Evaluating Stormwater Retrofit Potential to Reduce Flood Impacts and Improve Water Quality in Urban Coastal Plain Communities

Grant Code: ECU021PRE1

Final Project Report Submitted to the Environmental Enhancement Grant Program

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Contents

Executive Summary

This project developed an approach to identify unmapped stormwater control measures (dry detention basins or DDBs) in the City of Greenville, NC and evaluated a range of potential retrofit opportunities for a subset (34) of the DDBs that were identified. In addition, trash deposition, suspended sediments during storm events, and water levels were evaluated in a subset of DDBs and a range of educational activities were conducted to help enhance awareness of stormwater management challenges and potential solutions for Coastal Plain communities. Overall, a total of 214 DDBs were identified, and a geographical information system was developed that mapped these systems throughout the city. Based on GIS analysis, approximately 93-114 DDBs were in underserved communities.

Trash deposition was evaluated at 50 DDB sites. Plastic trash, such as bottles and bags, was the dominant type of trash at most sites (74%). Overall, the field assessment results indicated that sites that drained residential housing developments that were regularly landscaped had limited trash deposition in DDBs. Sites that drained commercial development generally had more trash collecting in DDBs, with the most severe trash deposition at sites that drained parking lots from malls, fast food restaurants, and hotels. In the future, outreach efforts to address trash issues at commercial sites may help via cleanups, encouraging availability of trash receptacles, and community education efforts. Storm event water quality assessments at a subset of 4 DDBs indicated that water quality treatment by DDBs is highly variable and DDBs may function as sources or sinks of total suspended sediments depending on site and storm conditions.

The field condition and retrofit assessment revealed a range of conditions across the DDBs. Of the 34 DDBs that were assessed, 9 were considered well-maintained, 23 needed routine maintenance, and 2 needed immediate attention. Challenges observed included: trash deposition, poorly maintained/clogged inlets and/or outlets, damaged inlets and/or outlets, erosion and sedimentation, unmaintained vegetation, tree growth on berms, and shallow groundwater.

Retrofit prioritization criteria included: pond condition, pollutant reduction, constraints, ownership, socioeconomic status, maintenance burden, and educational opportunities. The types of retrofits that would be feasible include: conversion to stormwater wetlands, infiltration basins, bioretention areas, wet ponds, and tree planting. Infiltration basins and stormwater wetlands can provide substantial water quality improvements relative to DDBs; however, infiltration basins may be unfeasible at sites with shallow groundwater conditions. At some sites with shallow groundwater, DDBs had indicators of wetland conditions (wetland vegetation, soils, standing water), suggesting that wetland conversion at these sites may be a feasible retrofit approach.

The benefits of this project included:

- The development of an approach to locate unmapped dry detention basins in Coastal Plain communities
- The development of a geographic information system and mapping of 214 DDBs and their locations relative to underserved communities in the City of Greenville
- The analysis of retrofit potential for 34 DDBs that can be used to improve stormwater treatment
- The identification of DDB sites that had excessive trash deposition and can be targeted for cleanups in the future
- Training and educational opportunities that helped approximately 50 students and over 300 citizens learn more about DDBs and stormwater challenges in Coastal Plain communities
- Funding obtained through the US EPA for future work on stormwater challenges in Greenville

Introduction

Dry detention basins (DDBs) are typically installed to provide stormwater quantity control through detention of stormwater runoff and slow release to reduce the impacts of peak flows on streams. DDBs temporarily store incoming stormwater, trap suspended sediments and associated contaminants, and reduce the peak discharge from the site (**Figure 1**). These features can reduce downstream flooding and erosion impacts. The design guidelines for DDBs in North Carolina indicate that DDBs should draw down within two to five days following precipitation events (NC DEQ 2020).

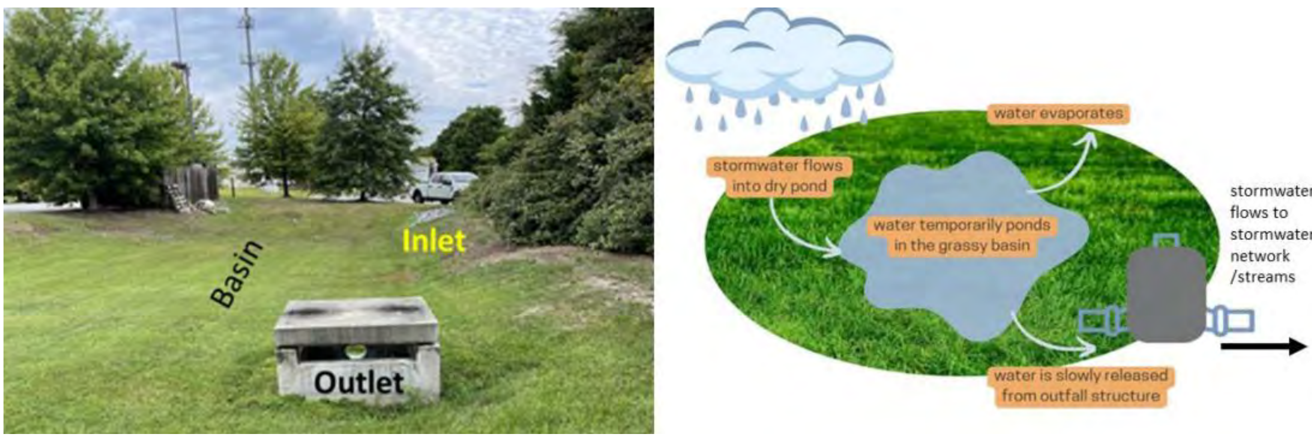


Figure 1. Example dry detention basin located behind Dollar General on 1601 Evans St., Greenville, NC. Illustration depicts how conventional dry detention basins temporarily store and release stormwater (modified from Nashville, 2024).

Conventional DDBs are not designed for stormwater pollutant removal. The North Carolina Stormwater Control Measure Credit Document (NC DEQ, 2017) estimates minimal nutrient treatment (10%) for DDBs, however they have been shown to perform better for total suspended sediment removal (median removal efficiency of 58%). In Greenville, NC there has not been a requirement for registration or maintenance/inspection for DDBs prior to 2017. Inspections and maintenance of these systems are needed due to the potential for sediment buildup and clogging of pipes by trash and debris and their impacts to downstream waterways. Recent studies in Greenville and in other urban Coastal Plain cities have revealed that DDBs provide minimal stormwater quality treatment and retrofits can improve water quality and volume control (NC DEQ, 2017, Humphrey and Iverson, 2020). This project was implemented due to a growing need to locate and map unmapped DDBs to evaluate their influence on urban flooding and stormwater quality, address basins in need of maintenance, to identify candidate basins for potential retrofits that can reduce environmental impacts and provide local benefits in underserved communities, and to improve understanding of stormwater infrastructure and functionality across the city.

Study Area and Methods

The city of Greenville was founded in 1787. Since then, urban expansion has occurred due to Greenville's role as an agricultural, industrial, medical, and educational hub for eastern North Carolina. Population and urban development have expanded as East Carolina University has grown, particularly over the last half century. Population density in Greenville has remained relatively constant since the 1980s. However, the municipal land area has increased from 39 km^2 (1980) to 101 km^2 (2023), to accommodate a 2.6-fold increase in population from 35,740 (1980) to 90,057 (2022) (OSBM, 2024, US Census, 2023, Greenville, NC, 2024). Recent population and land-use trends suggest urban expansion will continue into the future. Currently, 75% of the population of Pitt County resides in urban areas. Based on long-term records at the Greenville airport (1876-2023), the city receives approximately 45 inches of precipitation per year (NC State Climate Office, 2024). Urbanization trends and recent trends of increased intense precipitation in the region (NC DOT, 2018, Paerl et al., 2019, Dello et al., 2020) suggest that stormwater management will be increasingly important in the future. Tributary streams in the northern areas of the City drain to the Tar River. The largest stream, Greens Mill Run, is affected by urban stormwater runoff and is listed on the NC 303(d) list of impaired streams (NC DEQ, 2024). In the southern portion of the City, Swift Creek (also impaired and on the 303(d) list) and Fork Swamp drain to the Neuse River. Both the Tar and Neuse Rivers are considered nutrient-sensitive waterbodies and stormwater management efforts are working to reduce nutrient exports (**Figure 2**).

Identifying Unmapped Dry Detention Basins

To identify unmapped DDBs in the City, a GIS methodology was developed as outlined in **Figure 3**. Light Detection and Ranging (LiDAR) is a technology used to create high-resolution models of ground elevation. In the early 2000s, a case study utilized bare-earth LiDAR DEMs to identify detention basins through the Houston metropolitan area of Texas (Wang & Liu, 2006; Liu & Wang, 2008). This earlier work indicated that LiDAR based approaches can assist with efforts to identify unmapped DDBs. The availability of high-quality, dense LiDAR point clouds and derived digital elevation models (DEMs) covering the entire study extent allowed us to consider several approaches for automating the delineation of closed depression boundaries. For this work, we selected a hybrid raster-vector approach, that begins by contouring the available 3.25-ft resolution DEM at a fixed ½-ft interval before then analyzing the generated contours to identify the boundaries. Contouring of a raster DEM is a function available in all modern GIS software and the produced contour features can be analyzed using the same product, allowing all steps to be automated in the same application.

The LiDAR data from 2015 were obtained from NC Department of Public Safety-Emergency Management and provided detailed information on land surface elevation, adhering to the USGS 3DEP Quality Level 2 standard with at least 2 laser returns per square meter and a vertical accuracy (RMSEz) of ~10cm. A LiDAR-derived DEM with a spatial resolution of 1m was processed to identify closed depressions in the study area, to find potential sites where DDBs may be located. Initial efforts revealed 36,431 closed depressions within the Greenville extraterritorial jurisdiction. Closed depressions can include natural features (e.g., wetlands) and anthropogenic features (e.g., artificial ponds, ditches, and other features); therefore, it was necessary to develop an approach to further screen out features that were not DDBs. A machine learning approach using a random forest model (Breiman, 2001) was used to remove depressions that were not DDBs. The random forest model was selected because it has an established track record when used as a classifier with very complex data, is widely supported by software, computationally efficient to train, and simple to explain to those already familiar with basic decision tree models. Initial filtering was performed on the generated contours to eliminate any that did not enclose at least 1/50th of an acre, to reduce noise due to the small contouring interval. Next, a second filter was applied to eliminate any contours that did not form closed loops within the analysis extent, which was defined as a rectangle enclosing the Greenville extraterritorial jurisdiction. The resulting set of closed loop contours were then converted into polygon discs (shapes which enclose stacks of nested contours), the relationship between discs computed, and ridges and very shallow depressions excluded. Subsequent filtering was performed by intersecting the discs with ancillary datasets to exclude those that intersect buildings, roads and railroads, known hydrographic features, and that fall outside of the Greenville, NC extraterritorial jurisdiction. The final set of candidate depressions was developed by stacking the discs into discrete groups, each of which represents a possible DDBs. The delineation of these boundaries provides the required input for the subsequent classification of artificial features used as DDBs. Additional "shape metrics" and other parameters were generated from the candidate basins to improve any future model's ability to separate DDBs from non-DDBs. A complete list of parameters computed from the candidate basin shapes is found in Table 1.

Many depressions were identified in the previous step that are not DDBs and these false positives had to be removed before the final list of DDBs could be compiled from the data. Once a final set of candidate depression boundaries was delineated, a random forests ensemble classifier was applied to classify each feature using a binary scheme: DDB or non-DDB. A training dataset was used including the list of known stormwater control measures provided by the City of Greenville along with additional features identified visually by inspecting the orthoimagery and LiDAR. A random subset was used to train the model while the remaining subset was used for validation. Once the model was trained and validated, we applied it to all candidate features to produce the final list of detected DDBs.

A field and aerial imagery verification effort was conducted in 2023-2024 to evaluate the accuracy of the GIS approach for predicting the location of DDBs. The candidate DDB list was created from the closed depression mapping and random forest model efforts. Sites identified on this list were visited and/or studied via aerial imagery to confirm the presence or absence of DDBs. After field or aerial image verification, the DDB GIS layer was updated to produce a final DDB map. At some sites, access was not possible due to site security and fencing, we attempted to identify evidence of DDBs through aerial photos in areas where there were depressions, and the model indicated that the depressions had shape characteristics indicative of DDBs. In most cases, inlets and outlets could be seen in the imagery. However, there may be some uncertainty at sites solely based on aerial verification. In addition, it was challenging to identify parking lot DDBs, these were not directly targeted, but several sites (3,4, and 305) had evidence (smaller outlet pipes draining from parking lot stormwater drains) that they may serve these functions.

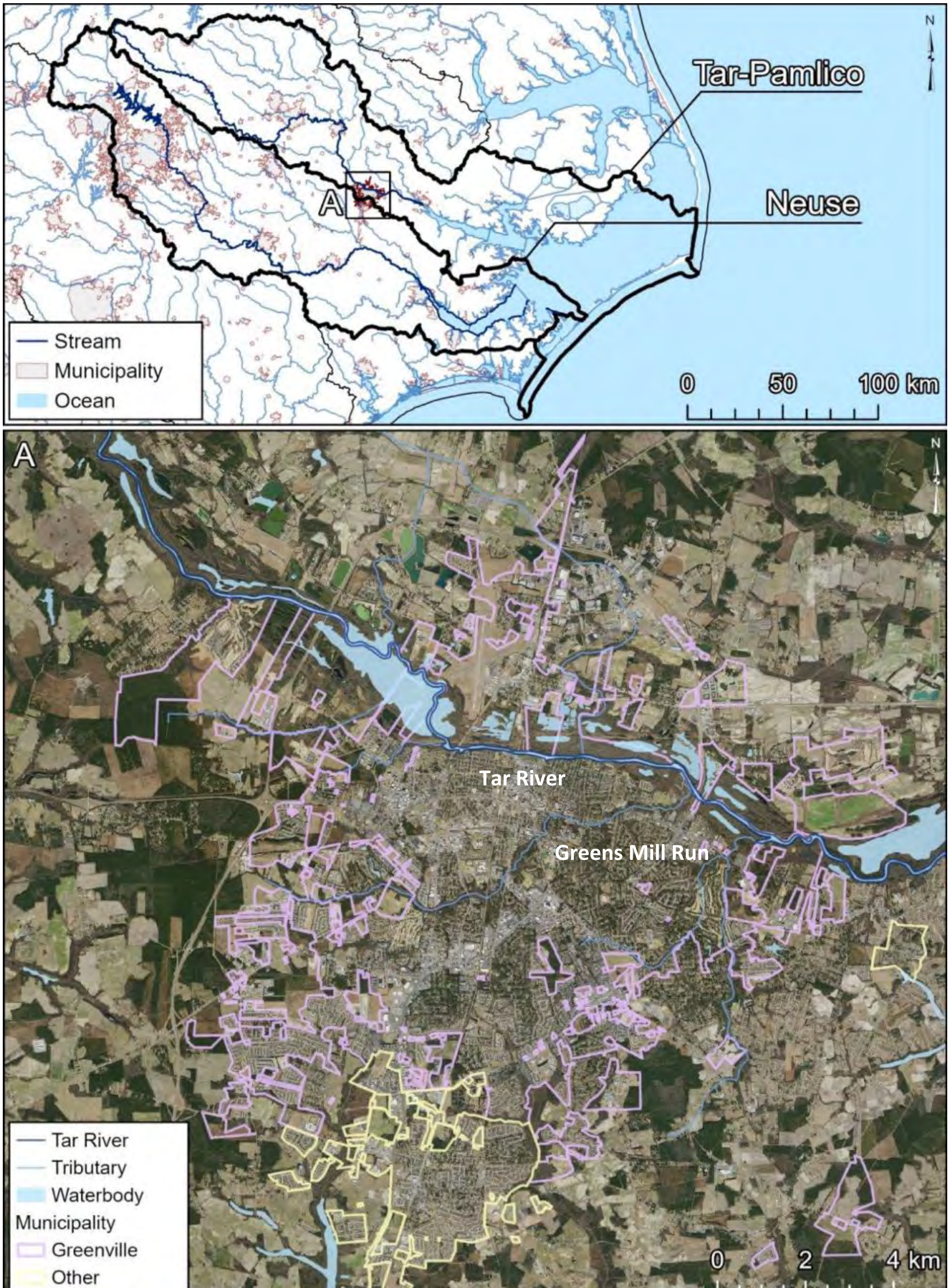


Figure 2. Map of the Tar-Pamlico and Neuse River Basins. Inset A) illustrates the Tar River and its main tributaries near Greenville, NC and the study area.

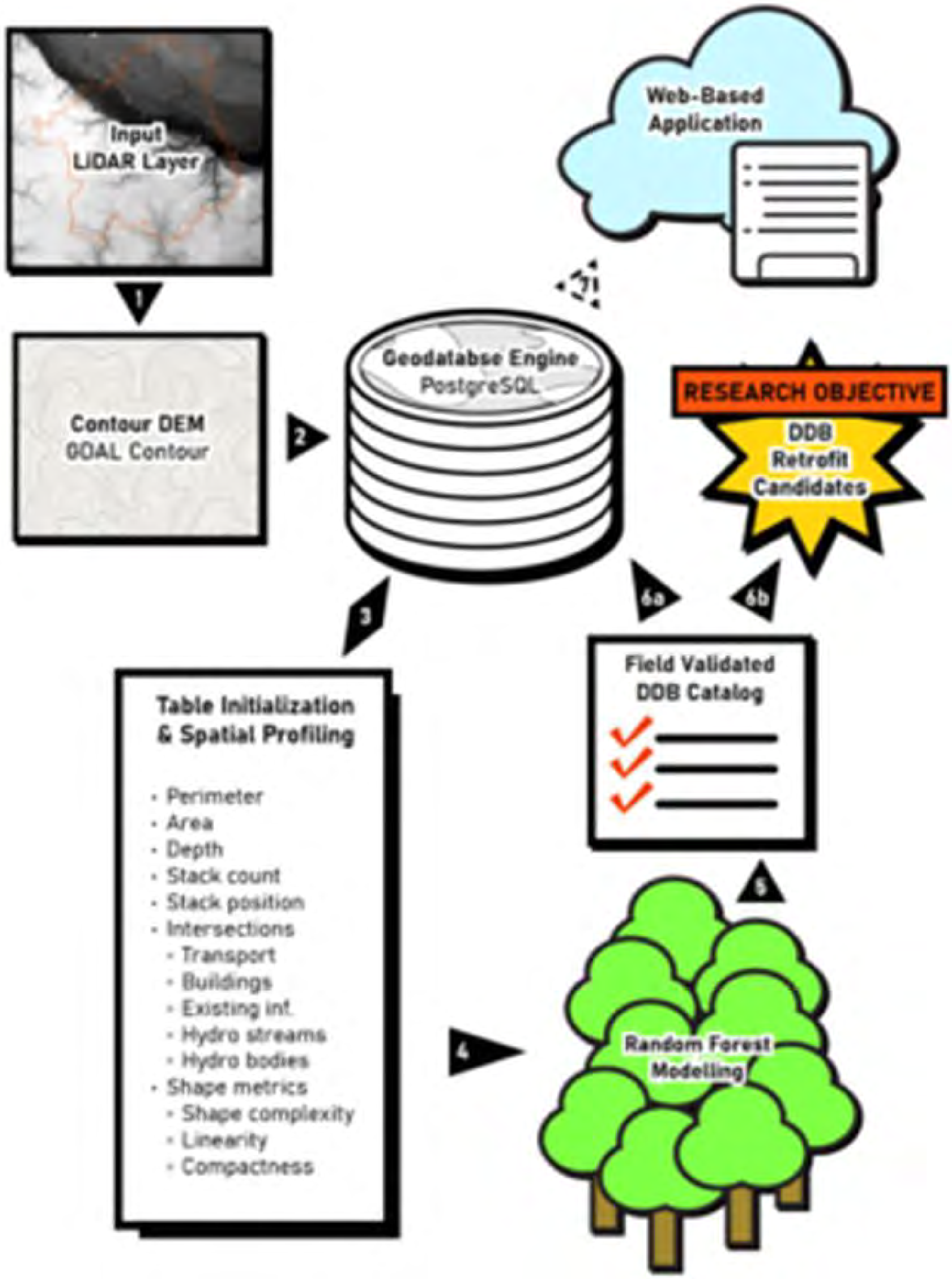


Figure 3. Diagram showing a generalized view of the data flow between input, storage, and prediction steps. [4] and [5] show LiDAR-derived input data flow through the random forest model to yield a set of predictions which can then be used for field validation. [7] shows how the same data store could be used to power web-based, interactive exploration tools.

Table 1. A list of all parameters computed from depression boundary shapes and contour-to-contour relationships for use with the random forest ensemble classifier.

PARAMETER	PARAMETER DESCRIPTION
IS_SPECK (BOOL)	Whether the depression perimeter is less than 100-ft in length.
PERIMETER (DOUBLE)	The total length of the external boundary of the depression.
AREA (DOUBLE)	The total area of the disc feature formed by the depression boundary.
IX_ETJ (BOOL)	Whether the depression falls inside the Greenville extraterritorial jurisdiction.
IX_PARCELS (DOUBLE)	The total number of parcels intersected by the depression.
IX_HYDRO (BOOL)	Whether the depression intersects a known hydrographic feature.
IX_TRANSPORT (BOOL)	Whether the depression intersects a road or railroad feature.
IX_BUILDING (BOOL)	Whether the depression intersects a building feature.
IX_CHANNEL (BOOL)	Whether the depression intersects a known drainage channel.
IX_PIPE_END (BOOL)	Whether the depression intersects a stormwater pipe end mapped in the Greenville stormwater GIS.
IX_POND_STRUCT (BOOL)	Whether the depression intersects a pond structure mapped in the Greenville stormwater GIS.
IX_DROP_INLET (BOOL)	Whether the depression intersects a drop inlet mapped in the Greenville stormwater GIS.
IX_SLAB_INLET (BOOL)	Whether the depression intersects a slab inlet mapped in the Greenville stormwater GIS.
IX_YARD_INLET (BOOL)	Whether the depression intersects a yard inlet mapped in the Greenville stormwater GIS.
IX_SOIL (STIRNG[])	The list of symbols for soil units intersected by the depression.
IX_SOILS_HYDGRP (STRING[])	The list of hydrologic soil groups for soil units intersected by the depression.
SM_PAR (DOUBLE)	The perimeter to area ratio of the depression boundary shape.
SM_SCI (DOUBLE)	The Shape Complexity Index of the depression boundary shape.
SM_FRACTAL (DOUBLE)	The fractal dimension of the depression boundary shape.
SM_LINEARITY (DOUBLE)	The linearity of the depression boundary shape.
RM_FCAR (DOUBLE)	The percent change in area between this contour and it's first child contour.
RM_FCVR (DOUBLE)	The percent change in volume between this contour and it's first child.
RM_ACAR (DOUBLE)	The average percent change in area between parent-child pairs within this contour's children
RM_ACVR (DOUBLE)	The average percent change in volume between parent-child pairs within this contour's children.
RM_HAUSDORFF (DOUBLE)	The Hausdorff distance between this contour and its immediate parent.
RM_USDMIN (DOUBLE)	The minimum distance between this contour and that of its immediate parent.
RM_USDMAX (DOUBLE)	The maximum distance between this contour and that of its immediate parent.
RM_USDAVG (DOUBLE)	The average distance between this contour and that of its immediate parent.
RM_USDSTD (DOUBLE)	The standard deviation of the distances between this contour and that of its immediate parent.

Mapping of Underserved Neighborhoods

The distribution of underserved communities throughout the City of Greenville was also evaluated using data provided by NC DEQ (2022) and US EPA (2024). NC DEQ (2022) classifies census blocks as “potentially underserved blocks” (PUBs) based on racial and income demographics. More specifically, they define a PUB as any census block that meets the following criteria: 1) the percentage of non-white and Hispanic or Latino population is > 50% or the percentage of non-white and Hispanic or Latino population is at least 10% greater than the county or state share; and 2) percentage of population experiencing poverty is > 20% and percentage of households in poverty is at least 5% greater than the county or state share (NC DEQ, 2022). US EPA (2024) identifies census tracts as “disadvantaged communities” (DCs) based on environmental, climate, and/or socioeconomic burden. More specifically, they evaluate 8 environmental, climate, socioeconomic, or other burden categories, including: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. For most burdens, except workforce development, if a census tract is at or above the 90th percentile for 1 associated criterion and at or above the 65th percentile for low income, then it is identified as a DC. Housing and legacy pollution include other burden-specific conditions that may result in identification of a DC, even if none of the other criteria exceed the 90th percentile. For housing, a census track may be considered a DC if it has experienced historic underinvestment. For legacy pollution, a census track may be considered burdened if it has at least one abandoned mine land or formerly used defense site. If either housing or legacy pollution conditions exist, the census tract must also be at or above the 65th percentile for low income to be considered a DC. For workforce development, if the census tract is at or above the 90th percentile for 1 associated criterion and > 10% of people aged 25 years or older whose high school education is less than a high school diploma then it is identified a DC. More information about the evaluation metrics for each burden is available at CEQ (2022). Flood zone information was collected from FEMA (2024). After compiling these data, the City of Greenville and Pitt County were evaluated to identify underserved communities, which were compared to the location of DDBs.

Water Level Monitoring

To evaluate general drainage patterns of DDBs in Greenville, Onset hobo pressure transducers were installed at ten sites. Five sites that appeared to experience less vegetation maintenance (overgrowth of vegetation) and five sites that appeared to be well-maintained (grass lawn with regular mowing and landscaping) were selected for water level monitoring. Air pressure for barometric compensation was monitored at ECU Flanagan Building. Water level monitoring at 15-minute intervals at sites initiated in October 2023 and continued for over 1 year, finishing in November 2024. **Table 2** provides information on the monitoring sites. Water level data at the 10 monitored sites were summarized to evaluate the percent of time that drainage occurred from basins and if there were occurrences when systems held water for greater than 5 days. The total annual rainfall (Nov. 1, 2023-Oct. 31, 2024) at the USGS gage at Town Commons in Greenville was 44.6 inches, slightly lower than the long-term average of 48 inches/yr (1974-2023; https://products.climate.ncsu.edu/climate/station-percentiles/). During the study period, limited rainfall occurred in February, April, June, and October 2024, however the months of July-September 2024 were wetter than average, due to several large storms (**Figure 4**).

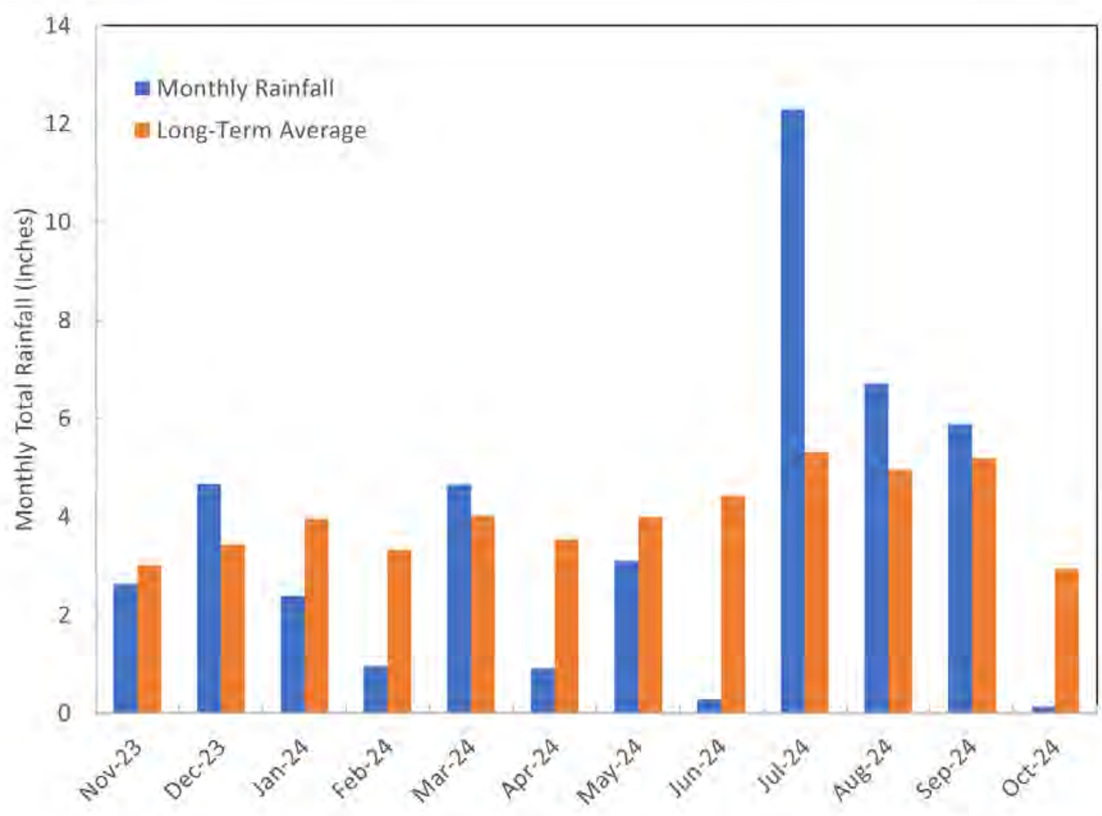


Figure 4. Monthly total rainfall from Nov. 2023-Oct. 2024 compared to the long-term average total monthly rainfall at Greenville (1974-2023, source: NC State Climate Office: https://products.climate.ncsu.edu/climate/station-percentiles/)

Table 2. Dry detention basin water level monitoring sites. Asterisk indicates sites where water quality sampling was also conducted. Hydrologic drainage groups: A-high infiltration; B-moderate infiltration; C-slow infiltration; D- very slow infiltration

Site Location	*ID Number (ogc_fid)*	*DDB Field Site Number*	*Vegetation Characteristics*	*Soil Type (Hydrologic Drainage Group)*	*Basin Area (acres)*	*Approx. Volume (gallons)*
Carolina Vision Care*	12198261	30	Grassy	B/D (100%)	0.135	122681
Oakdowne Cell Tower	10499698	54	Grassy	A (51.5%), D (48.5%)	0.097	52438
Mt. Calvary	9515804	9	Grassy	B (100%)	0.108	55580
Lowes Hardware	12011793	7	Grassy	B/D (76.8%), B (23.2%)	0.315	169808
Fire Dept. *	11410298	8	Grassy	A (100%)	0.156	97247
Ample Storage *	10242674	24	Forested	B (88.9%), C (11.1%)	0.177	139886
Scales Place	9785449	143	Forested	A/D (81.8%) B/D (18.1%)	0.668	424894
Greenville Mall*	10743520	405	Forested	A/D (94.8%) C (6.2%)	2.195	3089455
Belvoir Dental	6604727	357	Forested	A (100%)	0.122	97995
Physicians East	9867247	215	Forested	B (52.5%) B/D (47.5%)	0.631	374026

Water Quality Monitoring

In November 2023, two undergraduate students (Camryn Landreth and Paige Brown) received an ECU Undergraduate Research and Creative Activity Award that funded water quality monitoring of 4 DDBs. Four of the 10 DDBs where water level data was collected were selected for monitoring. These 4 DDBs were adjacent to Carolina Vision Care (DDB 30), a fire station (Rollins Dr.- DDB 8), Ample Storage (DDB 24), and the Greenville Mall (DDB 405) (Table 2). A total of 3 storms were sampled on 12 February 2024, 16 September 2024, and 27 September 2024. Discharge was also calculated using the partially filled round pipe equation, which requires the diameter of the pipe, the water height in the pipe, and the velocity (ft/sec). The diameter of each culvert was measured at the beginning of the study using a survey grade rod. During each sampling event, the water depth in the pipe was measured using a survey grade rod and the flow velocity was measured using a *Global Water* FP-111 flow meter. Some DDBs contained multiple inlets that intermittently flowed based on the size of the storm. The inlet discharge for these DDBs was estimated by summing the measured discharge from each flowing inlet. Water samples were collected into HDPE bottles, stored on ice, and transported to the Environmental Research Laboratory at ECU to analyze total suspended solids (TSS) concentrations.

In the laboratory, each sample was vacuum-filtered to separate the solid particles, and the volume of water filtered was recorded. Filters containing the solid particles were dried in an oven at 105 °C to evaporate water until a consistent weight was recorded for at least 2 consecutive days. After the drying process was completed, the TSS concentration was calculated based on the mass of solid particles in a specific volume of water (i.e., the volume of water that was filtered). TSS concentrations in DDB inlets and outlets were compared to determine if DDBs improved water quality. Using the discharge (L/sec) and the TSS concentration (mg/L), the TSS mass (g/hr) was calculated for each DDB inlet and outlet to estimate the sediment mass transport during each sampled storm. The TSS mass was calculated by multiplying the discharge and TSS concentration, then converting from mg/sec to g/hr. The treatment efficiency was calculated by using the percent difference equation to determine the concentration and mass reduction of TSS for each DDB (Eq. 1). If concentrations or masses were greater in the outlet than the inlet, then the percent reduction is negative indicating that water quality worsened after passing through the DDB.

$$Treatment\ Efficiency = \frac{Inlet_{TSS} - Outlet_{TSS}}{Inlet_{TSS}} \times 100 \qquad \text{Eq. 1}$$

where TSS= the concentration or the mass of TSS.

Trash Deposition in Dry Detention Basins

A field assessment of trash deposition in DDBs was conducted in Fall 2024. The Survey 123 app was used to collect trash abundance and characteristics in 50 DDBs throughout the City of Greenville. A rapid trash assessment approach was developed, modified from earlier approaches (Moore et al., 2007). At each DDB, a 50 ft. transect was measured from the outlet and trash counts were conducted visually for a 20 ft. wide area (1000 sq ft). Sites were considered to have minimal trash impacts when counts were less than 10, moderate impacts when counts were 10-20, and poor condition when counts were > 20. Site coordinates, photos, and total trash counts were recorded for each site. In addition, the total count of plastic items, and average size of items was estimated, as well as the approximate dimensions of the outlet structure and the adjacent land use draining to the DDB.

Retrofit Evaluation (Center for Watershed Protection Report)

To evaluate the potential for improved stormwater management via DDB retrofits, a retrofit evaluation was conducted for 34 DDB sites. A detailed summary of this work is provided in the Dry Detention Basin Condition and Retrofit Evaluation Report that is attached at the end of this document.

Results and Discussion

Dry Detention Basins in Greenville, NC

Initial records from the City of Greenville indicated 9 DDBs were included in their stormwater database and approximately 20 others were known (**Figure 5**). Through the project efforts a total of 214 DDBs were identified in the City of Greenville (**Figure 6**). The size of DDBs varied across the City, the average surface area of DDBs was 11,431 sq. ft and the range of areas was 1,249 to 161,925 sq. feet. Larger systems often drained several properties, for example the regional drainage basin (DDB 255) at WH Smith Blvd (~ 119,000 square ft. or 2.7 acres). Typically, DDBs were found at higher densities in commercial districts that have greater impervious area and adjacent to housing developments (**Figure 6**). There are several zones of high densities of basins adjacent to major roads with substantial commercial development such as Greenville Blvd., Memorial Blvd., and Firetower Rd. In general, there is a higher density of DDBs on the south side of the Tar River. Many DDBs are located in the middle and upper portions of Greens Mill Run watershed. Retrofits to these systems could help improve water quality in Greens Mill Run, which is a community goal since that stream is listed as impaired on the NC 303(d) list.

Detailed information on DDB retrofit potential in the City of Greenville is provided in the Dry Detention Basin Condition and Retrofit Evaluation Report at the end of this report. Observations from field visits to DDBs suggested several challenges including: trash deposition, poorly maintained/clogged inlets and/or outlets, damaged inlets and/or outlets, erosion and sedimentation, unmaintained vegetation, tree growth on berms, and shallow groundwater. Numerous sites had shallow groundwater conditions. At sites with shallow groundwater, DDBs can develop wetland characteristics over time. Wetland indicators observed include: waterlogged soils, standing water, and wetland vegetation (**Figure 7**). Although this can create a nuisance, by having standing water in the features (e.g. mosquito issues, inability to mow, potential for vegetation to clog inlets/outlets), it also leads to growth of wetland vegetation that can potentially help with nutrient and sediment treatment. At sites where wetland conversion has begun naturally, retrofits to enhance wetland nutrient treatment may be a cost-effective approach to improve water quality. The retrofit evaluation identified 5 primary approaches that would enhance stormwater volume and water quality at the assessed DDB sites: wetland conversion, bioretention, infiltration, wet ponds, and tree planting. These approaches are discussed in detail in the Dry Detention Basin Condition and Retrofit Evaluation Report section.

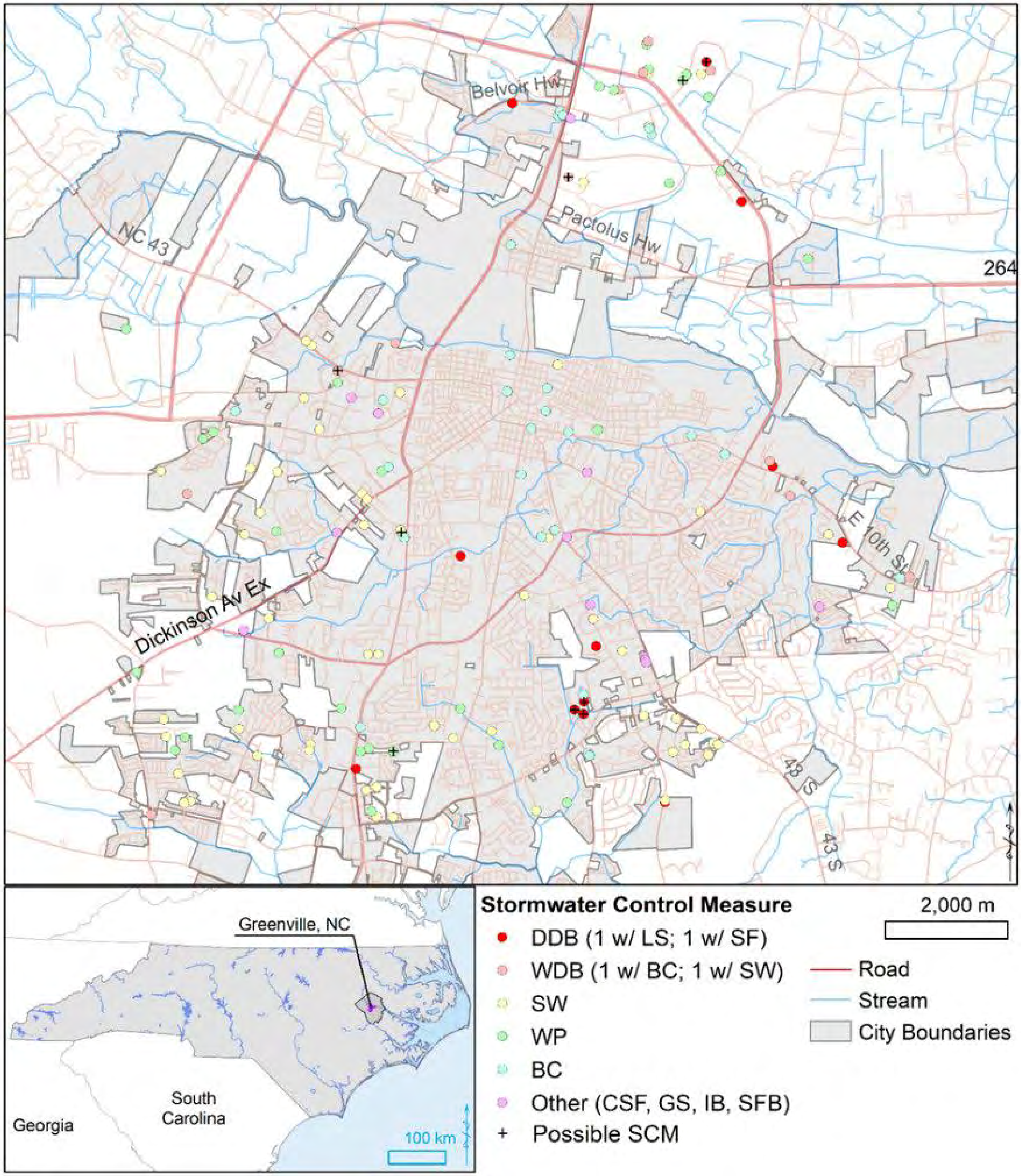


Figure 5. Initial estimate of known DDBs at the initiation of the project. DDB: dry detention basin; LS: level spreader; SF: sand filter; SW: stormwater wetland; WP: wet pond; BC: bioretention cell; CSF: Contech storm filter; GS: grassed swale; IB: infiltration basin; SFB: sand filter basin

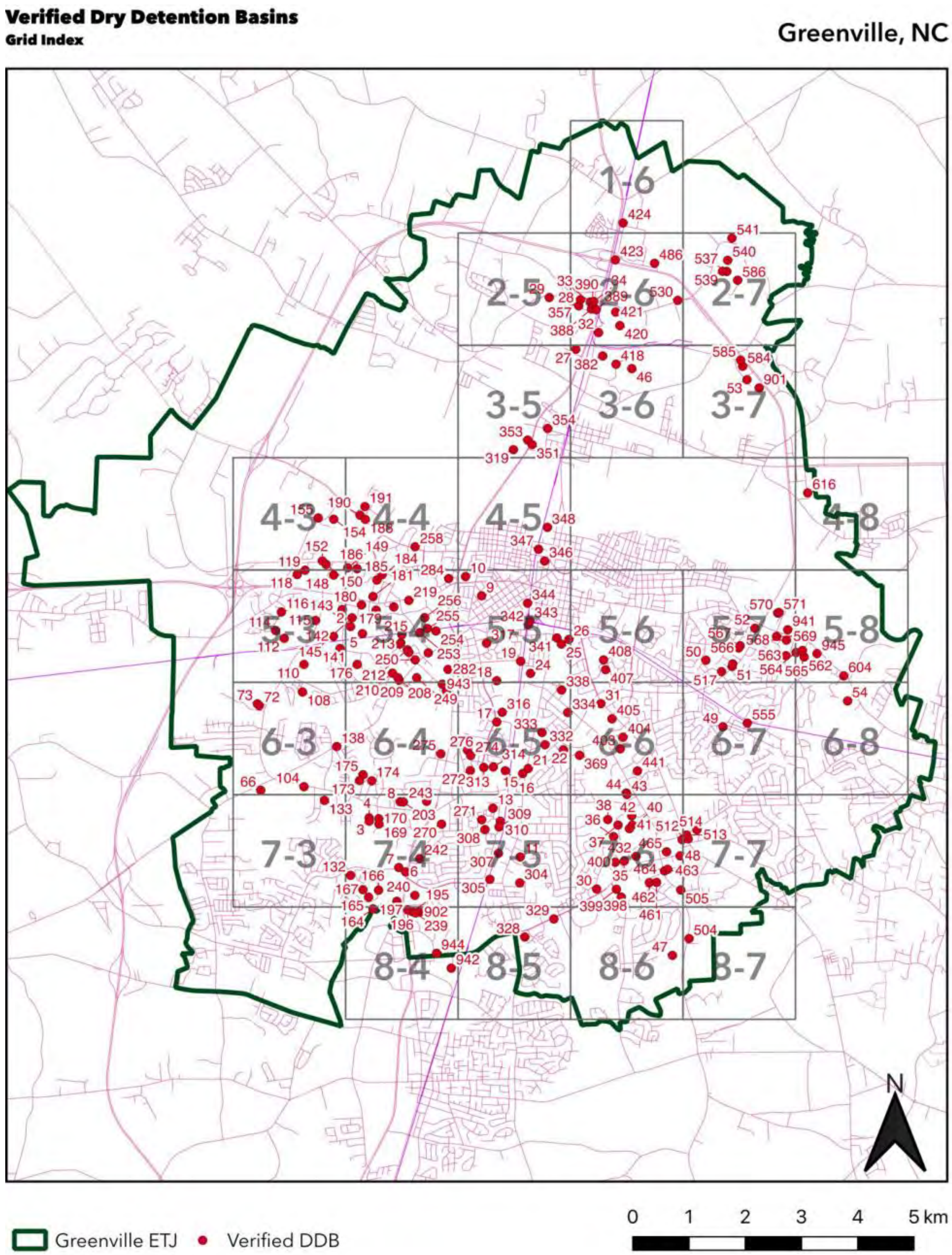


Figure 6. Map showing the location of dry detention basins with basin ID number and index locations for detailed maps in appendix. Data will be provided by request.

Figure 7. Examples of observed dry detention basin challenges including shallow groundwater, trash deposition, unmaintained vegetation, erosion, and clogged inlets/outlets.

Water Level Variations at Monitored Dry Detention Basins

The observations of standing water at several DDB sites suggested shallow groundwater conditions may affect DDB functionality at numerous sites. Water level data at the 10 monitored sites were summarized to evaluate the percent of time that drainage occurred from basins and if systems held water for greater than 5 days. Basins had a wide range of soil hydrologic drainage groups and there was not a clear relationship between soil hydrologic drainage group, vegetation, and percent of time inundated. However, there was a positive linear relationship between DDB surface area and the percent of time the DDB was wet, indicating that larger DDBs were more likely to have standing water in between rainfall events (**Figure 8**). Basin 405 had the largest surface area, as well as drainage area, and this basin also saw the greatest percentage of time inundated at the outlet. Of the 10 sites, 7 had at least one occurrence of drainage for > 5 days following rainfall events. The 3 sites that drained quicker and always had shorter recession periods (<5 days) were sites 24, 30 and 357. Basins 24 and 357 were generally forested and had well-drained soils, those sites may experience greater infiltration and less outflow relative to the other observed basins (inflow data would help clarify). For example, a comparison of basins 24 and 8 shows how water level variations at the outlets can vary and the data suggest that some sites, such as 24 may infiltrate more stormwater (**Figure 9**). When this information is paired with water quality data (**Figure 14**), it suggests that basins with greater outflow are more likely to affect downstream water quality. More information is needed to understand how local groundwater depths and soils can influence the potential for infiltration and runoff at these sites. Future work will aim to evaluate groundwater depth and its interaction with dry detention basin function.

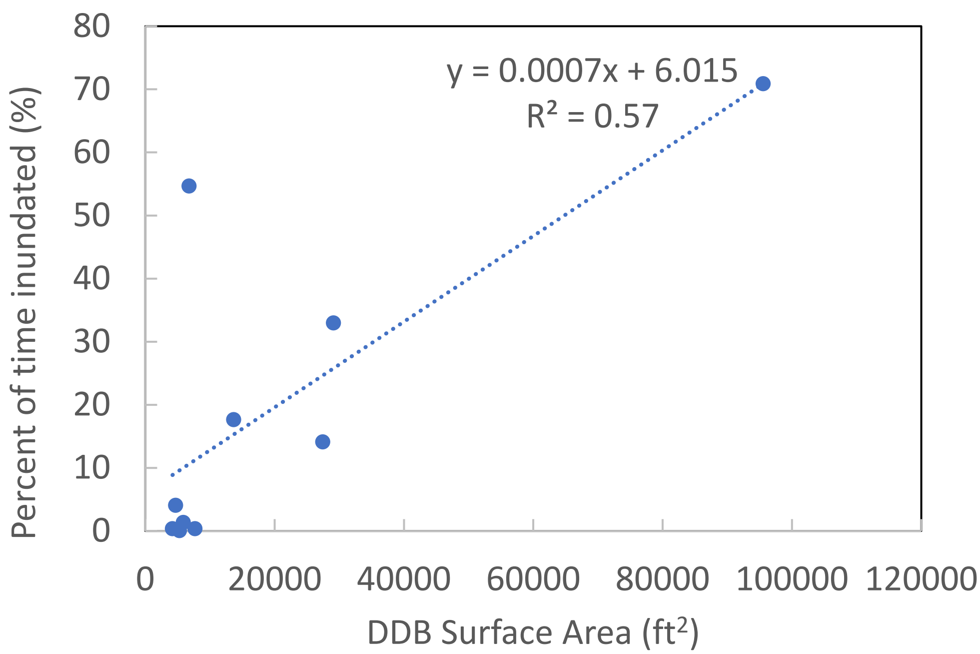


Figure 8. The surface area of the dry detention basin vs. the percent of time the dry detention basin was inundated (wet conditions at outlet) during the monitoring period (Oct. 2023-Nov. 2024).

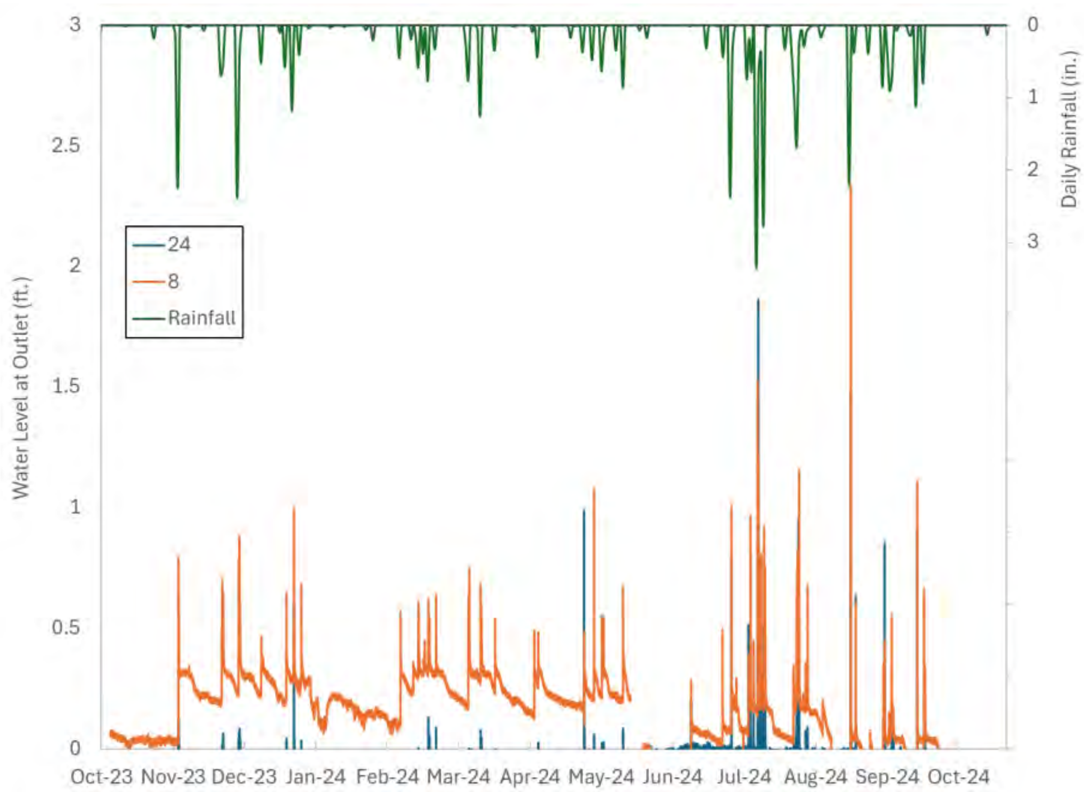
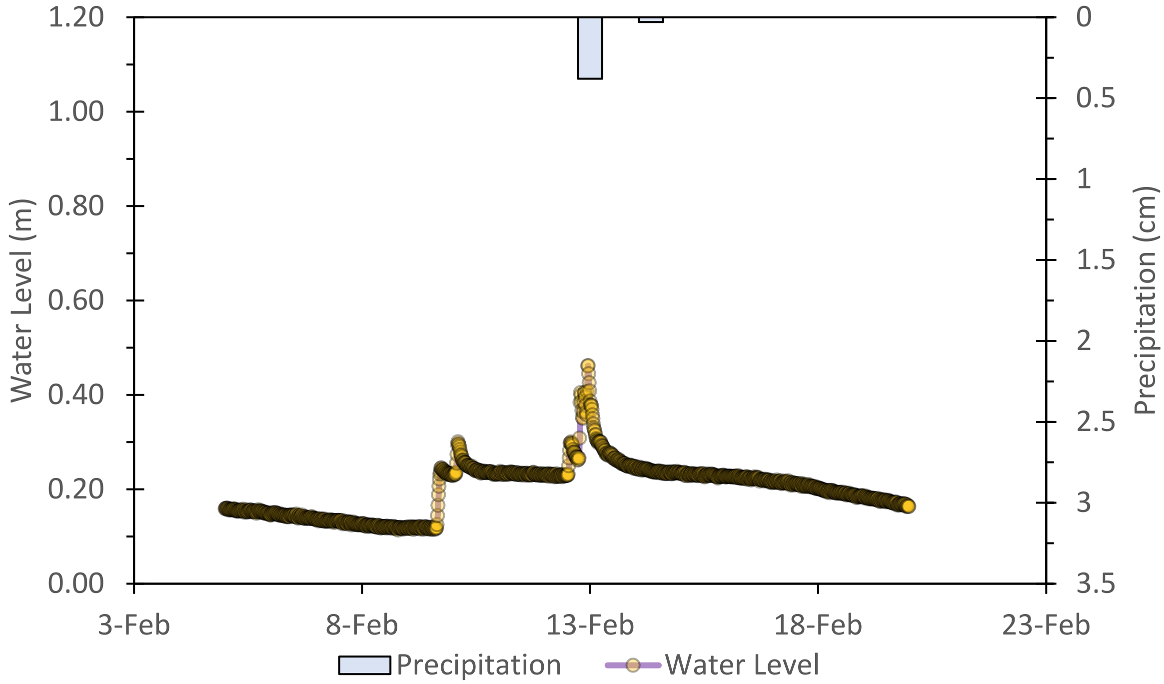


Figure 9. Water levels at the outlets of basins 8 and 24 and daily rainfall during the monitoring period (Oct. 2023-Nov. 2024). At basin 24, water levels were less responsive to rainfall indicating that infiltration may have a greater influence on reducing runoff at this site (or less inflow).

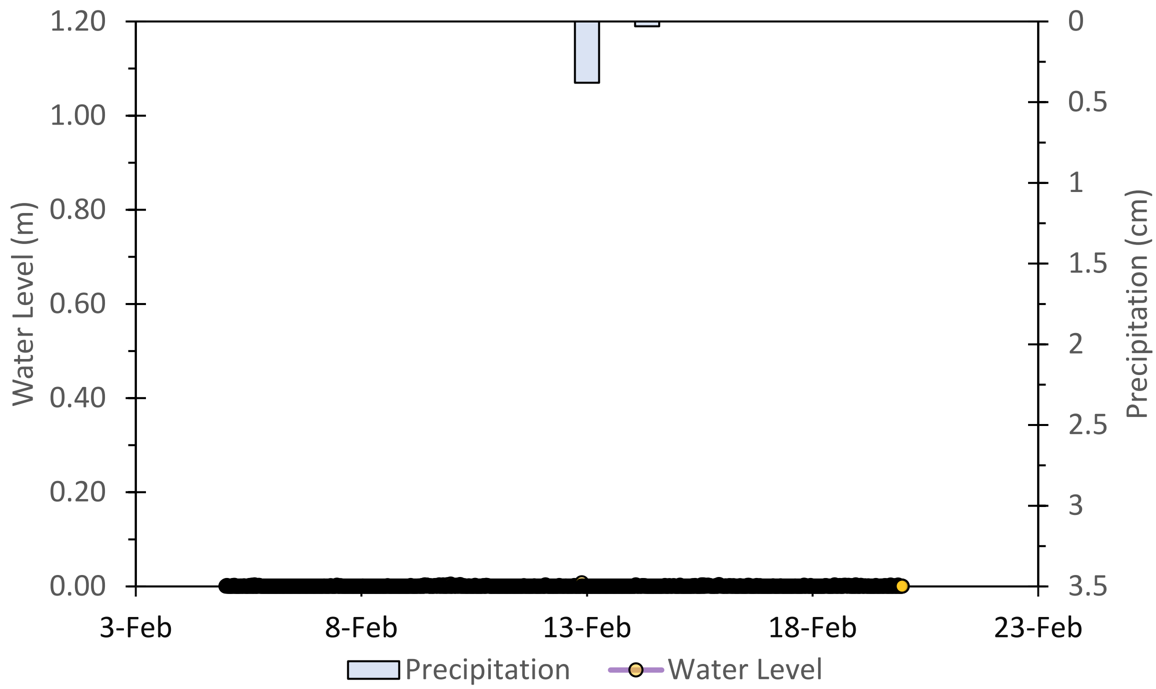
Treatment of Total Suspended Solids by Monitored Dry Detention Basins

Results from the water quality monitoring suggested that DDBs inconsistently provided water quality benefits. The storm that passed through Greenville on 13 February was a small storm and most DDBs were unresponsive to the low precipitation amount (approx. 0.5 cm or 0.2 in) (**Figures 10 and 11**). Due to the small storm, there was insufficient runoff generated to collect samples from inlets and outlets of all the studied DDBs. Samples were collected from the inlet and outlet from the Greenville Mall and Carolina Vision Care, but only the inlet could be sampled at Ample Storage and the DDB at the Fire Department was dry. This issue did not occur during the storms in September 2024 since these storms were larger (**Figures 12 and 13**). Two storms passed through the Greenville area on 16 September and 27 September generating approximately 1.8 and 3.3 cm (0.7-1.3 in) of rainfall, respectively. Water level responses to the storm were variable between the 4 studied DDBs. The DDBs serving the Greenville Mall and Ample Storage were overgrown with numerous trees and other herbaceous vegetation, which is uncommon for well-maintained DDBs. Furthermore, the DDB at Ample Storage may benefit from maintenance to excavate sediment banks that may impede runoff from entering the practice.

Water quality treatment by DDBs was variable between practices and storms (**Figure 14**; **Tables 3 and 4**). Overall, the mean and median concentration of TSS tended to be greater in DDB outlets compared to inlets (**Figure 14**). Similarly, concentration and mass reductions by the mean DDB were negative indicating that outlets tended to contain greater TSS concentrations and masses relative to inlets (**Tables 3 and 4**). The Greenville Mall (DDB-1 in **Figure 14**) was the only DDB that consistently contained lower TSS in the outlet compared to the inlet. During the larger September storms, this DDB reduced TSS concentrations by about 20% between the inlet and outlet (**Tables 3 and 4**). However, this practice is less effective at retaining sediment loads during larger storms as documented by the increase in sediment mass transport during the 27 September 2024 storm (**Table 4**). Treatment by the DDB serving Carolina Vision Care was likely underestimated. During the 16 September 2024 storm, TSS was below detection, which likely occurred due to the sampling technique. This basin has a small sediment bank that has created a small forebay, which likely encourages sedimentation. Thus, we were unable to estimate concentration and mass reductions during this storm. Despite the issue with sampling, the DDB reduced discharge by about 74% during this storm, which could also translate to a mass reduction, but this could not be confirmed. During the 27 September 2024 storm, we sampled directly from the inlet pipe upgradient from the sediment bank and found a more representative TSS sample. The concentration reduction of TSS during this storm was 99%, thus TSS concentrations in previous storms may have been underestimated. Treatment by the DDB serving the Fire Department was inconsistent. A 73% reduction in TSS concentration was observed on 16 September (**Table 3**); however, on 27 September, TSS concentrations in the outlet were more than triple that of the inlet (**Table 4**). This may be linked to erosion along a gully along the south side berm of the basin. Furthermore, this DDB was not effective at reducing TSS masses (**Tables 3 and 4**). It was difficult to assess treatment by the DDB serving Ample Storage due to the forementioned maintenance issues.

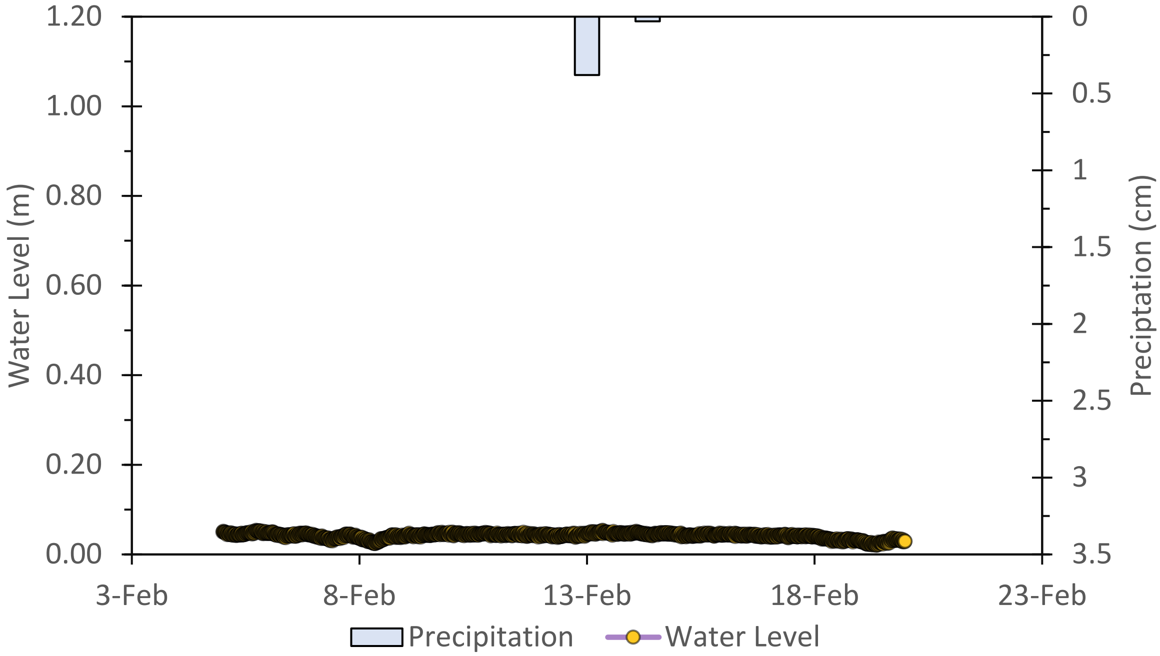


A



B

Figure 10. Water level responses to the storm on 13 February 2024 at the Greenville Mall (A) and Carolina Vision Care (B).



A

B

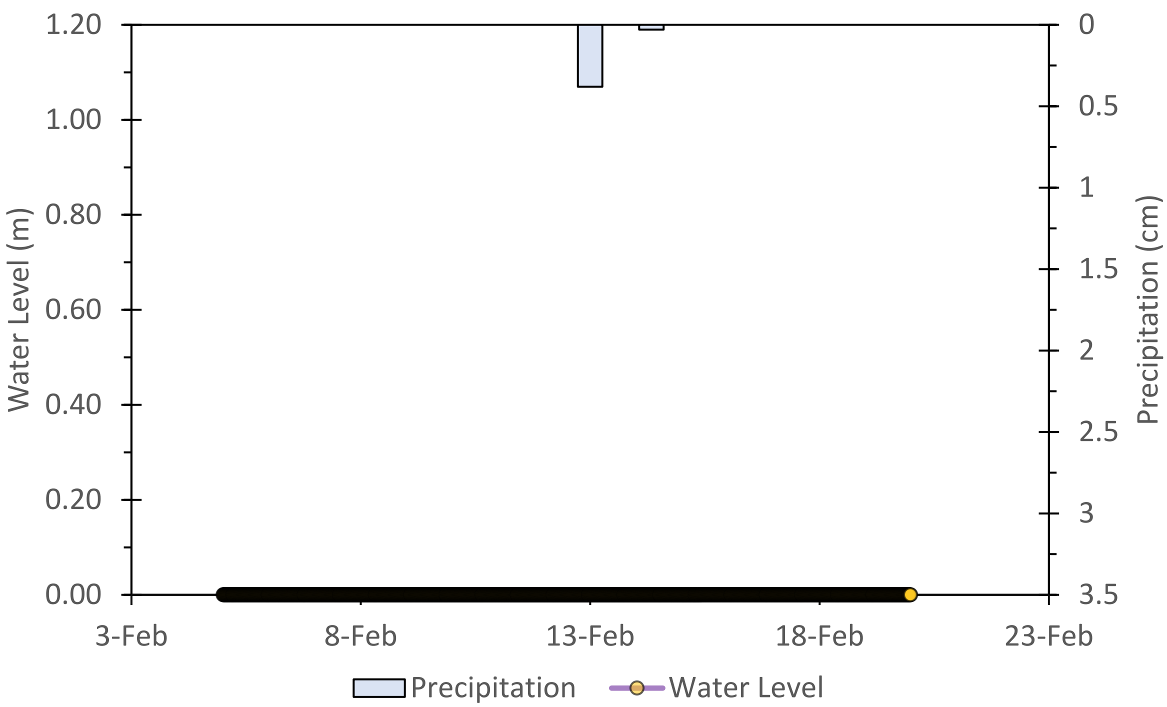
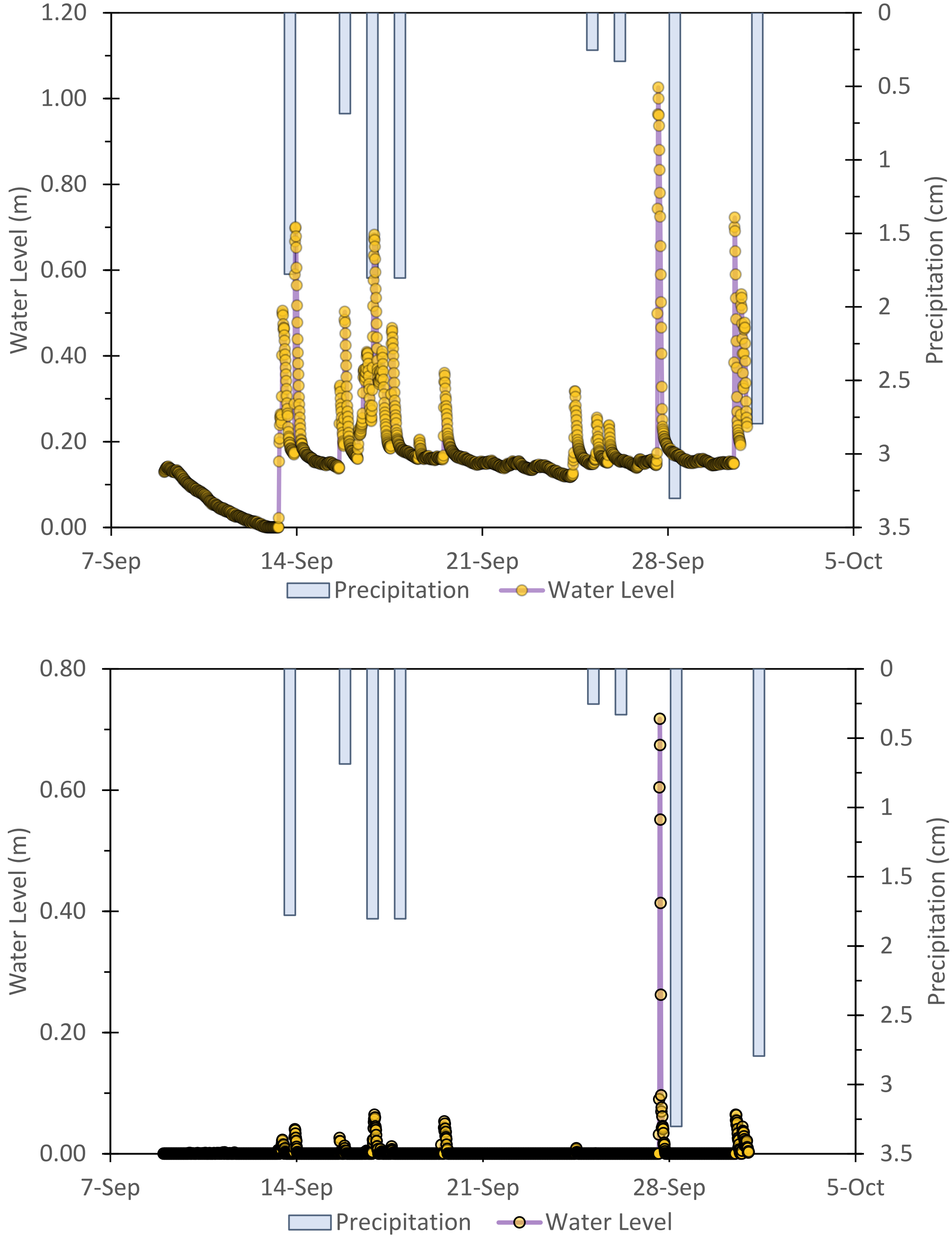


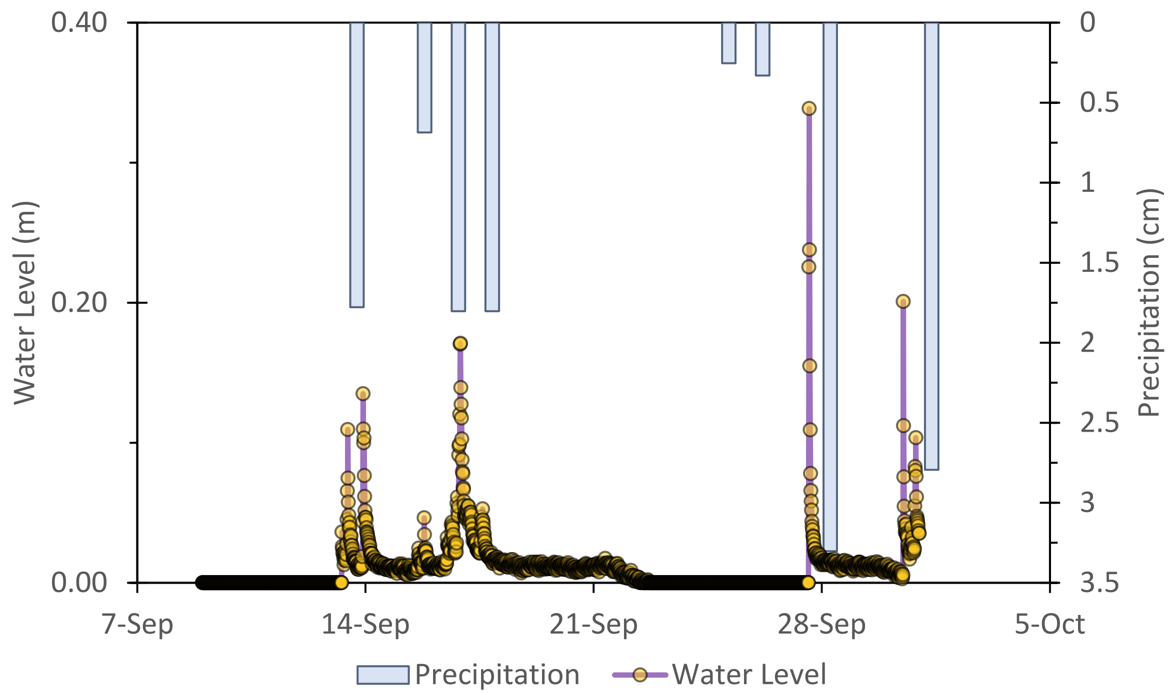
Figure 11. Water level responses to the storm on 13 February 2024 at the Fire Department (A) and Ample Storage (B).



A

B

Figure 12. Water level responses to the storms on 16 September and 27 September 2024 at the Greenville Mall (A) and Carolina Vision Care (B).



A

B

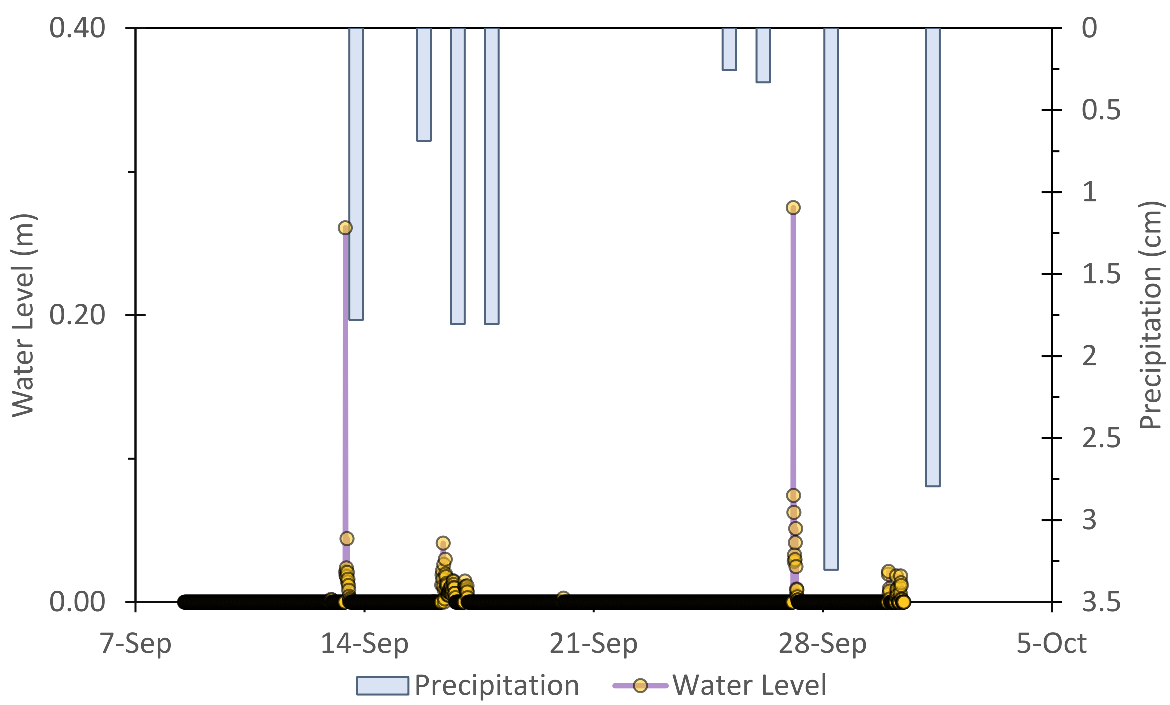


Figure 13. Water level responses to the storms on 16 September and 27 September 2024 at the Fire Department (A) and Ample Storage (B).

Overall, the data suggest that TSS treatment by DDBs is highly variable. Due to variations in site and storm conditions, basins may serve as sources or sinks of TSS. More monitoring data is needed to better characterize treatment by the studied DDBs, especially at finer temporal resolutions. Grab sampling techniques are cost effective methods to estimate treatment; however, it is possible that the first flush was missed during some storms, which may explain the negative reductions in TSS concentrations and masses. Partnering grab sampling techniques with stage samplers or automated storm samples and autonomous loggers would better characterize treatment. Utilizing these techniques to sample at least 6 storms with varying precipitation depths and season would better constrain treatment by DDBs.

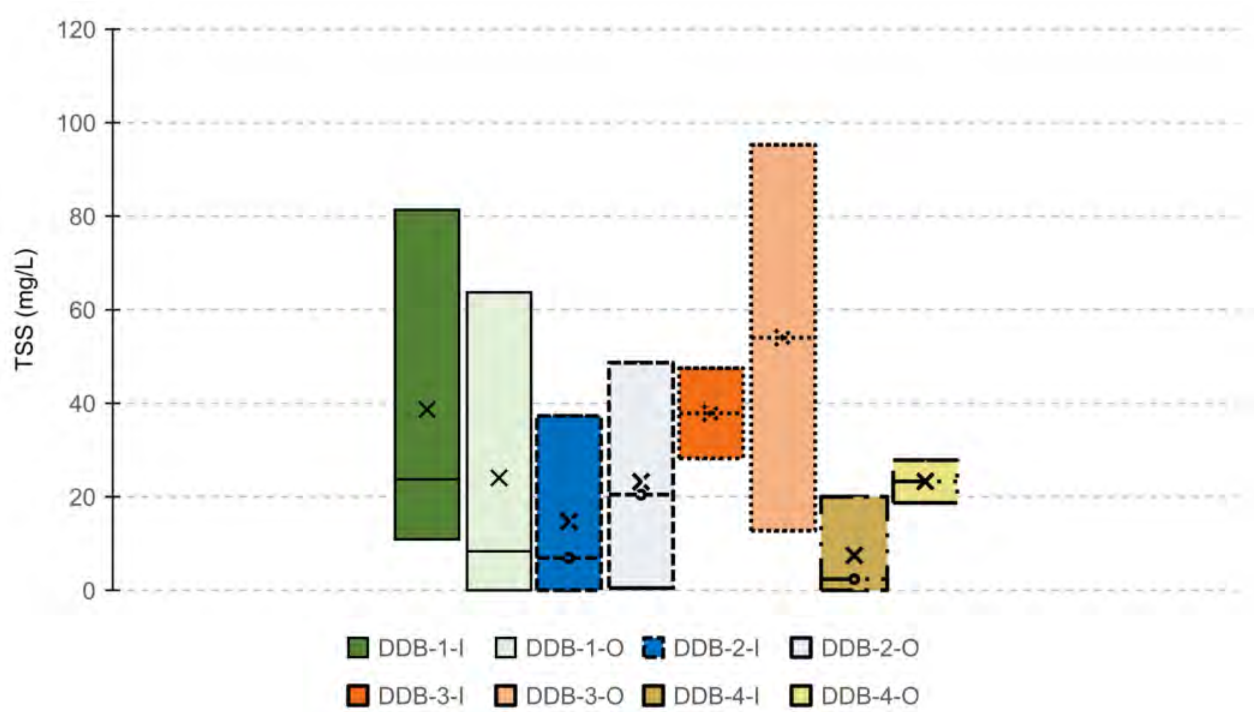


Figure 14. Boxplot of total suspended solids (TSS) concentrations in monitored dry detention basins (DDBs). DDB-1= Greenville Mall (site 405); DDB-2= Carolina Vision Care (site 30); DDB-3= Fire Department (site 8); DDB-4= Ample Storage (site 24); I= Inlet; O= Outlet.

Table 3. Discharge (Q), concentrations and masses of total suspended solids (TSS), and concentration (Conc) and mass reductions of TSS for each DDB and the mean DDB for the 16 September 2024 storm.

Site	Location	Discharge Q (L/sec)	TSS Concentration (mg/L)	Conc Reduction (%)	TSS Mass (g/hr)	Mass Reduction (%)
DDB1	Inlet	57.0	10.91		2237.7	
	Outlet	60.6	8.37	23%	1826.9	18%
DDB2	Inlet	6.5	0.00		0.0	
	Outlet	1.7	20.45		127.4	
DDB3	Inlet	0.1	47.50		18.1	
	Outlet	31.5	12.73	73%	1444.4	-7880%
DDB4	Inlet	0.0	0.00		0.0	
	Outlet	0.1	18.70		6.4	
Mean DDB	Inlet	15.9	14.60		564.0	
	Outlet	23.5	15.06	-3%	851.3	-51%

Table 4. Discharge (Q), concentrations and masses of total suspended solids (TSS), and concentration (Conc) and mass reductions of TSS for each DDB and the mean DDB for the 27 September 2024 storm.

Site	Location	Discharge Q (L/sec)	TSS (mg/L)	Conc Red (%)	TSS Mass (g/hr)	Mass Reduction (%)
DDB1	Inlet	691.2	81.33		202384.2	
	Outlet	1083.3	63.72	22%	248503.1	-23%
DDB2	Inlet	75.1	37.27		10071.7	
	Outlet	20.8	0.47	99%	34.8	99%
DDB3	Inlet	10.3	28.18		1048.0	
	Outlet	3.1	95.24	-238%	1048.5	0%
DDB4	Inlet	0.1	20.00		7.4	
	Outlet	9.3	27.80	-39%	933.6	-12486%
Mean DDB	Inlet	194.2	41.70		53377.8	
	Outlet	279.1	46.81	-12%	62630.0	-17%

Trash Deposition in Dry Detention Basins

Locations for the 50 sites selected for trash deposition surveys are provided in **Figure 15**. Results for total trash counts revealed that 26/50 sites (52%) had 10 or less trash items per 50 ft. transect. However, 17/50 (34%) sites had > 20 trash items/1000 square ft. with 5 sites (sites 566, 569, 567, 568, and 571) that had severe trash accumulation with 90 or more trash items (**Figure 16**). Plastic trash, such as bottles and bags, was the dominant type of trash at most sites (74%). The sites with severe trash accumulation all drained lots with commercial developments. In contrast, sites that drained residential housing complexes typically had < 20 trash counts, indicating that the type of land use that drained to the DDB had an influence on trash deposition. Overall, the field trash deposition results indicated that sites that drained residential housing developments that were regularly landscaped had minimal trash deposition. Sites that had more trash collecting in DDBs were generally associated with commercial development, with the most severe trash deposition at sites that drained parking lots from malls, fast food restaurants, and hotels. In the future, outreach and community education efforts to address trash issues at commercial sites can help via cleanups and encouraging availability and regular maintenance of trash receptacles at local businesses. Further details are provided in **Appendix 2**.

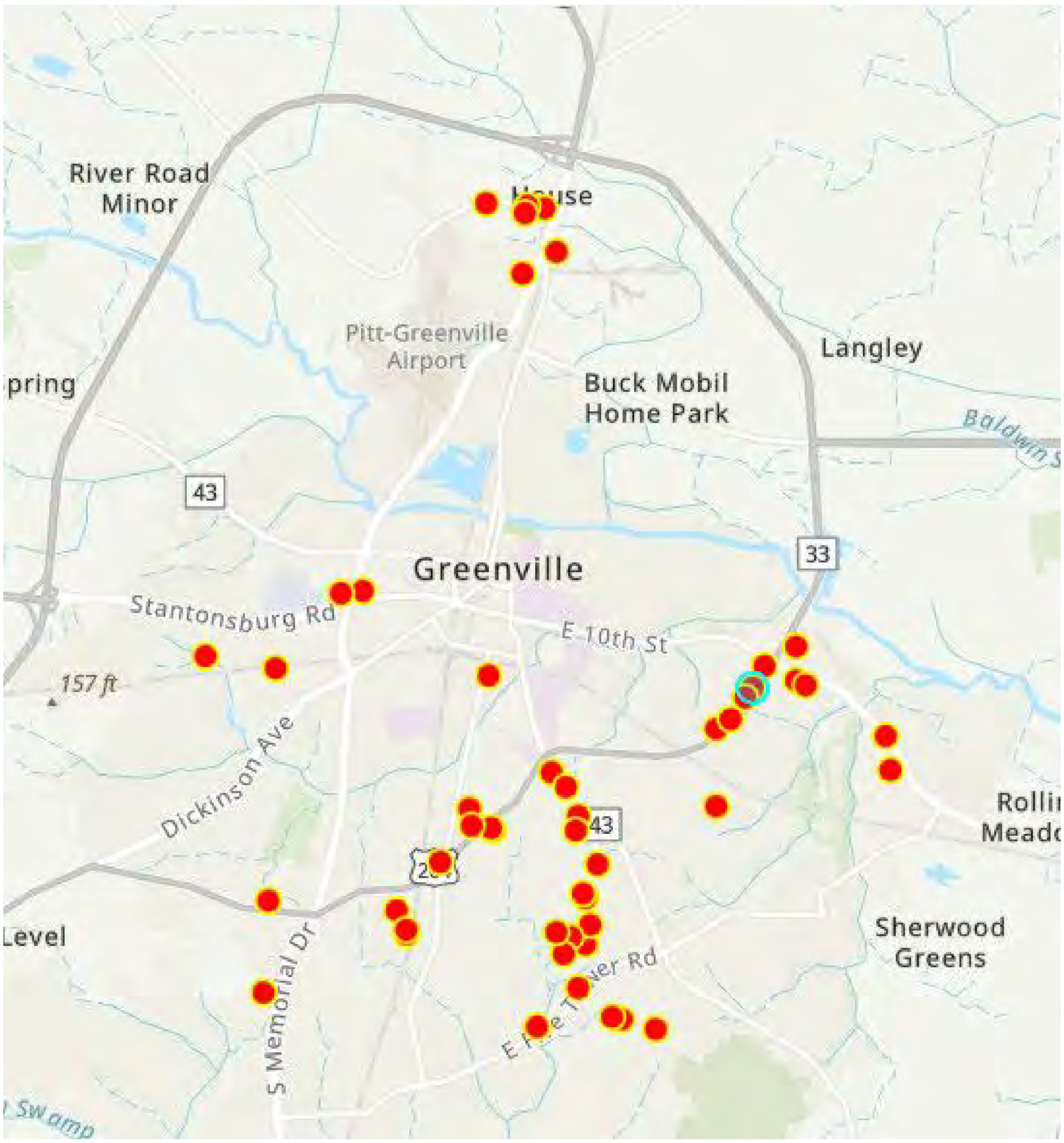


Figure 15. 50 dry detention basin sites in Greenville evaluated for trash deposition.

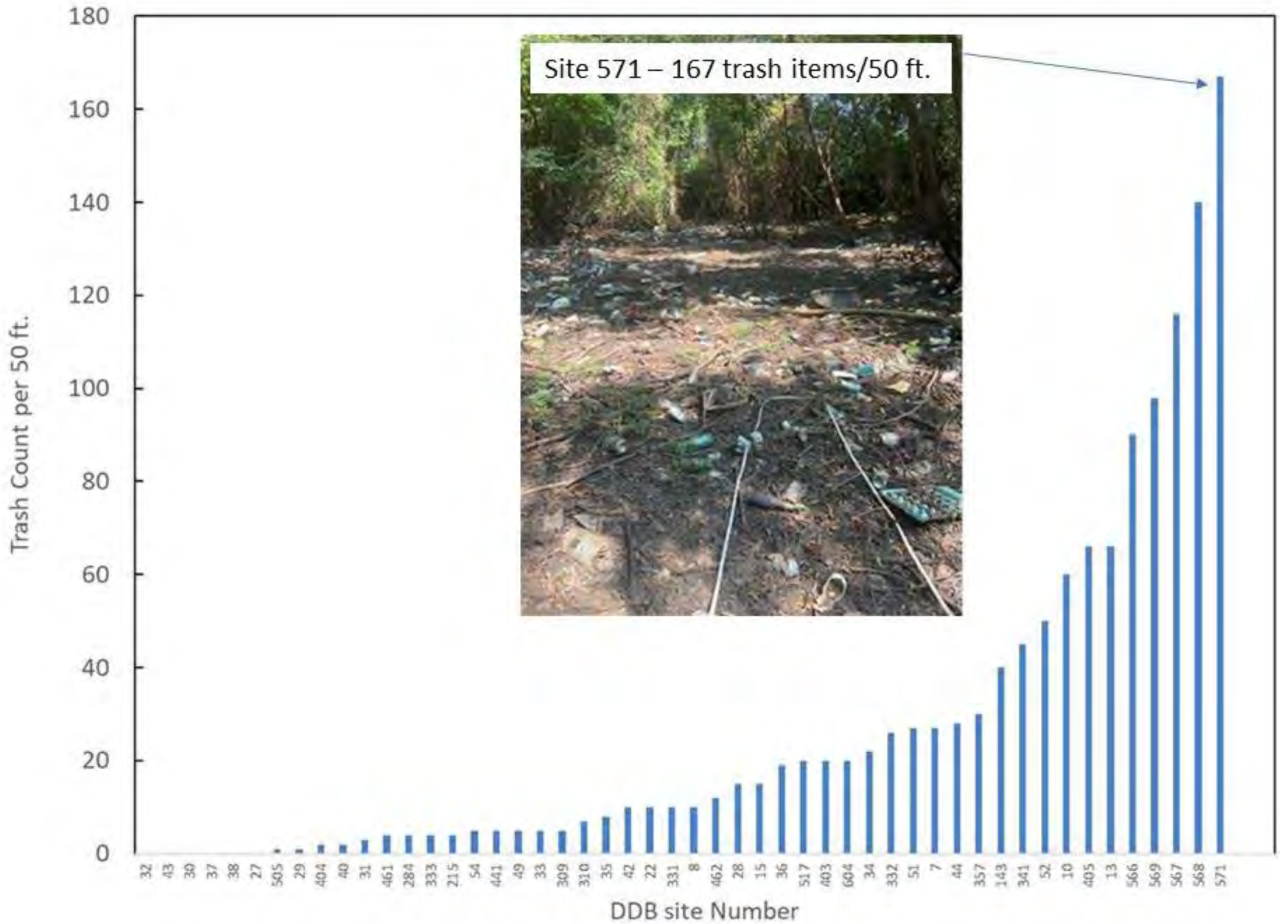


Figure 16. Trash counts along 50 ft. transects in DDBs. Most sites had 10 or less pieces of trash per 100 ft^2. The most severe (top 5) sites had 90 or more pieces of trash. Site 571 had the highest trash count (167 trash items along 50 ft. transect). The dominant type of trash was plastic at most sites.

Mapping of Underserved Neighborhoods

The City contains numerous underserved communities, as indicated by the percent of the population below the poverty level. The highest percentages of poverty in Pitt County are found within the City of Greenville, particularly in communities that are adjacent to or near (within 3.2 km or 2 mi) the Tar River. Most of the census blocks near the Tar River contain a population experiencing poverty that is greater than 40%, and 2 blocks exceed 80% (**Appendix 1**). Some of these census blocks are much greater than the county and state poverty percentages of 22.9% and 14.7%, respectively (NC DEQ, 2022). Similarly, there are numerous communities of color that live adjacent to or near the Tar River. There are at least 9 census blocks where the percentage of nonwhite and Hispanic or Latino population exceeds 75% (**Appendix 1**). NC DEQ (2022) identifies PUBs based on both demographic data, thus there are several PUBs located both within Greenville's city limits and near the Tar River (**Appendix 1**). There are a total of 96 census blocks located in Pitt County, and 69.8% (67 out of 96) are wholly or partially within the city limits of Greenville. Of the 96 census blocks in the county, 29 are identified as PUBs and more than 70% of these PUBs (21 out of 29) are wholly or partially within the city limits of Greenville (**Table 5**). There are 125 census tracts in Pitt County, 47% of these tracts (59 out of 125) are identified as a DC. The City of Greenville wholly or partially contains 85 of the tracts in the county, 36% of these tracts (31 out of 85) are identified as a DC (**Table 5**). There are also numerous underserved or disadvantaged communities located in floodprone areas both within the City of Greenville and Pitt County (**Appendix 1**). Of the 96 census blocks in Pitt County, 87.5% of blocks (84 out of 96) are intersected by the A or AE flood zone, which is the 100-yr floodplain. Similarly, 86.2% (25 out of 29) of the PUBs in Pitt County are intersected by Zone A or AE. Of the 125 census tracts, 83.2% (104 out of 125) are intersected by the A or AE flood zone. Similarly, 83.1% (49 out of 59) of the DCs in Pitt County are intersected by Zone A or AE (**Table 5**). The most floodprone areas within Pitt County are low-lying areas adjacent to streams with wide floodplains (e.g., Tar River, Contentnea Creek, Swift Creek, Clayroot Swamp) and their tributaries, particularly those within urban areas with greater percentages of impervious surfaces (e.g., Greens Mill Run, Meeting House Branch, Hardee Creek, Fornes Branch, Reedy Branch).

Table 5. Summary of underserved communities in Pitt County based on administrative boundaries and flood zones. Census blocks and potentially underserved blocks (PUBs) evaluated by NC DEQ (2022), while census tracts and disadvantaged communities (DCs) evaluated by CEQ (2022) and US EPA (2024). Flood zone assessment was based on presence/absence of any area of Zone A or AE using data provided by FEMA (2024).

	Total Blocks	PUBs	Total Tracts	DCs
Location				
Greenville	67	21	85	31
Pitt County	96	29	125	59
Flood Zone				
A/AE	84	25	104	49
X	12	4	21	10
Total	96	29	125	59
% in floodplain	87.5%	86.2%	83.2%	83.1%

There was roughly equal distribution of DDBs between areas identified a PUB or DC (**Table 6**). Most of the PUBs and DCs were located near the Tar River (**Figures 17 and 18**). These data suggest that there are numerous DDBs (93-114) in PUBs or DCs that could be identified for retrofit opportunities, especially if the DDB is overgrown and/or located in low-lying areas with shallow water tables. **Appendix 1** contains maps summarizing the percentage of communities of color and poverty in the study area.

Table 6. Summary of DDBs located in potentially underserved blocks (PUBs) or disadvantaged communities (DCs). PUBs were classified by NC DEQ, whereas DCs were classified by the US EPA.

Agency	DDB (#)	Percent of Total
NC DEQ (2022)		
PUB	114	53.3%
Not a PUB	100	46.7%
US EPA (2024)		
DC	93	43.5%
Not a DC	121	56.5%

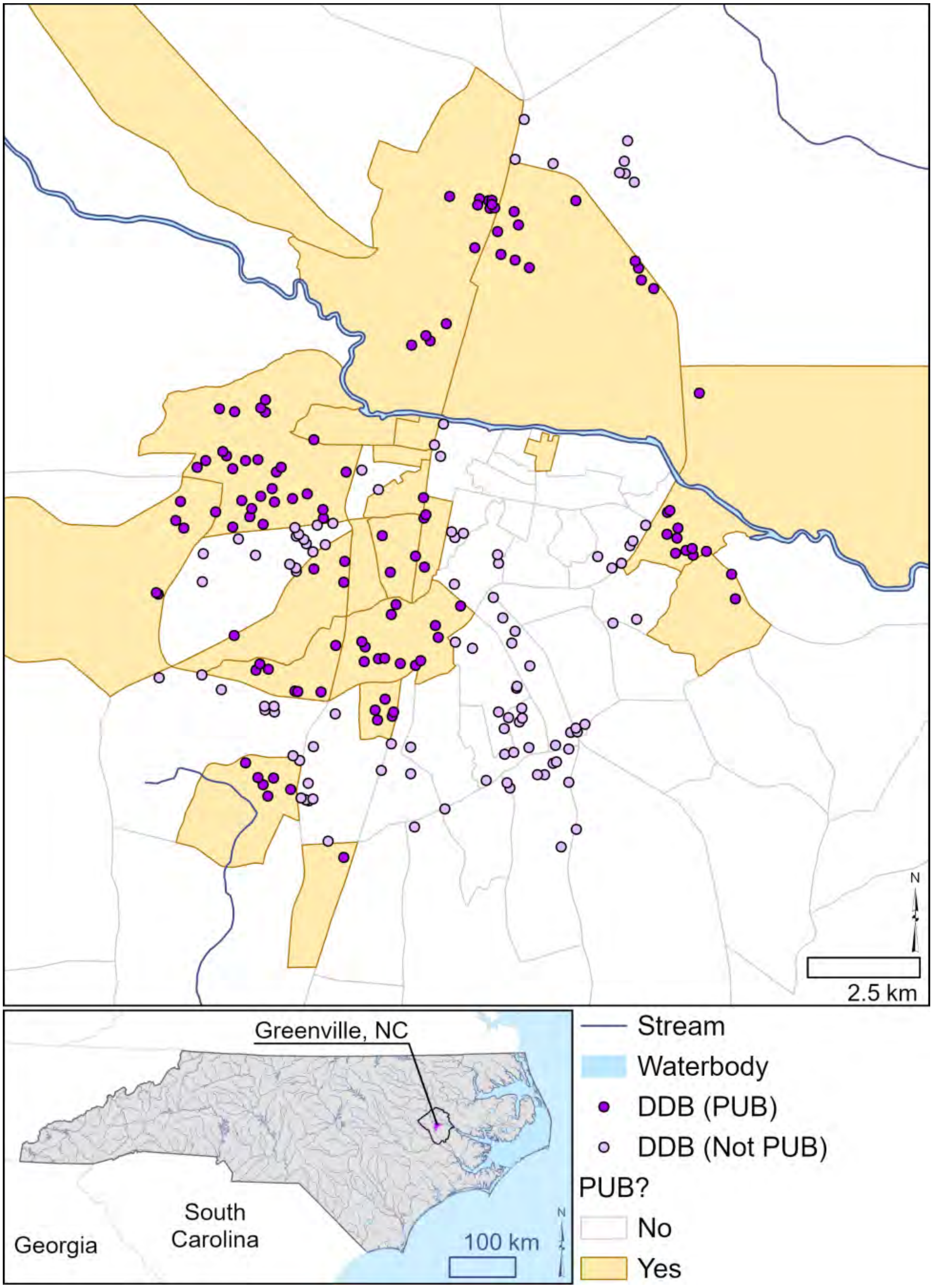


Figure 17. Map of DDBs located within potentially underserved blocks (PUBs; yellow-shaded regions) compared to those outside of PUBs. Dark purple shaded circles indicate a DDB within a PUB. PUBs were classified by NC DEQ (2022).

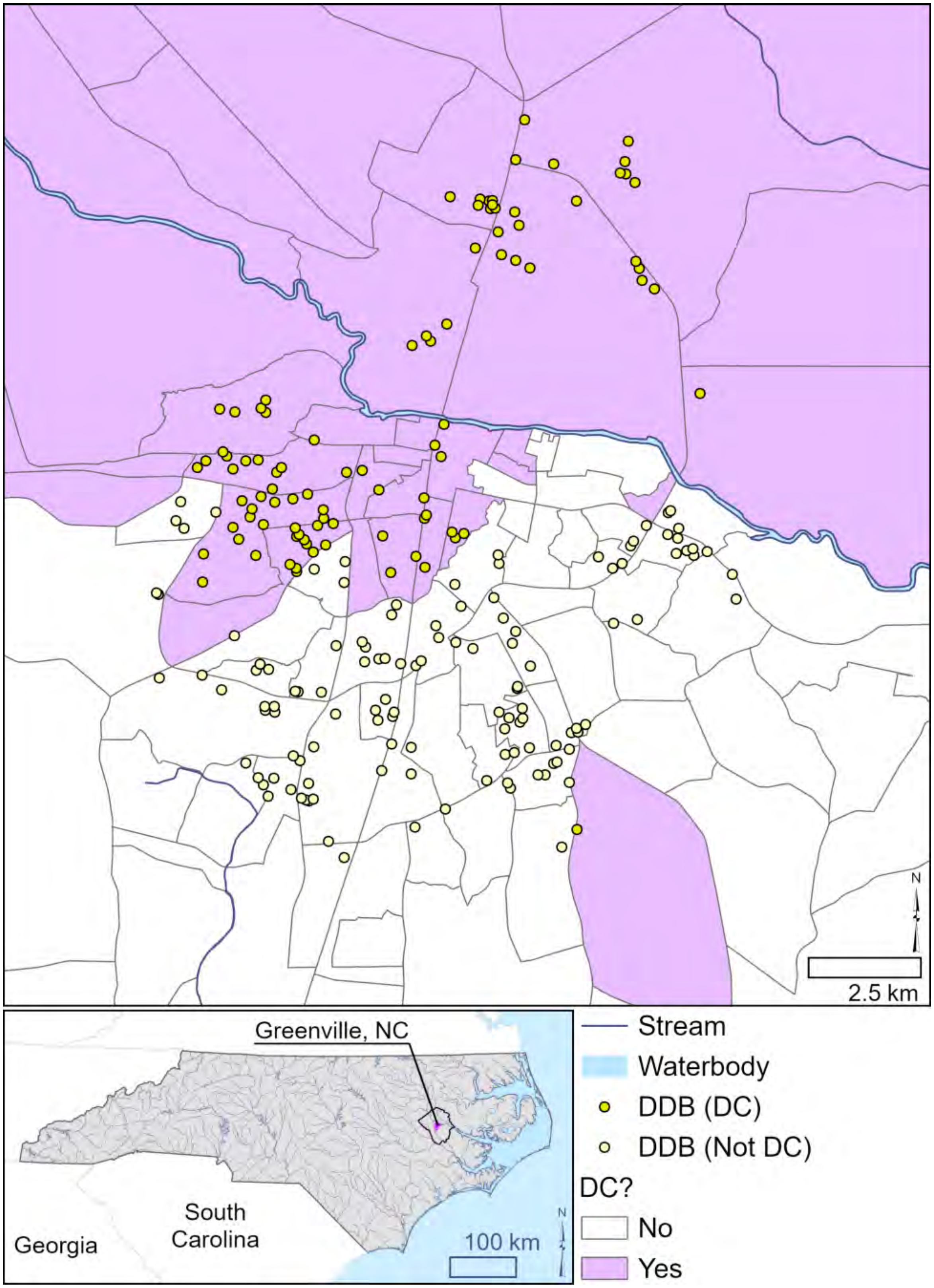


Figure 18. Map of DDBs located within disadvantaged communities (DCs; purple shaded regions) compared to those outside of DCs. Dark gold shaded circles denote a DDB within a DC. DCs were classified by US EPA (2024).

Educational Opportunities and Proposals for Future Work

The project provided a range of educational opportunities engaging undergraduate and graduate students and faculty in field trips, presentations, research experiences, a capstone project, and outreach efforts.

Students in Geology 3500 (Hydrogeology and the Environment-11 undergraduate students 2023, 18 undergraduate students 2024) and Geology 5700 students (3 graduate, 3 undergraduate 2023) participated in field trips to learn about stormwater management and the impacts of urban stormwater on local streams, including visits to DDBs on Charles Blvd. and Allen Rd. Three undergraduate engineering students (Grace Jacobson, William Shouse, and Landon Woolard) participated in an Engineering Capstone Project in 2022. Over the course of the project, they researched stormwater retrofit approaches for dry detention basins that can improve water quality and reduce flood impacts. They identified a DDB on County Home Rd. (Pitt County Council on Aging) and developed a stormwater wetland retrofit design for the basin (**Appendix 3**). They noted the benefits of converting DDBs to stormwater wetlands including: improved flood control and stormwater quality treatment, enhanced habitat and biodiversity; and community aesthetics.

Two undergraduate students (Kaleigh Bell and Sam Matney) and three graduate students (Philip Van Wagoner, Jennifer Richardson, and Joseph Abuarab) participated as research assistants over the course of the project. Kaleigh Bell assisted with mapping underserved communities and soil properties and drainage area delineation to support the development of the dry detention basin GIS. Sam Matney assisted with field verification of DDBs. Joseph Abuarab assisted with field verification of DDBs, GIS, and field monitoring of water levels. Jennifer Richardson assisted with GIS. Philip Van Wagoner assisted with the development of the DDB geodatabase, field reconnaissance, and conceptualization. Philip completed a report entitled “Desktop Recon: Cataloguing Dry Detention Basins Using GIS and Remote Sensing in Greenville, North Carolina” to document the research experience. Joseph Abuarab is conducting his MS Thesis research on the effects of maintenance on the functionality of DDBs. In addition, several student and faculty volunteers assisted with field visits including Braden McPhillips, Rebecca Reibel, John Hoben, Neda Safari, and Matt Sirianni.

Four undergraduate students participated in guided research and outreach projects associated with the project. Camryn Landreth and Paige Brown conducted research on water quality treatment at DDBs, Taylor Fairclough contributed to the development of outreach materials and events, and Austin Smith evaluated trash deposition in DDBs. Camryn and Paige leveraged data generated by this project to acquire an ECU Undergraduate Research and Creative Activity Award, which provided funding for water quality monitoring of 4 DDBs. Camryn and Paige used data from the grants to serve as the basis for their Undergraduate Honors Thesis, which was submitted in Fall 2024. Overall, a total of 42 undergraduate and 8 graduate students benefited from educational opportunities associated with this project.

Educational Activities and Proposals for Future Work

A variety of project-related presentations and educational events (14 total) were conducted over the course of the project, with substantial student engagement. Student participants are indicated with an asterisk. These presentations included:

Howard, R. and *Van Wagoner, P. Finding dry detention basins (DDBs) in Greenville, North Carolina—An application of LiDAR and FOSS. North Carolina GIS Conference. Winston-Salem, NC. March 8-10, 2023.

*Van Wagoner, P. and Howard R. Automated detection of dry detention basins using LiDAR. ECU Coastal Studies Institute/Geography, Planning, and Environment Research Symposium. Wanchese, NC. March 31, 2023.

* Bell, K., Iverson, G., O'Driscoll, M., Howard, R., Van Wagoner, P., and Humphrey, C. A Preliminary assessment of uncatalogued stormwater control practices in Greenville, NC. Soil Science Society of North Carolina Annual Conference. Raleigh, NC. April 17, 2023.

* Bell, K., Iverson, G., O'Driscoll, M., Howard, R., Van Wagoner, P., and Humphrey, C. Identification and characterization of dry detention basins in the City of Greenville, NC: A preliminary assessment. Research and Creative Achievements Week. Greenville, NC. April 5, 2023.

O'Driscoll, M., Peralta, A., Etheridge, J. R., Hoben, J., Walker, J. , and Vance Chalcraft, H. CUREs for water pollution: Engaging undergraduates in water resources research. Universities Council on Water Resources Annual Conference. Fort Collins, CO. June 15, 2023.

O'Driscoll, M. Howard, R., Iverson, G., *Van Wagoner, P., Abuarab, J., Humphrey, C., Fraley-McNeal, L., Lee, A., Hoffman, G., Norris, D., Walton-Corbett, N., and Thompson, B. Detection and evaluation of unmapped stormwater detention infrastructure to reduce flood impacts & improve water quality in the NC Coastal Plain. American Water Resources Association Annual Conference. Raleigh, NC. Nov. 8. 2023.

O'Driscoll, M. Howard, R., Iverson, G., *Van Wagoner, P., Abuarab, J., Humphrey, C., Fraley-McNeal, L., Lee, A., Hoffman, G., Norris, D., Walton-Corbett, N., and Thompson, B. Detection and evaluation of dry detention basins in the North Carolina Coastal Plain. North Carolina Water Resources Research Institute Conference. Raleigh, NC. March 20, 2024.

*Landreth, C., *Brown, P., Iverson, G., O'Driscoll, M., and Abuarab, J. Preliminary evaluation of flood control and treatment of total suspended solids by dry detention basins in Greenville, NC. North Carolina Water Resources Research Institute Conference. Raleigh, NC. March 20, 2024.

*Abuarab, J., O'Driscoll, M., Iverson, G., and Howard, R. Assessing the function of select dry detention basins to evaluate retrofit potential for water quality. ECU Research and Creative Achievements Week. Greenville, NC. April 3, 2024.

*Landreth, C., *Brown, P., Iverson, G., O'Driscoll, M., and Abuarab, J. Preliminary evaluation of flood control and treatment of total suspended solids by dry detention basins in Greenville, NC. ECU Research and Creative Achievements Week. Greenville, NC. April 3, 2024.

*Abuarab, J., O'Driscoll, M., Iverson, G., and Howard, R. Assessing the function of select dry detention basins to evaluate retrofit potential for water quality. ECU Celebration of Engagement and Innovation. Greenville, NC. April 24, 2024.

Howard, R. Dry Detention Ponds: LiDAR Application. Quarterly meeting of the Local Government Committee of the N.C. Geographic Information Coordinating Council. March 6, 2024.

O'Driscoll, M. Urban stormwater challenges fieldtrip. Greenville, NC Faculty Workshop on Integrating Sustainability into the Curriculum. May 7, 2024.

*Fairclough, T. and O'Driscoll, M. Stormwater Science Table - What can you do to reduce stormwater impacts to streams? Tar River Community Science Festival. Nov. 9, 2024.

A community engagement event was held at the Tar River Community Science Festival on Nov. 9, 2024 (11 am – 4 pm). Undergraduate student, Taylor Fairclough, and Mike O'Driscoll hosted a stormwater science table at the event. Two main participatory activities were conducted at the table, with a focus on educating community participants on the connections between stormwater management and water quality, DDBs, and actions that community members can take to reduce stormwater quality impacts to local streams (**Figure 19**). The first activity was a spin wheel with stormwater questions, such as "where does stormwater go when it rains in Greenville?" we highlighted how the storm drains are connected to our streams and when respondents answered they won a small prize, such as sunglasses or candy. This led to follow up discussions on activities that citizens can do to reduce stormwater quality impacts on streams (highlighted in a factsheet provided in **Appendix 5**), such as picking up after pets, properly disposing of trash in receptacles, and limiting fertilizer and pesticide use. The second activity was a filtration demonstration, we explained how improvements to stormwater infrastructure around Greenville, such as retrofits that convert DDBs to stormwater wetlands can improve water quality by providing additional filtration. We used loose tea to mimic stormwater contaminants and added the tea to a clear water bottle, then poured the dirty water through a filter of sand and charcoal, so participants could see how filtering stormwater through wetlands can help us reduce some of the contaminants and provide cleaner water to our streams. Overall, the event was considered a success with an estimate of approximately 500 attendees. We estimated approximately 100 people visited our table and learned about local stormwater challenges and actions to improve stormwater quality and reduce impacts to local streams. For 9 of the participants that were interested in green stormwater infrastructure, we provided brochures for a self-guided walking tour to green stormwater infrastructure sites on ECU campus and downtown Greenville.

Figure 19. Stormwater science table at the Tar River Community Science Festival on Nov. 9, 2024. Taylor Fairclough (undergraduate- Environmental Studies) developed activities to engage participants on stormwater issues including a stormwater quiz and stormwater filtration activity.

Overall, it is estimated that 20-100 participants attended each presentation/event and over 300 attendees learned about dry detention basins through the educational efforts throughout the project.

Four proposals were submitted to augment the project and provide future research that will assist with stormwater management in Greenville, three of these were funded:

- Camryn Landreth and Paige Brown leveraged data generated by this project to acquire an ECU Undergraduate Research and Creative Activity Award, which provided funding for water quality monitoring of 4 DDBs. (funded).
- The Center for Watershed Protection in collaboration with ECU (O'Driscoll, Howard, and Iverson) and numerous universities throughout the southeast submitted a grant proposal to the US Environmental Protection Agency for a Coastal Stormwater Center of the Southeast in March 2024. This project was recently funded and will be led by The Center for Watershed Protection beginning in January 2025. ECU's contributions will build on the current project and pilot the use of publicly-available data to locate unmapped stormwater features and estimate the depth of the water table in Greenville, NC. The goal is to evaluate how shallow groundwater conditions can affect stormwater control measures in the City and evaluate potential remedial actions. (funded).
- Joseph Abuarab submitted a proposal to the ECU Water Resources Center to fund stormwater quality assessments at 4 dry detention basins in Greenville. This work will help to evaluate how vegetation management influences water quality. (funded).
- Guy Iverson submitted a pre-proposal to EEG entitled: "Developing Capacity to Restore Urban Streams in Greenville" in May 2022 (not funded).

Conclusions and Future Work

The approach developed in Greenville to identify unmapped DDBs allowed us to identify 214 dry detention basins. At the onset of the project, the number of DDBs mapped by the City was 9. With the additional information on location of DDBs in the City provided by this study, the capacity to understand and manage DDBs has been improved. An additional benefit is that this approach may be transferable to other municipalities in similar Coastal Plain settings that do not have an up-to-date inventory of DDBs. LiDAR data and GIS are crucial for the first step, identifying closed depressions. The GIS that was developed in this project provided the City with a database of the number, location, surface area and approximate storage volume of DDBs in the City, which has led to increased capacity to manage stormwater challenges. Trash surveys in DDBs indicated that at some sites excessive trash deposition was occurring with potential to cause impairment in downstream waterways and/or clog outlet pipes. Excessive trash predominantly occurred at sites draining lots with commercial development. Future inspections and trash cleanups can help to mitigate trash deposition at problematic sites. Water quality data indicated variable sediment treatment at DDB sites, suggesting that although DDBs may allow some sediments to settle, they also can be a source of suspended sediments to downstream waters.

Water level data and observations during field visits indicated that some DDBs remain wet during dry periods between rainfall events. In general, groundwater depth across Greenville is typically less than 6 ft. deep. In some basins, shallow groundwater has led to a natural conversion towards wetland conditions. When this occurs, it may limit the capacity to mow vegetation, potentially resulting in overgrown vegetation. At some sites with shallow groundwater, DDBs had indicators of wetland conditions (wetland vegetation, soils, standing water), suggesting that wetland conversion at these sites may be a feasible retrofit approach. Since wetland conversion can improve water quality, due to enhanced nutrient uptake and sediment retention functions, conversion of dry detention basins to stormwater wetlands may be a feasible option for Coastal Plain communities. When considering dry detention basin retrofit options to improve water quality, it is important to maintain or improve volume control functions due to flooding concerns. Infiltration basins and stormwater wetlands were considered the most feasible retrofit options that can provide substantial water quality improvements relative to DDBs, however there are constraints with infiltration basins in areas with shallow groundwater conditions.

The field condition and retrofit assessment revealed a range of conditions across the DDBs. Of the 34 DDBs that were assessed, 9 were considered well-maintained, 23 needed routine maintenance, and 2 needed immediate attention. Challenges observed at DDBs included: trash deposition, poorly maintained/clogged inlets and/or outlets, damaged inlets and/or outlets, erosion and sedimentation, unmaintained vegetation, tree growth on berms, and shallow groundwater. Retrofit prioritization criteria included: pond condition, pollutant reduction, constraints, ownership, socioeconomic status, maintenance burden, and educational opportunities. The types of retrofits that would be feasible include: conversion to stormwater wetlands, infiltration basins, bioretention areas, wet ponds, and tree planting. On average it was estimated that retrofits could reduce nitrogen (N) exports by approximately 2.2lbs-N/yr. per site, with the largest reduction at 9 lbs.-N/yr. These estimates indicate that potential N reductions associated with retrofits would range from 10s to hundreds of pounds of N per year, depending on the number of sites retrofitted and their size and drainage characteristics. There are substantial retrofit opportunities available in underserved communities in the City of Greenville. It was estimated that approximately 100 dry detention basins were in underserved communities, which is approximately 45% of all the identified DDBs. Educational opportunities during the project included a variety of presentations at a range of venues and participation in the Tar River Community Science Festival, which allowed us to share information on ways to reduce stormwater pollution in Greenville to a broad audience. In addition, we had approximately 50 students involved with the project through course fieldtrips, field verification, trash deposition surveys, capstone, honors and masters projects, and conference presentations.

Initially the City of Greenville planned to develop a citywide stormwater nutrient offset bank, where funding associated with stormwater nutrient treatment credits could be utilized to retrofit selected dry detention basins and provide local improvements in nutrient treatment. However, NC House Bill 600 (2023) recently curtailed the potential for this approach by including the statement: “No nutrient offset bank approved by the Department and owned by a unit of local government, shall sell nutrient offset credits to an entity other than a government entity or a unit of local government." Unfortunately, the Bill has reduced the City’s capacity to fund local efforts to retrofit DDBs through a citywide stormwater nutrient offset bank. Therefore, other approaches for funding retrofit opportunities will need to be developed. In the future a different financing model will be needed to fund these local efforts, options include new legislation, revisiting internal funding options, and seeking other opportunities through external funding.

Recently, the Center for Watershed Protection, in collaboration with East Carolina University, the North Carolina Coastal Federation, and other Universities in the southeast (Virginia Tech, Georgia, Florida, Clemson and Auburn), received approval for funding from the Environmental Protection Agency to initiate a Coastal Stormwater Center of the Southeast. This

Center will aim to provide data, tools, resources and guidance to assist Southeastern Coastal Plain communities with stormwater challenges. One goal of this project is to support further work to use publicly-available LiDAR and other data to locate unmapped stormwater features and estimate the depth of the water table in Greenville, NC. The new project which is slated to begin in January 2025 will aim to build on the current findings from this report, as well as develop a citywide groundwater map that will help to delineate suitability for retrofit and new stormwater control measures based on groundwater depth constraints. For example, infiltration basins have been shown to provide greater water quality treatment relative to most other stormwater control measures, however they generally require > 4 ft. groundwater depth. The mapping efforts will identify areas where groundwater depths are suitable for infiltration basins and porous pavement, as well as identify current measures that have reduced functionality due to groundwater inundation. These future efforts will aim to improve the understanding of how shallow groundwater interacts with stormwater infrastructure in Greenville and other Coastal Plain communities to assist with potential mitigation and planning strategies.

Performance Metrics

- Development of a GIS-based database of DDBs
- Development of a methodology to identify unmapped DDBs
- Number of DDBs identified and mapped (214)
- Status/Functionality of DDBs (assessed 34 sites for retrofit potential, 50 sites for trash deposition, 10 sites for water level variations, and 4 sites for sediment exports)
- Identification of malfunctioning/poorly functioning systems (identified 25 sites that required maintenance and/or improvements, 5 sites with severe trash deposition)
- Identification of systems that would benefit from retrofits (identified 34 sites that would benefit from retrofits)
- Estimated nutrient load reduction associated with recommended retrofits (site range of 0-9 lbs. TN/yr., average for all assessed sites 2.2 lbs.-TN/yr).
- Number of sites identified for retrofits in underserved communities (~ 100 potential sites in Greenville)
- Number of community members engaged in outreach event (approximately 100)
- Proposals submitted for future work (4 submitted; 3 funded)
- Number of students involved (~ 50)
- Development of a factsheet on stormwater pollution prevention
- Amount of funds secured for future BMP/monitoring/educational activities (CWP-EPA Grant - $200,000; URCA-$1,843; WRC-$3,300)

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Appendices

Appendix 1 – Socioeconomic Status Analysis

This appendix includes 6 maps characterizing potentially underserved or disadvantaged communities at the municipal- and county-scale. **Figure 1.1** identifies census blocks near Greenville, NC that are potentially underserved blocks (PUBs) based on racial and income demographics (NC DEQ, 2022). **Figure 1.2** illustrates census tracts identified as disadvantaged communities (DCs) based on 8 environmental, climate, socioeconomic, or other burden (CEQ, 2022; US EPA 2024). **Figures 1.3 and 1.4** compare these socioeconomic status layers to flood zones in Pitt County. **Figure 1.5** includes a map classifying census blocks based on racial demographics and **Figure 1.6** is a map classifying census blocks based on the percentage of the population experiencing poverty within each block. Both **Figures 1.5 and 1.6** include locations of DDBs within PUBs.

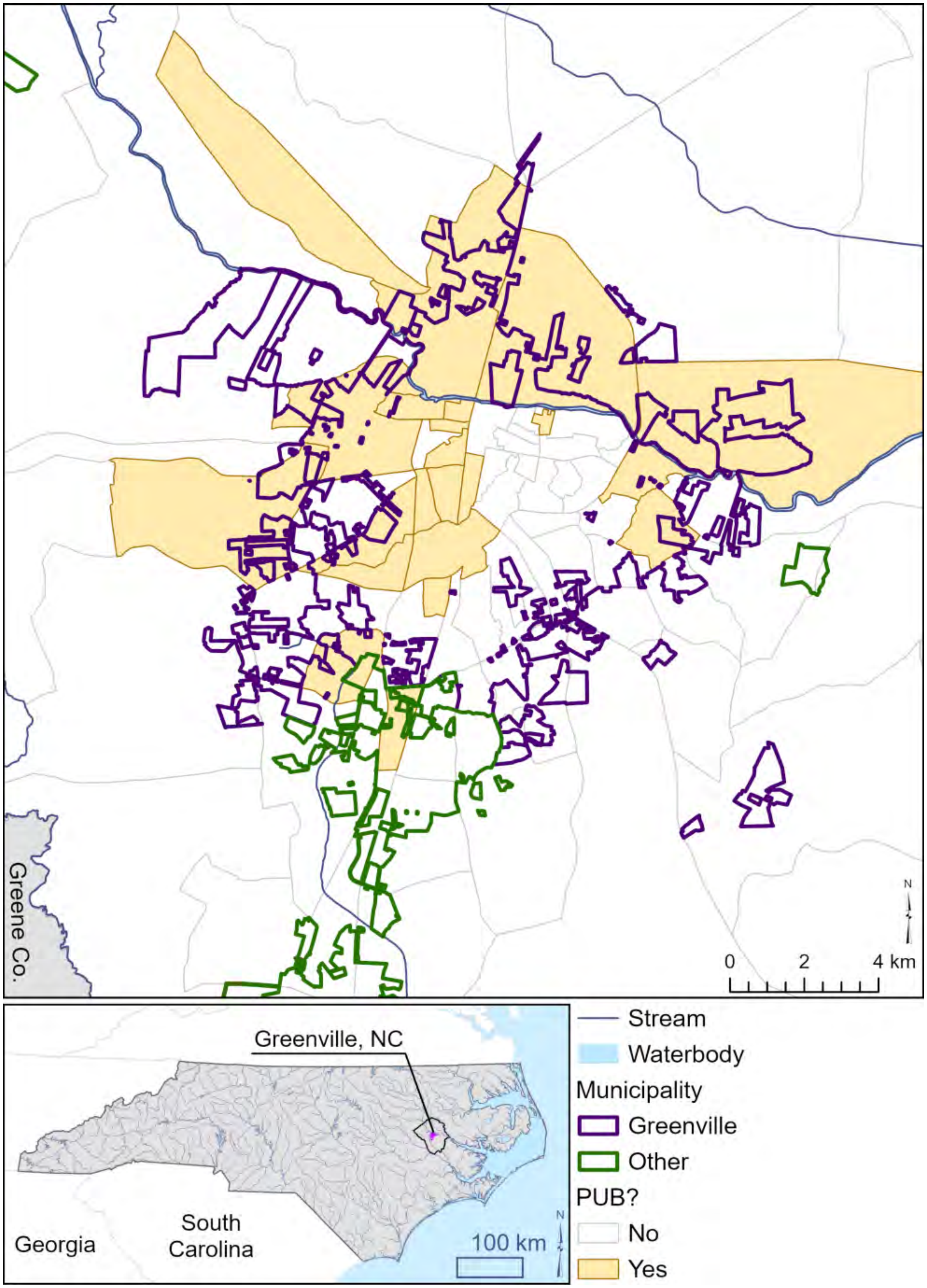

Figure 1.1. Map of potentially underserved blocks (PUBs; yellow shaded polygons) in Greenville, NC (purple outlined polygon).

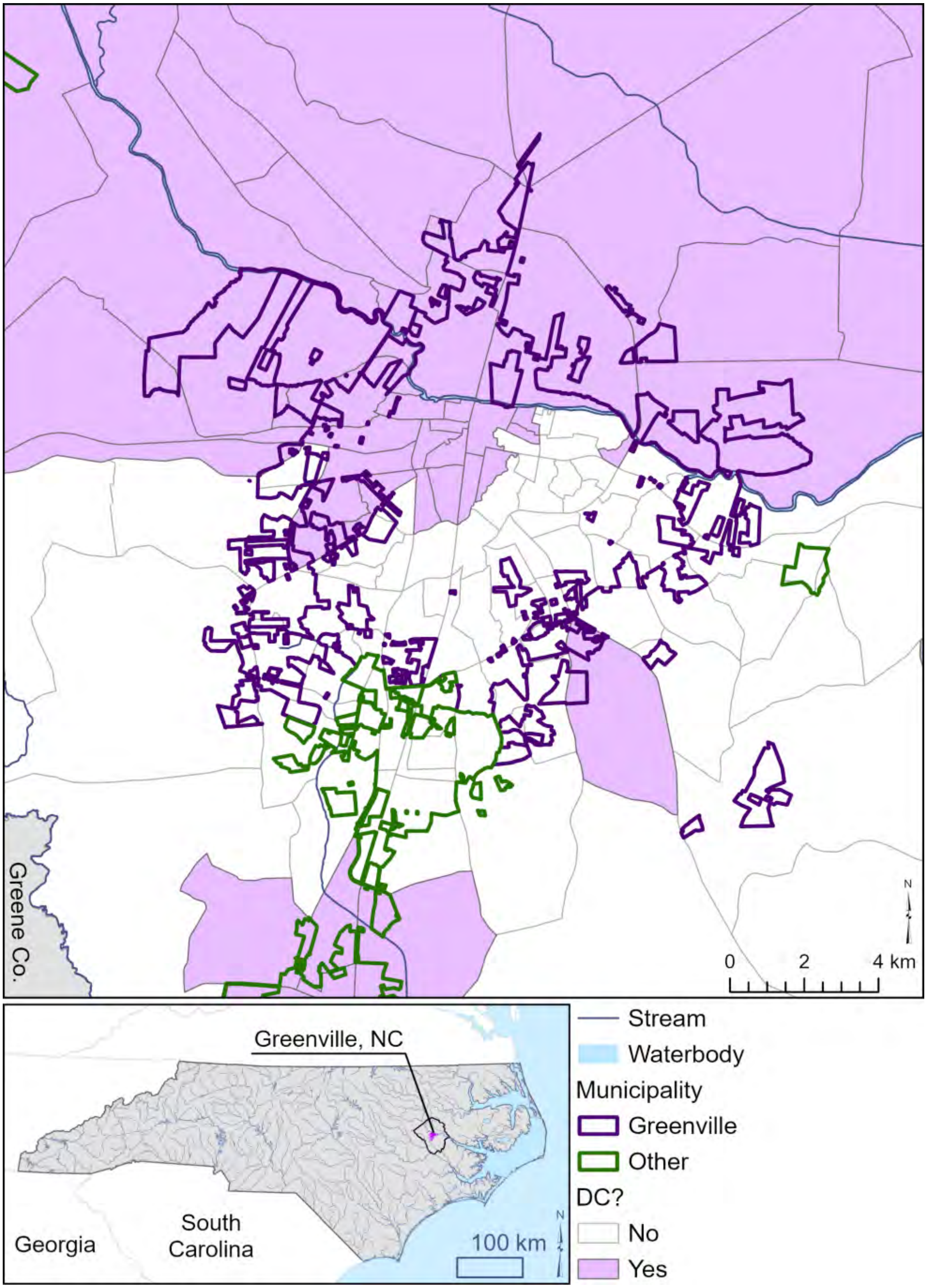

Figure 1.2. Map of disadvantaged communities (DCs; purple shaded polygons) in Greenville, NC (purple outlined polygon).

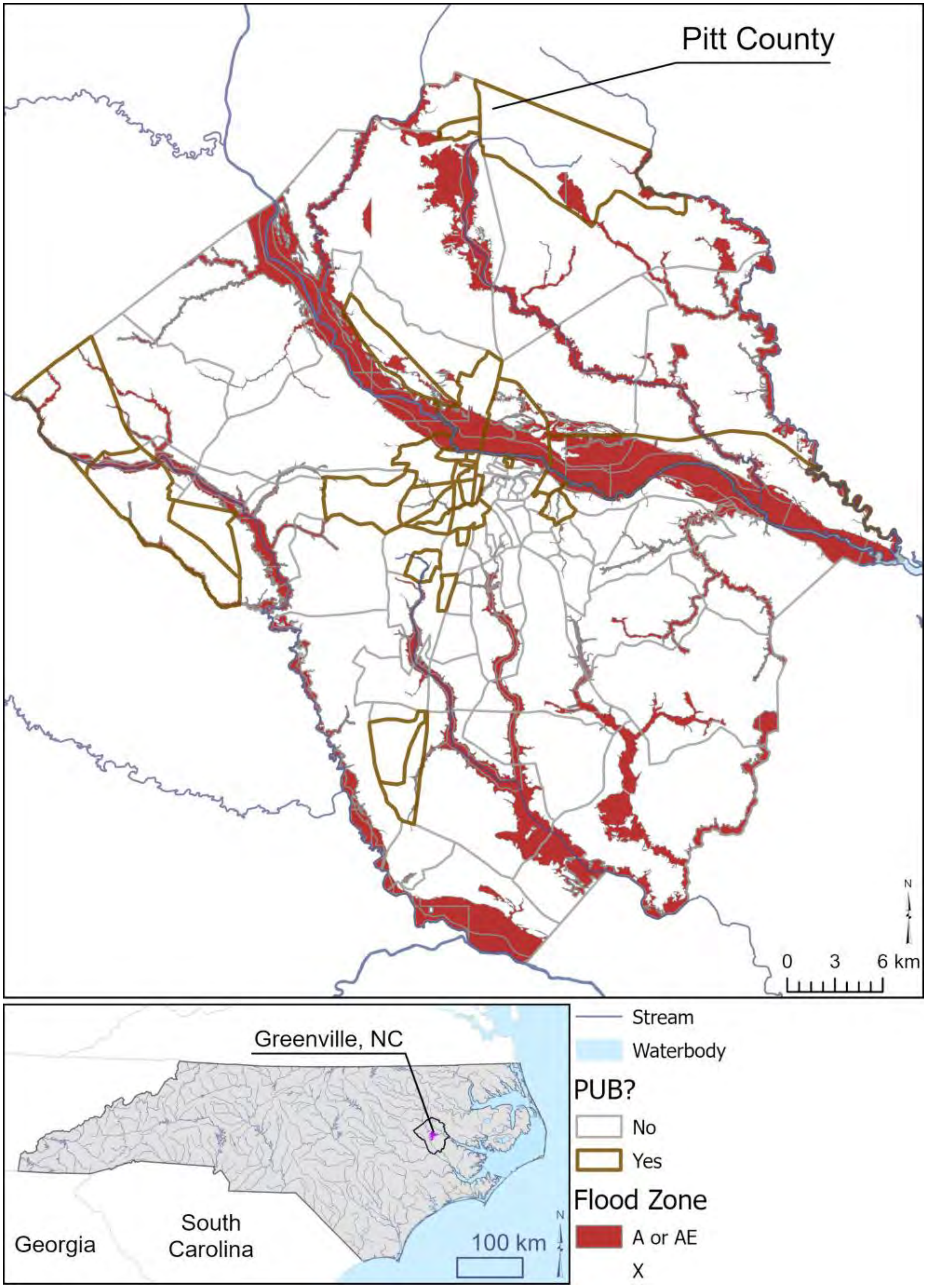

Figure 1.3. Map of Pitt County illustrating the 100-yr floodplain (Zone A or AE) relative to potentially underserved blocks (PUBs; yellow outlined polygons).

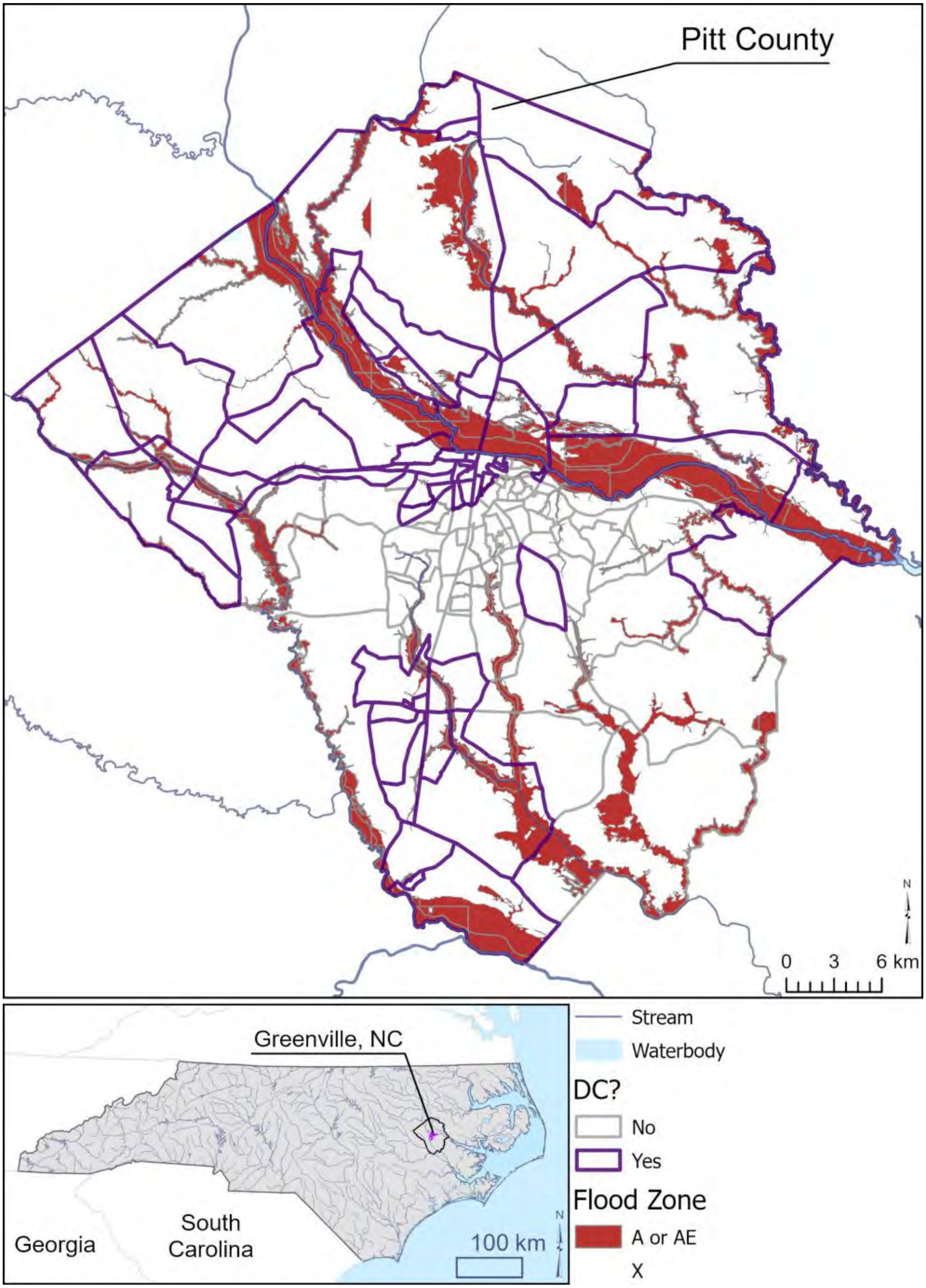

Figure 1.4. Map of Pitt County illustrating the 100-yr floodplain (Zone A or AE) relative to disadvantaged communities (DCs; yellow outlined polygons).

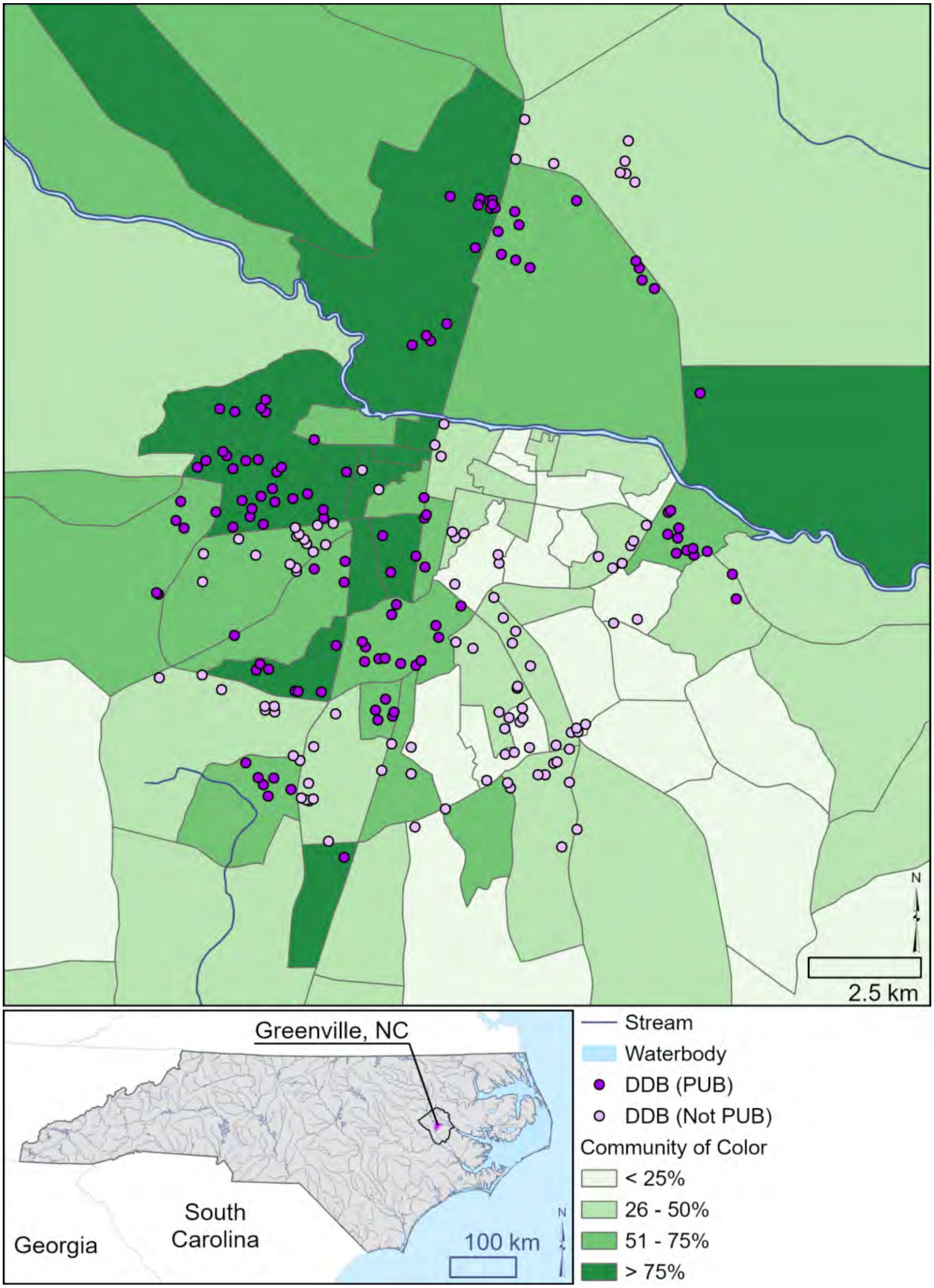

Figure 1.5. Map of census blocks classified by the percentage of the non-white and Hispanic or Latino population. Dark purple DDBs indicate basins located within a potentially underserved census block.

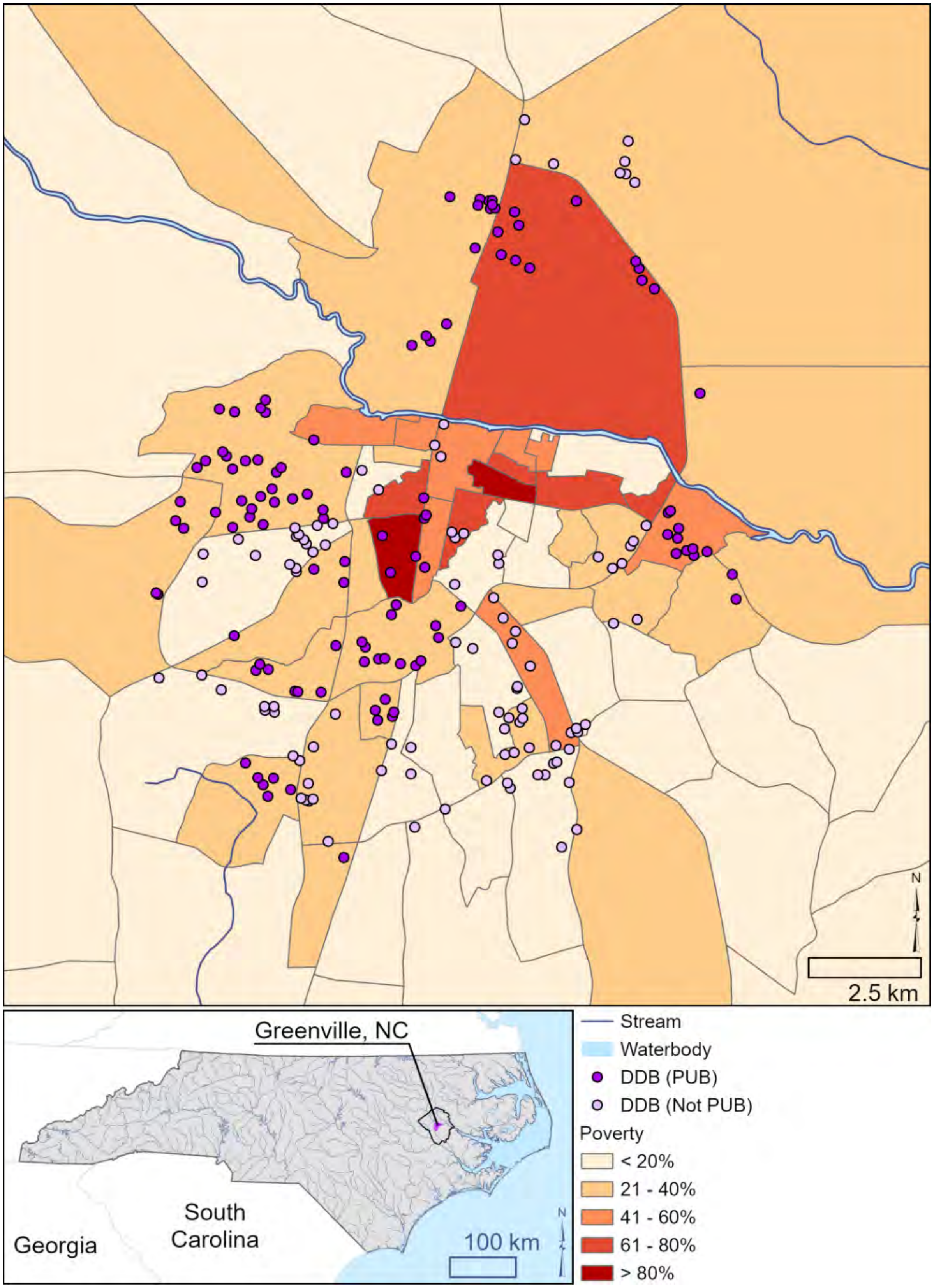

Figure 1.6. Map of census blocks classified by the percentage of the impoverished population. Dark purple DDBs indicate basins located within a potentially underserved census block.

Appendix 2- Trash Deposition in Dry Detention Basins in Greenville, NC

Trash Deposition in Dry Detention Basins in Greenville, NC

Austin Smith
Geology
East Carolina University
Greenville, North Carolina 27858

ABSTRACT

- **Study Overview**:
  - Analyzed 50 Dry Detention Basins in Greenville to assess the impact of pollution and trash deposition.
  - Trash counts varied significantly, with over 5 sites containing more than 80 trash items per 50-ft transect (Figure 2).
- **Key Findings**:
  - Plastics were the dominant type of trash.
  - **Commercial establishments**:
    - Had a higher average number of trash items per site.
    - Likely due to waste products from business operations, such as fast-food waste.
  - **Residential establishments**:
    - Showed a higher percentage of plastic waste per site.
    - Often better maintained, as residents are motivated to clean their living areas.
- **Recommendations**.
  - Implement regular maintenance checks for basins near commercial establishments.
  - Provide more waste disposal sites near commercial areas.
  - Organize community events to clean affected areas.
  - Educate the public on the environmental impacts of pollution to promote responsible waste disposal.

INTRODUCTION

•Impact of Pollution on Aquatic Ecosystems and Human Life:
- Pollution disrupts delicate aquatic ecosystems and negatively affects human life.
- Hazardous substances in trash, such as heavy metals and plastics, contaminate waterways, poisoning aquatic organisms and disrupting ecosystem balance.

•Plastics and Their Impact:
- Plastics, synthetic rubber, and synthetic cloth cause more harm than degradable materials like organic waste and paper (Morre et al. 2007).
- Plastics degrade into microplastics that:
  - Accumulate in marine life digestive systems, causing blockages, malnutrition, and a false sense of fullness.
  - Absorb toxic chemicals, which enter the food chain when ingested, affecting predators, including humans.

•Dry Detention Basin:
- A Dry Detention Basin collects stormwater runoff via an inlet and gradually releases it through an outlet, preventing downstream flooding during peak discharge.
- Pollutants settle due to the slow flow rate, but improper management can turn the basin into a pollution hotspot.

• Study Objective:
- Evaluate the current environmental state and their function as trash deposition sites of 50 Dry Detention Basin's located in Greenville, NC and determine possible solutions to mediate environmental stress.

METHODS & STUDY AREA

•Flooding in Greenville:
- Greenville experiences frequent flooding, especially after storm events.
- The Town Creek watershed has a high impervious area (~50%), increasing runoff that transports harmful pollutants to the Tar River (Blackman, 2017).
- Numerous Dry Detention Basins are installed across Greenville to manage flooding; however, this study was concerned with observing and evaluating their extent in functioning as trash deposition sites.

•Study Overview:
- Analyzed 50 Dry Detention Basins in Greenville, North Carolina (Figure 1).
- Study sites included both residential and commercial areas.

•Data Collection Process:
- Observed a 50 x 20-foot transect originating from each basin's inlet.
- Recorded data using the software Survey123 for analysis.
- Factors analyzed included:
  - Qualitative trash assessment.
  - Trash count and total number of plastic items.
  - Dominant type and size of trash particles.
  - Outlet size.
  - Adjacent land use draining into the basins.

Figure 1: Map showing sites visited in Greenville, NC.

•Qualitative Trash Assessment Criteria:
- Rating system from 1-3 based on trash quantity:
  - **1 (Poor)**: More than 20 trash items.
  - **2 (Moderate)**: 10-20 trash items.
  - **3 (Minimal)**: Fewer than 10 trash items.

•Additional Data Collected:
- Photos of the basins.
- GPS coordinates for precise location tracking.

RESULTS

Figure 2: Graph illustrating the amount of trash seen at all locations along with their corresponding site numbers.

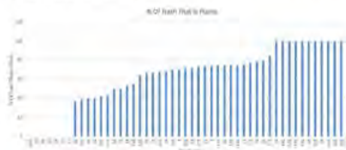

Figure 3: Graph illustrating the percent of plastic observed at all locations along with their corresponding site numbers.

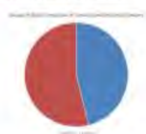

Figure 4: Pie chart comparing the average percent of plastic observed at commercial and residential domain

Average Amount of Trash	
Commercial	Residential
29.45	20.71

Figure 5: Average amount of trash per 50 foot transect, comparing commercial and residential domains.

Figures 6,7 & 8, the most prominent dry detention basins with the greatest quantity of trash observed per 50ft transect.

Figure 6: Photo from site 571, with a trash count of 167 items.

Figure 7: Photo from site 567, with a trash count of 116 items.

Figure 8: Photo from site 568, with a trash count of 140 items.

DISCUSSION AND CONCLUSIONS

• Trash Count Observations:
- Trash counts varied significantly across sites as shown in Figure 2, with the three most prominent trash sites shown in Figures 6, 7, and 8.
- Sites were categorized into two domains:
  - **Commercial**: Medical establishments, offices, and restaurants.
  - **Residential**: Housing and apartments.

• Comparison Between Commercial and Residential Domains:
- Residential domains generally had lower trash counts compared to commercial domains.
- Average trash counts (Figure 5):
  - **Commercial domains**: 29.45 items.
  - **Residential domains**: 20.71 items.
- Residential domains had a slightly higher percentage of plastic pollutants compared to commercial domains (Figure 4).

• Reasons for Lower Trash Counts in Residential Areas:
- Better upkeep and maintenance, often due to landscaping efforts.
- Commercial basins were frequently obscured by vegetation or barriers, allowing trash accumulation without community awareness.
- Commercial domains generally produce more trash due to the products being produced such as plastic bags and Styrofoam cups associated with fast food establishments.

• Recommendations for Maintenance and Prevention:
- Regular maintenance checks for basins near commercial establishments.
- More properly designated areas for waste disposal surrounding commercial domains.
- Organize community outreach events, such as sponsored clean-up days.
- Educate the public on the environmental impacts of improper trash disposal to prevent pollution in basins.
- It is recommended that future research be conducted to investigate the soil of the Dry Detention Basin to evaluate pollutants that penetrate the surface and that could contaminate groundwater.

ACKNOWLEDGEMENTS

- Thank you to Rob Howard the Co-director ECU center for GIS for creating the lidar scans that made it possible to locate the Dry Detention Basins.
- Thank you to Dr. Mike O'Driscoll an associate professor in the department of coastal studies at ECU for being my mentor thought the whole process.
- Thank you to the city of Greenville for permissions to access the Dry Detention Basins.

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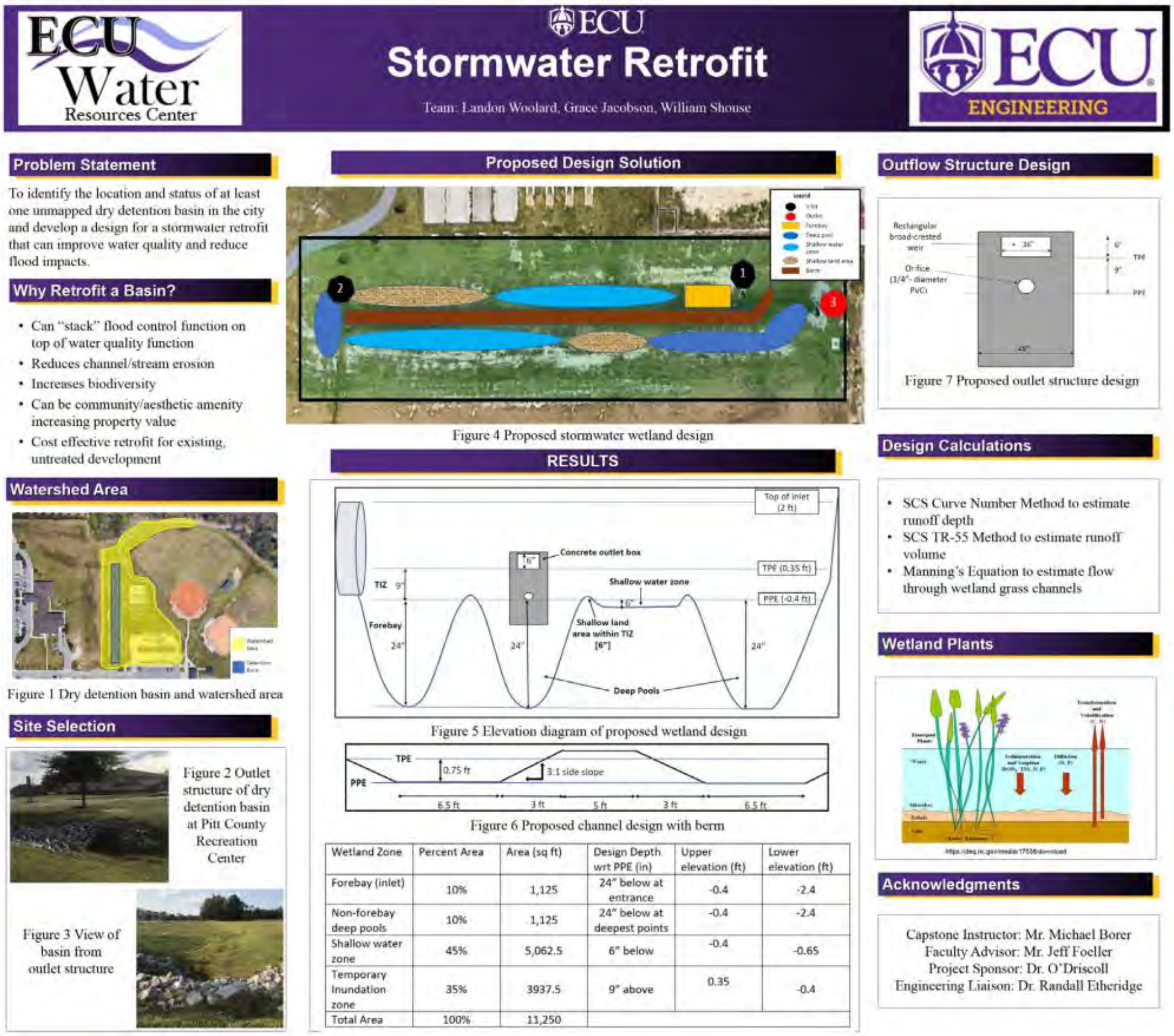
Appendix 3- Capstone Project- Stormwater Retrofit



Wetland Zone	Percent Area	Area (sq ft)	Design Depth wrt PPE (in)	Upper elevation (ft)	Lower elevation (ft)
Forebay (inlet)	10%	1,125	24" below at entrance	-0.4	-2.4
Non-forebay deep pools	10%	1,125	24" below at deepest points	-0.4	-2.4
Shallow water zone	45%	5,062.5	6" below	-0.4	-0.65
Temporary Inundation zone	35%	3937.5	9" above	0.35	-0.4
Total Area	100%	11,250			

Appendix 4: DDB Location Maps

This appendix contains the DDB location maps that correspond to the index labels shown on the grid in Figure 6.

Verified Dry Detention Basins

Grid Index 1-6

Greenville, NC

Greenville ETJ   Verified DDB

0   250   500 m

Verified Dry Detention Basins
Grid Index 2-5

Greenville, NC

Greenville ETJ
Verified DDB

0 250 500 m

Verified Dry Detention Basins
Grid Index 2-6

Greenville, NC

Verified Dry Detention Basins
Grid Index 2-7

Greenville, NC

Greenville ETJ   Verified DDB

0   250   500 m

Verified Dry Detention Basins

Grid Index 3-5

Greenville, NC

Verified Dry Detention Basins
Grid Index 3-6

Greenville, NC

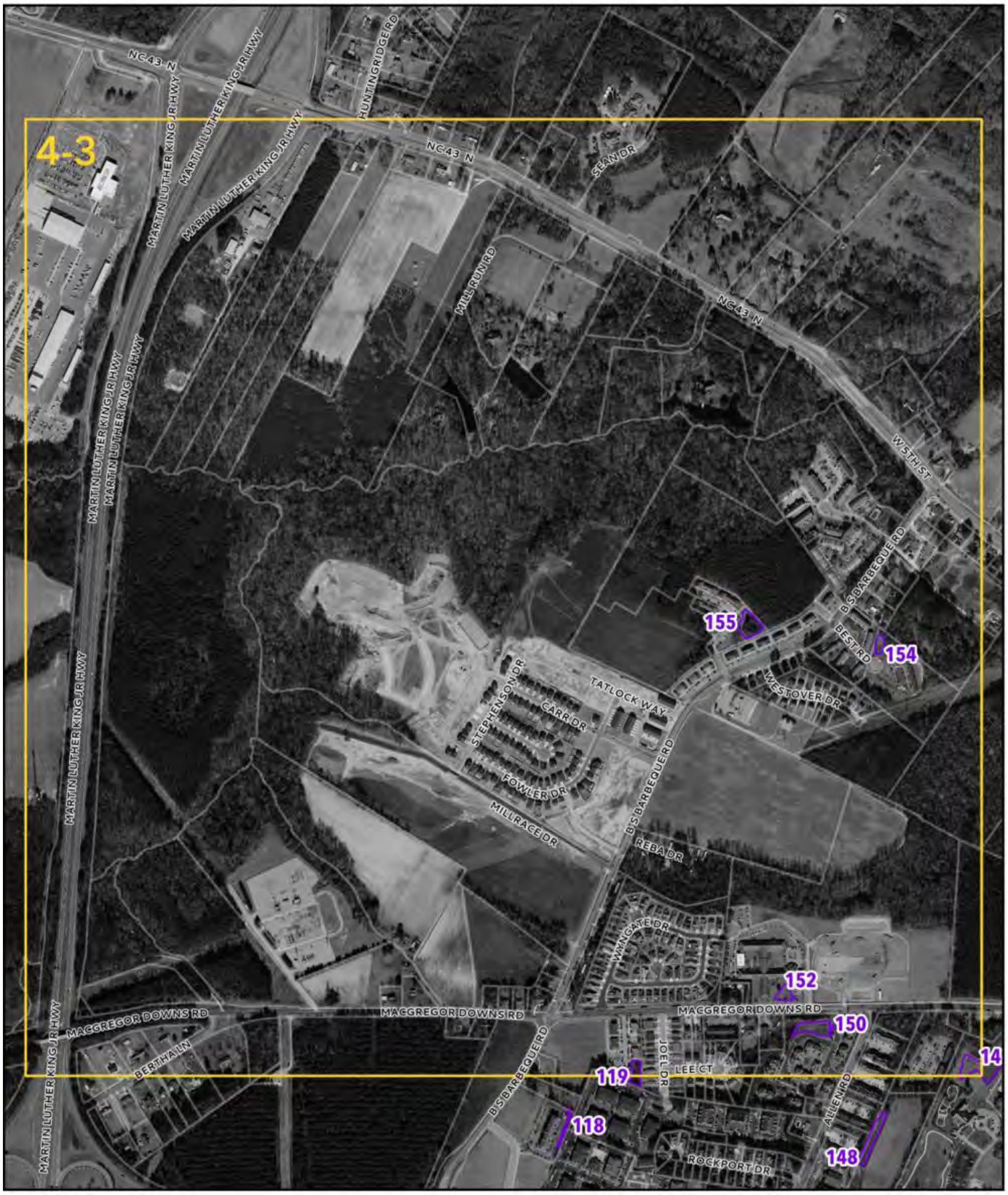
Verified Dry Detention Basins
Grid Index 3-7

Greenville, NC

Verified Dry Detention Basins

Grid Index 4-3

Greenville, NC



Verified Dry Detention Basins
Grid Index 4-4

Greenville, NC

Verified Dry Detention Basins
Grid Index 4-5

Greenville, NC

Verified Dry Detention Basins
Grid Index 4-8

Greenville, NC

Verified Dry Detention Basins

Grid Index 5-3

Greenville, NC

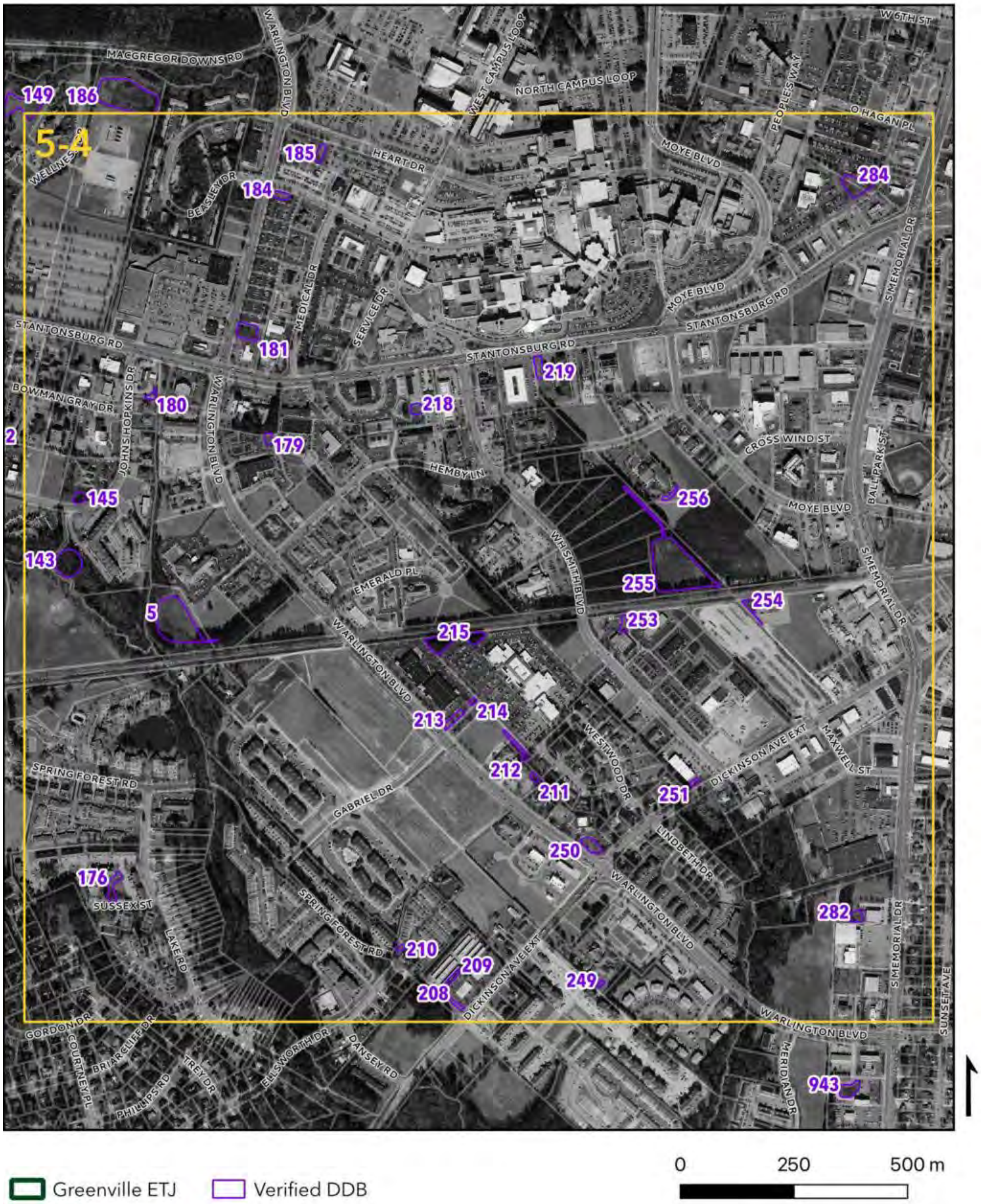
Greenville ETJ Verified DDB

0 250 500 m

Verified Dry Detention Basins

Grid Index 5-4

Greenville, NC



Verified Dry Detention Basins

Grid Index 5-5

Greenville, NC

Greenville ETJ | Verified DDB

0 250 500 m

Verified Dry Detention Basins

Grid Index 5-6

Greenville, NC

Greenville ETJ
Verified DDB

0 250 500 m

Verified Dry Detention Basins

Grid Index 5-7

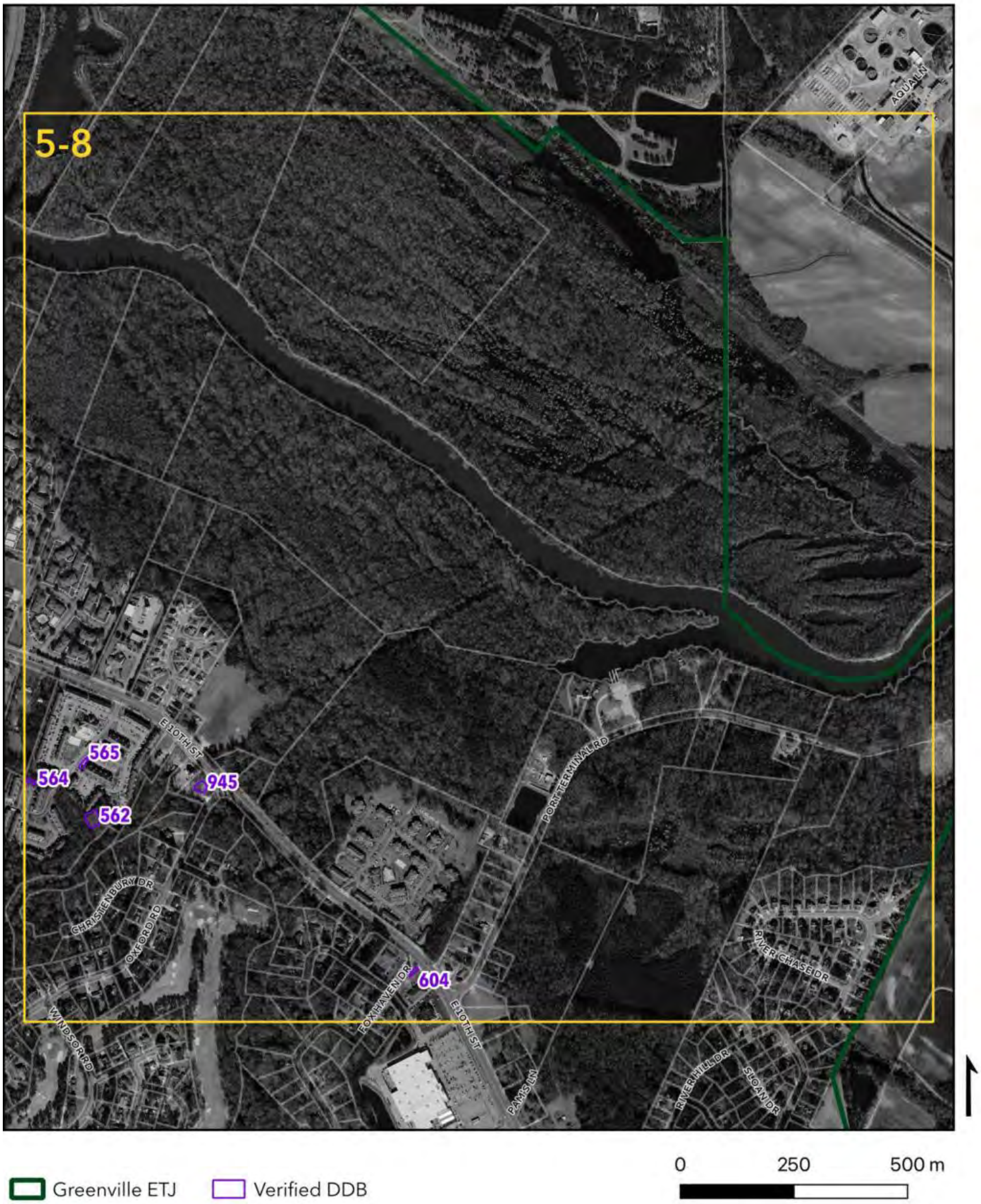
Greenville, NC

Greenville ETJ   Verified DDB

0   250   500 m

Verified Dry Detention Basins
Grid Index 5-8

Greenville, NC



Verified Dry Detention Basins

Grid Index 6-3

Greenville, NC

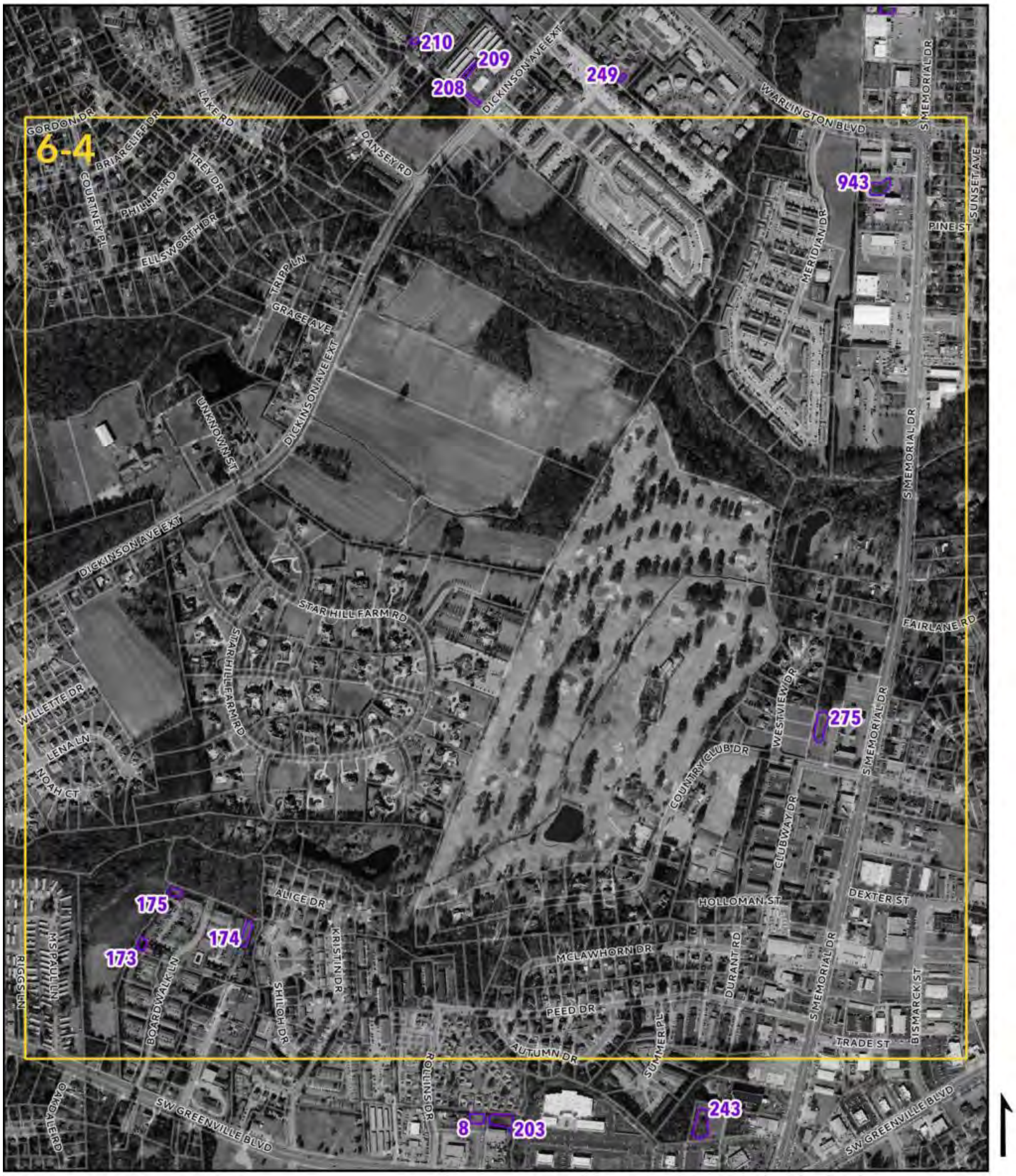
Greenville ETJ

Verified DDB

Verified Dry Detention Basins

Grid Index 6-4

Greenville, NC



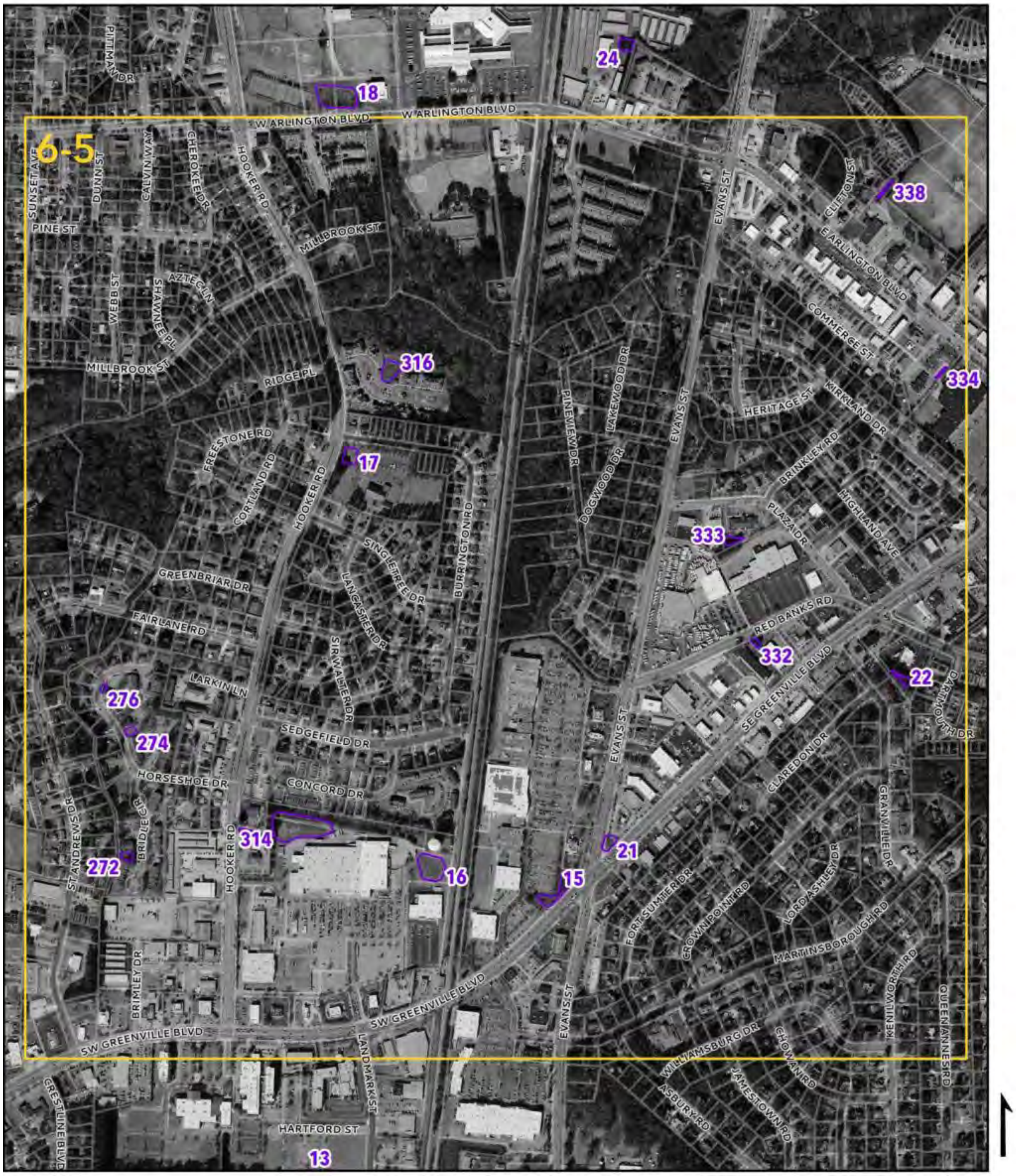
Greenville ETJ Verified DDB

0 250 500 m

Verified Dry Detention Basins

Grid Index 6-5

Greenville, NC



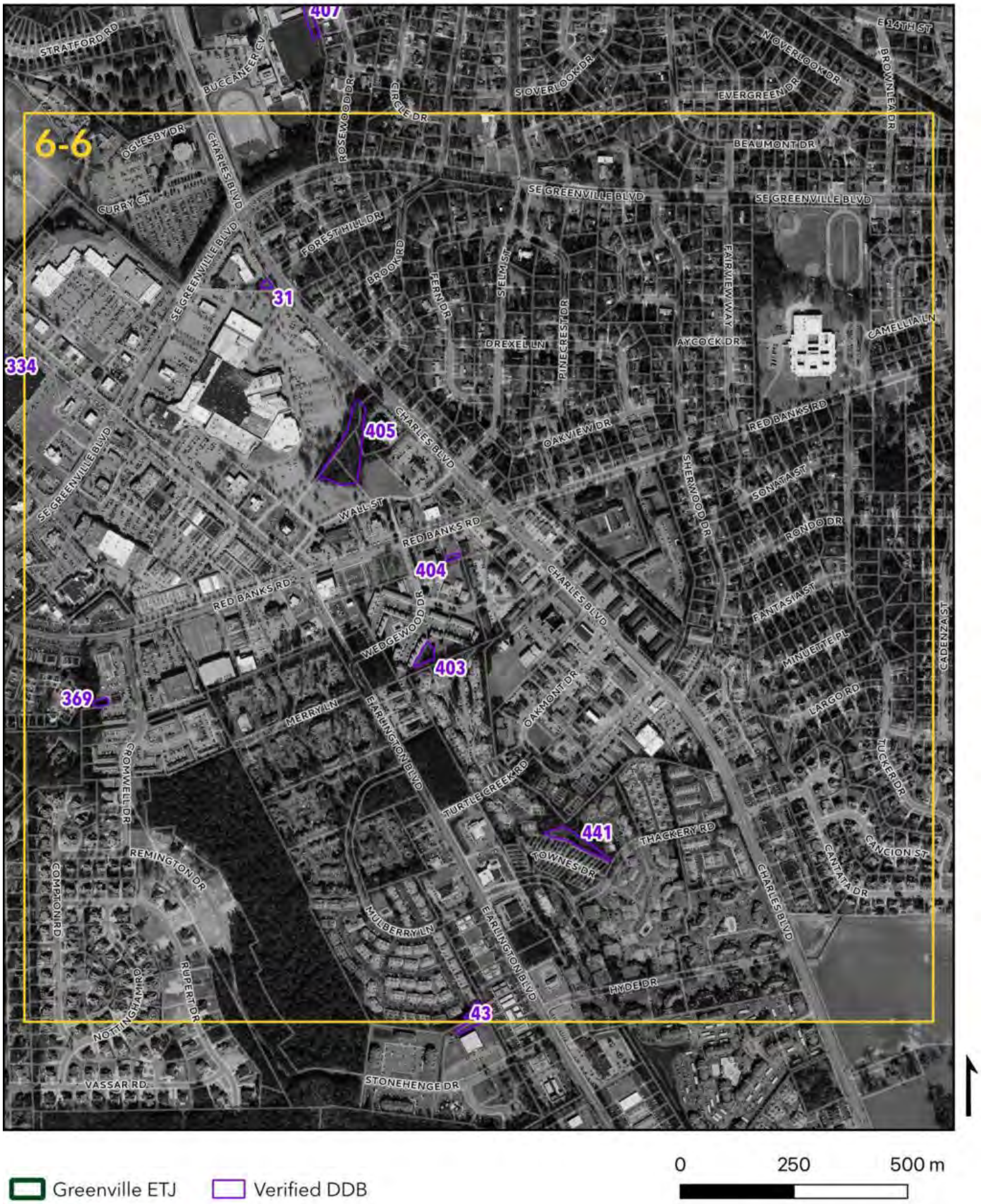
Greenville ETJ   Verified DDB

0   250   500 m

Verified Dry Detention Basins

Grid Index 6-6

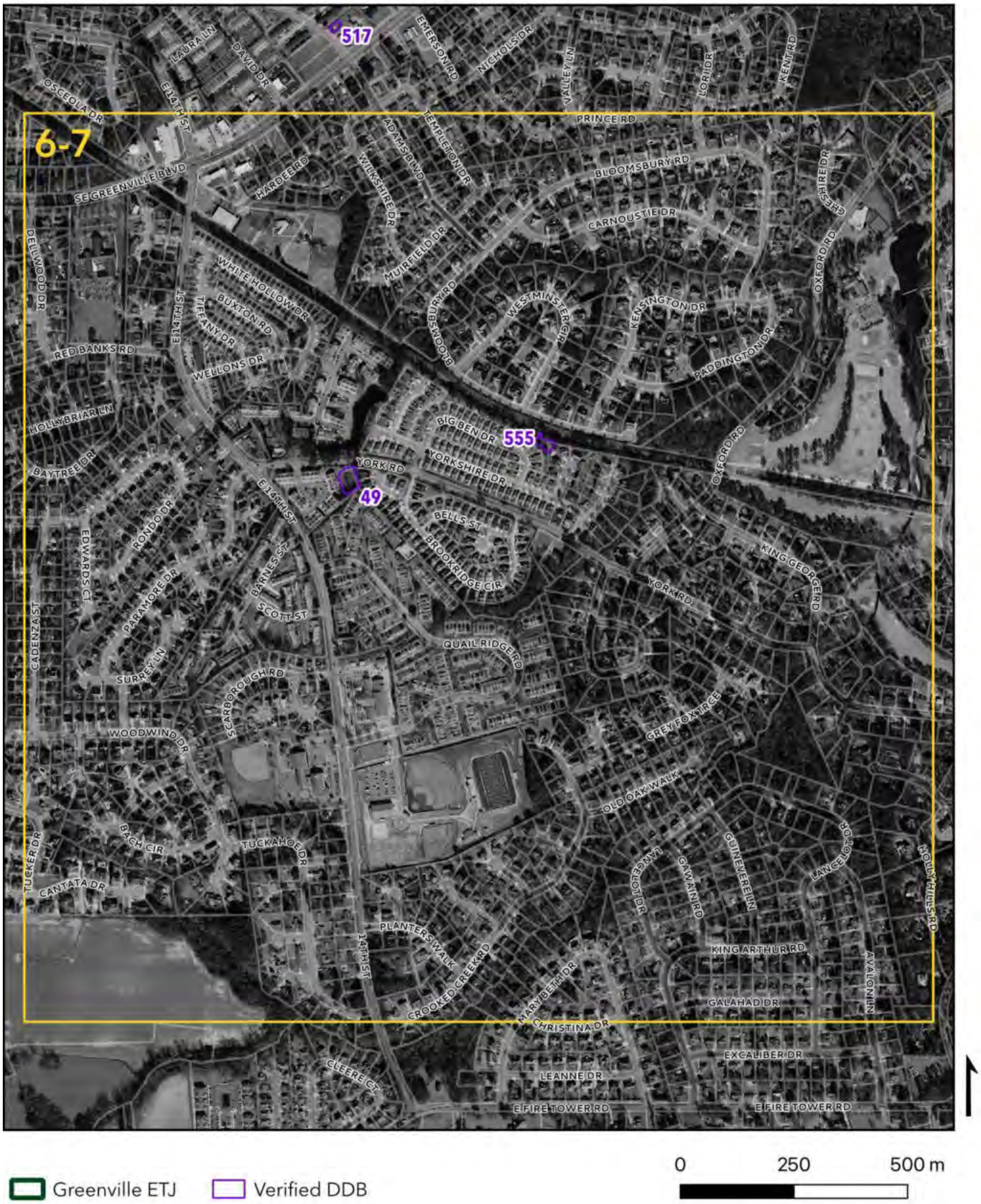
Greenville, NC



Verified Dry Detention Basins

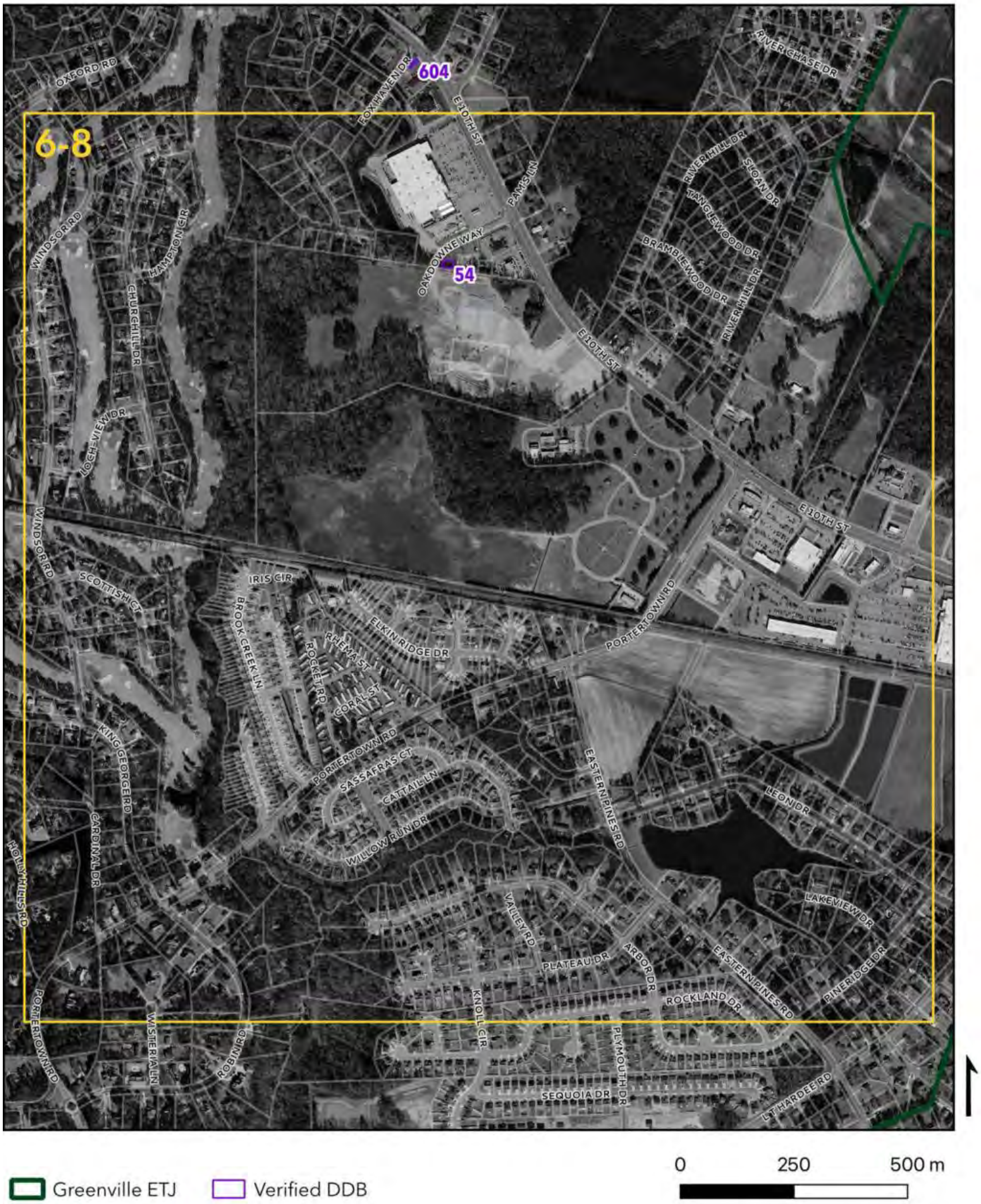
Grid Index 6-7

Greenville, NC



Verified Dry Detention Basins
Grid Index 6-8

Greenville, NC



Verified Dry Detention Basins

Grid Index 7-3

Greenville, NC

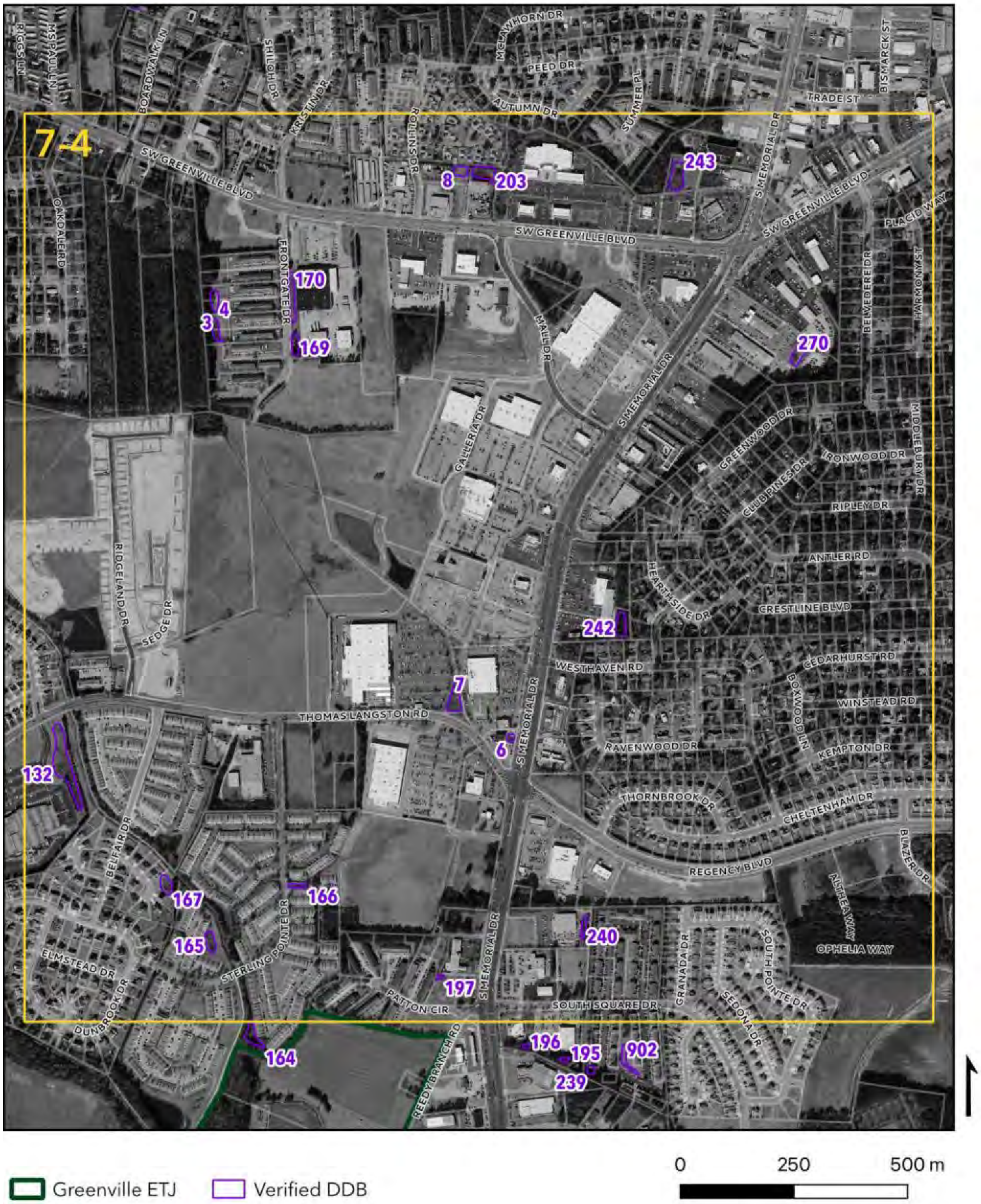
0 250 500 m

Greenville ETJ
Verified DDB

Verified Dry Detention Basins

Grid Index 7-4

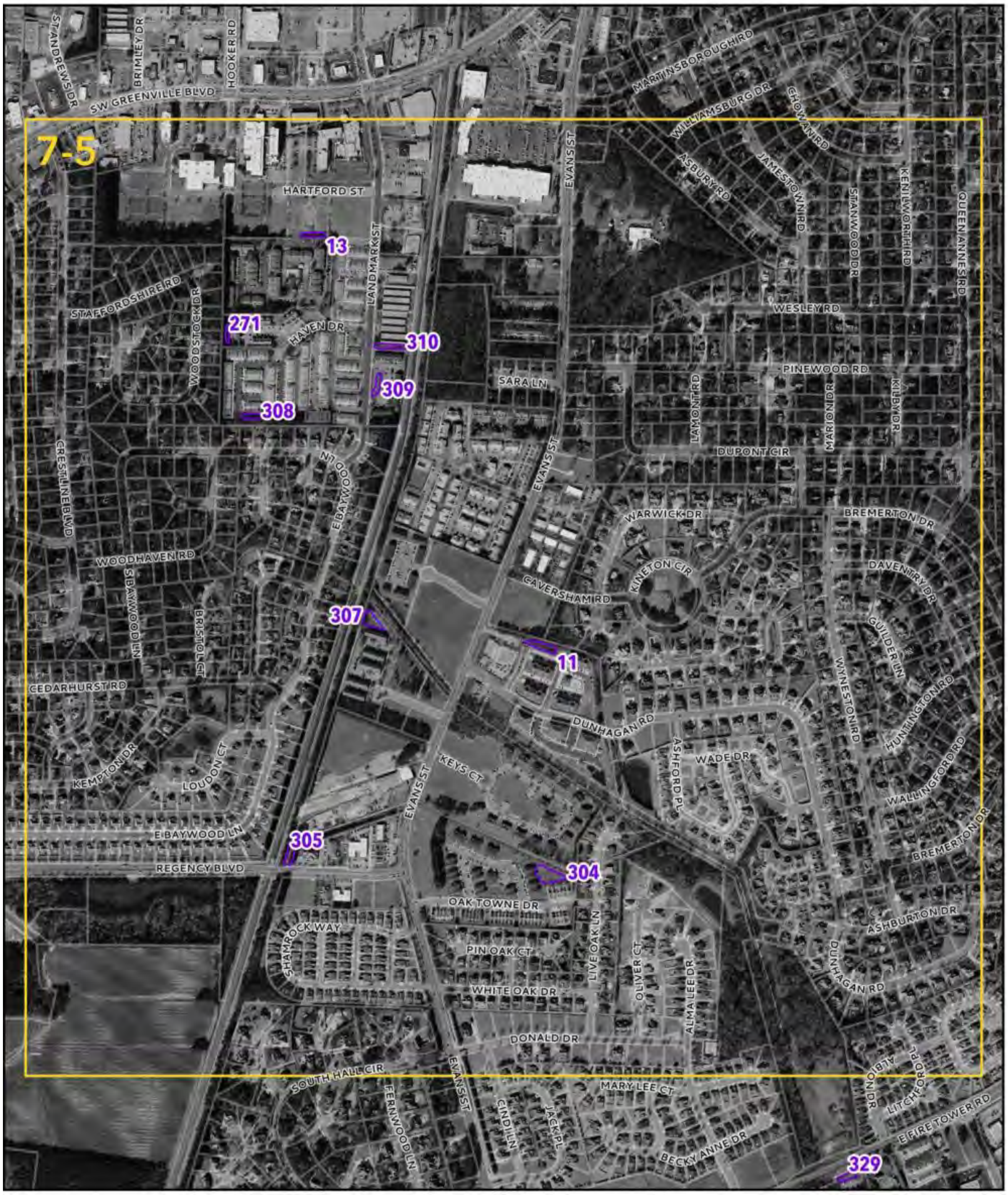
Greenville, NC



Verified Dry Detention Basins

Grid Index 7-5

Greenville, NC

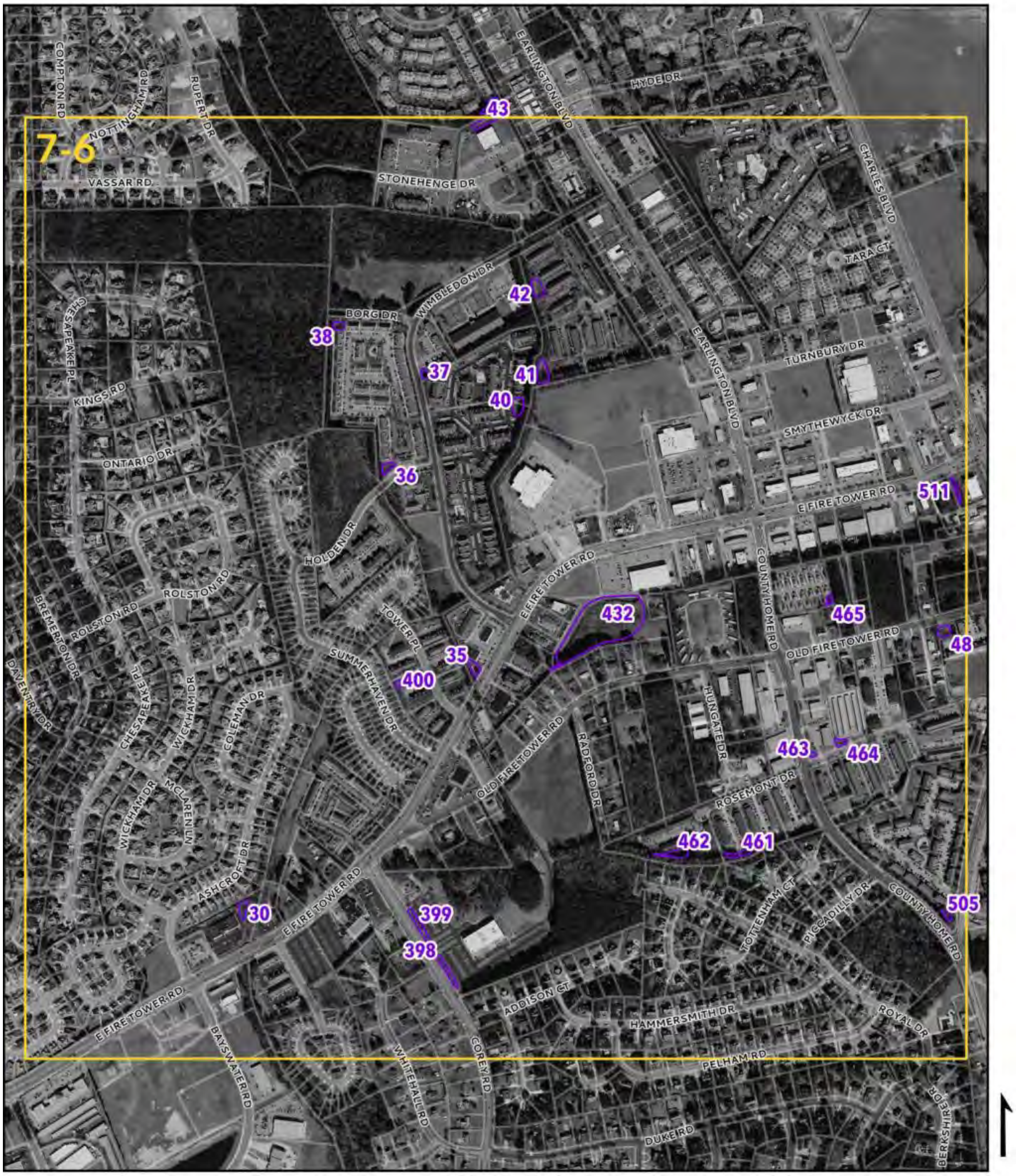


Greenville ETJ Verified DDB

0 250 500 m

Verified Dry Detention Basins
Grid Index 7-6

Greenville, NC



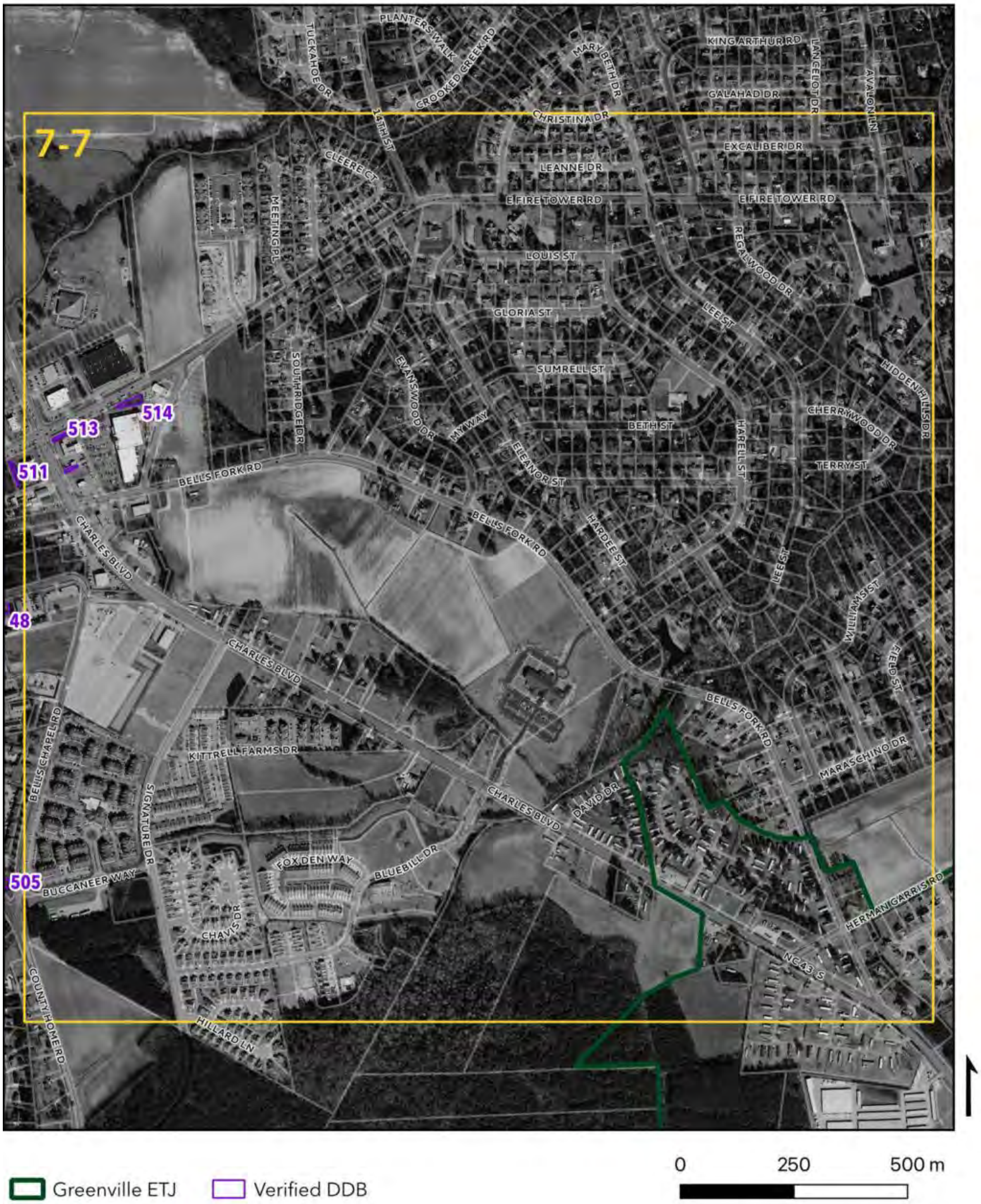
Greenville ETJ   Verified DDB

0   250   500 m

Verified Dry Detention Basins

Grid Index 7-7

Greenville, NC



Verified Dry Detention Basins

Grid Index 8-4

Greenville, NC

Verified Dry Detention Basins
Grid Index 8-5

Greenville, NC

Greenville ETJ   Verified DDB

0   250   500 m

Verified Dry Detention Basins
Grid Index 8-6

Greenville, NC

Verified Dry Detention Basins
Grid Index 8-7

Greenville, NC

Appendix 5- Stormwater factsheet

It is all Connected! Storm Drains and Links to Our Streams!

Storm Water Runoff

Storm water runoff is water from precipitation that is not absorbed into the ground due to impervious cover such as parking lots and roads. Storm water runoff is a concern because it causes flooding, and it carries pollutants that contaminate rivers/streams. Storm water pollutants are contaminants at the land surface that are picked up and carried by storm water to streams.

Storm Water Pollutants

These pollutants include litter/trash, pet waste, road salt, fertilizers, pesticides, chemicals from motor vehicles, detergents typically connect the drained surface with local streams. Enhanced awareness of the connections between our land management decisions, storm drains, and streams can help improve water quality in Greenville's streams, the Tar River and the Pamlico River estuary downstream.

Storm Drains Connect to Our Streams

During storm events, materials that flush off the land surface can drain into storm drains that are connected to local stormwater infrastructure and streams. This connection means that our land-use activities can impair the water quality and aquatic life in the streams in our neighborhoods.

How Can We Help Prevent Storm Water Pollution!

- Use designated receptacles for litter/trash and recyclables (don't throw trash in streets or gutters where it can be washed into culverts and
- Use designated receptacles for pet waste to prevent bacterial contamination
- Use lawn and garden fertilizers sparingly to decrease nutrient supply
- Schedule regular vehicle maintenance and repairs to prevent fluid leakage, and properly dispose of batteries, motor oil and other hazardous chemicals
- Properly dispose of household cleaners/chemicals and paint, never pour hazardous chemicals into yard/street/storm drains
- Use non-toxic alternatives to traditional household cleaners
- Bag and properly dispose of yard debris (grass clippings/leaves) and don't sweep into streets where they can clog storm drains
- Properly dispose of expired medication, never flush in toilet or pour
- Limit pesticide use and implement Integrated Pest Management (IPC) that combine techniques of biological control, habitat manipulation, and resistant varieties

ECU

Dry Detention Basin Condition and Retrofit Evaluation Report

Developed for:
East Carolina University
209 East 5th Street, Greenville, NC 27858

Developed by:
Center for Watershed Protection, Inc.
11711 E. Market Place Suite 200
Fulton, MD 20759
www.cwp.org

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Table of Contents

List of Tables

List of Figures

ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Definition
BMP	Best Management Practice
CDA	Contributing Drainage Area
CWP	Center for Watershed Protection, Inc.
DDB(s)	Dry Detention Basin(s)
ECU	East Carolina University
GIS	Geographic Information System
HSG	Hydrologic Soil Group
MS4	Municipal Separate Storm Sewer System
NC DEQ	North Carolina Department of Environmental Quality
RRI	Retrofit Reconnaissance Inventory
SCM(s)	Stormwater Control Measure(s)
SNAP	Stormwater Nitrogen and Phosphorus
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus

1. Introduction

Conventional dry detention basins (DDBs) are not designed for stormwater pollutant removal. The North Carolina Stormwater Control Measure Document (NC DEQ, 2023) estimates minimal nutrient treatment (10%) for dry detention basins; however, they have been shown to perform better for total suspended sediment removal (median removal efficiency of 58%). In Greenville, NC there has not been a requirement for registration or maintenance/inspection for dry detention basins prior to 2017. Inspections and maintenance of these systems are needed due to the potential for sediment buildup and clogging of pipes by trash and debris and their impacts to downstream waterways. Recent studies in Greenville and in other urban Coastal Plain cities have revealed that while dry detention basins reduce impacts of stormwater quantity by capturing and slowly releasing runoff, they do not provide significant stormwater quality treatment (NC DEQ, 2023; Humphrey and Iverson 2020). Retrofitting these existing DDBs provides a cost-effective method to achieve pollution reduction from urban stormwater and Total Maximum Daily Load (TMDL) goals (CWP and County of Albemarle VA, 2019).

The Center for Watershed Protection (CWP) performed a condition and stormwater retrofit assessment for dry detention basins in the City of Greenville, NC with East Carolina University as part of NC Department of Justice grant # ECU021PRE1, *"Evaluating Stormwater Retrofit Potential to Reduce Flood Impacts and Improve Water Quality in Urban Coastal Plain Communities*." The purpose of this task was to assess the current condition of a subset of dry detention basins throughout the City and identify opportunities to add water quality stormwater control measures (SCMs) to existing basins that are currently only designed to provide detention storage, with an emphasis on providing local benefits in underserved communities. This report summarizes the methods used during the assessment, current pond conditions and maintenance needs, and includes a prioritized list of retrofit opportunities.

2. Methods

Field Assessment

Two CWP staff (Lisa Fraley-McNeal and Allison Lee) conducted three days of condition and retrofit assessments for DDBs on May 1-3, 2023. They were accompanied by Mike O'Driscoll, Rob Howard, Philip Van Wagoner, Guy Iverson, Matt Sirianni, and Camryn Landreth, from East Carolina University (ECU).

A total of 617 potential DDB site locations were provided by ECU based on results of the GIS model developed to identify DDBs. Ratings of 0, 1, and 2, were assigned by ECU to each of the potential DDBs to identify low, medium, and high priority sites for field assessment, respectively. Of these 617 DDBs, 55 were given a medium or high priority (8.9%). ECU's dataset of DDBs included comprehensive attributes from their desktop GIS analysis, including but not limited to hydrologic soil group (HSG) dominant conditions, number of intersecting parcels, and site names/notes. The DDBs are illustrated by their assessment priority in Appendix B alongside the major river basin boundaries and underserved areas identified by NC DEQ.

As part of the field assessment, the following information was gathered:

- Verification of DDB Presence
- DDB Condition and Maintenance Needs
- Assessment of Retrofit Potential

- Field Confirmation of Contributing Drainage Area

CWP created an ArcGIS Field Maps App to collect information for a subset of the ECU-identified DDBs, targeting the 55 that were assigned a high or medium assessment priority. The main form in the Field Maps App was used to identify the locations and attributes of potential retrofit opportunities. This form included pre-populated information from ECU's analysis as well as open-ended questions to enter new information about the DDB's current conditions and proposed retrofit(s). This main form is included as Appendix A to this report. In addition to allowing the project team to log potential retrofit opportunities, the Field Maps App also included specialized forms to assess the current condition of inlets and outlets within the DDBs, and it allowed users to select or delineate representative drainage areas to each DDB. Ultimately, the project team assessed 41 DDBs in the field: 16 high priority, 23 medium priority, and two low priority. These 41 field-assessed DDBs are illustrated in Figure 1, and a map of all ECU-identified potential DDB sites is provided in Appendix B.

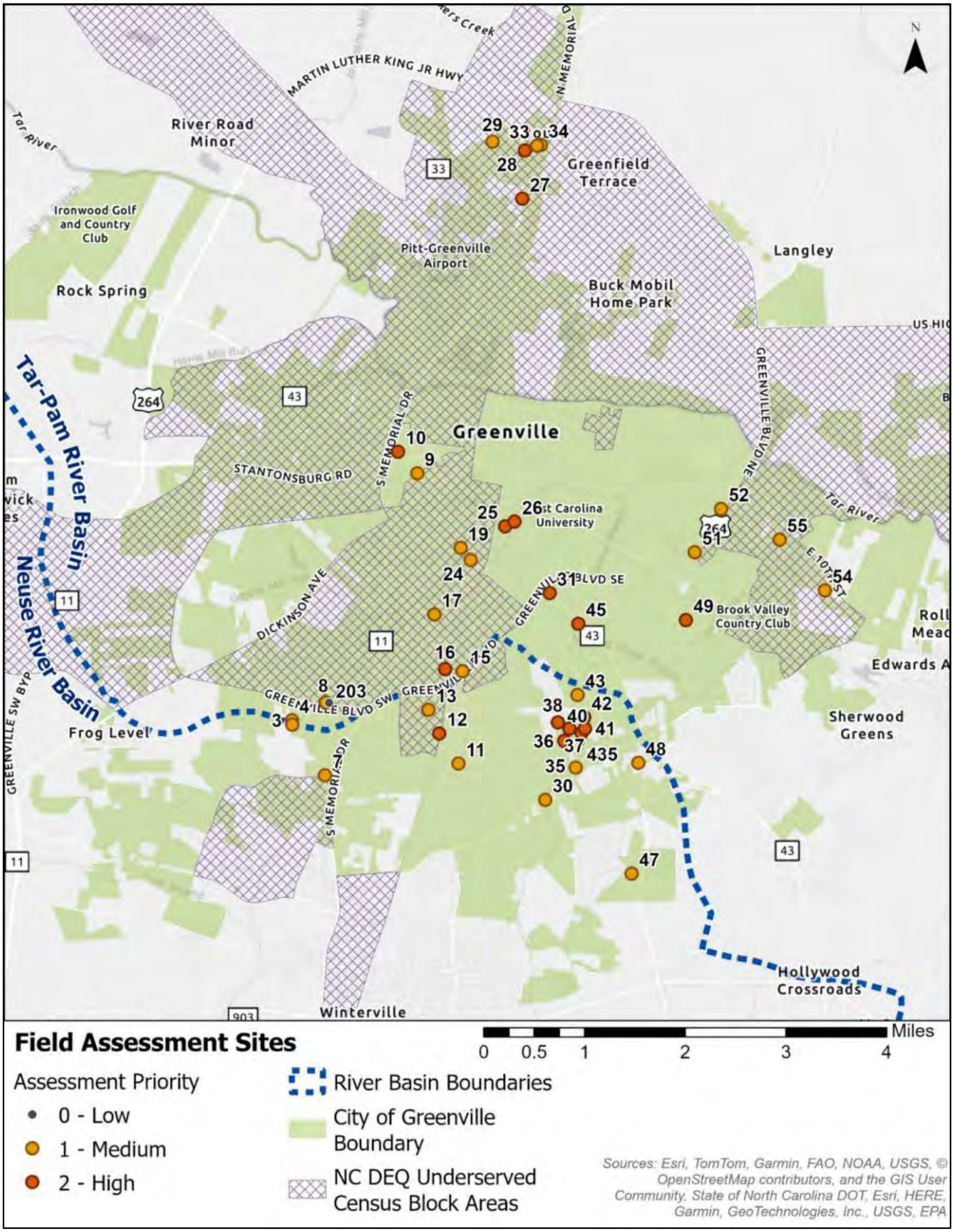

Figure 1. Map of the 41 sites that were assessed in the field, symbolized by assessment priority and labeled with their unique identifiers

Potential stormwater retrofit opportunities for the DDBs were evaluated following the Center's Retrofit Reconnaissance Inventory (RRI) protocols (Schueler et al., 2007). The RRI is designed to evaluate the feasibility of constructing a stormwater retrofit at each site and to collect enough information to develop a retrofit concept.

Potential retrofit options for each DDB were evaluated using a decision flow chart, which is provided as Appendix C. The number one goal for retrofitting was to avoid significant impacts to the function of the existing DDBs, so retrofits that would take up storage space or change a DDB's outlet configuration were not considered. Instead, only retrofits that involved excavation of the pond bottom, creating storage below the outlet structure were contemplated. Ultimately, prospective retrofits were evaluated in the following order of priority:

1. Stormwater Wetland
2. Infiltration
3. Bioretention
4. Wet Pond
5. Tree Planting

DDBs that had already begun converting to wetland-like conditions were proposed to be formally converted to a stormwater wetland, as it was clear that conditions were favorable for wetland creation. If there was no evidence of wetland conversion, and DDBs had soils with the capacity to infiltrate, infiltration practices were proposed, as infiltration practices have high pollutant removal rates and relatively low implementation costs. If infiltration was unlikely to be feasible, bioretention was proposed if an underdrain connection was available and feasible. If infiltration or bioretention were not feasible, but there was still space for excavation, the wet pond option was considered. Finally, if on-site constraints indicated no room for excavation, tree planting was proposed.

Potential Retrofit Project Ranking

Prioritization criteria developed with input from ECU and the City were evaluated for each of the candidate retrofits identified during the field assessment. This evaluation involved:

1. Selecting prioritization criteria that provide objective and subjective assessment of the relative value of candidate pond retrofit practices.
2. Scoring each candidate practice based on the prioritization criteria.
3. Ranking the retrofits based on their respective scores.

The prioritization criteria and scoring details are summarized in Table 1.

Table 1. Retrofit ranking prioritization criteria

Prioritization Criteria	Scoring	Max Possible Score
Pond Condition	Immediate need for repair = 25	25
	Routine maintenance needed = 10	

Table 1. Retrofit ranking prioritization criteria

Prioritization Criteria	Scoring	Max Possible Score
Existing pond condition in comparison to as-built, including factors such as erosion, vegetation overgrowth, sediment accumulation.	Well maintained, no action required = 0	
Pollutant Reduction Combines influence of total drainage area captured and treated and pollutant removal efficiency of proposed retrofit.	Each retrofit scored as % of best pollutant removal x 25	25
Constraints Presence and significance of utility conflicts or other site constraints, such as limited space, required grading, or property issues.	No apparent constraints = 10 Access somewhat constrained or utilities present but relatively easy to move (e.g., electric or phone lines) = 5 Poor access, major grading required, or major utilities must be moved (e.g., sewer) = 0	10
Ownership Public properties will be easier to access and won't require property owner permissions.	Public (City, County, State, and ECU-owned parcels) = 10 Private = 0	10
Socioeconomic Potential for a retrofit to benefit underserved or overburdened communities.	Location within NCDEQ underserved census block group = 10 Location outside of NCDEQ underserved census block group = 0	10
Maintenance Burden Difficulty/expense associated with SCM maintenance	Low = 10 Medium = 5 High = 0	10
Education/Exposure Opportunity The visibility and potential education value of the proposed retrofit.	High: Sites with public access, experience heavy use, are linked to trails and bikeways or have opportunities for signage and education = 10 Moderate: Moderate education/exposure opportunity = 5 Low: Location on private land, out of view or restricted, or with prohibited access = 0	10

Pollutant Reduction Calculations

Older Tar-Pamlico[1] and Neuse[2] Model Program crediting approaches were used as opposed to the newer and more robust Stormwater Nitrogen and Phosphorus (SNAP)[3] tool because they were a simplified way to obtain planning level estimates. In order to compare the pollutant reduction benefits of potential retrofits between the Neuse and Tar-

[1] https://deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/tar-pamlico-nutrient-strategy

[2] https://deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/neuse-nutrient-strategy

[3] https://edocs.deq.nc.gov/WaterResources/Browse.aspx?dbid=0&startid=2728691

Pamlico watersheds, the Tar-Pam BMP Removal Calculation Worksheet for the coastal plain was used to calculate total nitrogen (TN) loads for all DDBs. TN was selected for the comparison of pollutant reduction benefits because the crediting approach from the Neuse Model Program does not include TP. The required land cover types to complete the spreadsheet were delineated from each DDB's contributing drainage area through GIS which includes transportation impervious, roof impervious, managed impervious, and SCM land covers. The nutrient removal rate for each SCM was provided in the spreadsheet, with the exception of infiltration (the nutrient removal rate for infiltration was assumed to be the same as bioretention). TN removal rates included 40% for stormwater wetlands, 35% for bioretention and infiltration, 25% for wet ponds, 10% for dry ponds, and 0% for tree planting.

Next, the target treatment volume for the proposed SCMs was calculated based on the goal of treating the runoff from a 1-inch storm and using an assumed runoff coefficient of 0.95 for runoff from impervious portions for the contributing drainage area and 0.25 for runoff from pervious areas.

To calculate TN removal, first, the effects of the existing DDBs and the presence of wetlands were considered. As mentioned above, dry ponds are assigned a 10% TN removal credit, so this credit was applied to each retrofit to represent existing conditions. If a DDB had begun to convert to a wetland, CWP estimated the percentage of the DDB covered by wetland and assumed a shallow treatment depth – 6 inches. Multiplying the treatment depth by the wetland area, CWP estimated a treatment volume for the wetland within the DDB pond. Then, CWP calculated the percentage of the target treatment volume that was addressed by the wetland conversion and multiplied this percentage by 40% (the assigned TN removal credit for constructed wetlands) to estimate the TN removal percentage from the existing wetlands. In all cases, this was a fairly low value. The largest wetland treated still captured less than 10% of the target treatment volume and therefore added less than 4% TN removal to the existing DDB credit.

With existing TN removal conditions determined, and found to be so low that they would not impact calculations for the proposed practices, CWP estimated the TN removal for the proposed SCMs independently. To do this, the proposed SCM volume was multiplied by the pond area by an estimated average SCM storage depth – three feet for wetlands and infiltration, four feet for wet ponds, and two feet for bioretention areas – and comparing the volume captured to the target treatment volume. This yielded the percentage of the target treatment volume the proposed SCM could capture. Finally, multiplying this value by the SCM's nutrient removal rate and the TN load indicated the TN removal for the proposed SCM. Appendix D provides the TN removal calculations for all proposed DDB retrofits.

Maintenance Burden

While all SCMs require maintenance, some SCM types require more frequent maintenance than others. For this prioritization, bioretention areas, which are often cared for like a landscaped garden were categorized as high maintenance. Wetlands and wet ponds, with a wilder look were categorized as medium maintenance, and infiltration basins, with very little vegetation needs were categorized as low maintenance. Tree planting, since it has less of a direct water management component, was also categorized as low maintenance.

3. Summary of Pond Verification, Conditions, and Maintenance Needs

Of the 41 assessed sites, 26 were confirmed as DDBs, 8 were DDBs that had predominantly converted to wetlands, and 7 were not DDBs. Details on the non-DDB sites are included at the end of this section. The majority of the 34 verified DDBs were either well-maintained or in need of routine maintenance (Table 2). Only two DDBs needed immediate repair due to drainage issues, standing water, excessive sedimentation, and/or damaged or poorly maintained inlet or outlet structures (Table 3). Routine maintenance needs include trash cleanup, unclogging inlets or outlets, and repairing erosion (Table 4). The overall conditions of all 41 field-assessed sites are presented in Figure 2.

Table 2. Overall pond condition of field-verified DDBs

Pond Condition	Count of Verified DDBs
Immediate Need for Repair	2
Routine Maintenance Needed	23
Well Maintained (No Action Required)	9

Table 3. Two field-verified dry detention basins that have an immediate need for repair	
Site 28 – Bernstein Community Health Center Flooded basin with poorly maintained inlets	
	
Site 33 – Pitt County ABC Damaged outlet structure causing poor drainage	
	

<table>
<tr><th colspan="2">Table 4. Examples of sites with routine maintenance needs</th></tr>
<tr><td colspan="2">Trash and Littering</td></tr>
<tr><td>
Site 16 – Habitat for Humanity</td><td>
Site 7 – Lowes on Thomas Langston Rd</td></tr>
<tr><td colspan="2">Clogged or Damaged Inlets/Outlets</td></tr>
<tr><td>
Site 25 – The Bower Student Living 3</td><td>
Site 34 -Peaden’s Restaurant</td></tr>
</table>

Clogged or Damaged Inlets/Outlets		
 Site 19 – J. H. Rose High School	 Site 10 - Bojangles	 Site 51 – Kings Place Apartments
Erosion and Sedimentation		


Site 8 – Greenville Fire Dept. Station 5


Site 41 – 1812 Bradford Dr


Site 42 – Bradford Park Apartments

Tree Growth in Berm


Site 26 – The Bower Student Living 3


Site 11 – Fit for Life 24

The sites that were verified not to be DDBs were either areas misidentified by the GIS model as being DDBs, potential overflow/surcharge ponds, or sites with unknown features for further investigation, as shown in Table 5.

Table 5. Photos and descriptions of seven (7) sites that were verified not to be dry detention basins	
	**Site 3 – Boulevard West 3** (Not a DDB) This site appears to be an overflow pond, not a dry detention basin. The overflow pond has no inlets and only one outlet structure. No retrofits were proposed.
	**Site 4 – Boulevard West 2** (Not a DDB) This site appears to be an overflow pond, not a dry detention basin. The overflow pond has no inlets and only one outlet structure. The adjacent parking lot inlet is tied into the outlet structure. A retrofit was not proposed because an approach to direct runoff from the site into the pond was not identified.

Table 5. Photos and descriptions of seven (7) sites that were verified not to be dry detention basins

	**Site 45 – Southern Bank SCM** (Not a DDB) This site appears to potentially be an infiltration basin, not a dry detention basin. It does not have an outlet structure, though there may be a grate outlet buried beneath detritus and sediment. The site appears to accept some runoff from the adjacent parking lot. No retrofit was proposed.
	**Site 47 – Wintergreen Elementary** (Not a DDB) This site appears to be a possible overflow area for a stormdrain network. It has no inlets and only one grate outlet. The primary proposed retrofit was infiltration, and the secondary proposed retrofit was infiltration. Both options would cover approximately 75% of the existing site footprint, avoiding trees.
	**Site 55 – Copper Beach 2** (Not a DDB) This site's purpose is unknown. It is a depression on the property with evidence of heavy runoff and erosion. The site has one inlet and no outlet.

Table 5. Photos and descriptions of seven (7) sites that were verified not to be dry detention basins	
	**Site 12 – Ivy Court Apartments** (Not a SCM) This site appears to be a small drainage swale, not a dry detention basin or a stormwater control measure. No retrofit was proposed.
	**Site 435 – Movie Theater** (Not a SCM) This site is a road inlet behind a movie theater, not a dry detention basin or a stormwater control measure. No retrofit was proposed.

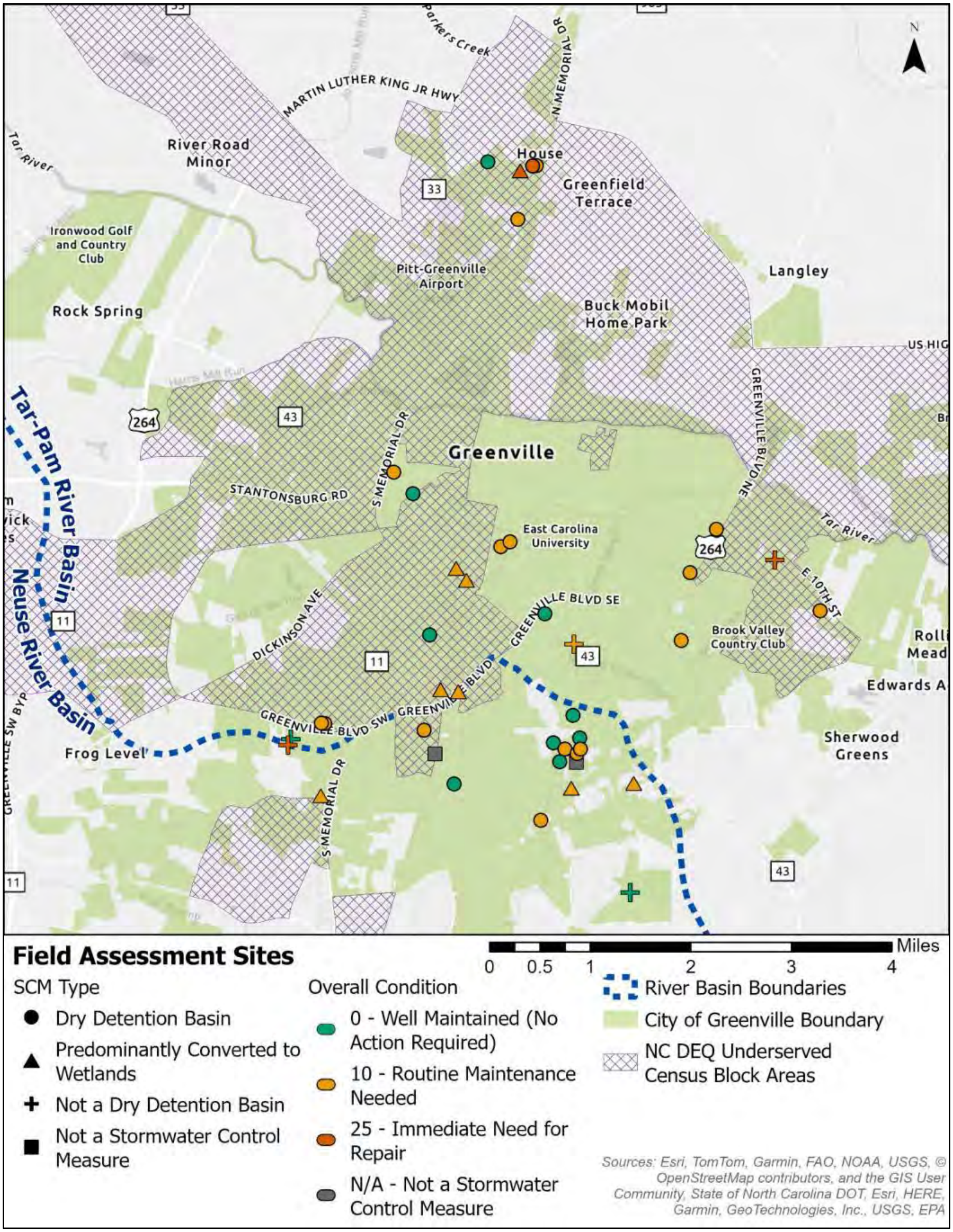

Figure 2. Sites assessed in the field symbolized by existing type of Stormwater Control Measure (SCM) and overall condition

4. Retrofit Project Ranking

A total of 34 retrofits were identified, the majority of which were either stormwater wetland or infiltration practices. Figure 3 illustrates the locations of these retrofits by type and rank, and provides a list of the 34 retrofits in ranked order. For each site, the parameters outlined in Table 1 were used to rank the proposed projects. Appendix E includes the full prioritization spreadsheet used to determine these rankings.

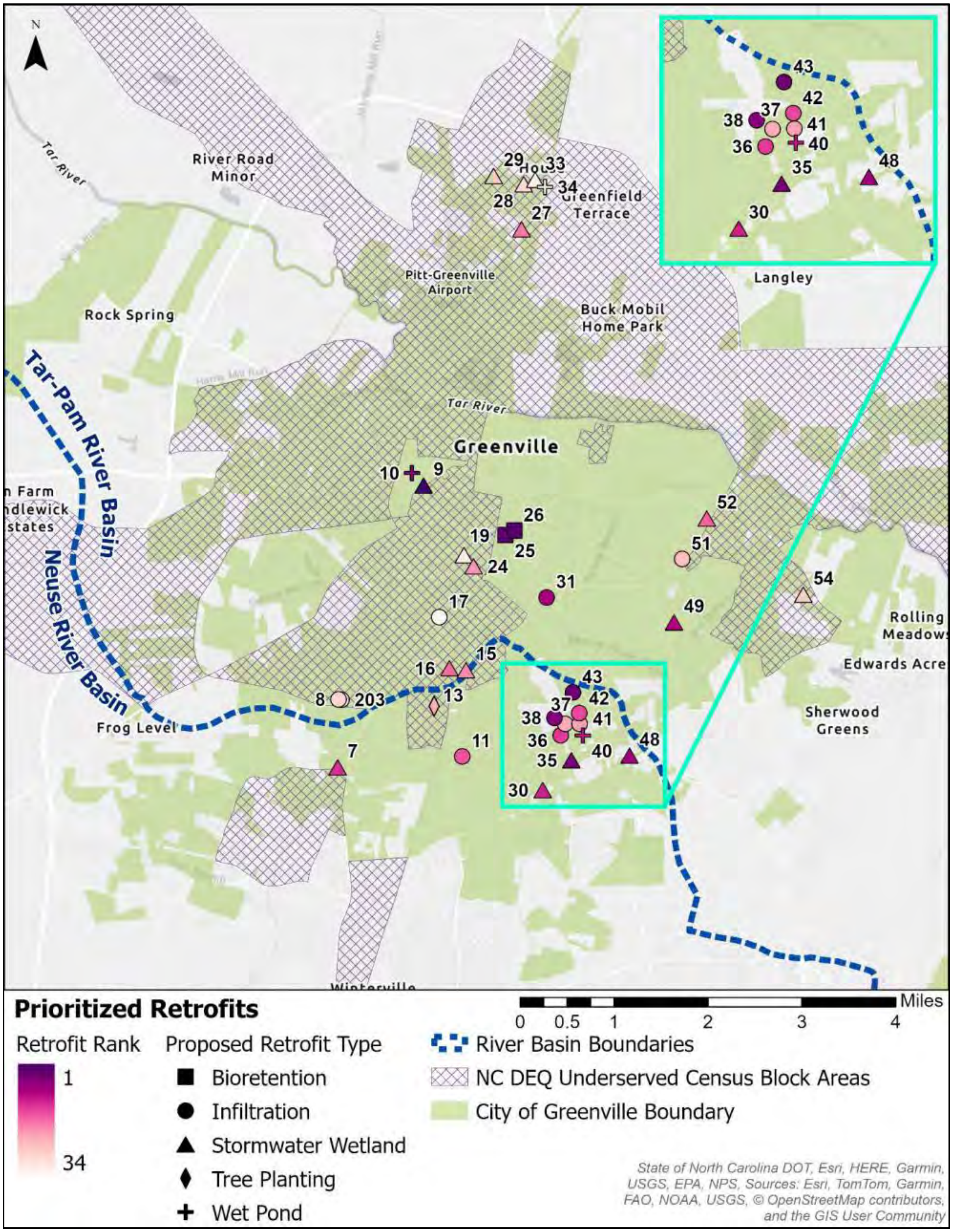

Figure 3. Proposed DDB retrofits symbolized by proposed SCM type and prioritized rank

Table 6. Prioritized ranking of sites with retrofit opportunities					
Rank	**Site ID**	**Primary Proposed SCM**	**Total Score**	**TN Load Reduction (lbs/yr)**	**Impervious Cover within Drainage Area (acres)**
1	17	Infiltration	60.0	9.0	1.8
2	33	Stormwater Wetland	59.1	1.5	3.1
3	19	Stormwater Wetland	58.4	1.2	3.5
4	34	Wet Pond	48.4	4.8	3.7
5	203	Infiltration	45.7	2.0	0.5
6	28	Stormwater Wetland	45.3	0.1	1.1
7	8	Infiltration	43.7	1.3	0.5
8	54	Stormwater Wetland	41.7	0.6	0.2
9	29	Stormwater Wetland	41.3	2.3	0.9
10	51	Infiltration	40.5	5.6	2.4
11	13	Tree Planting	40.0	0.0	0.7
12	37	Infiltration	39.8	1.7	0.7
13	41	Infiltration	39.5	3.4	1.7
14	24	Stormwater Wetland	38.9	1.4	1.1
15	15	Stormwater Wetland	38.8	1.4	2.3
16	27	Stormwater Wetland	38.2	1.1	1.6
17	16	Stormwater Wetland	37.4	2.7	11.9
18	52	Stormwater Wetland	33.5	3.1	1.1
19	11	Infiltration	31.4	4.1	0.6
20	42	Infiltration	30.9	3.9	1.5
21	36	Infiltration	30.7	2.0	1.4
22	7	Stormwater Wetland	30.3	1.9	6.8
23	30	Stormwater Wetland	29.5	1.6	0.7
24	40	Wet Pond	28.0	1.1	0.6
25	49	Stormwater Wetland	27.3	2.6	1.6
26	31	Infiltration	26.6	2.4	2.4

Table 6. Prioritized ranking of sites with retrofit opportunities

Rank	Site ID	Primary Proposed SCM	Total Score	TN Load Reduction (lbs/yr)	Impervious Cover within Drainage Area (acres)
27	48	Stormwater Wetland	26.5	0.5	0.9
28	10	Wet Pond	26.4	2.3	1.5
29	38	Infiltration	22.9	1.0	0.6
30	35	Stormwater Wetland	22.8	1.0	1.5
31	43	Infiltration	22.0	2.5	1.4
32	25	Bioretention	21.2	1.9	3.1
33	26	Bioretention	20.5	1.6	0.9
34	9	Stormwater Wetland	20.0	0.0	0.5

5. Concept Designs

Stormwater Wetland

Stormwater wetlands are constructed systems that mimic natural wetlands. Stormwater wetlands temporarily store runoff in shallow pools that are planted with wetland vegetation, which helps to treat the runoff before being slowly released over a period of 2 to 5 days. Areas of the DDB that are proposed for stormwater wetland retrofit would be excavated to increase permanent pool storage and planted with wetland vegetation as necessary. A markup of the stormwater wetlands cross-section provided in the NCDEQ Stormwater Design Manual is provided in Figure 4 to show a stormwater wetland retrofit for DDBs.

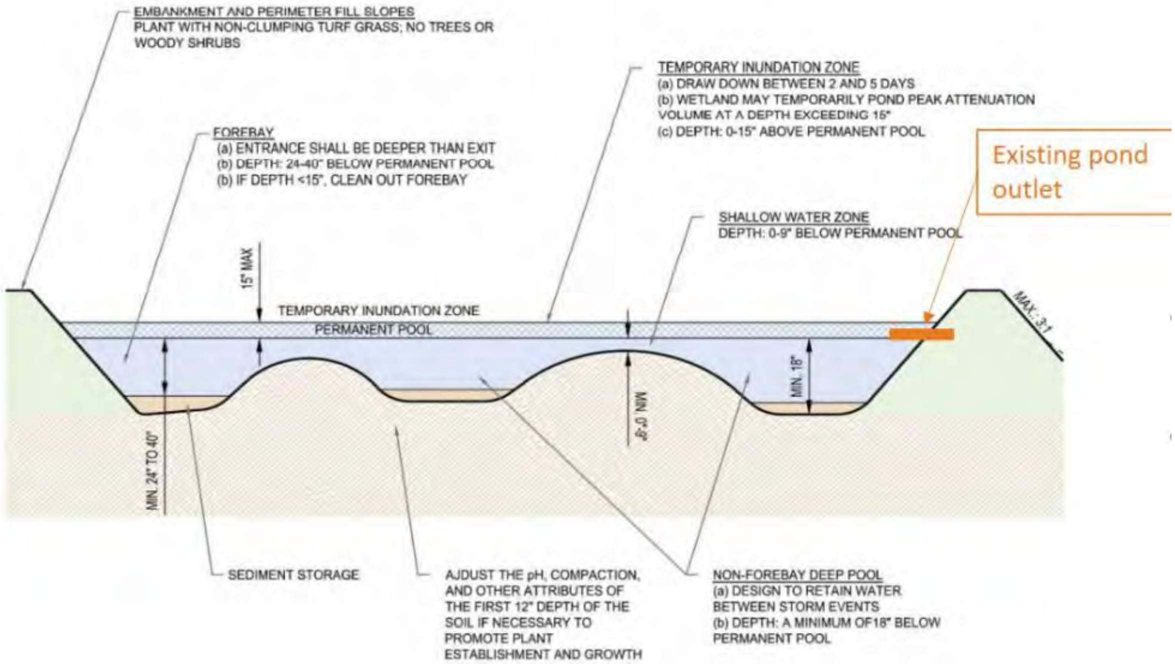

Figure 4. Stormwater Wetland Retrofit Markup

Infiltration Basin

Infiltration basins allow stormwater runoff to infiltrate into the surrounding soils. To retrofit an infiltration basin in an existing DDB, the bottom of the DDB would be excavated so allow runoff to pond and infiltrate rather than leaving directly though the outlet structure. A markup of the dry pond cross-section provided in the NCDEQ Stormwater Design Manual to show an infiltration basin retrofit for DDBs is provided in Figure 5.

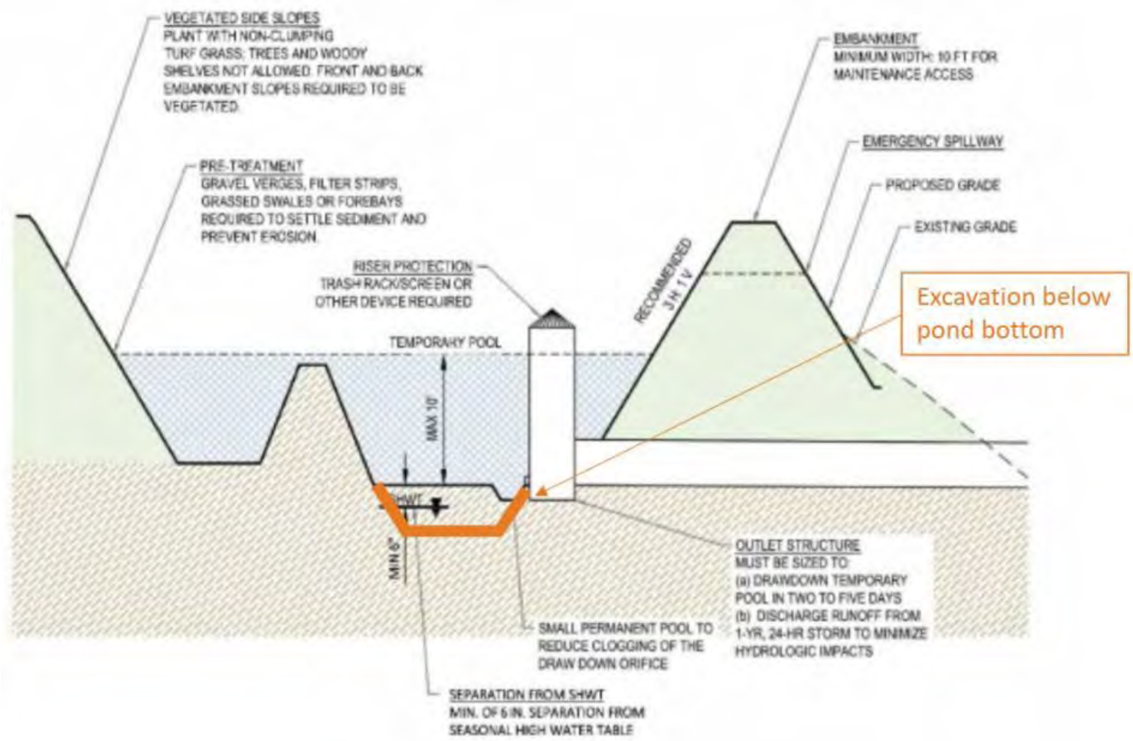

Figure 5. Infiltration Basin Retrofit Markup

Bioretention

Bioretentions capture, store, and treat runoff by filtering it through sandy soil media and gravel, before it infiltrates into the surrounding soils. To retrofit a bioretention into an existing DDB, soil in the existing DDB would be excavated and replaced with bioretention media and gravel. An underdrain would run through the proposed bioretention and connect back to the storm sewer system. The existing pond outlet would act as the overflow orifice for the bioretention retrofit. Water is expected to pond in the bioretention for 24-72 hours. The surface of the bioretention is planted with native species, that must be able to withstand widely varying soil conditions. A markup of the bioretention cross-section provided in the NCDEQ Stormwater Design Manual is provided in Figure 6 to show a bioretention retrofit for DDBs.

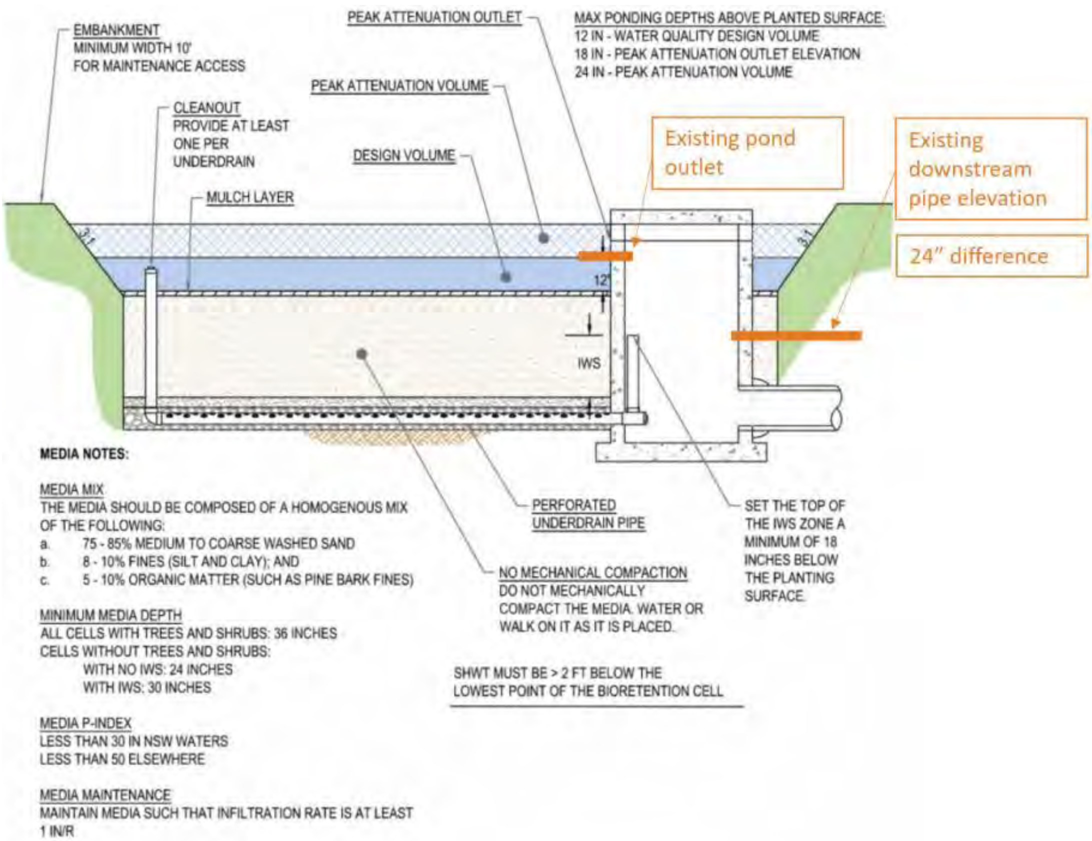

Figure 6. Bioretention Retrofit Markup

Wet Pond

A wet pond captures stormwater runoff and releases it slowly over a 2-to-5-day period though an outlet structure. To retrofit a wet pond in an existing DDB, the bottom of the DDB would be excavated for permanent pool storage. The existing DDB outlet would act as the wet pond's overflow orifice. A markup of the wet pond cross-section provided in the NCDEQ Stormwater Design Manual is provided in Figure 7 to show a wet pond retrofit for DDBs.

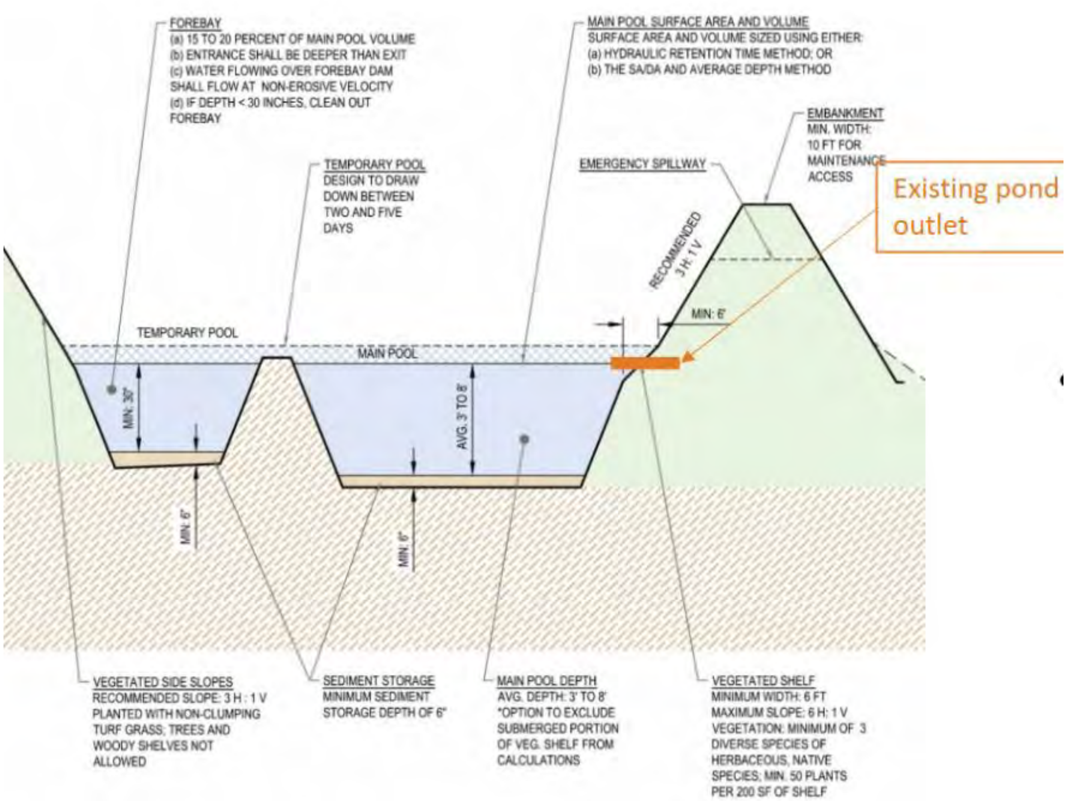

Figure 7. Wet Pond Retrofit Markup

Tree Planting

Tree plantings were recommended as the proposed SCM when no other SCM was feasible. Trees could be planted in the DDB as space allowed.

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Appendix A. Dry Detention Basin (DDB) Retrofit Assessment Field Form

Assessment Information 4

Assessment Priority

If this value is 1, this DDB is high priority for May 2023 fieldwork. If this value is 2, this DDB is second priority for May 2023 fieldwork. If this value is 0, it is not a priority DDB for May 2023 fieldwork, but could be assessed in future efforts.

Read-only

Date/Time of Assessment

--:-- --

Select the date/time that the assessment was completed.

* Required

Primary CWP Assessor Name

- Allison Lee
- Lisa Fraley-McNeal

Select the name of the CWP staff Team Lead. Only one choice is permitted; you can enter other staff in the "Other Assessor Name(s)" field.

Other Assessor Name(s)

Type the initials of other staff who completed this assessment (e.g., RH, PVW).

DDB Identification 6

Original Model ID (ogc_fid)

This is the original model ID (ogc_fid) for the DDB.

Read-only

DDB Fieldwork ID

This is the DDB Fieldwork ID.

Read-only

DDB Site Name

If not already populated, add a narrative site name for the DDB. E.g., Blue Ridge Apartments, Wintergreen Elementary Parking Lot, Chilwel Ct, etc.

* Required

DDB Site Address

Update the most representative street address for the DDB. Currently, each parcel address that intersects the DDB is listed and separated by semi-colons.

* Required

Number of Intersecting Parcels

This is the number of parcels that the DDB intersects according to ECU's calculations.

Read-only

Site Notes

Update or enter a brief description of the site.

DDB = Dry Detention Basin

Site Characterization 5

SCM Type

Select the type of Stormwater Control Measure (SCM) that best aligns with the DDB. If you select "Other," enter the details in the following Notes field.

* Required

Notes about SCM Type

If you selected "Other" for the SCM Type field, describe that choice here. Feel free to add any other details about the SCM Type that you selected.

Surface Area (sq ft)

This is the surface area of the SCM in square feet calculated by ECU.

Read-only

Volume (cu ft)

This is the volume of the SCM in cubic feet calculated by ECU.

Read-only

Hydrologic Soil Group (HSG)

This is the dominant HSG calculated by ECU.

Read-only

DDB = Dry Detention Basin
SCM = Stormwater Control Measure

Basin Assessment 10

Surface Type

- (selected) Mowed Grass
- Overgrown Grass/Perennial
- Trees
- Other (describe in following Notes field)

Select the surface type that best matches the basin. If you select "Other," enter the details in the following Notes field.

* Required

Notes about Surface Type

If you selected "Other" for the Surface Type field, describe that choice here.

Low Flow Channel Type

- Concrete
- Earthen
- Not Present
- Other (describe in following Notes field)

Select the option that best matches the type of low flow channel. If you select "Other," enter the details in the following Notes field.

* Required

Notes about Low Flow Channel

If you selected "Other" for the Low Flow Channel field, describe that choice here.

Standing Water Presence in Basin

- Major
- Minor
- None

Is STANDING WATER present in the basin?

* Required

Erosion Presence in Basin

Major

Minor

None

Is EROSION present in the basin?

* Required

Sedimentation Presence in Basin

Major

Minor

None

Is SEDIMENTATION present in the basin?

* Required

Debris Buildup Presence in Basin

Major

Minor

None

Is DEBRIS BUILDUP present in the basin?

* Required

Overall Condition of DDB

- Immediate Need for Repair
- Routine Maintenance Needed
- Well Maintained (No Action Required)

Select the option that best reflects the overall condition of the DDB.

* Required

General Notes about Basin Assessment

Enter any other general notes you have about the Basin Assessment for this DDB.

DDB = Dry Detention Basin
SCM = Stormwater Control Measure

Berm Assessment 5

Berm Presence

- Yes
- No

Is a berm present within this DDB? If Yes, fill out the remaining fields in this group. If No, leave the remaining Berm Assessment fields blank.

* Required

Berm Height (ft)

Enter the height of the berm in feet.

Erosion Presence in Berm

- Major
- Minor
- None

Is EROSION present in the berm?

Tree Growth Presence in Berm

- Major
- Minor
- None

Is TREE GROWTH present in the berm?

General Notes about Berm Assessment

Enter any other general notes you have about the Berm Assessment for this DDB.

DDB = Dry Detention Basin

Retrofit Potential 7

Depth Between Outlet and Accessible Connection to Storm Conveyance System (ft)

Enter the depth between the outlet and the closest accessible connection to the storm conveyance s ystem in feet. If an underdrain connection to the storm system is not feasible, enter 0.

Education/Exposure Opportunity

- High
- Medium
- Low

How much opportunity does this site present for education and community exposure?

* Required

Primary Proposed SCM

Select the primary proposed SCM retrofit. If you select "Other," enter the details in the following Not es field.

* Required

Area of Primary Proposed SCM (Portion of Entire Basin)

Enter the proportion of the basin proposed for the Primary SCM. For example, if 75% of the basin ha s converted to a wetland, and a wetland is being proposed, enter 0.25 to indicate that 25% of the ba sin still needs to be converted to a wetland.

* Required

Secondary Proposed SCM

Select the secondary proposed SCM retrofit. If you select "Other," enter the details in the following Notes field.

* Required

Area of Secondary Proposed SCM (Portion of Entire Basin)

Enter the proportion of the basin proposed for the Secondary SCM. For example, if 75% of the basin has converted to a wetland, and a wetland is being proposed, enter 0.25 to indicate that 25% of the basin still needs to be converted to a wetland.

* Required

Notes about Proposed SCM(s)

If you selected "Other" for the Primary or Secondary Proposed SCM fields, describe those choices he re. ALSO, describe the overall proposed retrofit here.

DDB = Dry Detention Basin
SCM = Stormwater Control Measure

Constraints 6

Accessibility Constraints

- Access Road Present
- Access Possible for One-Time Construction
- Access will be Difficult

Select the option that best reflects the accessibility of the site.

* Required

Tree Clearing Requirements

- Major
- Minor
- None

Select the option that best reflects the degree of tree clearing that will be required at the site.

* Required

Utility Constraints

Describe any utilities that might constrain retrofit design and construction. If there are no identified u tility constraints, enter "None". If it is unclear whether there are utility constraints, enter "Unclear".

* Required

Ownership

Select the option that best reflects the property ownership of the site. If you select "Other," enter the details in the following Notes field.

* Required

Notes about Ownership

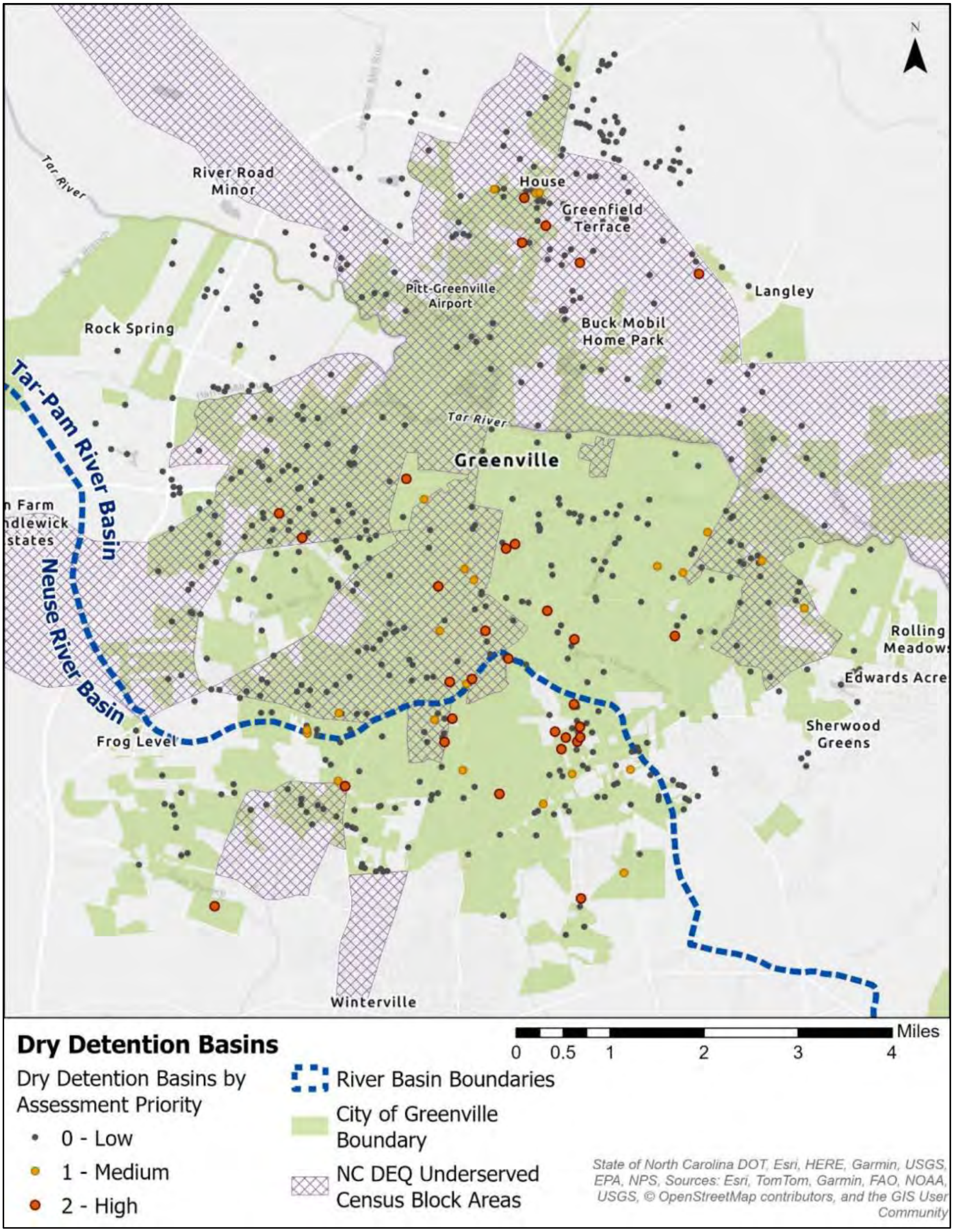
If you selected "Other" for the Ownership field, describe that choice here.

General Notes about Constraints

Enter any other general notes you have about the constraints for this DDB.

DDB = Dry Detention Basin

Appendix B. Map of all Dry Detention Basins Identified and Prioritized by ECU



Initial map of all potential dry detention basin sites provided by East Carolina University (ECU) to the Center for Watershed Protection (CWP), symbolized by assessment priority

Appendix C. Retrofit Decision Flow Chart

1. Has the pond already converted to a wetland?
   If yes, select stormwater wetland as the proposed SCM.

   Assess:

   - How much area (footprint) is available for excavation to increase permanent pool storage (Healthy, mature vegetation should be left alone)?
   - Is there a need for invasive species removal (cattails and phragmites)?
   - Is additional planting needed?

2a. Consider infiltration.

   Is the basin located in A/B soils?
   Is there area available for excavation? If yes to both, select infiltration as the proposed SCM.

   Assess:

   - Note if bioretention is also a possibility based on step 2b below.

2b. Consider bioretention.

   Is there at least a 1.5-foot difference between the pond outlet and a feasible underdrain connection point? (In the standpipe or a short distance downstream).

   Is there area available for excavation? If yes to both, select bioretention as the proposed SCM (or as a second-choice SCM if infiltration was already selected).

   Assess:

   - What is the depth available for the underdrain connection?
   - If both bioretention and infiltration are feasible, select infiltration as the proposed SCM.

3. Consider wet pond.

   Is there area available for excavation? If yes, select wet pond as the proposed SCM.

4. Consider tree planting.

   Is there space available for tree planting? If yes, select tree planting as the proposed SCM.

   Assess:

   - How much area is available for tree planting?

Appendix D. Pollutant Removal Calculations for Proposed Retrofits

The pollutant removal calculations for all proposed Dry Detention Basin (DDB) retrofits are provided as a separate spreadsheet attachment.

Appendix E. Prioritization Spreadsheet with Ranked Retrofits

The full prioritization details for all proposed Dry Detention Basin (DDB) retrofits are provided as a separate spreadsheet attachment.