.667 | 9 | 1,743.3333 | 3 | 08/05/2008 | 01/10/2013 | 96.6 |
| Retention | E515-01-00 Wet Detention Basin | 28,324.045 | 11 | 2,192.1667 | 9 | 07/20/2009 | 02/21/2013 | 92.3 |
| Retention | NCSU Wilmington | 15,670.143 | 21 | 12,621.286 | 21 | 01/17/2008 | 02/09/2010 | 19.5 |
| Retention | P518-02-00 Halls Bayou Regional Detention Basin | 24,292 | 1 | 473 | 1 | 02/06/2013 | 02/06/2013 | 98.1 |
| Retention | T501-01-00 Wet Detention Basin | 157,025.8 | 15 | 34,710.513 | 8 | 01/18/2008 | 01/31/2012 | 77.9 |
| Stormwater Wetland | Brays Bayou Stormwater Wetland | 61,229 | 1 | 278 | 1 | . | . | 99.5 |
| Stormwater Wetland | Exploration Green Recreation Park Phase 1 Stormwater Wetland | 8,743.75 | 1 | 7,779.375 | 1 | . | . | 11 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 4,013.5778 | 9 | 762.3 | 3 | 12/16/2004 | 03/13/2007 | 81 |
| Stormwater Wetland | Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | 444.8 | 1 | 3314 | 1 | . | . | -645.1 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 434,565.4 | 5 | 59,534.467 | 15 | 01/18/2008 | 01/31/2012 | 86.3 |
| Stormwater Wetland | University of Texas Recreation Park MD Anderson Campus Wetland | 27 | 1 | 640.7 | 1 | . | . | -2,273 |
| Swale | Birnamwood Dr. | 2,743 | 1 | 3,154.5 | 1 | . | . | -15 |
| Treatment Train | Birnamwood Dr. | 2,743 | 1 | 4,729.1 | 1 | . | . | -72.4 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 81 |

Caution again should be noted with the conclusions, as the small stormwater wetland sample size and the fact that the four stormwater wetlands presented here, had a net positive percent reduction, 100%, 86%, 81%, and 11%, respectively. Detention ponds, permeable pavement, and retention ponds also have a net positive reduction regarding the *E. coli* parameter.

## Total Suspended Solids

Total Suspended Solids, TSS can impact aquatic ecosystems as they can accumulate over important bed materials used by aquatic species, including oyster reefs, submerged aquatic vegetation, and sandy/rocky substrates. TSS can also harbor metals, pathogens, and other harmful organics that adsorb to the material. The authors decided not to review metals, impart because of the limited data, but also in that most metals would be expected to follow a similar pattern to TSS. GI practices that can filter out or allow for settling can then play an important role in managing TSS.

A review of the percent reduction results suggests most of the 13 GI practice types analyzed perform beneficially in reducing TSS (Figure 14), with the lone exception being green roofs. This is an expected result in that there should be very little TSS in rainwater. It was expected that as the rainwater flows through the soil matrix of the green roofs, that the water that outflows would increase the TSS load.



Figure 14. TSS Box Plot

Table 11. TSS Percent Reduction

| **BMP Design** | **Site Name** | **Average TSS Inflow  (mg/L)** | **No. of Samples Inflow** | **Average TSS Outflow**  **(mg/L)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 171.35417 | 24 | 33.9 | 22 | 09/12/2008 | 09/15/2010 | 80.2 |
| Bioretention | BRC Site A | 25.333333 | 18 | 10.947368 | 19 | 04/12/2008 | 03/01/2009 | 56.8 |
| Bioretention | BRC Site B | 25.333333 | 18 | 8.8947368 | 19 | 04/12/2008 | 03/01/2009 | 64.9 |
| Bioretention | Birnamwood Dr. | 9.83 | 1 | 6.79 | 1 | . | . | 30.9 |
| Bioretention | Charlottesville HS Biofilter | 30.72 | 10 | 8.5771429 | 7 | 07/10/2010 | 11/16/2010 | 72.1 |
| Bioretention | Cub Run Rec Center | 291.50596 | 16 | 13.6 | 10 | 09/25/2008 | 03/28/2010 | 95.3 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 3214417 | 1 | 307276 | 1 | . | . | 90.4 |
| Bioretention | I-95 Plaza Bioretention Cell | 288.1 | 10 | 90.181818 | 11 | 04/01/2005 | 11/15/2007 | 68.7 |
| Bioretention | Mango Creek | 48.5 | 30 | 41.1 | 30 | 11/02/2009 | 12/02/2010 | 15.3 |
| Bioretention | OP Recycling Center | 118.06452 | 31 | 25.172414 | 29 | 07/16/2010 | 09/19/2013 | 78.7 |
| Bioretention | SJC - Bio Ret 3B | 55 | 26 | 9.9545455 | 22 | 05/24/2012 | 09/28/2013 | 81.9 |
| Bioretention | SJC - Bio Ret 6 | 35.570645 | 31 | 8.5652174 | 23 | 05/24/2012 | 09/28/2013 | 75.9 |
| Detention | B504-03-00 Dry Detention Basin | 41.061563 | 32 | 26.567931 | 29 | 09/29/2005 | 02/06/2013 | 35.3 |
| Detention | Floating Wetland Retrofit North Carolina | 354 | 1 | 230 | 1 | . | . | 35 |
| Detention | Floating Wetland Retrofit North Carolina | 216 | 1 | 24 | 1 | . | . | 88.9 |
| Detention | SJC - Ext Dry | 30.75 | 4 | 36.166667 | 6 | 07/07/2011 | 04/23/2013 | -17.6 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 18 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 252 | 1 | 13 | 1 | . | . | 94.8 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 101 | 1 | 22 | 1 | . | . | 78.2 |
| Grass Strip | Westfield Level Spreader | 67.944444 | 18 | 30.333333 | 3 | 11/29/2005 | 01/05/2007 | 55.4 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 21.56 | 1 | 49.04 | 1 | . | . | -127.5 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 21.56 | 1 | 31.88 | 1 | . | . | -47.9 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 21.56 | 1 | 40.52 | 1 | . | . | -87.9 |
| Manufactured Device | Bama Belle UFF | 127.57143 | 49 | 24.7 | 50 | 07/16/2010 | 03/30/2013 | 80.6 |
| Manufactured Device | HC | 110 | 4 | 105.25 | 4 | 03/29/2007 | 06/30/2007 | 4.3 |
| Manufactured Device | I-95 Plaza BaySaver | 289.7 | 10 | 176.3 | 10 | 11/16/2005 | 11/13/2008 | 39.1 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 185.4 | 10 | 159.3 | 10 | 04/08/2006 | 04/28/2008 | 14.1 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 312.27273 | 11 | 134.6 | 10 | 12/13/2006 | 04/20/2009 | 56.9 |
| Manufactured Device | I-95 Plaza StormFilter | 151.90909 | 11 | 110 | 11 | 04/01/2005 | 11/15/2007 | 27.6 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 215.27273 | 11 | 29.4 | 10 | 04/27/2007 | 04/20/2009 | 86.3 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 421.54545 | 11 | 118.81818 | 11 | 12/13/2006 | 04/20/2009 | 71.8 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 568.2 | 10 | 80 | 10 | 12/13/2006 | 04/20/2009 | 85.9 |
| Manufactured Device | OP Soccer Complex | 53 | 4 | 79.8 | 5 | 06/27/2011 | 11/07/2011 | -50.6 |
| Manufactured Device | SC\_StructBMP1&2 | 163.58824 | 17 | 56.264706 | 17 | 04/07/2005 | 11/07/2006 | 65.6 |
| Manufactured Device | SC\_StructBMP3 | 78.583333 | 12 | 51.666667 | 12 | 04/07/2005 | 09/19/2006 | 34.3 |
| Manufactured Device | SC\_StructBMP4 | 132.41667 | 12 | 56.25 | 12 | 08/27/2005 | 09/19/2006 | 57.5 |
| Manufactured Device | SMNW HANCOR | 68.467742 | 31 | 45.764706 | 34 | 05/24/2011 | 09/28/2013 | 33.2 |
| Manufactured Device | VC | 104 | 4 | 48 | 4 | 05/02/2007 | 06/30/2007 | 53.8 |
| Media Filter | Highland View | 42.774194 | 31 | 18.625 | 32 | 09/12/2008 | 11/07/2011 | 56.5 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 141.31818 | 11 | 24.318182 | 11 | 04/01/2005 | 05/12/2008 | 82.8 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 27736 | 1 | 2180 | 1 | . | . | 92.1 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 27,736 | 1 | 1,773 | 1 | . | . | 93.6 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 27,736 | 1 | 3,524 | 1 | . | . | 87.3 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 27,736 | 1 | 3,825 | 1 | . | . | 86.2 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | 3,226.96 | 1 | 1,558.27 | 1 | . | . | 51.7 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | 3,226.96 | 1 | 3,266.01 | 1 | . | . | -1.2 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | 3,226.96 | 1 | 3,160.55 | 1 | . | . | 2.1 |
| Retention | B512-01-00 Wet Detention Basin | 161.7525 | 12 | 440.36364 | 11 | 12/29/2010 | 02/06/2013 | -172.2 |
| Retention | DeBary Detention with Filtration Pond | 47.185714 | 63 | 0.9222826 | 46 | 05/28/1992 | 11/30/1992 | 98 |
| Retention | E500-12-00 Wet Detention Basin | 61.442857 | 14 | 110 | 1 | 08/05/2008 | 01/10/2013 | -79 |
| Retention | E515-01-00 Wet Detention Basin | 244.5 | 13 | 14.885714 | 7 | 07/20/2009 | 02/21/2013 | 93.9 |
| Retention | P518-02-00 Halls Bayou Regional Detention Basin | 50.4 | 1 | 57.7 | 1 | 02/06/2013 | 02/06/2013 | -14.5 |
| Retention | T501-01-00 Wet Detention Basin | 715.01333 | 15 | 165.83 | 10 | 01/18/2008 | 01/31/2012 | 76.8 |
| Stormwater Wetland | Exploration Green Recreation Park Phase 1 Stormwater Wetland | 50.1875 | 1 | 19.8375 | 1 | . | . | 60.5 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 308.75 | 15 | 11.12 | 5 | 12/16/2004 | 03/13/2007 | 96.4 |
| Stormwater Wetland | Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | 3314 | 1 | 17.6 | 1 | . | . | 99.5 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 1,597.5 | 3 | 738.84 | 5 | 01/18/2008 | 01/31/2012 | 53.8 |
| Stormwater Wetland | University of Texas Recreation Park MD Anderson Campus Wetland | 5.9 | 1 | 3.8 | 1 | . | . | 35.6 |
| Swale | Birnamwood Dr. | 50.47 | 1 | 9.83 | 1 | . | . | 80.5 |
| Swale | Mango Creek | 63.052581 | 31 | 38 | 30 | 11/02/2009 | 12/13/2010 | 39.7 |
| Treatment Train | Birnamwood Dr. | 50.47 | 1 | 6.79 | 1 | . | . | 86.5 |

Retention ponds had the largest variability among all GI practices with three studies returning increased TSS averages with percent reductions of -172%, -79%, and -15% respectively. That said, two of the remaining three retention pond studies had positive percent reductions of 98% and 94%, with the final retention pond averaging a percent reduction of 77%.

## Volume Reduction

The principal function of GI practices is to use them in stormwater management as previously noted with the hydrograph (Figure 1). The Texas Water Development Board, drainage districts, municipalities, flood plain managers, and other organizations tapped to address stormwater flooding have traditionally focused on detention and retention ponds as key practices in reducing the impacts of flooding by reducing stormwater quantity. You would expect to see that in the results. Curiously, bioretention and detention were highly variable with some negative results (Figure 15). Four of the 13 bioretention studies saw a net increase in flow (Table 12). It was noted in the Birnamwood Dr. study that the bioretention cell was undersized and did not retain sufficient runoff flows, resulting in a number of mixed results for other parameters[[28]](#footnote-29). John S. Jacob and Marissa Sipocz stated that to treat 90% of storms while accounting for the amount of precipitation over the Gulf Coast region, requires a minimum of two days retention and should be sized “between 10 and 15% of the contributing watershed.”[[29]](#footnote-30)



Figure 15. Volumetric Flow Box Plot

Table 12. Volumetric flow Percent Reduction

| **BMP Design** | **Site Name** | **Average Volume Inflow**  **(m3)** | **No. of Samples Inflow** | **Average Volume Outflow (m3)** | **No. of Samples Outflow** | **Start Date** | **End Date** | **% Reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 22.760301 | 24 | 46.081444 | 9 | 09/12/2008 | 09/15/2010 | -102.5 |
| Bioretention | Charlottesville HS Biofilter | 92.682133 | 15 | 27.5642 | 15 | 07/10/2010 | 11/16/2010 | 70.3 |
| Bioretention | Greensboro bioretention-G1 | 46.911719 | 57 | 5.2599649 | 57 | 07/01/2003 | 09/27/2004 | 88.8 |
| Bioretention | Greensboro bioretention-G2 | 41.137985 | 65 | 3.9278 | 5 | 07/01/2003 | 09/27/2004 | 90.5 |
| Bioretention | I-95 Plaza Bioretention Cell | 7.0169146 | 10 | 7.0169146 | 10 | 04/01/2005 | 11/15/2007 | 0 |
| Bioretention | Louisburg bioretention-L1 | 78.5401 | 30 | 37.879933 | 30 | 05/30/2004 | 12/23/2004 | 51.8 |
| Bioretention | Louisburg bioretention-L2 | 40.6451 | 30 | 26.974067 | 30 | 05/30/2004 | 12/23/2004 | 33.6 |
| Bioretention | Mango Creek | 48.46848 | 44 | 63.301744 | 54 | 11/02/2009 | 12/02/2010 | -30.6 |
| Bioretention | OP Recycling Center | 26.742606 | 32 | 50.419 | 32 | 07/16/2010 | 09/19/2013 | -88.5 |
| Bioretention | SJC - Bio Ret 3B | 44.496154 | 26 | 79.553889 | 18 | 05/24/2012 | 09/28/2013 | -78.8 |
| Bioretention | SJC - Bio Ret 6 | 41.114118 | 34 | 37.95016 | 25 | 05/24/2012 | 09/28/2013 | 7.7 |
| Bioretention | Birnamwood Dr. | . | . | . | . | 06/01/2014 | 02/01/2017 | 2 |
| Bioretention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 09/01/2013 | 01/01/2015 | 49 |
| Detention | SJC - Ext Dry | 108.296 | 4 | 165.7715 | 6 | 07/07/2011 | 04/23/2013 | -53.1 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 62 |
| Grass Strip | Westfield Level Spreader | 1.4873478 | 23 | 0.2286522 | 23 | 11/29/2005 | 01/05/2007 | 84.6 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 68 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 78 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 79 |
| Manufactured Device | HC | 370.063 | 1 | 105.05733 | 3 | 03/29/2007 | 06/30/2007 | 71.6 |
| Manufactured Device | I-95 Plaza BaySaver | 176.94348 | 10 | 151.77263 | 10 | 11/16/2005 | 11/13/2008 | 14.2 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 37.834139 | 10 | 37.834139 | 10 | 04/08/2006 | 04/28/2008 | 0 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 38.77606 | 11 | 39.509724 | 11 | 12/13/2006 | 04/20/2009 | -1.9 |
| Manufactured Device | I-95 Plaza StormFilter | 96.837489 | 11 | 91.818405 | 11 | 04/01/2005 | 11/15/2007 | 5.2 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 26.113281 | 11 | 26.113281 | 11 | 04/27/2007 | 04/20/2009 | 0 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 28.067143 | 11 | 28.067143 | 11 | 12/13/2006 | 04/20/2009 | 0 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 45.423054 | 10 | 45.423054 | 10 | 12/13/2006 | 04/20/2009 | 0 |
| Manufactured Device | OP Soccer Complex | 915.34675 | 4 | 525.525 | 4 | 06/27/2011 | 11/07/2011 | 42.6 |
| Manufactured Device | SMNW HANCOR | 534.50406 | 32 | 541.88621 | 34 | 05/24/2011 | 09/28/2013 | -1.4 |
| Media Filter | Highland View | 38.124585 | 31 | 28.20525 | 8 | 09/12/2008 | 11/07/2011 | 26 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 109.23867 | 11 | 109.23867 | 11 | 04/01/2005 | 05/12/2008 | 0 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 79 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 85 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 81 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 73 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 12/01/2012 | 08/01/2012 | 43 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 12/01/2013 | 08/01/2013 | 19 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 12/01/2014 | 08/01/2014 | 14 |
| Retention | DeBary Detention with Filtration Pond | 579.21654 | 31 | 579.4663 | 41 | 05/28/1992 | 11/30/1992 | 0 |
| Swale | Birnamwood Dr. | . | . | . | . | 06/01/2014 | 02/01/2017 | 13 |
| Treatment Train | Birnamwood Dr. | . | . | . | . | 06/01/2014 | 02/01/2017 | 14 |

# Outreach

## GI Workshop

As part of this project the authors hosted a workshop on February 23, 2024, to report on the results (Figure 16). The workshop covered all aspects of GI. Attendees were given an overview of GI, two local projects currently underway in the region, and a review of the cost and benefits of GI. This project was highlighted, and results were presented. The workshop’s program and individual presentations can be accessed under Past Workshops/Stormwater at [Clean Waters Initiative Workshops | Houston-Galveston Area Council (H-GAC)](https://www.h-gac.com/clean-water-initiative-workshops).



Figure 16. GI Workshop, February 23, 2024

## Breakout Session

The second part of the workshop was an individual breakout session. The 35 attendees were asked to sit at four tables, one was virtual (Figure 17). Moderators were given prompted questions to encourage discussion, but attendees were welcomed to consider other questions related to GI. A summary of the attendees’ thoughts on GI and common themes are described below.

Attendees were receptive to GI but noted that for some of them their supervisors were more cautious and see the practices as costly and potentially ineffective. It was also noted that GI is site specific, and a site’s individual characteristics may not benefit from GI.

To overcome this attitude, attendees suggested greater access to data supporting GI use, receptiveness by residents and communities, and increased incentives are needed. It was suggested that more workshops and outreach should be conducted, particularly to target audiences. Higher visibility and signage should be encouraged at successful GI demonstration and commercial sites to better promote GI. Proponents of GI should highlight the benefits of GI. More demonstration sites with active monitoring are warranted. Appendix B provides more thoughts on the breakout session.



Figure 17. Breakout Session, GI Workshop

# Discussion and Conclusions

The project team set out with an initial goal of preparing a priority GI list. To that end, there was not one practice that stood out as sufficiently addressing all parameters of concern. Based on the lack of data and inability to perform statistical analyses to express any form of certainty, the team could not prepare a defined priority GI list. The results suggest a more nuanced expectation for water quality improvement. Within each practice, variability produced GI examples demonstrating the practice did not work in all instances. Caution should be taken not to assume the designed GI practice will meet end goal expectations. It was noted from the start that GI is not a solution for all situations. As seen throughout this report, more data is needed to clearly show GI practices work.

That said, this report’s analysis highlights overall positive impacts of GI practices on water quality improvement. While further data collection and analyses are warranted to better validate these observations and provide more robust insights for effective decision-making, some reasonable conclusions can be drawn. All GI practice types reviewed for this report demonstrated some ability to reduce water quality parameters.

In the resource community it is common to preach the need for local data to overcome the concerns that GI practices, while demonstrated to work elsewhere, will not work within our local conditions. This report allows the reader to observe how local data, limited though it is, performs against a broader set of out-of-region data. The teams’ general take is that nativist data stacks up well. A second observation is that GI practices that focus on storage capacity and holding time fare well across most parameters. A review of retention pond and stormwater wetland performance demonstrates this result. Both practices stand out for their ability to reduce most water quality parameters. Sizing in GI design should be a major component. Several journal authors noted that feature size compared with flow volume appeared to influence results.

A greater study on the effectiveness of bioretention and detention basins is recommended. Their variability across most parameters is potentially concerning for their practical use. Does this relate back to the basins simply being undersized, in the case of bioretention, or lacking sufficient holding time, in the case of detention basins?

Two other practices stand out for additional research. In looking at capacity and retention, one thought would be that a treatment train using different GI practices in series would be the best. That said, there were only a couple of examples to review. Neither performed well. On the other hand, the single journal article that provided data on floating wetlands showed their promise. Here again, we need more data to understand how to incorporate this practice. This region contains many retention ponds used to manage stormwater quantity but lack wetland plant margins. Retrofitting the ponds to incorporate wetland plants in many cases is not possible due to a lack of available space, depth, and other concerns. A floating wetlands design may present a solution.

Finally, using GI practices as part of a comprehensive stormwater management program is supported by the data analyzed. All GI practices reviewed reduced the peak volume of flow. Practices such as green roofs and rainwater harvesting, while not expected to perform well against water quality parameters like *E.coli*, can play a role in intercepting rainfall and provide a measure of storage capacity.

H-GAC plans to continue to encourage GI adoption through its many programs, including watershed-based planning and implementation. Outreach conducted as part of this review showed the need for more targeted technical assistance and education on GI, its uses, benefits, costs, and maintenance. Hesitancy on the part of certain groups still prevents wide scale GI implementation. In addition to focusing outreach targeting decision-makers and community organizations, additional GI demonstration projects and performance data are necessary to fully document GI water quality benefits. As part of any outreach program, successful projects need to be highlighted and an increase in project visibility is recommended.

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# Appendix A Project Committee Reports

Two project committee meeting were held during the project. Both summaries are presented below which follow each meeting’s agenda.

**Green Infrastructure Project**

Tuesday, March 21, 2023

1:00 P.M.- 3:00 P.M.

**Summary**

1:00 Welcome and Introductions

Attendees: Ryan Bare (HARC), Roberto Vega (HCFCD), Robert Snoza (HCFCD), Jenny Wrast-Oakley (UHCL), George Guillen (UHCL), Danielle Cioce (HC), Lam Tran (COH)

Project Staff: Christian Rines (TCEQ), Jessie Casillas (H-GAC), Rachel Windham (H-GAC), Steven Johnston (H-GAC)

1:10 Project Overview & Updates

Mr. Johnston provided a review of the project. He presented the project’s purpose and goals. This includes the collection and analysis of local green infrastructure practice efficacy data along with other related data. He noted the performance data will be augmented by other projects from around the state and US. Analysis, along with recommendations made from the committee will be used to prepare a designated priority GI list. Outreach via one-on-one meetings and a workshop will be used to share the list.

1:30 Data Review and Discussion:

* HCFCD Stormwater Database – Jessica Casillas
  + Ms. Casillas provided a review of her efforts to gather data from the Harris County Flood Control District (HCFCD). She noted the difficulty in determining if everything was downloaded successfully. Mr. Vega suggested that H-GAC come by with a portable hard drive to ensure that all project data is received. Additionally, newer project data, work done after 2013, would be made available.
* International Stormwater Database – Rachel Windham
  + Ms. Windham presented her effort to gather information from the database and to begin analysis. She discussed H-GAC’s process for determining which areas of the US would be considered appropriate for use.
* Periodical Review – Steven Johnston
  + Mr. Johnston gave a review of his efforts to gather GI performance research to help augment local GI project data. He noted the challenge of gathering journal articles by a non-researcher. Dr. Guillen offered to assist but concurred with Mr. Johnston that conducting web searches will often lead to free versions of the research.

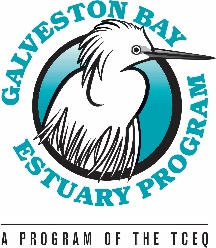
2:15 H-GAC Database Setup – Rachel Windham

Ms. Windham reviewed the H-GAC database structure, noting that is being developed based on the structure contained within the International Database. H-GAC is working to pull in HCFCD, local projects, and other state and US projects into the database.

2:30 Timeline and Next Steps

Mr. Johnston reviewed the next steps in the project. This includes analysis of the projects placed within the database. The analysis will determine performance measures, e.g., pollutant reduction, flow mitigation, cost, maintenance. Not all projects will contain the identified measures, so the committee will be convened in the summer to assist with categorizing the appropriate measures, determining how to address projects that did not collect all measures, and helping to prioritize. Mr. Johnston noted that after the group meets in the summer, a future meeting will be held to plan a workshop to convey project results. That meeting will be held in the fall.

3:00 Adjourn

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This project is funded by the Galveston Bay Estuary Program, a program of the Texas Commission on Environmental Quality

**Green Infrastructure Project**

Wednesday, February 14, 2024

1:00 P.M.- 3:00 P.M.

**Summary**

1:00 Welcome and Introductions

Attendees: Ryan Bare (HARC), Kaylei Diane Chau (EIH), Jesuina Chipindula (COHPW), Danielle Cioce (HC), Fouad H. Jaber (TX AgriLife), Jenny Wrast-Oakley (UHCL), Kelli Ondracek (COHPRD), Robert Snoza (HCFCD), Lam Tran (COH), Roberto Vega (HCFCD), Ivy Wang (COHPW)

Project Staff: Christian Rines (TCEQ), Jessie Casillas (H-GAC), Steven Johnston (H-GAC), Thushara Ranatunga (H-GAC), Megha Shrestha (H-GAC), Rachel Windham (H-GAC)

1:10 Project Overview

Mr. Johnston gave a review of the project. He provided an overview of the project’s scope and goals. The current project status was discussed, and the remaining deliverables presented.

1:20 Data Source Review:

* HCFCD Stormwater Database
  + Ms. Casillas presented the completed work capturing GI data from the Harris County Flood Control Department database. She provided the steps taken to download the data and he work with staff to ensure all data was captured correctly.
* International Stormwater Database
  + Ms. Windham reviewed her work downloading the database from the International Stormwater Database website. She reviewed the data and structure of the database and its use as a backbone for H-GAC’s setup.
* Periodical Review
  + Mr. Johnston discussed the collection of journal articles and local data gathered for the project. He provided a table of resources used. He noted that the data presented would be summary as that is how the information is presented in the articles.

1:45 Data Analysis and Discussion

Ms. Shrestha reviewed the H-GAC database set up and how the data was analyzed. SAS was used to develop code for data extraction and visualization. She presented several visual graphics of analysis results. Ms. Shrestha noted that while attempts were made to complete statistical analyses, the size of the data was insufficient to meet the minimum requirements for the test. Results were based on a percentage reduction and comparative analysis was used to interpret results.

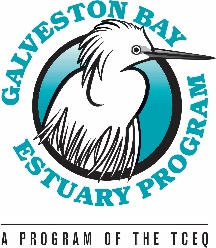
2:30 GI Workshop

Mr. Johnston noted that the workshop would be held on February 23, 2024, at H-GAC. The agenda was being finalized, but that results of this project would be presented. Other potential speakers include Greenrise Technology and HARC. Finally, there would be a breakout session to encourage attendee participation.

2:45 Next Steps

Mr. Johnston reviewed progress and the next steps. He noted that in addition to the workshop, the final report is being prepared.

3:00 Adjourn

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This project is funded by the Galveston Bay Estuary Program, a program of the Texas Commission on Environmental Quality

# Appendix B Outreach Report

**Clean Waters Initiative: Green Infrastructure and Stormwater Management**

One feature of the GI efficacy project was outreach. A workshop was held on February 23, 2024. Invitees from the Houston-Galveston Region were invited to hear the authors describe the project and results. Additionally, the workshop’s agenda included presentations from two local projects that are currently gathering performance data on permeable pavement, bioretention, and floating wetlands. The final presenter reviewed cost, maintenance, and thoughts on future applications of GI. The workshop’s program, presenter bios, and presentations can be found under Past Workshops/Stormwater at [Clean Waters Initiative Workshops | Houston-Galveston Area Council (H-GAC)](https://www.h-gac.com/clean-water-initiative-workshops).

The 35 attendees (Table B-13) were invited to stay for a breakout session to discuss GI, needs, future, and opportunities.

**Breakout Sessions**

**Table 1**

Group Demographics

* City of Houston Stormwater
* Harris County Engineering Department
* Bayou Preservation
* Harris County
* Environmental Institute of Houston

**What’s your interest in Green Infrastructure?**

~Looking for different ideas to encourage people, such as permits. Not a lot of water quality designs.

~New to role. Came from Africa where clean water is so important – looking for ideas for overcoming barriers. Water is the next big thing. We need to enforce whoever is not doing the right thing.

~Working with the permit department to make sure to help MS4 program – storm water quality is important.

~Trying to learn more about green infrastructure and trying to find ways to be innovative, looking for information on who might be interested in engaging and partnering – we don’t own any land and must work with partners who do.

~Interested in what’s going on in green infrastructure.

**Is LID on the table for decision-makers?**

~Our group is in its infancy. We’re encouraging but getting design ideas and trying to start something.

**What are some barriers to adopting Green Infrastructure?**

~Is it cost effective? Is it worth it?

~Many projects have been in process for years and we are past the point of being able to change anything or add green infrastructure. Individuals are pro-green infrastructure, but we’ve been slow to move on a community/entity level.

~The time and effort to change and public perception.

~People building new developments want to do the minimum.

**What are good ways to get the information to people?**

~Highlight H-GAC’s database. Show the connection between water quality and economics. Be general and clear. Who attends these workshops? Maybe steer some toward developers and private industry (noted that we’d like to and could use some help making those connections!)

~Gather data and show how green infrastructure is much better for entities. Not sure about developers.

~Show data and benefits. Like after Harvey, show flood control benefits – even construction companies will want that.  And I’m sure residents will want it too.

~Send brochures home with kids – send projects home to make parents think about it. (noted that we have the games and demos available)

**What do we need?**

~Public perception can be improved with signage and education, but funding may be an issue

~Need to help people see that areas are not being neglected, but explain why. Even if they don’t read the sign, they will know there’s a sign there and know it’s intentional.

~Go directly to leadership. We see them coming up with ideas. Incentives – trying to change permit requirements – see ordinances – everyone is trying to see what’s feasible – going back and forth – not fully implementing. If leadership are the ones that have the power to make the changes, they need to see the benefits. If they change the rules, the construction companies will comply. An incentive might be to let people skip the line an expedite the permit process.

~Target workshops toward elected officials and leadership

~Show how much it would cost and how much might be lost without the improvements.

~We had one of our bosses come to a meeting and they were surprised to see what can get in water – help to get the information to the upper levels in our organization – to see what can get in their own water.

~Folks in the breakout session had an overall good response to the workshop.  They all feel more of this type of coming together and networking are important.  They want to see more of these workshops.

**Table 2 (virtual room)**

Group Demographics

* Bayou Preservation Association
* Harris County Flood Control District
* Harris County
* San Jacinto River Authority

A few key takeaways were captured:

~Money for putting in the LID practice is not the issue.  Acquiring right of way and excavation are the biggest costs. (Federal grants are available to assist- most require nature based solutions).

~Underestimating maintenance costs is easy to do.

~Stakeholder feedback on GI/LID projects is mostly favorable.  Residents love the amenities that they provide.

~GI/LID solutions are very site specific.  Not a one size fits all proposition.

~The big question is – Where can I do what?  Helpful guide(s) for homeowners, developers, environmental organizations to help in the decision making process.

**Table 3**

Group Demographics

* Harris County Engineering
* Bayou Preservation Association
* Texas A&M AgriLife
* Water Conservation

**Question 1: Experience with GI/LID?**

~Agreed LID projects are completely disregarded at their supervisor’s level(s) – any ideas related to GI are thrown out of the conversation. People believe it is costly and does not have demonstrated performance results. Supervisors are all about data.

~One mentioned she is a new employee who has just started working with taking GI/LID ideas to audiences. They organize courses that target homeowners and anyone who may attend a workshop. Workshops are created every 3-6 months in Harvey impacted areas. Next workshop is June 2024.  Asked if H-GAC creates messages to highlight LID practices/projects? Any newsletters that provide information about the subject?

~One weighed in that Harris Co and City has a great opportunity to highlight this practice in their new transportation development projects. She mentioned the expansion projects and inquired if anyone of us saw the project plan and whether it mentioned LID at all?

**Question 2: What is needed to expand GI?**

~All agreed data was absolutely necessary!

~One person mentioned there was not enough incentives by the government for builders to want to bring in LID projects. If homeowners are not informed about GI practices, there would be no customer demand for builders to include it either. BPA person mentioned that outreach should target homeowner association groups to begin GI/LID discussions at the smaller levels to bring attention at larger levels.

~Demonstrations of successful projects are needed.

**Table 4**

Group Demographics: engineers, inspectors, researchers, and academics.

* City of Houston
* Harris County Flood Control District
* HARC
* Harris County Engineering
* Galveston Bay Estuary Program

**Discussion key points:**

~How is GIS implemented in Houston? – It is not that popular. Mostly it is last minute implementation to fulfill the contract.

~Discussed to role of contractors and other institutes in implementing GI.

~Discussed educational, contractual, and financial interventions at different levels of construction projects to effectively implement GI.

~Discussed real world issues of disconnect between academics, researchers with people working on the ground.

Table B-13. Workshop Attendees

| **Date** | **Event** | **Online/ In**  **Person** | **Contact Last**  **Name** | **Contact First**  **Name** | **Company/Organization** | **City** | **County** | **What best describes your role at**  **this meeting?** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2/23/2024 | CWI-2/23/24 | In Person | Baptiste | Aiyana | Texas A&M AgriLife  Extension | Houston | Harris | State Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Bare | Ryan | HARC |  |  | Non-Profit Volunteer/Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Berg | Matthew | Simfero |  | Montgomery | Private Industry Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Bower | Justin |  |  |  | H-GAC Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Casillas | Jessica | Houston-Galveston Area  Council | Houston |  | H-GAC Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Chau | Kaylei | Environmental Institute of  Houston | Houston | Harris | Educational Institute Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Chipindula | Jesuina | City of Houston | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Fereday | Kelli | Friends of Woodland Park/WOBA/Bayou  Preservation | Houston | Harris | Non-Profit Volunteer/Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Henske | Morgan | Harris County Engineering | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Lu | Jeff | Harris County Engineering  Department | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Ly | Khoa | City of Houston | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Ly | Carter | Harris County Engineering  Department | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Moss | Grant | Program Manager | Houston | Harris | Non-Profit Volunteer/Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Mouton | Dave |  | Alvin | Brazoria | Interested Resident |
| 2/23/2024 | CWI-2/23/24 | In Person | NAEGER | ROBERT | Coastal Prairie Chapter  Texas Master Naturalist | Richmond | Fort Bend | Interested Resident |
| 2/23/2024 | CWI-2/23/24 | In Person | Nelson | Paul | Bayou Preservation  Association | Houston/The W | Montgomery | Non-Profit Volunteer/Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Rines | Christian | Galveston Bay Estuary  Program | Houston | Harris | State Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Santillan | Jonathan | Harris county engineering  department | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Tantillo | Andrea | Houston-Galveston Area  Council | Houston | Galveston | H-GAC Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Toure | Bacary | Harris County | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Whetstone | Tim | Harris County | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Woods | Danielle | HCFCD | Houston | Harris | City/County Government Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Shrestha | Megha | H-GAC | Houston | Harris | H-GAC Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Lu | Fangy | Greens Bayou Coalition | Houston | Harris | Private Industry Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Johnston | Steven |  |  |  | H-GAC Staff |
| 2/23/2024 | CWI-2/23/24 | In Person | Windham | Rachel |  |  |  | H-GAC Staff |
| 2/23/2024 | CWI-2/23/24 | Online | Ashcroft | Amanda | H-GAC |  |  |  |
| 2/23/2024 | CWI-2/23/24 | Online | Ervin | Bill | H-GAC |  | Harris |  |
| 2/23/2024 | CWI-2/23/24 | Online | Flowers | Brittani | Bayou Preservation  Association | Houston |  |  |
| 2/23/2024 | CWI-2/23/24 | Online | Newton | Jack | San Jacinto River Authority | Conroe |  |  |
| 2/23/2024 | CWI-2/23/24 | Online | Garrison | Jennifer O. | Harris County Flood  Control District | Houston | Harris |  |
| 2/23/2024 | CWI-2/23/24 | Online | Holley | Jonathan | Harris County Flood  Control District | Houston | Harris |  |
| 2/23/2024 | CWI-2/23/24 | Online | Guidroz | Kendall |  |  |  |  |
| 2/23/2024 | CWI-2/23/24 | Online | Raymundo | Monica | Harris County | Houston | Harris |  |
| 2/23/2024 | CWI-2/23/24 | Online | Running | Todd | H-GAC |  | Harris |  |

# Appendix C SAS Analyses





| **BMP\_Design** | **SiteName** | **Lat** | **Long** | **AvgTKN\_in** | **No\_of\_in** | **AvgTKN\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 38.9720 | -94.6761 | 4.8181818 | 22 | 2.695 | 20 | 09/12/2008 | 09/15/2010 | 44.1 |
| Bioretention | BRC Site A | 35.9705 | -77.9340 | 0.7581667 | 18 | 0.5398421 | 19 | 04/12/2008 | 03/01/2009 | 28.8 |
| Bioretention | Birnamwood Dr. | 30.0723 | -95.3743 | 0.4597 | 1 | 0.3767 | 1 | 06/01/2014 | 02/01/2017 | 18.1 |
| Bioretention | Cub Run Rec Center | 38.8893 | -77.4670 | 4.8866125 | 16 | 0.935 | 10 | 09/25/2008 | 03/28/2010 | 80.9 |
| Bioretention | Greensboro bioretention-G1 | 36.1526 | -79.8716 | 2.6147368 | 19 | 4.6142857 | 14 | 07/01/2003 | 09/27/2004 | -76.5 |
| Bioretention | Greensboro bioretention-G2 | 36.1536 | -79.8716 | 1.3125 | 16 | 11.275 | 4 | 07/01/2003 | 09/27/2004 | -759 |
| Bioretention | I-95 Plaza Bioretention Cell | 39.6629 | -75.6903 | 5.719 | 10 | 2.7990909 | 11 | 04/01/2005 | 11/15/2007 | 51.1 |
| Bioretention | Louisburg bioretention-L1 | 36.1326 | -78.2221 | 1.4825 | 12 | 1.0558333 | 12 | 05/30/2004 | 12/23/2004 | 28.8 |
| Bioretention | Louisburg bioretention-L2 | 36.1336 | -78.2221 | 1.66 | 12 | 1 | 13 | 05/30/2004 | 12/23/2004 | 39.8 |
| Bioretention | Mango Creek | 35.7843 | -78.5134 | 0.5427667 | 30 | 0.6646 | 30 | 11/02/2009 | 12/02/2010 | -22.4 |
| Bioretention | OP Recycling Center | 38.9116 | -94.6798 | 11.832759 | 29 | 2.4925926 | 27 | 07/16/2010 | 09/19/2013 | 78.9 |
| Bioretention | SJC - Bio Ret 3B | 39.0243 | -94.7817 | 1.2365385 | 26 | 2.2590909 | 22 | 05/24/2012 | 09/28/2013 | -82.7 |
| Bioretention | SJC - Bio Ret 6 | 39.0233 | -94.7810 | 1.0409091 | 33 | 1.292 | 25 | 05/24/2012 | 09/28/2013 | -24.1 |
| Detention | B504-03-00 Dry Detention Basin | 29.7604 | -95.3698 | 2.8996875 | 32 | 4.789931 | 29 | 09/29/2005 | 02/06/2013 | -65.2 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 1.43 | 1 | 0.97 | 1 | 11/01/2008 | 03/01/2010 | 32.2 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 0.88 | 1 | 0.35 | 1 | 11/01/2008 | 03/01/2010 | 60.2 |
| Detention | SJC - Ext Dry | 39.0228 | -94.7818 | 1.1333333 | 3 | 1.6333333 | 6 | 07/07/2011 | 04/23/2013 | -44.1 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 3.32 | 1 | 0.37 | 1 | 07/01/2010 | 09/01/2011 | 88.9 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 0.84 | 1 | 0.55 | 1 | 07/01/2010 | 09/01/2011 | 34.5 |
| Grass Strip | Westfield Level Spreader | 35.1811 | -80.8488 | 128.37105 | 19 | 0.96 | 3 | 11/29/2005 | 01/05/2007 | 99.3 |
| Manufactured Device | HC | 39.6629 | -75.6903 | 1.825 | 4 | 1.95 | 4 | 03/29/2007 | 06/30/2007 | -6.8 |
| Manufactured Device | I-95 Plaza BaySaver | 39.6629 | -75.6903 | 10.622 | 10 | 7.497 | 10 | 11/16/2005 | 11/13/2008 | 29.4 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 39.6629 | -75.6903 | 11.056 | 10 | 11.424 | 10 | 04/08/2006 | 04/28/2008 | -3.3 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 39.6629 | -75.6903 | 5.5618182 | 11 | 2.539 | 10 | 12/13/2006 | 04/20/2009 | 54.3 |
| Manufactured Device | I-95 Plaza StormFilter | 39.6629 | -75.6903 | 7.5790909 | 11 | 7.1581818 | 11 | 04/01/2005 | 11/15/2007 | 5.6 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 39.6629 | -75.6903 | 5.4036364 | 11 | 1.161 | 10 | 04/27/2007 | 04/20/2009 | 78.5 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 39.6629 | -75.6903 | 11.179091 | 11 | 9.86 | 11 | 12/13/2006 | 04/20/2009 | 11.8 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 39.6629 | -75.6903 | 4.921 | 10 | 3.928 | 10 | 12/13/2006 | 04/20/2009 | 20.2 |
| Manufactured Device | OP Soccer Complex | 38.8820 | -94.7053 | 1.35 | 4 | 1.42 | 5 | 06/27/2011 | 11/07/2011 | -5.2 |
| Manufactured Device | SMNW HANCOR | 39.0057 | -94.7348 | 1.1216667 | 30 | 1.5867647 | 34 | 05/24/2011 | 09/28/2013 | -41.5 |
| Manufactured Device | VC | 39.0100 | -94.7363 | 2.525 | 4 | 2.25 | 4 | 05/02/2007 | 06/30/2007 | 10.9 |
| Media Filter | Highland View | 38.8556 | -94.6916 | 2.2035714 | 28 | 2.2448276 | 29 | 09/12/2008 | 11/07/2011 | -1.9 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 39.6629 | -75.6903 | 2.9054545 | 11 | 1.6995455 | 11 | 04/01/2005 | 05/12/2008 | 41.5 |
| Retention | B512-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 2.208 | 12 | 0.905 | 10 | 12/29/2010 | 02/06/2013 | 59 |
| Retention | E500-12-00 Wet Detention Basin | 29.7604 | -95.3698 | 2.4792 | 15 | 1.75 | 1 | 08/05/2008 | 01/10/2013 | 29.4 |
| Retention | E515-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 1.1672308 | 13 | 0.622375 | 8 | 07/20/2009 | 02/21/2013 | 46.7 |
| Retention | T501-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 3.9116 | 15 | 0.9453 | 10 | 01/18/2008 | 01/31/2012 | 75.8 |
| Stormwater Wetland | EIH UHCL Wetland | 29.5830 | -95.1001 | 2.23 | 1 | 3.23 | 1 | 04/01/2012 | 05/01/2012 | -44.8 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 29.7604 | -95.3698 | 1.3472 | 15 | 1.736 | 5 | 12/16/2004 | 03/13/2007 | -28.9 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 29.7604 | -95.3698 | 1.11 | 3 | 1.6114 | 5 | 01/18/2008 | 01/31/2012 | -45.2 |
| Stormwater Wetland Primary | EIH UHCL Wetland | 29.5830 | -95.1001 | 3.57 | 1 | 2.63 | 1 | 04/01/2012 | 05/01/2012 | 26.3 |
| Stormwater Wetland Secondary | EIH UHCL Wetland | 29.5840 | -95.1011 | 2.63 | 1 | 2.23 | 1 | 04/01/2012 | 05/01/2012 | 15.2 |
| Swale | Birnamwood Dr. | 30.0723 | -95.3743 | 0.5369 | 1 | 0.4597 | 1 | 06/01/2014 | 02/01/2017 | 14.4 |
| Swale | Mango Creek | 35.7843 | -78.5134 | 0.6284375 | 32 | 0.6074194 | 31 | 11/02/2009 | 12/13/2010 | 3.3 |
| Treatment Train | Birnamwood Dr. | 30.0723 | -95.3743 | 0.5369 | 1 | 0.3767 | 1 | 06/01/2014 | 02/01/2017 | 29.8 |
| Treatment Train | EIH UHCL Wetland | 29.5830 | -95.1001 | 3.57 | 1 | 3.23 | 1 | 04/01/2012 | 05/01/2012 | 9.5 |





















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| The following graph is for values more than -200. |

























| **BMP\_Design** | **SiteName** | **AvgEnter\_in** | **No\_of\_in** | **AvgEnter\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | I-95 Plaza Bioretention Cell | 77450 | 8 | 38555 | 10 | 04/01/2005 | 11/15/2007 | 50.2 |
| Detention | B504-03-00 Dry Detention Basin | 15293.895 | 19 | 16592.132 | 19 | 09/29/2005 | 02/06/2013 | -8.5 |
| Manufactured Device | Bama Belle UFF | 5864.875 | 48 | 2734.5102 | 49 | 08/14/2010 | 03/30/2013 | 53.4 |
| Manufactured Device | I-95 Plaza BaySaver | 62297.143 | 7 | 36372 | 10 | 11/16/2005 | 11/13/2008 | 41.6 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 42775 | 8 | 44250 | 8 | 05/26/2006 | 04/28/2008 | -3.4 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 33403.636 | 11 | 37820 | 10 | 12/13/2006 | 04/20/2009 | -13.2 |
| Manufactured Device | I-95 Plaza StormFilter | 8927.2727 | 11 | 36120 | 10 | 04/01/2005 | 11/15/2007 | -304.6 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 71794 | 10 | 34043.333 | 9 | 12/13/2006 | 04/20/2009 | 52.6 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 6807.5 | 8 | 11682.5 | 8 | 12/13/2006 | 04/20/2009 | -71.6 |
| Manufactured Device | SC\_StructBMP1&2 | 7377.0625 | 16 | 8826.6875 | 16 | 04/07/2005 | 11/07/2006 | -19.7 |
| Manufactured Device | SC\_StructBMP3 | 6290.5 | 10 | 3543.5 | 10 | 04/07/2005 | 09/19/2006 | 43.7 |
| Manufactured Device | SC\_StructBMP4 | 12007 | 10 | 8427.5 | 10 | 10/05/2005 | 09/19/2006 | 29.8 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 6250 | 10 | 1040 | 10 | 04/01/2005 | 04/28/2008 | 83.4 |
| Retention | B512-01-00 Wet Detention Basin | 30595.778 | 9 | 1057.625 | 8 | 12/29/2010 | 02/06/2013 | 96.5 |
| Retention | E500-12-00 Wet Detention Basin | 48392 | 1 | 7270 | 1 | 03/12/2009 | 01/10/2013 | 85 |
| Retention | E515-01-00 Wet Detention Basin | 3400 | 1 | 70 | 1 | 02/23/2010 | 02/24/2010 | 97.9 |
| Retention | NCSU Wilmington | 12490.227 | 22 | 9407.5909 | 22 | 01/17/2008 | 02/09/2010 | 24.7 |
| Retention | P518-02-00 Halls Bayou Regional Detention Basin | 19924 | 1 | 583 | 1 | 02/06/2013 | 02/06/2013 | 97.1 |
| Retention | T501-01-00 Wet Detention Basin | 196912 | 15 | 25968.488 | 8 | 01/18/2008 | 01/31/2012 | 86.8 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 46699 | 5 | 70591.867 | 15 | 01/18/2008 | 01/31/2012 | -51.2 |













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| The following graph is for values more than -200. |

















| **BMP\_Design** | **SiteName** | **AvgEcoli\_in** | **No\_of\_in** | **AvgEcoli\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | Birnamwood Dr. | 3154.5 | 1 | 4729.1 | 1 | . | . | -49.9 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 31855184 | 1 | 11489962 | 1 | . | . | 63.9 |
| Detention | B504-03-00 Dry Detention Basin | 34981.737 | 19 | 5990.7368 | 19 | 09/29/2005 | 02/06/2013 | 82.9 |
| Grass Strip | Westfield Level Spreader | 2200.4833 | 6 | 2400 | 1 | 11/29/2005 | 01/05/2007 | -9.1 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 104 | 1 | 346 | 1 | . | . | -232.7 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 104 | 1 | 1149 | 1 | . | . | -1004.8 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 104 | 1 | 715 | 1 | . | . | -587.5 |
| Manufactured Device | Bama Belle UFF | 6063.8936 | 47 | 3432.2766 | 47 | 07/16/2010 | 03/30/2013 | 43.4 |
| Manufactured Device | SC\_StructBMP1&2 | 5953.7273 | 11 | 7408.0833 | 12 | 04/07/2005 | 11/07/2006 | -24.4 |
| Manufactured Device | SC\_StructBMP3 | 5801.8182 | 11 | 4824.5455 | 11 | 04/07/2005 | 09/19/2006 | 16.8 |
| Manufactured Device | SC\_StructBMP4 | 8572.2727 | 11 | 4139 | 11 | 08/27/2005 | 09/19/2006 | 51.7 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 20600 | 1 | 18500 | 1 | . | . | 10.2 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 20600 | 1 | 10597 | 1 | . | . | 48.6 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 20600 | 1 | 8842 | 1 | . | . | 57.1 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 20600 | 1 | 1121 | 1 | . | . | 94.6 |
| Retention | B512-01-00 Wet Detention Basin | 39035.889 | 9 | 1296.875 | 8 | 12/29/2010 | 02/06/2013 | 96.7 |
| Retention | E500-12-00 Wet Detention Basin | 52011.667 | 9 | 1743.3333 | 3 | 08/05/2008 | 01/10/2013 | 96.6 |
| Retention | E515-01-00 Wet Detention Basin | 28324.045 | 11 | 2192.1667 | 9 | 07/20/2009 | 02/21/2013 | 92.3 |
| Retention | NCSU Wilmington | 15670.143 | 21 | 12621.286 | 21 | 01/17/2008 | 02/09/2010 | 19.5 |
| Retention | P518-02-00 Halls Bayou Regional Detention Basin | 24292 | 1 | 473 | 1 | 02/06/2013 | 02/06/2013 | 98.1 |
| Retention | T501-01-00 Wet Detention Basin | 157025.8 | 15 | 34710.513 | 8 | 01/18/2008 | 01/31/2012 | 77.9 |
| Stormwater Wetland | Brays Bayou Stormwater Wetland | 61229 | 1 | 278 | 1 | . | . | 99.5 |
| Stormwater Wetland | Exploration Green Recreation Park Phase 1 Stormwater Wetland | 8743.75 | 1 | 7779.375 | 1 | . | . | 11 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 4013.5778 | 9 | 762.3 | 3 | 12/16/2004 | 03/13/2007 | 81 |
| Stormwater Wetland | Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | 444.8 | 1 | 3314 | 1 | . | . | -645.1 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 434565.4 | 5 | 59534.467 | 15 | 01/18/2008 | 01/31/2012 | 86.3 |
| Stormwater Wetland | University of Texas Recreation Park MD Anderson Campus Wetland | 27 | 1 | 640.7 | 1 | . | . | -2273 |
| Swale | Birnamwood Dr. | 2743 | 1 | 3154.5 | 1 | . | . | -15 |
| Treatment Train | Birnamwood Dr. | 2743 | 1 | 4729.1 | 1 | . | . | -72.4 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 81 |





















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| The following graph is for values more than -200. |























| **BMP\_Design** | **SiteName** | **Lat** | **Long** | **AvgNN\_in** | **No\_of\_in** | **AvgNN\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 38.9720 | -94.6761 | 0.8113636 | 22 | 4.497 | 20 | 09/12/2008 | 09/15/2010 | -454.3 |
| Bioretention | BRC Site A | 35.9705 | -77.9340 | 0.1932222 | 18 | 0.5968947 | 19 | 04/12/2008 | 03/01/2009 | -208.9 |
| Bioretention | BRC Site B | 35.9705 | -77.9340 | 0.174 | 4 | 1.1041053 | 19 | 04/12/2008 | 03/01/2009 | -534.5 |
| Bioretention | Birnamwood Dr. | 30.0723 | -95.3743 | 0.2435 | 1 | 0.3618 | 1 | 06/01/2014 | 02/01/2017 | -48.6 |
| Bioretention | Cub Run Rec Center | 38.8893 | -77.4670 | 0.6781688 | 16 | 0.273 | 10 | 09/25/2008 | 03/28/2010 | 59.7 |
| Bioretention | Greensboro bioretention-G1 | 36.1526 | -79.8716 | 0.209 | 20 | 0.27 | 14 | 07/01/2003 | 09/27/2004 | -29.2 |
| Bioretention | Greensboro bioretention-G2 | 36.1536 | -79.8716 | 0.334375 | 16 | 0.19625 | 4 | 07/01/2003 | 09/27/2004 | 41.3 |
| Bioretention | I-95 Plaza Bioretention Cell | 39.6629 | -75.6903 | 2.12 | 10 | 1.3022727 | 11 | 04/01/2005 | 11/15/2007 | 38.6 |
| Bioretention | Louisburg bioretention-L1 | 36.1326 | -78.2221 | 0.3583333 | 12 | 0.2825 | 12 | 05/30/2004 | 12/23/2004 | 21.2 |
| Bioretention | Louisburg bioretention-L2 | 36.1336 | -78.2221 | 0.53 | 12 | 0.2038462 | 13 | 05/30/2004 | 12/23/2004 | 61.5 |
| Bioretention | Mango Creek | 35.7843 | -78.5134 | 0.3356667 | 30 | 0.201 | 30 | 11/02/2009 | 12/02/2010 | 40.1 |
| Bioretention | OP Recycling Center | 38.9116 | -94.6798 | 0.6792308 | 26 | 1.2791667 | 24 | 07/16/2010 | 09/19/2013 | -88.3 |
| Bioretention | SJC - Bio Ret 3B | 39.0243 | -94.7817 | 0.62625 | 24 | 1.02 | 19 | 05/24/2012 | 09/28/2013 | -62.9 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 0.2 | 1 | 0.08 | 1 | 11/01/2008 | 03/01/2010 | 60 |
| Detention | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 0.12 | 1 | 0.06 | 1 | 11/01/2008 | 03/01/2010 | 50 |
| Detention | SJC - Ext Dry | 39.0228 | -94.7818 | 0.57 | 3 | 0.575 | 6 | 07/07/2011 | 04/23/2013 | -0.9 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 36.0271 | -78.9002 | 0.17 | 1 | 0.06 | 1 | 07/01/2010 | 09/01/2011 | 64.7 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 36.0247 | -78.9442 | 0.34 | 1 | 0.06 | 1 | 07/01/2010 | 09/01/2011 | 82.4 |
| Grass Strip | Westfield Level Spreader | 35.1811 | -80.8488 | 6.0584211 | 19 | 0.3066667 | 3 | 11/29/2005 | 01/05/2007 | 94.9 |
| Manufactured Device | HC | 39.6629 | -75.6903 | 0.4733333 | 3 | 0.81 | 3 | 03/29/2007 | 06/30/2007 | -71.1 |
| Manufactured Device | I-95 Plaza BaySaver | 39.6629 | -75.6903 | 1.806 | 10 | 1.1475 | 10 | 11/16/2005 | 11/13/2008 | 36.5 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 39.6629 | -75.6903 | 1.978 | 10 | 1.6775 | 10 | 04/08/2006 | 04/28/2008 | 15.2 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 39.6629 | -75.6903 | 0.9118182 | 11 | 11.609 | 10 | 12/13/2006 | 04/20/2009 | -1173.2 |
| Manufactured Device | I-95 Plaza StormFilter | 39.6629 | -75.6903 | 1.6127273 | 11 | 1.9045455 | 11 | 04/01/2005 | 11/15/2007 | -18.1 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 39.6629 | -75.6903 | 1.3088636 | 11 | 0.49125 | 10 | 04/27/2007 | 04/20/2009 | 62.5 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 39.6629 | -75.6903 | 1.125 | 11 | 0.9968182 | 11 | 12/13/2006 | 04/20/2009 | 11.4 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 39.6629 | -75.6903 | 0.87 | 10 | 1.026 | 10 | 12/13/2006 | 04/20/2009 | -17.9 |
| Manufactured Device | OP Soccer Complex | 38.8820 | -94.7053 | 0.73 | 4 | 0.734 | 5 | 06/27/2011 | 11/07/2011 | -0.5 |
| Manufactured Device | SMNW HANCOR | 39.0057 | -94.7348 | 0.3314286 | 28 | 0.5429032 | 31 | 05/24/2011 | 09/28/2013 | -63.8 |
| Manufactured Device | VC | 39.0100 | -94.7363 | 0.43 | 3 | 0.3333333 | 3 | 05/02/2007 | 06/30/2007 | 22.5 |
| Media Filter | Highland View | 38.8556 | -94.6916 | 0.6221429 | 28 | 1.3617241 | 29 | 09/12/2008 | 11/07/2011 | -118.9 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 39.6629 | -75.6903 | 1.6409091 | 11 | 2.5627273 | 11 | 04/01/2005 | 05/12/2008 | -56.2 |
| Retention | B512-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 0.741 | 1 | 0.05 | 1 | 12/29/2010 | 02/06/2013 | 93.3 |
| Retention | DeBary Detention with Filtration Pond | 28.8763 | -81.2977 | 0.2291641 | 64 | 0.1180617 | 47 | 05/28/1992 | 11/30/1992 | 48.5 |
| Retention | E515-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 0.162 | 1 | 0.05 | 1 | 07/20/2009 | 02/21/2013 | 69.1 |
| Retention | T501-01-00 Wet Detention Basin | 29.7604 | -95.3698 | 1.63 | 1 | 0.25 | 1 | 01/18/2008 | 01/31/2012 | 84.7 |
| Stormwater Wetland | EIH UHCL Wetland | 29.5830 | -95.1001 | 0.14 | 1 | 0.84 | 1 | 04/01/2012 | 05/01/2012 | -500 |
| Stormwater Wetland | Exploration Green Recreation Park Phase 1 Stormwater Wetland | 29.5633 | -95.1206 | 0.475 | 1 | 0.509 | 1 | 09/01/2019 | 07/01/2020 | -7.2 |
| Stormwater Wetland | Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | 29.6956 | -95.4001 | 2.51 | 1 | 0.642 | 1 | 09/01/2019 | 07/01/2020 | 74.4 |
| Stormwater Wetland | University of Texas Recreation Park MD Anderson Campus Wetland | 29.6929 | -95.3973 | 0.413 | 1 | 0.075 | 1 | 09/01/2019 | 07/01/2020 | 81.8 |
| Stormwater Wetland Primary | EIH UHCL Wetland | 29.5830 | -95.1001 | 13.16 | 1 | 0.67 | 1 | 04/01/2012 | 05/01/2012 | 94.9 |
| Stormwater Wetland Secondary | EIH UHCL Wetland | 29.5840 | -95.1011 | 0.67 | 1 | 0.14 | 1 | 04/01/2012 | 05/01/2012 | 79.1 |
| Swale | Birnamwood Dr. | 30.0723 | -95.3743 | 0.2142 | 1 | 0.2435 | 1 | 06/01/2014 | 02/01/2017 | -13.7 |
| Swale | Mango Creek | 35.7843 | -78.5134 | 0.4053125 | 32 | 0.3677419 | 31 | 11/02/2009 | 12/13/2010 | 9.3 |
| Treatment Train | Birnamwood Dr. | 30.0723 | -95.3743 | 0.2142 | 1 | 0.3618 | 1 | 06/01/2014 | 02/01/2017 | -68.9 |
| Treatment Train | EIH UHCL Wetland | 29.5830 | -95.1001 | 13.16 | 1 | 0.84 | 1 | 04/01/2012 | 05/01/2012 | 93.6 |





















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| The following graph is for values more than -200. |

























| **BMP\_Design** | **SiteName** | **AvgTP\_in** | **No\_of\_in** | **AvgTP\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 0.6063636 | 22 | 1.9505 | 20 | 09/12/2008 | 09/15/2010 | -221.7 |
| Bioretention | BRC Site A | 0.0727778 | 18 | 0.0727778 | 18 | 04/12/2008 | 03/01/2009 | 0 |
| Bioretention | BRC Site B | 0.0727778 | 18 | 0.0596316 | 19 | 04/12/2008 | 03/01/2009 | 18.1 |
| Bioretention | Charlottesville HS Biofilter | 0.2055556 | 9 | 0.1185714 | 7 | 07/10/2010 | 11/16/2010 | 42.3 |
| Bioretention | Cub Run Rec Center | 0.7884375 | 16 | 0.1265 | 10 | 09/25/2008 | 03/28/2010 | 84 |
| Bioretention | Greensboro bioretention-G1 | 0.2231579 | 19 | 0.7185714 | 14 | 07/01/2003 | 09/27/2004 | -222 |
| Bioretention | Greensboro bioretention-G2 | 0.208 | 15 | 9.1 | 4 | 07/01/2003 | 09/27/2004 | -4275 |
| Bioretention | I-95 Plaza Bioretention Cell | 0.639 | 10 | 0.2918182 | 11 | 04/01/2005 | 11/15/2007 | 54.3 |
| Bioretention | Louisburg bioretention-L1 | 0.3275 | 12 | 0.2491667 | 12 | 05/30/2004 | 12/23/2004 | 23.9 |
| Bioretention | Louisburg bioretention-L2 | 0.15375 | 12 | 0.25 | 13 | 05/30/2004 | 12/23/2004 | -62.6 |
| Bioretention | Mango Creek | 0.115 | 30 | 0.2086667 | 30 | 11/02/2009 | 12/02/2010 | -81.4 |
| Bioretention | OP Recycling Center | 7.7737097 | 31 | 1.2182759 | 29 | 07/16/2010 | 09/19/2013 | 84.3 |
| Bioretention | SJC - Bio Ret 3B | 0.4223077 | 26 | 0.6440909 | 22 | 05/24/2012 | 09/28/2013 | -52.5 |
| Bioretention | SJC - Bio Ret 6 | 0.1843939 | 33 | 0.2788 | 25 | 05/24/2012 | 09/28/2013 | -51.2 |
| Detention | B504-03-00 Dry Detention Basin | 1.279 | 32 | 1.7173103 | 29 | 09/29/2005 | 02/06/2013 | -34.3 |
| Detention | SJC - Ext Dry | 0.1466667 | 3 | 0.2391667 | 6 | 07/07/2011 | 04/23/2013 | -63.1 |
| Grass Strip | Westfield Level Spreader | 2.9210526 | 19 | 0.9566667 | 3 | 11/29/2005 | 01/05/2007 | 67.2 |
| Manufactured Device | Bama Belle UFF | 2.0808163 | 49 | 0.9382 | 50 | 07/16/2010 | 03/30/2013 | 54.9 |
| Manufactured Device | HC | 0.17125 | 4 | 0.19125 | 4 | 03/29/2007 | 06/30/2007 | -11.7 |
| Manufactured Device | I-95 Plaza BaySaver | 1.183 | 10 | 0.666 | 10 | 11/16/2005 | 11/13/2008 | 43.7 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 1.461 | 10 | 1.368 | 10 | 04/08/2006 | 04/28/2008 | 6.4 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 0.9795455 | 11 | 0.3335 | 10 | 12/13/2006 | 04/20/2009 | 66 |
| Manufactured Device | I-95 Plaza StormFilter | 0.6481818 | 11 | 0.6481818 | 11 | 04/01/2005 | 11/15/2007 | 0 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 0.4113636 | 11 | 0.1095 | 10 | 04/27/2007 | 04/20/2009 | 73.4 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 1.3772727 | 11 | 1.0936364 | 11 | 12/13/2006 | 04/20/2009 | 20.6 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 0.3955 | 10 | 0.326 | 10 | 12/13/2006 | 04/20/2009 | 17.6 |
| Manufactured Device | OP Soccer Complex | 0.1475 | 4 | 0.238 | 5 | 06/27/2011 | 11/07/2011 | -61.4 |
| Manufactured Device | SC\_StructBMP1&2 | 0.5758824 | 17 | 0.4156471 | 17 | 04/07/2005 | 11/07/2006 | 27.8 |
| Manufactured Device | SC\_StructBMP3 | 0.2757273 | 11 | 0.2514167 | 12 | 04/07/2005 | 09/19/2006 | 8.8 |
| Manufactured Device | SC\_StructBMP4 | 1.19 | 12 | 0.7275 | 12 | 08/27/2005 | 09/19/2006 | 38.9 |
| Manufactured Device | SMNW HANCOR | 0.104 | 30 | 0.1498529 | 34 | 05/24/2011 | 09/28/2013 | -44.1 |
| Manufactured Device | VC | 0.3825 | 4 | 0.24125 | 4 | 05/02/2007 | 06/30/2007 | 36.9 |
| Media Filter | Highland View | 0.1516071 | 28 | 0.6148276 | 29 | 09/12/2008 | 11/07/2011 | -305.5 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 0.2586364 | 11 | 0.1140909 | 11 | 04/01/2005 | 05/12/2008 | 55.9 |
| Retention | B512-01-00 Wet Detention Basin | 4.0017667 | 12 | 0.2813 | 11 | 12/29/2010 | 02/06/2013 | 93 |
| Retention | DeBary Detention with Filtration Pond | 1.0218281 | 64 | 0.053 | 47 | 05/28/1992 | 11/30/1992 | 94.8 |
| Retention | E500-12-00 Wet Detention Basin | 1.6120667 | 15 | 1.69 | 1 | 08/05/2008 | 01/10/2013 | -4.8 |
| Retention | E515-01-00 Wet Detention Basin | 0.3632308 | 13 | 1.1610625 | 8 | 07/20/2009 | 02/21/2013 | -219.6 |
| Retention | T501-01-00 Wet Detention Basin | 1.9312 | 15 | 0.6946 | 10 | 01/18/2008 | 01/31/2012 | 64 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 1.379 | 15 | 0.349 | 5 | 12/16/2004 | 03/13/2007 | 74.7 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 1.4933333 | 3 | 1.8646 | 5 | 01/18/2008 | 01/31/2012 | -24.9 |
| Swale | Mango Creek | 0.160625 | 32 | 0.1554839 | 31 | 11/02/2009 | 12/13/2010 | 3.2 |

















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| The following graph is for values more than -200. |





















| **BMP\_Design** | **SiteName** | **AvgTSS\_in** | **No\_of\_in** | **AvgTSS\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 171.35417 | 24 | 33.9 | 22 | 09/12/2008 | 09/15/2010 | 80.2 |
| Bioretention | BRC Site A | 25.333333 | 18 | 10.947368 | 19 | 04/12/2008 | 03/01/2009 | 56.8 |
| Bioretention | BRC Site B | 25.333333 | 18 | 8.8947368 | 19 | 04/12/2008 | 03/01/2009 | 64.9 |
| Bioretention | Birnamwood Dr. | 9.83 | 1 | 6.79 | 1 | . | . | 30.9 |
| Bioretention | Charlottesville HS Biofilter | 30.72 | 10 | 8.5771429 | 7 | 07/10/2010 | 11/16/2010 | 72.1 |
| Bioretention | Cub Run Rec Center | 291.50596 | 16 | 13.6 | 10 | 09/25/2008 | 03/28/2010 | 95.3 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 3214417 | 1 | 307276 | 1 | . | . | 90.4 |
| Bioretention | I-95 Plaza Bioretention Cell | 288.1 | 10 | 90.181818 | 11 | 04/01/2005 | 11/15/2007 | 68.7 |
| Bioretention | Mango Creek | 48.5 | 30 | 41.1 | 30 | 11/02/2009 | 12/02/2010 | 15.3 |
| Bioretention | OP Recycling Center | 118.06452 | 31 | 25.172414 | 29 | 07/16/2010 | 09/19/2013 | 78.7 |
| Bioretention | SJC - Bio Ret 3B | 55 | 26 | 9.9545455 | 22 | 05/24/2012 | 09/28/2013 | 81.9 |
| Bioretention | SJC - Bio Ret 6 | 35.570645 | 31 | 8.5652174 | 23 | 05/24/2012 | 09/28/2013 | 75.9 |
| Detention | B504-03-00 Dry Detention Basin | 41.061563 | 32 | 26.567931 | 29 | 09/29/2005 | 02/06/2013 | 35.3 |
| Detention | Floating Wetland Retrofit North Carolina | 354 | 1 | 230 | 1 | . | . | 35 |
| Detention | Floating Wetland Retrofit North Carolina | 216 | 1 | 24 | 1 | . | . | 88.9 |
| Detention | SJC - Ext Dry | 30.75 | 4 | 36.166667 | 6 | 07/07/2011 | 04/23/2013 | -17.6 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 18 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 252 | 1 | 13 | 1 | . | . | 94.8 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 101 | 1 | 22 | 1 | . | . | 78.2 |
| Grass Strip | Westfield Level Spreader | 67.944444 | 18 | 30.333333 | 3 | 11/29/2005 | 01/05/2007 | 55.4 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 21.56 | 1 | 49.04 | 1 | . | . | -127.5 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 21.56 | 1 | 31.88 | 1 | . | . | -47.9 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 21.56 | 1 | 40.52 | 1 | . | . | -87.9 |
| Manufactured Device | Bama Belle UFF | 127.57143 | 49 | 24.7 | 50 | 07/16/2010 | 03/30/2013 | 80.6 |
| Manufactured Device | HC | 110 | 4 | 105.25 | 4 | 03/29/2007 | 06/30/2007 | 4.3 |
| Manufactured Device | I-95 Plaza BaySaver | 289.7 | 10 | 176.3 | 10 | 11/16/2005 | 11/13/2008 | 39.1 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 185.4 | 10 | 159.3 | 10 | 04/08/2006 | 04/28/2008 | 14.1 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 312.27273 | 11 | 134.6 | 10 | 12/13/2006 | 04/20/2009 | 56.9 |
| Manufactured Device | I-95 Plaza StormFilter | 151.90909 | 11 | 110 | 11 | 04/01/2005 | 11/15/2007 | 27.6 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 215.27273 | 11 | 29.4 | 10 | 04/27/2007 | 04/20/2009 | 86.3 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 421.54545 | 11 | 118.81818 | 11 | 12/13/2006 | 04/20/2009 | 71.8 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 568.2 | 10 | 80 | 10 | 12/13/2006 | 04/20/2009 | 85.9 |
| Manufactured Device | OP Soccer Complex | 53 | 4 | 79.8 | 5 | 06/27/2011 | 11/07/2011 | -50.6 |
| Manufactured Device | SC\_StructBMP1&2 | 163.58824 | 17 | 56.264706 | 17 | 04/07/2005 | 11/07/2006 | 65.6 |
| Manufactured Device | SC\_StructBMP3 | 78.583333 | 12 | 51.666667 | 12 | 04/07/2005 | 09/19/2006 | 34.3 |
| Manufactured Device | SC\_StructBMP4 | 132.41667 | 12 | 56.25 | 12 | 08/27/2005 | 09/19/2006 | 57.5 |
| Manufactured Device | SMNW HANCOR | 68.467742 | 31 | 45.764706 | 34 | 05/24/2011 | 09/28/2013 | 33.2 |
| Manufactured Device | VC | 104 | 4 | 48 | 4 | 05/02/2007 | 06/30/2007 | 53.8 |
| Media Filter | Highland View | 42.774194 | 31 | 18.625 | 32 | 09/12/2008 | 11/07/2011 | 56.5 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 141.31818 | 11 | 24.318182 | 11 | 04/01/2005 | 05/12/2008 | 82.8 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 27736 | 1 | 2180 | 1 | . | . | 92.1 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 27736 | 1 | 1773 | 1 | . | . | 93.6 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 27736 | 1 | 3524 | 1 | . | . | 87.3 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 27736 | 1 | 3825 | 1 | . | . | 86.2 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | 3226.96 | 1 | 1558.27 | 1 | . | . | 51.7 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | 3226.96 | 1 | 3266.01 | 1 | . | . | -1.2 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | 3226.96 | 1 | 3160.55 | 1 | . | . | 2.1 |
| Retention | B512-01-00 Wet Detention Basin | 161.7525 | 12 | 440.36364 | 11 | 12/29/2010 | 02/06/2013 | -172.2 |
| Retention | DeBary Detention with Filtration Pond | 47.185714 | 63 | 0.9222826 | 46 | 05/28/1992 | 11/30/1992 | 98 |
| Retention | E500-12-00 Wet Detention Basin | 61.442857 | 14 | 110 | 1 | 08/05/2008 | 01/10/2013 | -79 |
| Retention | E515-01-00 Wet Detention Basin | 244.5 | 13 | 14.885714 | 7 | 07/20/2009 | 02/21/2013 | 93.9 |
| Retention | P518-02-00 Halls Bayou Regional Detention Basin | 50.4 | 1 | 57.7 | 1 | 02/06/2013 | 02/06/2013 | -14.5 |
| Retention | T501-01-00 Wet Detention Basin | 715.01333 | 15 | 165.83 | 10 | 01/18/2008 | 01/31/2012 | 76.8 |
| Stormwater Wetland | Exploration Green Recreation Park Phase 1 Stormwater Wetland | 50.1875 | 1 | 19.8375 | 1 | . | . | 60.5 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 308.75 | 15 | 11.12 | 5 | 12/16/2004 | 03/13/2007 | 96.4 |
| Stormwater Wetland | Proton Therapy Parking Lot Expansion Wetland Basin MD Anderson South Campus | 3314 | 1 | 17.6 | 1 | . | . | 99.5 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 1597.5 | 3 | 738.84 | 5 | 01/18/2008 | 01/31/2012 | 53.8 |
| Stormwater Wetland | University of Texas Recreation Park MD Anderson Campus Wetland | 5.9 | 1 | 3.8 | 1 | . | . | 35.6 |
| Swale | Birnamwood Dr. | 50.47 | 1 | 9.83 | 1 | . | . | 80.5 |
| Swale | Mango Creek | 63.052581 | 31 | 38 | 30 | 11/02/2009 | 12/13/2010 | 39.7 |
| Treatment Train | Birnamwood Dr. | 50.47 | 1 | 6.79 | 1 | . | . | 86.5 |



























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| The following graph is for values more than -200. |































| **BMP\_Design** | **SiteName** | **AvgVF\_in** | **No\_of\_in** | **AvgVF\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 22.760301 | 24 | 46.081444 | 9 | 09/12/2008 | 09/15/2010 | -102.5 |
| Bioretention | Charlottesville HS Biofilter | 92.682133 | 15 | 27.5642 | 15 | 07/10/2010 | 11/16/2010 | 70.3 |
| Bioretention | Greensboro bioretention-G1 | 46.911719 | 57 | 5.2599649 | 57 | 07/01/2003 | 09/27/2004 | 88.8 |
| Bioretention | Greensboro bioretention-G2 | 41.137985 | 65 | 3.9278 | 5 | 07/01/2003 | 09/27/2004 | 90.5 |
| Bioretention | I-95 Plaza Bioretention Cell | 7.0169146 | 10 | 7.0169146 | 10 | 04/01/2005 | 11/15/2007 | 0 |
| Bioretention | Louisburg bioretention-L1 | 78.5401 | 30 | 37.879933 | 30 | 05/30/2004 | 12/23/2004 | 51.8 |
| Bioretention | Louisburg bioretention-L2 | 40.6451 | 30 | 26.974067 | 30 | 05/30/2004 | 12/23/2004 | 33.6 |
| Bioretention | Mango Creek | 48.46848 | 44 | 63.301744 | 54 | 11/02/2009 | 12/02/2010 | -30.6 |
| Bioretention | OP Recycling Center | 26.742606 | 32 | 50.419 | 32 | 07/16/2010 | 09/19/2013 | -88.5 |
| Bioretention | SJC - Bio Ret 3B | 44.496154 | 26 | 79.553889 | 18 | 05/24/2012 | 09/28/2013 | -78.8 |
| Bioretention | SJC - Bio Ret 6 | 41.114118 | 34 | 37.95016 | 25 | 05/24/2012 | 09/28/2013 | 7.7 |
| Bioretention | Birnamwood Dr. | . | . | . | . | 06/01/2014 | 02/01/2017 | 2 |
| Bioretention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 09/01/2013 | 01/01/2015 | 49 |
| Detention | SJC - Ext Dry | 108.296 | 4 | 165.7715 | 6 | 07/07/2011 | 04/23/2013 | -53.1 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 62 |
| Grass Strip | Westfield Level Spreader | 1.4873478 | 23 | 0.2286522 | 23 | 11/29/2005 | 01/05/2007 | 84.6 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 68 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 78 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 79 |
| Manufactured Device | HC | 370.063 | 1 | 105.05733 | 3 | 03/29/2007 | 06/30/2007 | 71.6 |
| Manufactured Device | I-95 Plaza BaySaver | 176.94348 | 10 | 151.77263 | 10 | 11/16/2005 | 11/13/2008 | 14.2 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 37.834139 | 10 | 37.834139 | 10 | 04/08/2006 | 04/28/2008 | 0 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 38.77606 | 11 | 39.509724 | 11 | 12/13/2006 | 04/20/2009 | -1.9 |
| Manufactured Device | I-95 Plaza StormFilter | 96.837489 | 11 | 91.818405 | 11 | 04/01/2005 | 11/15/2007 | 5.2 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 26.113281 | 11 | 26.113281 | 11 | 04/27/2007 | 04/20/2009 | 0 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 28.067143 | 11 | 28.067143 | 11 | 12/13/2006 | 04/20/2009 | 0 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 45.423054 | 10 | 45.423054 | 10 | 12/13/2006 | 04/20/2009 | 0 |
| Manufactured Device | OP Soccer Complex | 915.34675 | 4 | 525.525 | 4 | 06/27/2011 | 11/07/2011 | 42.6 |
| Manufactured Device | SMNW HANCOR | 534.50406 | 32 | 541.88621 | 34 | 05/24/2011 | 09/28/2013 | -1.4 |
| Media Filter | Highland View | 38.124585 | 31 | 28.20525 | 8 | 09/12/2008 | 11/07/2011 | 26 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 109.23867 | 11 | 109.23867 | 11 | 04/01/2005 | 05/12/2008 | 0 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 79 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 85 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 81 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 03/01/2013 | 03/01/2015 | 73 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 12/01/2012 | 08/01/2012 | 43 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 12/01/2013 | 08/01/2013 | 19 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | . | . | . | . | 12/01/2014 | 08/01/2014 | 14 |
| Retention | DeBary Detention with Filtration Pond | 579.21654 | 31 | 579.4663 | 41 | 05/28/1992 | 11/30/1992 | 0 |
| Swale | Birnamwood Dr. | . | . | . | . | 06/01/2014 | 02/01/2017 | 13 |
| Treatment Train | Birnamwood Dr. | . | . | . | . | 06/01/2014 | 02/01/2017 | 14 |























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| The following graph is for values more than -200. |



























| **BMP\_Design** | **SiteName** | **AvgNitrate\_in** | **No\_of\_in** | **AvgNitrate\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | Birnamwood Dr. | 0.1991 | 1 | 0.3363 | 1 | . | . | -68.9 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 45476 | 1 | 13804 | 1 | . | . | 69.6 |
| Detention | B504-03-00 Dry Detention Basin | 0.6786645 | 31 | 0.3807552 | 29 | 09/29/2005 | 02/06/2013 | 43.9 |
| Detention | Dallas Urban Center Stormwater BMPs | . | . | . | . | 02/01/2015 | 06/01/2015 | 91 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 1.8 | 1 | 3.85 | 1 | . | . | -113.9 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 1.8 | 1 | 6.67 | 1 | . | . | -270.6 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 1.8 | 1 | 8.76 | 1 | . | . | -386.7 |
| Manufactured Device | Bama Belle UFF | 0.5118367 | 49 | 0.345 | 50 | 07/16/2010 | 03/30/2013 | 32.6 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 81.68 | 1 | . | . | 56.5 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 53.57 | 1 | . | . | 71.5 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 84.58 | 1 | . | . | 55 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 187.92 | 1 | 125.98 | 1 | . | . | 33 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | 235.09 | 1 | 117.16 | 1 | . | . | 50.2 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | 235.09 | 1 | 120.35 | 1 | . | . | 48.8 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | 235.09 | 1 | 90.77 | 1 | . | . | 61.4 |
| Retention | B512-01-00 Wet Detention Basin | 5.7679091 | 11 | 0.12709 | 10 | 12/29/2010 | 02/06/2013 | 97.8 |
| Retention | E500-12-00 Wet Detention Basin | 0.4197333 | 15 | 0.311 | 1 | 08/05/2008 | 01/10/2013 | 25.9 |
| Retention | E515-01-00 Wet Detention Basin | 0.7529583 | 12 | 0.3798571 | 7 | 07/20/2009 | 02/21/2013 | 49.6 |
| Retention | T501-01-00 Wet Detention Basin | 0.7419286 | 14 | 0.78 | 9 | 01/18/2008 | 01/31/2012 | -5.1 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 0.6053 | 15 | 0.1 | 5 | 12/16/2004 | 03/13/2007 | 83.5 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 0.5993333 | 3 | 0.731 | 5 | 01/18/2008 | 01/31/2012 | -22 |
| Swale | Birnamwood Dr. | 0.2098 | 1 | 0.1991 | 1 | . | . | 5.1 |
| Treatment Train | Birnamwood Dr. | 0.2098 | 1 | 0.3363 | 1 | . | . | -60.3 |





















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| The following graph is for values more than -200. |

























| **BMP\_Design** | **SiteName** | **AvgOrthoP\_in** | **No\_of\_in** | **AvgOrthoP\_out** | **No\_of\_out** | **DateSample** | **DateSample** | **pct\_reduction** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bioretention | 87th Metcalf BMP | 35.014444 | 18 | 5.23625 | 16 | 09/12/2008 | 09/15/2010 | 85 |
| Bioretention | BRC Site A | 0.0270625 | 16 | 0.0292353 | 17 | 04/12/2008 | 03/01/2009 | -8 |
| Bioretention | BRC Site B | 0.0270625 | 16 | 0.0284706 | 17 | 04/12/2008 | 03/01/2009 | -5.2 |
| Bioretention | Birnamwood Dr. | 0.0639 | 1 | 0.0629 | 1 | . | . | 1.6 |
| Bioretention | Cub Run Rec Center | 0.1864133 | 15 | 1.1035 | 10 | 09/25/2008 | 03/28/2010 | -492 |
| Bioretention | Dallas Urban Center Stormwater BMPs | 10351 | 1 | 565 | 1 | . | . | 94.5 |
| Bioretention | Greensboro bioretention-G1 | 0.0647368 | 19 | 0.6107143 | 14 | 07/01/2003 | 09/27/2004 | -843.4 |
| Bioretention | Greensboro bioretention-G2 | 0.171875 | 16 | 8.2 | 4 | 07/01/2003 | 09/27/2004 | -4670.9 |
| Bioretention | I-95 Plaza Bioretention Cell | 0.4282 | 10 | 0.1718182 | 11 | 04/01/2005 | 11/15/2007 | 59.9 |
| Bioretention | Louisburg bioretention-L1 | 0.2016667 | 12 | 0.1716667 | 12 | 05/30/2004 | 12/23/2004 | 14.9 |
| Bioretention | Louisburg bioretention-L2 | 0.0141667 | 12 | 0.1823077 | 13 | 05/30/2004 | 12/23/2004 | -1186.9 |
| Bioretention | OP Recycling Center | 0.0982609 | 23 | 0.3977273 | 22 | 07/16/2010 | 09/19/2013 | -304.8 |
| Bioretention | SJC - Bio Ret 3B | 0.0971429 | 21 | 0.4888235 | 17 | 05/24/2012 | 09/28/2013 | -403.2 |
| Detention | B504-03-00 Dry Detention Basin | 0.9821406 | 32 | 0.7430517 | 29 | 09/29/2005 | 02/06/2013 | 24.3 |
| Detention | Floating Wetland Retrofit North Carolina | 0.14 | 1 | 0.12 | 1 | . | . | 14.3 |
| Detention | Floating Wetland Retrofit North Carolina | 0.13 | 1 | 0.07 | 1 | . | . | 46.2 |
| Floating Wetland 18% coverage | Floating Wetland Retrofit North Carolina | 0.24 | 1 | 0.02 | 1 | . | . | 91.7 |
| Floating Wetland 9% coverage | Floating Wetland Retrofit North Carolina | 0.12 | 1 | 0.07 | 1 | . | . | 41.7 |
| Green Roofs 1 | Dallas Urban Center Stormwater BMPs | 0.48 | 1 | 1.85 | 1 | . | . | -285.4 |
| Green Roofs 2 | Dallas Urban Center Stormwater BMPs | 0.48 | 1 | 2.02 | 1 | . | . | -320.8 |
| Green Roofs 3 | Dallas Urban Center Stormwater BMPs | 0.48 | 1 | 1.77 | 1 | . | . | -268.8 |
| Manufactured Device | Bama Belle UFF | 0.3811111 | 9 | 0.323 | 10 | 07/16/2010 | 03/30/2013 | 15.2 |
| Manufactured Device | HC | 0.025 | 3 | 0.0333333 | 3 | 03/29/2007 | 06/30/2007 | -33.3 |
| Manufactured Device | I-95 Plaza BaySaver | 0.39 | 10 | 0.1885 | 10 | 11/16/2005 | 11/13/2008 | 51.7 |
| Manufactured Device | I-95 Plaza HydroKleen Filter | 1.156 | 10 | 0.858 | 10 | 04/08/2006 | 04/28/2008 | 25.8 |
| Manufactured Device | I-95 Plaza Plus Antimicrobial Additive | 0.2463636 | 11 | 0.135 | 10 | 12/13/2006 | 04/20/2009 | 45.2 |
| Manufactured Device | I-95 Plaza StormFilter | 0.2445455 | 11 | 0.1777273 | 11 | 04/01/2005 | 11/15/2007 | 27.3 |
| Manufactured Device | I-95 Plaza Suntree Grate Inlet Skimmer | 0.3418182 | 11 | 0.075 | 8 | 04/27/2007 | 04/20/2009 | 78.1 |
| Manufactured Device | I-95 Plaza Ultra-Urban Filter | 0.545 | 11 | 0.3454545 | 11 | 12/13/2006 | 04/20/2009 | 36.6 |
| Manufactured Device | I-95 Plaza UltraDrainguard Filter | 0.137 | 10 | 0.088 | 10 | 12/13/2006 | 04/20/2009 | 35.8 |
| Manufactured Device | OP Soccer Complex | 0.045 | 4 | 0.07 | 5 | 06/27/2011 | 11/07/2011 | -55.6 |
| Manufactured Device | SMNW HANCOR | 1.304 | 25 | 1.1728571 | 28 | 05/24/2011 | 09/28/2013 | 10.1 |
| Manufactured Device | VC | 0.1133333 | 3 | 0.07 | 3 | 05/02/2007 | 06/30/2007 | 38.2 |
| Media Filter | Highland View | 0.0460526 | 19 | 0.41325 | 20 | 09/12/2008 | 11/07/2011 | -797.3 |
| Media Filter | I-95 Plaza Delaware Sand Filter | 0.1095455 | 11 | 0.0940909 | 11 | 04/01/2005 | 05/12/2008 | 14.1 |
| Permeable Pavement 1 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 0.24 | 1 | . | . | 60 |
| Permeable Pavement 2 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 17.16 | 1 | . | . | -2760 |
| Permeable Pavement 3 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 1.03 | 1 | . | . | -71.7 |
| Permeable Pavement 4 | Dallas Urban Center Stormwater BMPs | 0.6 | 1 | 6.86 | 1 | . | . | -1043.3 |
| Rainwater Harvesting 1 | Dallas Urban Center Stormwater BMPs | 94.26 | 1 | 20.07 | 1 | . | . | 78.7 |
| Rainwater Harvesting 2 | Dallas Urban Center Stormwater BMPs | 94.26 | 1 | 44.71 | 1 | . | . | 52.6 |
| Rainwater Harvesting 3 | Dallas Urban Center Stormwater BMPs | 94.26 | 1 | 5.05 | 1 | . | . | 94.6 |
| Retention | B512-01-00 Wet Detention Basin | 0.598675 | 12 | 0.3822727 | 11 | 12/29/2010 | 02/06/2013 | 36.1 |
| Retention | DeBary Detention with Filtration Pond | 0.0517228 | 57 | 0.0769149 | 47 | 05/28/1992 | 11/30/1992 | -48.7 |
| Retention | E515-01-00 Wet Detention Basin | 0.2920833 | 12 | 0.19225 | 8 | 07/20/2009 | 02/21/2013 | 34.2 |
| Retention | T501-01-00 Wet Detention Basin | 1.2722667 | 15 | 0.4356 | 10 | 01/18/2008 | 01/31/2012 | 65.8 |
| Stormwater Wetland | EIH UHCL Wetland | 0.22 | 1 | 0.37 | 1 | . | . | -68.2 |
| Stormwater Wetland | P700-01-00 Wetlands Mitigation Bank | 1.6736667 | 15 | 0.2656 | 5 | 12/16/2004 | 03/13/2007 | 84.1 |
| Stormwater Wetland | T101-00-00 Riparian Channel | 3.2966667 | 3 | 2.846 | 5 | 01/18/2008 | 01/31/2012 | 13.7 |
| Stormwater Wetland Primary | EIH UHCL Wetland | 2.64 | 1 | 0.38 | 1 | . | . | 85.6 |
| Stormwater Wetland Secondary | EIH UHCL Wetland | 0.38 | 1 | 0.22 | 1 | . | . | 42.1 |
| Swale | Birnamwood Dr. | 0.0429 | 1 | 0.0639 | 1 | . | . | -49 |
| Treatment Train | Birnamwood Dr. | 0.0429 | 1 | 0.0629 | 1 | . | . | -46.6 |
| Treatment Train | EIH UHCL Wetland | 2.64 | 1 | 0.37 | 1 | . | . | 86 |

























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| The following graphs are for values more than -200. |























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