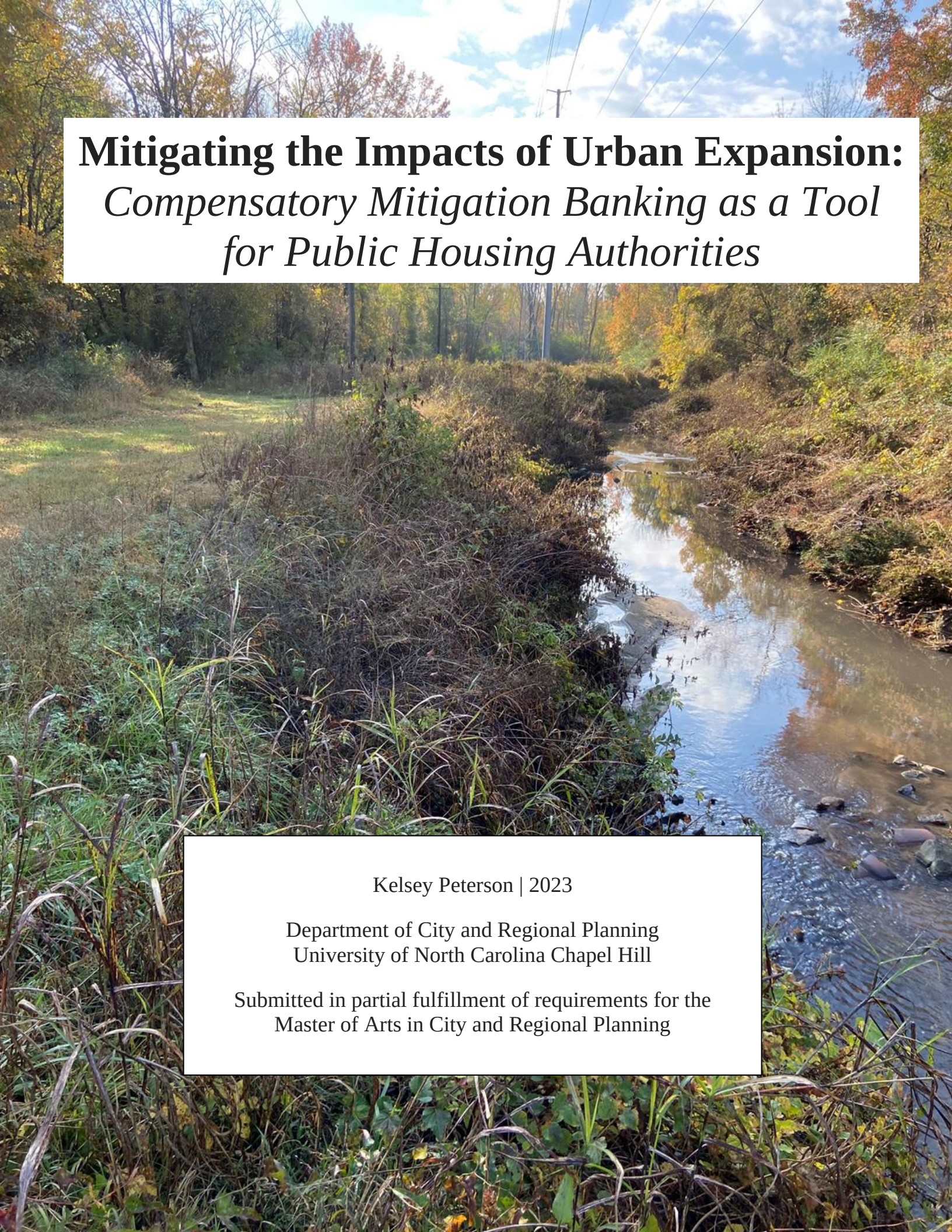

Mitigating the Impacts of Urban Expansion:
Compensatory Mitigation Banking as a Tool for Public Housing Authorities

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Submitted in partial fulfillment of requirements for the
Master of Arts in City and Regional Planning

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Introduction

Since the 1950s, the U.S. has experienced some of the most rapidly sprawling development patterns in the world (Vogler & Vukomanovic, 2021). One driver of America's sprawling development patterns has been widespread affordable housing stock shortages in urban areas, which have prompted residents to seek less expensive options at the urban fringe (Brooks, 2022). When residents are pushed further away from centralized urban areas, increased ex-urban development – and its associated environmental impact – typically follows (Aurand, 2013; Hamidi & Ewing, 2015).

This low-density urban growth has led to the replacement of natural ecosystems with spatially-expansive impervious surfaces, which exacerbate air quality, water quality, flooding, and other environmental problems (Bierwagen et al., 2010). Historically, the United States government sought to manage these impacts through policies that relied on standard setting, permitting, and enforcement that have proven ineffective in offsetting the environmental repercussions of urban expansion (ELI, 2022). More recently, ecosystem service markets have begun to arise as an alternative to these command-and-control strategies by providing incentives to both private and public organizations to offset the impacts of development (ELI, 2022). These markets have emerged to offset development's impacts to several ecosystem services, including carbon sequestration, endangered species habitat, and streams and wetlands (EPA 2016).

One ecosystem service market strategy that has seen major growth in the past 20 years is stream and wetland compensatory mitigation (Lave & Doyle, 2021).While the market structure can be quite complex, it can be summarized fairly quickly: development projects ("impactors") that unavoidably impact aquatic resources protected under the US Clean Water Act enter one side of a dual-sided permitting system administered by the U.S. Army Corps of Engineers (USACE, 2023; Ostrom et al., 1994). Under the USACE's requirements and oversight, permitted impactors compensate for their impacts by either restoring wetlands or streams themselves (known as "permittee responsible mitigation;" EPA, 2015) or paying third parties ("mitigators") to perform the restoration on their behalf (and thus transferring away their liability for mitigation). Impactors can do this by purchasing mitigation credits from "mitigation bankers" – typically private firms that speculatively restore wetlands or streams – or from in-lieu fee (ILF) programs – a pool of resources managed by a state/local government or NGO that uses fees collected from impactors to conduct mitigation activities (Berahzer, 2015). The mitigation process, whether performed by impactors, bankers, or ILF programs, requires approvals from the USACE (thus representing the second side of the permitting system) once mitigation sites have met certain ecological thresholds, thereby allowing them to sell credits to impactors.

Paralleling the growth of wetland and stream mitigation as an effort to address the environmental impacts of sprawl has been the growth of public housing authorities (PHAs), which are today some of the primary entities addressing insufficient affordable housing in urban centers. PHAs are independent non-profit organizations, chartered under individual state laws, which receive direct financial support from the U.S. Department of Housing and Urban Development (McMarty, 2014) to support housing assistance and increase affordable housing stock in their communities. The 3,300 PHAs in the U.S. work closely with local, state, and federal agencies on

a range of activities to provide decent and safe housing to low-income families, the elderly, and people with disabilities (HUD, 2023).

While mitigation and PHAs appear to be in completely different fields of work, their goals align in many ways. The rapid expansion of urban development throughout the U.S. has had significant impacts on affordable housing stocks as well as ecosystems and aquatic resources. PHAs and mitigators seek to offset these respectively impacts through market-based approaches. Several studies have shown that a major challenge in establishing environmental offsets through mitigation is that land markets often pressure restoration activities into rural areas, where land values are low and water regimes are such that restoration projects can be more easily (and inexpensively) sustained (Madureira & Andresen, 2014; Klaus & Kiehl, 2021; Stefanakis, 2019). Over time, this can result in a systematic shift of aquatic resources from urban to rural areas (Womble & Doyle, 2012; BenDor & Stewart, 2011; BenDor et al., 2009).

PHAs may be in a unique position to overcome the challenges associated with implementing mitigation in urban and suburban areas as they often own portfolios of land parcels within these settings in order to carry out their mission of providing affordable housing (Kleit et al., 2019). The potential for PHAs to restore aquatic resources – on unbuildable portions of their properties – while using the revenue generated from mitigation credit sales to provide their communities with affordable, safe, and decent housing options is a topic that has received no attention within the academic and professional literature.

How could involvement in wetland or stream mitigation impact PHA missions? What processes can PHAs use to assess the feasibility and cost/benefit structure of implementing mitigation within their real estate portfolios? What are the factors that affect PHA implementation of mitigation projects? In this paper, I address these questions through a case study of the Durham Housing Authority (DHA), which has operated in the City of Durham, North Carolina since 1939 (DHA, 2023). The DHA offers an ideal case study of this topic as it is both strongly representative (in its size, resources, and overall mission) of many PHAs around the country, as well as unique in that its service area straddles two rapidly developing watersheds, the Neuse and Cape Fear River basins. These watersheds are home to some of the most active aquatic ecosystem service markets in the nation, including private mitigation markets for wetlands and streams and novel ILF programs for riparian buffers and water quality (nitrogen) administered by the State of North Carolina (Hill et al., 2013).

In this case study, I used several methods to address this paper's research questions including geospatial, mitigation demand, cost-benefit scenario, and program analyses as well as three interviews with related stakeholders. The results of these methods led me to identify three potential DHA mitigation sites containing aquatic resources of sufficient size, health, and correlation to ongoing watershed planning efforts. The identified sites have a combined stream length of 11,229 linear feet, with one site containing a 9-acre wetland area. I found total net revenue for mitigation activities on the three sites positively contribute to DHA's low-income public housing operating budget across all four cost-benefit scenarios. The results I have summarized in this paper support the conclusion that stream and wetland mitigation markets and low-income housing markets can intersect to achieve mutually beneficial results for communities.

Background

The Impetus for Public Housing Authorities

The concept of public housing authorities (PHAs) in the US was first implemented as a component of the New Deal through the U.S. Housing Authority Act of 1937 (NLIHC, 2023). PHAs operate in a unique manner, in comparison to other non-profit organizations, due to their close financial and operational ties with federal, state, and local governments (McMarty, 2014). The term "quasi-governmental" is often used to describe PHAs as they are private, not-for-profit entities that rely on federal, state, and local funding and technical support for their work (Kleit & Page, 2015). While PHAs receive a majority of their funding from federal sources, the overall federal spending on affordable housing programs has declined since the 1980s, leading PHAs to adopt private, market-based approaches to carry out their mission (Kleit et al., 2019).

Beginning in the 1990s and continuing into today, PHAs have experienced a shift in federal policy from one of supply to a demand focused strategy that incorporates the private market through private and public funding. HOPE VI, Low-Income Housing Tax Credit program, and Rental Assistance Demonstration (RAD) are primary examples of this shift to a demand based, decentralization of the public housing sector. The hybridized approach included mixed financing and private market strategies, which resulted in an overall decrease in federal funding support as (Kleit et al., 2019; Nguyen et al., 2012). The growing amount of PHAs implementing housing stock without relying solely on federal support has led to greater flexibility and innovations within the space. One of the primary private financing mechanisms that is estimated to have funded a third of all multifamily rental housing between 1987 and 2006 is the Low-Income Housing Tax Credit program that provides tax credits to those who provide equity for affordable housing (Kleit & Page, 2015).

While these methods were initially successful, the recession of 2008 prompted the collapse of housing tax credits due to the primary investors of the program, large banks, were no longer profitable and could not use the credits. This resulted in a significant decrease in demand and price that left many public housing projects that relied on the tax credit funding stalled or abandoned (JCHS-Harvard University, 2009; Kleit & Page, 2015). The collapse of the affordable tax credit market alongside a marked contraction of housing bond markets, forced many PHAs to sell their property portfolios through PHA established, separate, legal, ownership entities that are meant to further PHA's goals. While individual state law regulates what kind of ownership entities are permissible, PHAs have the ability to create for-profit, non-profit, limited liability corporations as well as limited partnerships to assist in the mixed financing federal policy approach (Kleit & Page, 2015; PIH 2017).

Mitigation strategies may offer a partial solution to the lack of sufficient private market funding strategies by allowing PHAs to generate assets from land unsuited for construction due to floodplains and protected natural resources. The potential for PHAs to leverage their close relationships with local, state, and federal government agencies by aligning public housing financing with environmental restoration may generate significant support for technical and

funding support in the implementation of mitigation banks as local and state governments could accomplish two objectives at one time.

Mitigation Banking Regulatory Development

The history and regulatory structure of stream and wetland compensatory mitigation banking is rooted in the US Clean Water Act (CWA) of 1972 (13 USC 1251, et seq.). Under Section 404 of the CWA, any development that impacts a designated wetland or stream is required to seek a permit from the U.S. Army Corps of Engineers (USACE) (USACE, 2023). Prior to 2008, development projects received permits under this regulatory structure if their activities avoided impacts where possible, minimized unavoidable impacts, and conducted permittee responsible mitigation as compensation for the impacts to protected aquatic resources (BenDor & Doyle 2009). This structure invoked criticism due to the promotion of permittee responsible mitigation where developers are responsible for offsetting their impacts, which sometimes results in substandard restoration (Inkinen et al., 2022; Bronner et al., 2013). In the 1990s, private entrepreneurs started conducting mitigation banking activities and generating credits that developers could purchase to fulfill the requirements of the CWA (Wilkinson et al., 2002). In 2008, the USACE, in partnership with the EPA, issued revised regulations on compensatory mitigation in order to improve the effectiveness of mitigation, expand public participation, and increase both efficiency and predictability of the review process (EPA 2015). The new regulations…

- Emphasize a watershed approach to site selection.
- Require measurable and enforceable ecological standards.
- Require documented monitoring of completed banks.
- Clarify compensation plans based on the principles of aquatic ecosystem science.
- Emphasize the use of science-based assessment procedures.

The shift in regulatory regime more clearly defined the field of mitigation banking and favored the practice by creating a hierarchy of preference in satisfying CWA 404 requirements with mitigation banking credits as the first option with in-lieu fee programs and permittee-responsible mitigation following. In-lieu fee programs offer projects required to offset their impact the ability to pay a fee in an amount determined by the relevant regulatory agency. In-lieu fees act as an advanced credit that transfers mitigation responsibilities from the development project to the regulatory agency who utilizes revenue from the fees to conduct mitigation. Permittee responsible mitigation is the least preferred form of compensatory mitigation as history has proven that mitigation projects conducted by developers have a higher likelihood of failing or performing below the required compensation. The 2008 ruling and guidance resulted in a decrease of permittee responsible mitigation from 60% of all compensation in 2008 to only 33% between 2015-2020 while private mitigation banking has grown to 51% of all compensatory mitigation during this time (Inkinen et al., 2022). Mitigation banks have grown from an estimated 450 banks in 2005 to over 2,000 sites in 2015 (Spanjer, 2018).

While the 2008 regulations aimed to create an equal set of standards for all forms of compensatory mitigation, the power of enforcement and interpretation rests in the hands of

USACE regulatory districts. The various districts of USACE spread across the United States are responsible for the approval of bank sites and the application of the watershed approach.

Study Area

Durham Housing Authority (DHA)

The DHA works in the City of Durham, North Carolina, a rapidly growing municipality with a 24 percent change increase in population between 2010 and 2020. Durham County being the second most urban county in the state, behind only Mecklenburg County, with 86.3% of residents living within the City of Durham's municipal area (OSBM, 2020). The Durham Housing Authority (DHA) was founded in 1949 by a group of local residents, appointed by Mayor Daniel Edwards, to provide better housing opportunities for low-income persons (DHA, 2023). DHA's mission is to "develop, own, manage, and contribute to diverse communities of choice" by serving as the leading provider of affordable housing in the City of Durham (DHA, 2023). DHA has a full-time staff of 115 persons and provides 1,201 public housing units to low-income families, people with disabilities, and the elderly, as well as manages 3,078 housing choice vouchers for local landlords (DHA, 2023). The DHA has an approximate annual operating budget of $42 million according to the latest publicly available report in 2021. The budget is broken into four parts including low-income public housing ($10 million), central office cost center ($5 million), housing choice voucher program administration ($2 million) and housing assistance payments ($21 million) (DHA, 2021). As the City of Durham continues to grow both in population and geographic expanse, DHA will face increasing strain on their capacity to meet demand for affordable housing. DHA's (2017) Strategic Plan outlines six key goals for meeting these challenges:

- Strengthen financial stability and operational efficiency.
- High performing organization in both public housing and HCV program
- Build strong community partnerships.
- Provide quality customer service.
- Create healthy and sustainable communities.
- Build a strong asset portfolio.

North Carolina Stream and Wetland Market Context

North Carolina's ecosystem service markets, specifically those related to aquatic resources, are unique due to the interaction between private and public mitigation markets (BenDor & Doyle, 2009). North Carolina offers a unique case study on mitigation banking due to its robust stream credit market, having been one of the first states to incorporate stream credits as a major component of their mitigation work. The NC Division of Mitigation Services alongside USACE has evolved the market and regulatory structure into one of the most developed programs in the country through a statewide strategic plan for ecosystem services (Lave et al., 2008; U.S. DOT-FWA, 2005).

In 2020, under NC House Bill 1087, North Carolina expanded the regulatory system of mitigation banking in North Carolina to include the restoration and monitoring of projects or

land acquisitions that create or restore flood storage capacity. While new, the inclusion of flood storage projects has the potential to significantly increase the amount of flood mitigation projects throughout a state that has experienced a number of damaging floods in recent years including Hurricane Florence and Matthew.

The state government further participates in mitigation banking through the N.C. Department of Environmental Quality's (NC DEQ) Division of Water Resources (DWR) and the Division of Mitigation Services (DMS). The DWR is responsible for "the environmental protection and quality of the State's surface water and groundwater, and to ensure safe drinking water for its residents" (DWR, 2023). To fulfill these responsibilities the DWR co-administers Section 404 and 401 of the Clean Water Act as well as the North Carolina Coastal Area Management Act (CAMA) and the coastal Dredge and Fill Law in conjunction with the USACE Wilmington District. The DWR administers these laws through setting regulatory standards and participating in the Interagency Review Team (IRT) responsible for reviewing and approving permits and mitigation activities. The IRT is chaired by USACE-Wilmington District who have final decision-making power over mitigation banks and in-lieu fee programs and is often composed of representatives from the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), NOAA Fisheries, the Natural Resources Conservation Service (NRCS), NC DEQ, NC Wildlife Resources Commission (WRC), and other related state and federal agencies (Kihslinger et al., 2020).

The DMS, previously named the North Carolina Ecosystem Enhancement Program, acts as North Carolina State Government's mitigation banker and is responsible for restoring and protecting wetlands and waterways to offset unavoidable environmental impacts from development. The DMS was primarily formed to provide the N.C. Department of Transportation (DOT) with mitigation credits due to the department's continual and significant impact to the state's environment through the construction of new transportation infrastructure (DMS 2023). DMS also administers four in-lieu fee programs including the NCDOT Stream/Wetland, Statewide Stream/Wetland, Riparian Buffer, and Nutrient Offset programs that offer public and private organizations the opportunity to purchase credits when private bank credits within the 8-digit HUC where the impact occurred are unavailable. DMS programs are supported through design-bid-build, design-build, full delivery services as well as mitigation bank purchases. The design-bid-build mitigation process is where DMS contracts the design of a mitigation site and the construction of that site separately. The design-build process is where DMS contracts the design and construction of a site to one firm and then assumes monitoring and maintenance responsibilities. In recent years, DMS has shifted its preference to full delivery contract services where private mitigation bankers are responsible for all steps in the mitigation banking process and delivery credits. The shift to a full delivery preference was a result of risk reduction efforts by DMS's as managing multiple contracted firms can be challenging (DMS 2019).

Mitigation Bank Application and Approval Process

Implementing stream and wetland mitigation banks can be a complex process and the urban environment of Durham may add further complexity. Designing successful restoration instruments can be challenging in an urban environment due to the substantial amounts of impervious surfaces that cause stormwater runoff to flow into streams like Third Fork and Ellerbe Creeks at above average volumes and speed (Shoredits & Clayton, 2013). Designing stream or wetland restoration will require an environmental engineering organization experienced with working in urban contexts. The regulatory requirements, difficult market analysis, and extensive staff over an approximate 10-year time frame required to implement a mitigation bank may exceed the DHA's organizational capacity and expertise. The process by which an organization can implement a mitigation bank be broken into five phases including…

- Evaluating the opportunity and options
- Evaluating mitigation sites
- Permitting and design
- Implementing mitigation activities
- Monitoring, maintenance, and the sale of credits

Phase one, evaluating the opportunity and options, often includes a market analysis to determine demand for credits, assessing the costs and benefits, and forming partnerships with other organizations to support the mitigation banking project. The second phase, evaluating mitigation sites, includes both on and off-site data collection and analysis to determine the type, amount, and quality of environmental resources. Once all of the preliminary data has been collected and analyzed, an organization seeking to implement a mitigation bank must receive approval from the Interagency Review Team.

The permit application process, which is illustrated in greater detail in Figure 5, located in the Appendix section, can take between 17 and 39 months with a recent study finding the average timeline for mitigation banking instrument approval to be 33 months (Kihslinger et al., 2020; Martin & Madsen, 2023). The prospectus acts as a preliminary assessment for the IRT to determine whether the applicant's bank is feasible and should move forward to the more detailed banking instrument. A mitigation banking instrument consists of all relevant project details on the mitigation plan, bank evaluation and development, bank operation, responsibilities of the involved parties, etc.

Once the project sponsor receives approval from the IRT and constructs the bank site a monitoring and maintenance period begins with a required seven-year period of annual monitoring that assesses the state of vegetation and ground water at bank sites. The purpose of required monitoring is to ensure completed bank sites maintain their integrity in the long term to achieve the overall goal of no-net loss to aquatic resources. Mitigation credits are released to the bank sponsor on a predetermined schedule that corresponds to the performance of the bank over the monitoring period. The schedule can vary based on the environmental resources (forested wetlands, non-forested wetlands, or streams) managed by the bank.

Mitigation project sponsors seeking to partner with the DMS must go through an additional process for DMS contract awards. Design-bid-build projects are administered through the Department of Administration-State Construction Office while all other contracts, including mitigation credit procurement are managed by the Department of Administration-Purchases and Contracts Division (DMS, 2023). Design-bid-build projects include a five-step procurement process that begins with DMS posting a request for services or mitigation credits on the North Carolina Interactive Purchasing System. Interested organizations submit proposals and qualifications that are reviewed by the DMS based on quality and cost (DMS, 2023). Once approved by DMS the Department of Administration makes the award and the Department of Environmental Quality-Financial Services formally contracts with the project sponsor.

Methods and Data

In this study, I will evaluate the feasibility and cost-benefit structure of implementing mitigation strategies within PHAs real estate portfolios. The three primary components any organization looking to assess whether stream and wetland mitigation banking as an option are 1) the presence, composition, and relative health of aquatic resources; 2) the demand for mitigation credits within the 8-digit HUC service area from permittees; and 3) the associated costs and benefits of implementing a mitigation project through different mitigation strategies (i.e., mitigation banking or ILF programs). To do this, I perform geospatial analysis, conduct a market demand analysis, evaluate scenarios for a cost-benefit analysis, and interview a senior staff member of the DHA, a project supervisor for a mitigation bank based in an urban area of Charlotte, North Carolina, and chief mitigation officer for the USACE Wilmington District.

Geospatial Analysis

All geospatial analyses were completed using ESRI's ArcGIS Pro v. 3.4 (ESRI, 2023). The first step in understanding whether mitigation banking is a feasible option for the DHA was to identify all DHA owned properties in the City of Durham that intersect a protected aquatic resource. Initially, every DHA owned property was identified using a basic filter on the comprehensive parcel shapefile dataset, obtained from City of Durham's (2023) Open Data Portal, which listed property owner identification for the City of Durham. These results were cross checked with a list of owned properties provided by the DHA. I then added open channel (Open Data, 2023), FEMA designated floodplains (National Flood Hazard Layer, 2023), and wetland shapefiles (National Wetland Inventory, 2023) to the map and found where DHA parcels intersected an aquatic resource (Figure 1). Open channel data was filtered to remove waterways that were not classified as either a stream or river. Next, parcels with aquatic resources were then assessed based on their spatial relation to the City of Durham's existing Watershed Improvement Plans that identify areas of concern and prioritized restoration locations so that DHA's bank sites would be in alignment with the watershed approach outlined in the 2008 USACE regulations (City of Durham, 2023).

Once the potential bank sites were identified, I clipped stream lines, floodplains and wetland polygons to the parcel boundaries (calculating their respective lengths and areas) and added a

50ft riparian buffer, in accordance with USACE requirements, to assess whether a stream restoration project would intersect with non-DHA owned properties. To increase the level of certainty for wetland areas identified by the National Wetland Inventory, I used the U.S. Natural Resource Conservation Service's (2023) Web Soil Survey that generates site specific soil maps and descriptions of what soil types indicate. Using the now identified and feasible sections of the aquatic resources I calculated the total length of stream length (in linear U.S. survey feet) and wetland area (in U.S. survey acres). The sum of identified wetland area within the 50ft riparian buffer was subtracted from the total wetland area in accordance with USACE regulations that prohibit mitigation banking projects from double counting mitigation activities (USACE, 2008).

Mitigation Demand Analysis

In order to gain perspective on the stream and wetland mitigation credit market for the two watersheds where potential DHA bank sites were identified, Haw and Upper Neuse Watersheds, I compared permits requiring compensatory mitigation and existing bank credits. Using a permit dataset from 2017 through 2021, obtained from USACE's ORM2 database, I initially filtered the data so that only permits requiring compensatory mitigation in the study area were included. The dataset was then organized based on the watersheds HUC 8 service area code, the year permits were issued, and mitigation credit type. I then calculated the annual sum of stream and wetland mitigation credits in each watershed separately. Using the calculated sums for credit type, an average annual credit amount required by permittees was calculated for both stream and wetland credits in each watershed.

I identified credit availability in 2023 within each watershed by using data obtained from USACE's RIBITS database. RIBITS contains a reporting tool that provides credit tracking information for each HUC 8 watershed including information on potential, released, withdrawn, and available credits for each approved bank site. I calculated the sum of available stream and wetland credits currently available and compared the results to average annual credit demand in order to assess how the supply of credits relates to average annual demand. The location of project permits requiring stream or wetland permits was then mapped in relation to the City of Durham and the three potential DHA bank sites.

Cost-Benefit Scenario Analysis

I performed a basic cost-benefit analysis for stream and wetland mitigation on the identified sites to assess the financial feasibility of DHA implementing banks on each of the identified sites (Table 2). I used the City of Charlotte's Stream and Wetland Umbrella Mitigation Bank credit costs for 2022-2023 as the estimated implementation costs for this analysis because the bank conducts mitigation in a similarly urban environment as well as their status as a public entity. The bank is a public entity and sells credits at cost and only to departments of the City of Charlotte, Mecklenburg County and Charlotte-Mecklenburg Schools in three HUC 8 watersheds that intersect the municipal boundaries. One project supervisor for Charlotte's mitigation bank shared in an information interview that the administrative and staff related expenses are funded

through the city's stormwater utility fee, so credits sold at cost solely reflect the planning, design, construction, monitoring, and maintenance costs for mitigation bank projects.

The analysis used the average stream credit price across the three Charlotte watersheds as the proxy for implementation cost estimates. Charlotte's bank provides wetland credits at the same price for each watershed, so no calculations were required (for more information on the City of Charlotte's mitigation bank see Supplementary Material section). The project supervisor further shared that real estate expenses constitute 6% of stream restoration project costs, for mitigation activities implemented in the urban core and surrounding area (primarily the HUC 8 Lower Catawba Watershed). Wetland restoration real estate related expenses are harder to estimate due to the city having exploited a majority of the wetland area opportunities. However, based on previous wetland restoration projects the project supervisor expressed that land costs are significant due to larger and more spread-out project areas in comparison to narrower, corridor-like land areas acquired for stream restoration. I used information from the interview to estimate wetland restoration real estate expenses at 20% of total implementation cost. Since the DHA would implement mitigation activities on their own land, the real estate expenses were removed from the DHA stream and wetland implementation costs.

Four scenarios were performed to provide a greater perspective on the financial feasibility of DHA implementing mitigation banks. Scenario one considers a situation where the DHA's implementation costs are estimated by the City of Charlotte's credit sales price (where credits are sold at cost), and the credit sales price is set using the DMS's statewide credit sales price standard for 2022-2023 so that the two organizations evenly split the net revenue generated by the purchase of those credits by In-Lieu Fee Program participants. In the second scenario, the implementation cost is varied to reflect a lower estimate made by a recent publication on the implementation of stream, wetland, and other natural infrastructure practices' estimated costs and revenues in eastern North Carolina while the DHA's credit sales price remains the same as scenario 1 (Hovis et al., 2022). The third and fourth scenarios have a consistent implementation cost, reflecting the higher Charlotte estimate, while varying the credit sales price to reflect the DHA receiving 25% and 75% of the net revenue generated, respectively. Scenarios 3 and 4 also change the baseline credit sales price by using the average private mitigation banking firm's estimated price for 2021-2022, which was obtained from the DMS's 2021-22 Annual Report (DMS, 2022).

As mentioned in the background section of this paper, the ratio of mitigation conducted and credits received is not always 1:1 and can vary based on a number of factors including buffer widths, mitigation activity conducted, location of the site, etc. In this study the ratio of linear feet/acres of restored aquatic resources is assumed to be 1:1 for simplicity. However, in an interview with the Chief Officer for the USACE Wilmington District Mitigation Branch it was noted that increased ratios may be granted to mitigation projects located in urban environments due to the lack of projects being conducted in these spaces. This was also confirmed in another interview with the Project Supervisor for the City of Charlotte's Umbrella Stream and Wetland Mitigation Bank (for more information see Supplementary Material). Further, the price of mitigation credits provided by private entities vary annually based on a number of factors including credit availability contingent on banks meeting annual performance standards, annual permitted impacts requiring compensatory mitigation, per unit cost of construction material and

labor, etc. The total net revenue for each mitigation activity was finally calculated by subtracting total implementation costs from total revenue.

Interviews and Program Analysis

To clarify and augment the findings of the previous analyses, I interviewed a professional working in each of the subject fields this study covers including housing authorities, mitigation providers, and regulators. The methodology and structure of the interviews was reviewed by the Institutional Review Board (IRB) of the Office of Human Research Ethics at the University of North Carolina at Chapel Hill and determined that the research did not require IRB approval (IRB Study # 22-2967, 2023). The interviewees included a member of the Executive Office for the DHA, a Project Supervisor for the Charlotte-Mecklenburg Stormwater Services Umbrella Stream and Wetland Mitigation Bank, and the Chief Officer for the USACE Wilmington District Mitigation Branch. I conducted the mitigation provider and regulator interviews online using the video communication software Zoom where the audio was recorded and transcribed using Microsoft Word's Transcribe feature. I was able to conduct the housing authority interview in person where I took notes manually that were later transcribed to an online version for later review.

The program analysis I conducted considered the DHA's organizational capacity, the regulatory framework for stream and wetland mitigation in North Carolina, the City of Durham's watershed improvement planning efforts, and the City of Charlotte's Umbrella Stream and Wetland Mitigation Bank. The DHA program analysis focused on their internal staff capacity, ongoing projects and programs as well as their budget constraints. The information I reviewed for the DHA analysis included the interview with a member of DHA's Executive Office, information published on the DHA website (DHA, 2021 & 2023), and Durham Housing Authority Resolution that was approved by the local government (City of Durham, 2020). For the regulatory framework for stream and wetland mitigation analysis I reviewed information gathered from the interview with the Chief Officer of for the USACE Wilmington District, the EPA and USACE promulgated rules that govern compensatory mitigation (EPA, 2008), and North Carolina Administrative Code sections 15A NCAC 02H .0506(c) (2003) and 15A NCAC 02H .1305(c) (1996) that requires compensatory mitigation for losses of streams and wetlands. I analyzed the City of Durham's watershed restoration program by reviewing the Ellerbe Creek Watershed Improvement Plan (City of Durham, 2023) and the Third Fork Creek Watershed Improvement Plan (City of Durham, 2023). Finally, I used information gathered from the interview with Project Supervisor for the City of Charlotte's mitigation banking program along with mitigation feasibility reports (which have since been archived and removed from public accessibility), primarily the Reedy Creek Feasibility Report (City of Charlotte, 2023).

Results

Geospatial Analysis

The geospatial analysis revealed three potential bank sites for the DHA depicted in Figure 1. Sites 1 and 2 are located in the south Durham area and contain portions of the Third Fork Creek. The aquatic resources on both sites are a component of the Haw Watershed. The Third Fork Creek Watershed covers an area of 16.6 miles hosting the second highest population density among Durham's eight HUC 12 watersheds and as a result the stream system experiences elevated levels of pollution and ecosystem degradation. The City of Durham is one of the fastest growing municipalities in North Carolina having experienced a 25% increase in population between 2010 and 2020 (U.S. Census Bureau, 2023). This trend is likely to continue as the city's future land use plan projects almost 20,000 acres of land demand for development purposes by 2045 (City of Durham, 2019). The impacts of this growth have led Third Fork Creek to be placed on the EPA's 303(d) list, a list of waters protected by the Clean Water Act that have exceeded water quality standards. The stream was first designated as impaired in 2005 for exceeding fecal, fecal coliform, mercury in fish tissue, sediment, and turbidity standards (EPA, 2023). The city was required to plan for and implement restoration activities to meet total maximum daily loads, a calculation of the maximum number of pollutants that can be present in a waterbody while still meeting water quality standards (EPA, 2015). Third Fork Creek remains on the 303(d) list as of 2020, however, ongoing efforts by the city including the drafting of a watershed management plan in 2012 and continued restoration projects have slowly begun to improve the stream's water quality (City of Durham, 2023).

Site 1, depicted in Figure 1 is located on the corner of Weaver St. And E Cornwallis Rd in the South Durham area. The parcel is owned by the DHA and contains an existing affordable housing development with several structures. The parcel contains approximately 3,191 ft of Third Fork Creek and 14.24 acres of freshwater forested/shrub wetlands of which 9 acres would be available for restoration. Mapping products produced by the USDA's Web Soil Survey indicated a majority (52.5%) of Site 1 is composed of Chewacla and Wehadkee soils, which are classified by the USDA Natural Resources Conservation Service as hydric. Hydric soils indicate conditions where saturation, flooding, and or ponding occurs frequently during the primary growing season creating anaerobic conditions in the upper parts of the ground (USDA-NRCS, 2023). Anaerobic conditions are one primary criteria in the NCWAM tool used by the USACE Wilmington District to delineate wetlands, adding greater weight to Site 1's wetland area obtained from the National Wetland Inventory (USACE Wilmington District, 2015). The potential bank area is located primarily in the 100-year floodplain with some portions falling into the 500-year.

Figure 1. DHA's real estate portfolio in the City of Durham (NW corner of Figure 1) and identified mitigation bank sites (Site 1 - NE corner, Site 2 - SW corner, and Site 3 - SE corner).
**It is important to note Site 2 is not currently a part of the DHA portfolio but the result of a partnership with NC State and NC Agricultural Foundation*

Site 2 is composed of three parcels located on the western edge of South Bridge Avenue. Two of the parcels composing Site 2 are owned by Durham Technical Community College, a tax supported, public, non-profit educational institution, managed through the NC Community College System. The third parcel comprising the southern section of the site is owned by NC Agricultural Foundation, a corporation that provides support and financial assistance to the College of Agriculture and Life Sciences at North Carolina State University. Durham Tech and the NC Ag. Foundation expressed the possibility of DHA obtaining an easement for mitigation work for little to no cost on this parcel. Two buildings are located on the parcels including Durham Tech's George W. Newton Industrial and Engineering Technologies Center and Durham Tech/Glaxo Wellcome Technology Center. The site contains no wetlands identified by the National Wetland Inventory with soil map products indicating the site is composed of 30% hydric soil surrounding the portion of Third Fork Creek. Site 2 has a longer reach of stream in comparison to site 1 with approximately 5,863 linear feet of the Third Fork Creek. The potential bank area is located primarily in the 100-year floodplain with some portions falling into the 500-year.

Site 3 is located on a multi-parcel DHA development and contains a tributary of Ellerbe Creek. The site's tributary drains directly into the main Ellerbe Creek, located less than half a mile away. From where the tributary enters the main creek, water flows approximately five miles into Falls Lake, a man-made reservoir. The entirety of Ellerbe Creek, from its headwaters to where it drains into Falls Lake has been listed on the 303(d) list since 1998 with an impaired for water contact recreation status due to fecal coliform bacteria levels and other pollutants exceeding water quality standards. Site 3 contains 2,175 linear feet of stream along with a riparian area that separates DHA's development from another privately owned development. Restoration of the Ellerbe Creek tributary, including the area required for a 50ft riparian buffer, would result in the project intersecting three privately owned parcels (Figure 4). Unlike sites 1 and 2 this would require the DHA to obtain conservation easement agreements from affected private landowners. The southern portion of the bank site parcels including a portion of the potential mitigation site is a FEMA designated 100-year floodplain.

Market Analysis

Figure 2 shows the total number of permits issued for impacts to aquatic resources in the Haw and Upper Neuse Watershed service areas, where compensation was required, and mitigation banking credits were used to satisfy the requirement. The Upper Neuse Watershed had a greater amount of these permits every year and aquatic resource type in comparison to the Haw Watershed. Table 1 depicting available credits in 2023 in comparison to a five year (2017-2021) average annual credit demand, shows the Upper Neuse mitigation credit market to be oversaturated with both stream and wetland credits. The Haw also contains more available stream credits than average annual permit demand, however, in 2023 there are currently less available wetland credits. The number of available credits in each watershed would suggest a saturated market where no other work is needed. However, the Project Supervisor for Charlotte's Stream and Wetland Umbrella Mitigation Bank discussed the difficulties of fluctuating demand for stream and wetland credits due constant changes in existing and new development projects.

Figure 2. Permittees required to compensate for impacts using mitigation and in-lieu fee credits between 2017-2021 in the service areas of Site 3 (Upper Neuse Watershed; HUC 03020201) and Sites 1 and 2 (Haw River Watershed; HUC 03030002)

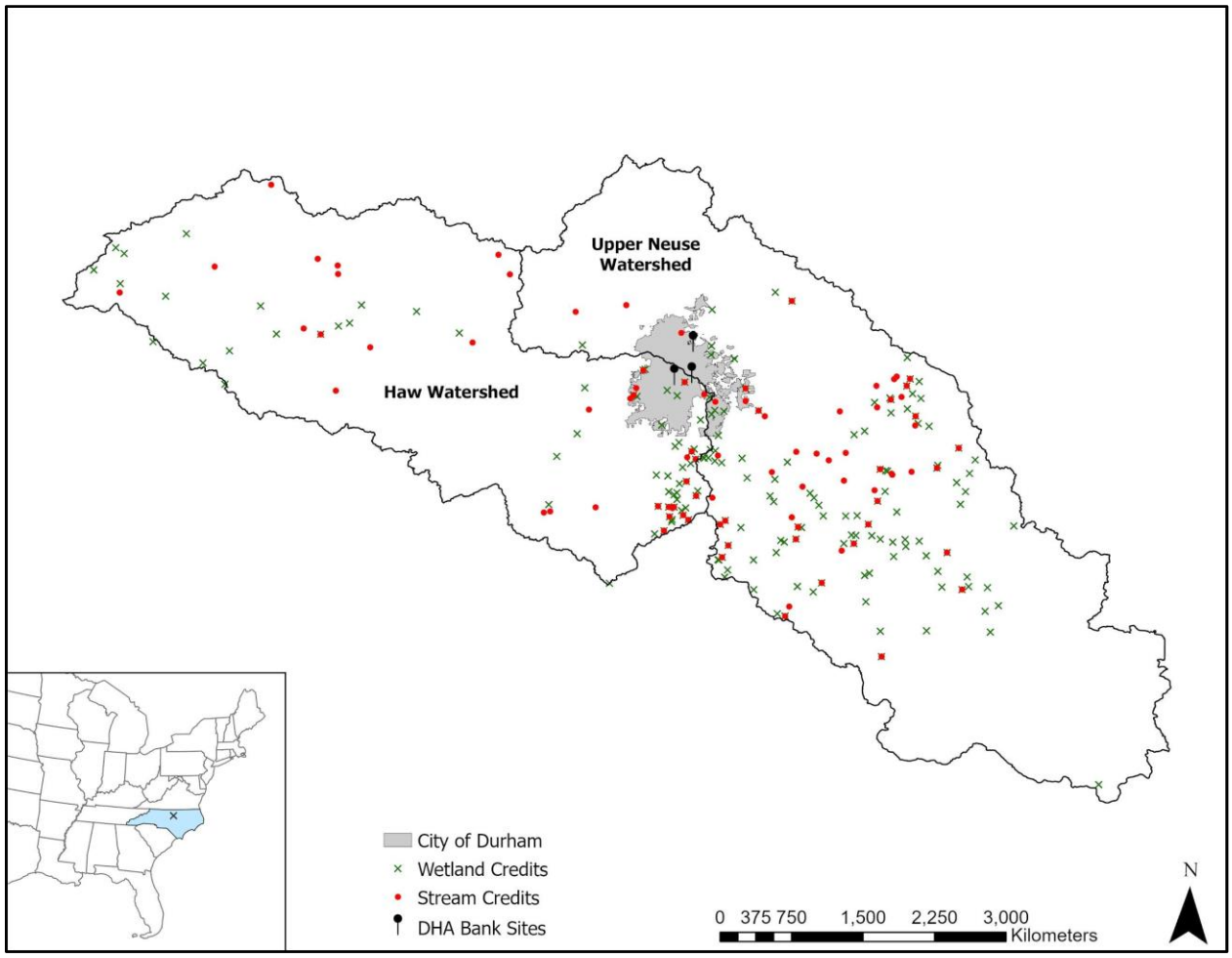

Table 1. Credits purchased by permittees between 2017 and 2021, obtained from USACE's ORM2 database (USACE, 2021), compared to available credits, obtained from USACE's RIBITS database (USACE, 2023).

	Haw Watershed		Upper Neuse Watershed	
Year	Stream	Wetland	Stream	Wetland
2017	3,501	8	3,872	10
2018	2,892	8	8,035	15
2019	1,340	9	19,752	30
2020	13,781	10	2,485	11
2021	278	5	5,668	20
Average Annual Credit Demand (2017-2021)	4,360	8	7,962	17
Available Credits (4/6/23)	30,995	7	90,285	84

Cost-Benefit Scenario Analysis

Through an assessment of four potential scenarios where the credit price and implementation cost of mitigation activities varied, stream restoration consistently returned a positive net revenue to the DHA. The sum of net revenue for all three sites across the four scenarios, excluding when wetland restoration resulted in a net loss, resulted in scenario B having the greatest return of $2,123,765.24. This was not unexpected as Scenario B included the low implementation cost and even split of net revenue generated by the distribution of credits in the In-Lieu Fee Program. Scenario A had the next highest return with $978,277.45. Scenarios C ($78,940.43) and D ($236,821.30) resulted in the lowest sum of net revenue (while still positive and significant). Wetland restoration resulted in an almost constant net revenue loss across the four scenarios with only scenario B, which reduced implementation costs by an approximate 25%, barely breaking even with a net revenue of $3,097. This finding aligns with past research that has found large scale wetland restoration in urban areas to be both expensive and difficult to maintain (Ravit et al., 2017; Alikhani et al., 2021; Canning et al., 2021).

The results of the cost-benefit analysis depict a wide range of possibilities the DHA could experience given the implementation of these banks under varying conditions. Estimating credit

sales prices is a challenging task due to the watershed service area specific markets, rate of credit demand by permittees, the stock of available credits at a point and time, labor, and material costs. These results offer only a cursory image, based on currently available information, of what the DHA or other PHAs would need to consider financially when implementing a bank.

Table 2. Cost-benefit scenarios for Sites 1, 2, and 3 under varying conditions of implementation costs and credit sale prices

**IC represents "Implementation Cost."*

Scenario	Site	Unit Ic	Total IC	Unit Sales Rate	Total Revenue	DHA Revenue Per Credit	Net Revenue
A	1	$472	$1,505,580	$646	$2,061,510	$87	$277,965
	1	$94,179	$828,777	$70,939	$624,265	-$11,620	-$102,256
	2	$472	$2,766,774	$646	$3,788,395	$87	$510,811
	3	$472	$1,026,424	$646	$1,405,427	$87	$189,502
B	1	$268	$856,389	$646	$2,061,510	$189	$602,561
	1	$70,235	$618,070	$70,939	$624,265	$352	$3,097
	2	$268	$1,573,768	$646	$3,788,395	$189	$1,107,314
	3	$268	$583,840	$646	$1,405,427	$189	$410,794
C	1	$472	$1,505,580	$500	$1,595,300	$7	$22,430
	1	$94,179	$828,777	$60,000	$528,000	-$8,545	-$75,194
	2	$472	$2,766,774	$500	$2,931,650	$7	$41,219
	3	$472	$1,026,424	$500	$1,087,590	$7	$15,292
D	1	$472	$1,505,580	$500	$1,595,300	$21	$67,290
	1	$94,179	$828,777	$60,000	$528,000	-$25,634	-$225,583
	2	$472	$2,766,774	$500	$2,931,650	$21	$123,657
	3	$472	$1,026,424	$500	$1,087,590	$21	$45,875

Interviews and Program Analysis: Barriers and Challenges for DHA Involvement

Stream and wetland mitigation banking activities most often occur outside of urban environments where larger, less expensive, and more connected tracts of aquatic resources and land can be found. The responsibility of preservation, conservation, restoration, and enhancement of aquatic resources located in urban settings usually falls onto local, state, and federal government entities along with non-profit organizations due to the higher costs and technical requirements that can carry greater risk to a project's overall success. In order to explore this concept a manual observation of existing bank site locations within the two-study area watershed service areas was conducted using the USACE's RIBITS database and reporting tools where it became clear that a majority of banks are located outside sprawling urban environments.

In an interview with a Charlotte Stream and Wetland Umbrella Mitigation Bank Project Supervisor the difficulty of managing hundreds of conservation easements on bank site locations was highlighted as one of the primary challenges in urban mitigation banking. Since a bank project requires a certain amount of stream length or wetland areas have to be great enough to meet the overall mitigation objectives urban mitigation often requires the organization implementing the project to obtain dozens if not hundreds of conservation easement agreements from local residents and businesses. Acquiring easements from the general public can be a lengthy and sometimes charged process when a majority of landowners agree but a few residents hold out, slowing the project as all required conservation easements must be obtained prior to initial credit releases. Further, managing those easements in perpetuity requires extensive staff time to ensure current and future owners of the land where the easements are held understand where those easements start and stop on the property as well as the associated restrictions that come with them.

During an interview with the Chief Officer for the USACE Wilmington District Mitigation Branch existing site conditions can make implementing mitigation banks in urban areas difficult. Utility lines like sewers and electric are often located in low lying and flood prone areas where land is cheaper to acquire and typically separated from the urban core. Utility infrastructure requires easements be placed on the land for the protection and management of that infrastructure. This can make placing the necessary conservation easements for mitigation banks challenging or at times not possible, resulting in projects needing to design piecemealed restoration that carries less credit generating and ecological uplift potential.

One major advantage that opens several options for DHA is that the organization already owns the land or has the potential to acquire the land at little to no cost. During both interviews it was noted that a major upfront cost that increases the risk of mitigation banking for private mitigation banking firms is the acquisition of land or conservation easements to implement bank activities.

The City of Durham operates a Watershed Restoration group that evaluates HUC 12 watersheds in the municipality and implements projects to improve them (City of Durham, 2023). In 2012, the Watershed Restoration group completed a watershed management plan for Third Fork Creek and identified "keystone properties" and "urban gems" that are high priority parcels for

watershed improvement projects (City of Durham, 2023) (Figure 3). These properties are prioritized by the city for restoration, conservation, and preservation projects to improve the Third Fork Creek watershed. Sites 1 and 2 are both directly adjacent to two or three keystone properties and near at least one urban gem property connected by a similar reach of Third Fork Creek while site 3 is located in a city designated high priority protection area (City of Durham, 2023; Wilbur, 2021).

Discussion

The case study analysis that assessed the feasibility, costs and benefits, implementation factors, and impact on DHAs overall mission, revealed stream and wetland mitigation banking has the potential to make an overall positive contribution to increasing decent and affordable housing options in the City of Durham, NC. Three potential bank sites were identified with one or more aquatic resources located in the DHA owned areas. The aquatic resources were large enough to justify mitigation activities while being found to have direct correlation to ongoing local government planning efforts to protect the watersheds that provide local residents with important ecosystem services. The watershed service areas were found to have an excess of stream mitigation credits available in comparison to average annual credit demand, however, data accuracy and the discussed market dynamics make it difficult to make a definitive conclusion. Under almost all cost-benefit scenarios, mitigation banking on the three sites resulted in positive net revenue that could be used to contribute to affordable housing projects. Mitigation banking was found to align with DHAs overall mission and strategic plan while interviews with both a mitigation provider and regulator identified a key challenge DHA will face if they decide to move forward with implementation as well as a key advantage DHA and other public housing authorities have in implementing banks on their own real estate portfolios.

Impact on DHA's Strategic Mission

Mitigation banking is one strategy the DHA could explore to meet several of these goals and better prepare the organization for a to meet the growing demand for affordable housing in Durham. By implementing mitigation banking the DHA would not only be strengthening their financial stability through diversifying revenue sources but also building a strong asset portfolio by increasing the attractiveness and environmental functionalities of their properties through mitigation activities. Beyond the financial benefits, mitigation banking would provide vulnerable populations housed in their developments with greater access to well maintained and protected ecosystems in an urban environment, which typically sees some of the greatest environmental degradation. Several published studies have found evidence that increasing urban green space leads to increased mental and physical health in residents (USDA 2021; van den Bosch & Ode Sang, 2017). While the purpose of mitigation banking is primarily to improve the quality and functionality of aquatic resources, large body of literature has proven that these practices have the added benefit of mitigation the impacts of urban heat islands, which are caused by impervious surface cover retaining heat at unnatural levels (Saaroni et al., 2018; Madureira & Andresen, 2014; Abdulateef & A. S. Al-Alwan, 2022).

Implementing mitigation banking projects would also foster new and diverse relationships with both private and public sectors as the DHA would need technical and possibly funding support. The DHA, as a quasi-governmental organization, already has a close working relationship with the City of Durham who is already actively working to fulfill the goals set in six watershed improvement plans (City of Durham, 2023). The cities accumulated experience from ongoing watershed improvement activities and connections to both private and public organizations in the field of environmental preservation, conservation, restoration, and enhancement would give the DHA a leg up in beginning to explore mitigation banking as a feasible strategy for meeting their goals.

Data and Result Limitations

The wetland areas estimated in this study used data provided by the NWI can only be considered a preliminary determination as the Inventory collects data using high altitude imagery that can carry large margins of error due to changing land uses, the age of the data, computational and sensor errors, etc. (Gale, 2021). Similarly, soil data obtained from the USGS Web Soil Survey are considered generalized and require onsite testing for confirmation (Sayidov et al., 2020). If the DHA decides to explore mitigation banking on the two proposed sites, professional environmental scientists from either a private or public organization should be used to complete standard testing of the parcel to determine the extent and quality of the onsite aquatic resources.

Data delineating the stream channels identified in this study were obtained from the open channel data set located on the City of Durham Open Data Portal while data identifying wetlands came from the U.S. Fish and Wildlife National Wetland Inventory (NWI). While the City of Durham's open channel data tends to be generally accurate as a result of the city using the dataset for planning and watershed management activities, the data set is not comprehensive. Attributes missing from the dataset include stream width as well as channel classification (i.e., ephemeral, intermittent, perennial), which may have an impact on mitigation bank feasibility in relation to the current definition of "waters of the U.S." (EPA, 2023). As of March 20th, 2023, a revised definition for what is defined as "waters of the U.S." will be implemented by the EPA and Army Corps of Engineers that includes some major changes like the broadening interpretation of what constitutes a tributary and wetland under federal jurisdictional protection by the Clean Water Act (EPA, 2023). These changes include manmade and natural ditches as well as wetlands that demonstrate a significant connection to a "water of the U.S." that meet the relative permanence and significant nexus test where the ditch or wetland are must be "relatively permanent, standing, or continuously flowing waters" or where these aquatic resources have a continuous surface connection that "significantly affect the chemical, physical or biological integrity of navigable waters" (Gimont, 2022 & EPA 2023). While the implementation of these rule changes has yet to occur at the time of this paper, newly classified ditches and wetlands under federal regulatory protection may increase both demand for mitigation banking as well as the total amount of mitigation available to the DHA on identified bank sites.

Partnerships

DHA can leverage their existing relationships with local and state organizations in several ways to both relieve capacity restraints and increase revenue. Partnering with a private (third party) mitigation banking firm with experience in urban environments is one option available to the DHA. The DHA can approach this option in several ways including whether the private firm provides a full delivery including fulfilling permitting and regulatory requirements, feasibility studies, mitigation design, construction, and site monitoring that will require either a higher upfront cost or greater share of the revenue generated by the bank's credits. Another option is to partner with a firm to design and build the project while partnering with either a land trust, local government, or local research institution to conduct the preliminary data collection and required annual monitoring of the site.

The potential bank sites proximity to the cities prioritized watershed improvement areas not only fulfills the USACE mitigation banking watershed approach but presents an opportunity for the DHA to partner with the City of Durham (USACE, 2008). The City of Durham's Stormwater Division has both experience in implementing stream and wetland restoration in the urban environment of Durham as well as regulatory expertise. The City of Durham's ongoing work in the Third Fork Creek and Ellerbe Watersheds presents a partnership opportunity for the DHA to form an umbrella stream and wetland mitigation bank. An umbrella mitigation bank is the regulatory term for several banks managed by one organization (USACE, 2008). Due to DHA's close relationship with the city and the shared goals between the organizations, a partnership between the two may be beneficial. An official or unofficial agreement between the DHA and City of Durham to share the revenue in support of affordable housing would provide both organizations a win in the public eye as the partnership would increase the cities affordable housing stock, funded in part through the restoration and conservation of local aquatic resources that would improve water quality and ecosystem health.

If the DHA decides to pursue mitigation banking in whichever partnership scenario, the credits generated will need to be sold and distributed to projects negatively impacting the protected aquatic resources of that watershed service area. The DHA would have two markets to choose from when selling their credits including working with the DMS to provide credits to the State's In-Lieu Fee Program or selling them on the private market once they have been released by USACE after meeting monitoring and performance requirements. While the scenarios illustrated in Table 1 clearly point towards the ILF program being the most fiscally beneficial option, the DMS does not constantly buy any and all available credits within a watershed. The organization uses a statewide strategic plan for engaging in ecosystem services that incorporates an overall watershed planning approach with specific goals and objectives. DMS's primary objective is to begin the mitigation banking activities in advance of impacts to aquatic resources from future DOT projects. Watershed conditions and associated planning goals and transportation infrastructure projects are prone to constant change. These and other influences contribute to the DMS's request for bid process by which the organization obtains the credits deemed necessary for that service area. DMS may require a large number of stream credits one year and no stream credits but a large quantity of nutrient offset credits for the same service area in the next year.

Selling credits directly to permittees can reduce this risk when a bank is established in a watershed experiencing high rates of development and urban sprawl since these activities inevitably lead to aquatic resource impacts. When assessing whether a bank's credits will have sufficient demand, forming relationships with local development firms for on the ground information as well as extensive research into the area's growth is practice followed by many private banking organizations. As discussed previously, the DHA's relationship with the Durham local government would further assist them since no organization or person has a deeper understanding of ongoing and future development than the local government of that area.

Conclusion

The impacts of urban expansion are accumulated across sectors and so require cross-sector solutions. Finding the best combination of partnerships and markets can be a complex process taking time and effort for any organization looking to work in the ecosystem service markets. However, as discussed throughout this paper the DHA and other public housing authorities like it have several advantages that would ease the financial and technical burdens of these projects making stream and wetland mitigation banking a potentially useful tool in achieving decent and affordable housing for their communities. Public housing authorities' urban real estate portfolio advantage would allow them to conduct mitigation in some of the most environmentally degraded areas at reduced implementation costs making mitigation a more financially feasible option in the urban context. Their unique relationships with local governments and other nonprofits can help PHAs overcome the technical planning and implementation barriers while learning from professionals experienced in aquatic resource preservation, conservation, restoration, and enhancement work in bank sites' area. Future research and projects concerning the intersection of PHAs and the ecosystem service markets is needed to the test the findings of this study. The next step in progressing this study's findings is to working with a PHA to implement mitigation and provide concrete evidence that ongoing public housing and environmental mitigation efforts can be intersected and provide a net benefit to local communities.

The case study analysis I conducted on the DHA provides other PHAs with a framework of fundamental information needed to answer how their involvement in stream and wetland mitigation could impact their missions, what processes can be used to assess the feasibility and cost-benefit structure of implementing mitigation, and the factors that affect the implementation of mitigation projects. The case study serves as an example for other PHAs working for and with residents in areas experiencing urban sprawl and rapid development that impacts their natural environment as well as the affordability of housing in their communities. The advantages PHAs have the analysis results described in this paper indicate mitigation banking may be useful in addressing both.

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Supplementary Material

Case Study: The City of Charlotte's Umbrella Stream and Wetland Mitigation Bank

In order to gain a better understanding of how stream and wetland mitigation is implemented in an urban setting, an interview with two members of the City of Charlotte's Department of Storm Water Services that manage the city's Umbrella Stream and Wetland Mitigation Bank. The following case study will review the background, implementation process, timeline, funding, outcomes, and challenges of Charlotte's Umbrella Stream and Wetland Mitigation bank.

Background

The City of Charlotte's Stream and Wetland Mitigation Bank was formally established by CMSWS in 2004 to offset the impacts of municipal projects like roads, schools, and water lines to local aquatic resources. CMSWS is responsible for the year-round management of stormwater runoff, protection of water quality and reduction of overall flood risk as the primary stormwater utility for both the municipality of Charlotte and Mecklenburg County.

The City of Charlotte's Stream and Wetland Mitigation Bank was formed in response to a high demand for municipal projects needing to meet Section 404 compensation requirements. Initially, Charlotte-Mecklenburg Stormwater Services began implementing stream restoration in conjunction with their stormwater infrastructure projects to offset their own impacts. Overtime, the Stormwater Services Department recognized the need to implement stream and wetland mitigation projects in advance of impacts to allow the stream and wetland mitigation to mature, ensuring no-net loss. In 2004, the Stream and Wetland Mitigation Bank was formalized by the U.S. Army Corps of Engineers and remains one of the only and largest municipally operated banks in North Carolina.

Implementation

CMSWS implements stream and wetland mitigation banks through two phases including the initial site identification, design, permitting and construction phase as well as a monitoring phase. Project managers identify feasible bank sites by using a ranking protocol that was created in 2008 with assistance from a private consulting firm and the Mecklenburg County Land Use and Environmental Services Agency. The ranking protocol considers a diverse set of factors including:

- **GIS mapping:** topography, storm drainage, aerials, FEMA zones, water quality buffers, parcel data, soils mapping and national wetland inventory.
- **Ordinances and guidelines:** Charlotte post construction control ordinance, USACE-Wilmington District stream mitigation guidelines and CMSWS mitigation monitoring guidelines
- **Environmental Data Resources report (EDR)**
- **Qualitative and quantitative field data**: geomorphic survey and stability; geotechnical and soils; constraints analysis; jurisdictional determinations; biological and physicochemical

In 2021-22, CMSWS began the process of updating their protocol to incorporate lessons learned from 15 years of using the existing framework. Watershed Planning & Project Implementation Supervisor for CMSWS, Erin Shanaberger, shared that the new ranking protocol will be more flexible in its application, allowing for project managers to change certain aspects depending on CMSWS's current goals. The new protocol will also adopt some aspects of Mecklenburg County Land Use and Environmental Services' existing mitigation ranking protocol to better coordinate projects between the two organizations.

Once a potential site has been identified, project managers work with a private consulting firm to do a more detailed field reconnaissance. Erin Shanaberger expressed that CMSWS tries to work with the same consulting firm through all project steps including feasibility, design, construction, and monitoring to maintain consistency. The consulting firm uses the detailed field and ranking protocol data to draft a full feasibility report that is used to inform the design of the mitigation site. An engineering focused group within CMSWS acts as the primary project manager for the design phase, working closely with the consulting firm to form and execute mitigation plans.

During the design phase, project managers identify and approach residents or in the case of public land, the relevant local government agency, that own land on the potential site to purchase conservation easements. CMSWS manages these easements in perpetuity, working with adjacent landowners to ensure land use restrictions are properly followed. Project managers submit documentation of the easements along with the site-specific feasibility and design plans to an interagency review team that is chaired by USACE-Wilmington District and composed of representatives from the NC Department of Environmental Quality Division of Water Resources, NC Wildlife Resources Commission, and other related state and federal agencies. The interagency review team reviews the submitted plans and provides feedback to CMSWS before deciding whether to approve the mitigation bank. After the plans are approved, project managers solicit bids for the construction of the project and work with their internal engineering group and private consulting firm to oversee the construction process.

CMSWS receives mitigation credits for completed projects based on a credit release schedule created by the interagency review team. The credit release schedule is based on whether performance standards are met during a required seven-year period of annual monitoring that assesses the state of vegetation and ground water at bank sites. Credit release schedules vary based on whether the project addresses forested wetlands, non-forested wetlands, or streams. The purpose of required monitoring is to ensure completed bank sites maintain their integrity in the long term to achieve the overall goal of no-net loss to aquatic resources. The private consulting firm, which works with CMSWS throughout the mitigation banking process, is responsible for the annual monitoring activities.

Timeline

Mitigation banking projects have two primary phases including the initial site identification, design, and construction phase as well as a monitoring phase. Erin Shanaberger expressed that project timelines can vary based on the size of a project and unforeseen challenges; however, Shanaberger estimated the typical length of these phases be…

Phase One (4+ years)

- 3-6 Months: field recon and feasibility studies
- 18 Months: planning and design
- 3 Months: solicit bids for project construction.
- 12-18 Months: construction

Phase Two (7+ years)

- Required annual monitoring, management, and credit release.

A detailed description of annual monitoring and management activities as well as the corresponding credit releases can be found on pages 28-31 of the USACE Wilmington District Stream and Wetland Compensatory Mitigation Update.

Equity and Justice

While equity and justice are not explicitly addressed through Charlotte's Umbrella Stream and Wetland Mitigation Bank, the benefits to water quality and ecosystem services within the municipality are spread among all residents. Projects seeking to implement mitigation banks in an urban setting should include meaningful stakeholder engagement with local communities and familiarize themselves with existing research concerning how equity can be integrated into planning of mitigation and the impact to urban populations. Resources on land use planning, social equity, and ethics in mitigation banking and similar environmental offset markets can be found in the additional resource section of this case study.

Funding

Charlotte-Mecklenburg Stormwater Services receives no financial support from municipal tax revenue but instead funds their work entirely from the city's Stormwater Utility Fee. The original vision for Charlotte's Stream and Wetland Mitigation Bank was for it to be self-funding where revenue from the sale of credits generated from one mitigation project would be used to fund the next project. However, Charlotte-Mecklenburg Stormwater Services began prioritizing larger mitigation projects that required additional funding upfront. Supplemental funding from the Department's Stormwater Utility Fee is now used when the sale of mitigation credits does not cover existing needs. Project managers shared that estimating a mitigation bank's cost is highly variable based on several factors including site location, composition, construction material, etc.

Outcomes

Charlotte's Stream and Wetland Mitigation Bank, between 2001 and 2020, improved 24 miles of streams, improved, or preserved 34 acres of wetlands and holds approximately 400 acres in conservation easements. CMSWS is unique in the North Carolina mitigation banking market as a department of the City of Charlotte's local government. Unlike other third-party mitigation banking providers who can choose to sell their credits in the free market, CMSWS only sells credits to other local and county government organizations who require credits to offset the impacts of their development projects. The Charlotte Douglas International Airport is one major

consumer of CMSWS's mitigation credits as the construction of new runways and facilities can have unavoidable impacts to surrounding aquatic resources.

Lessons Learned

Mitigation credits can only be purchased to meet compensation requirements in the same watershed where the impacts to aquatic resources occurred. The City of Charlotte is located in three different watersheds including the Upper and Lower Catawba and Rocky-Yadkin basins. During the initial years of Charlotte's Stream and Wetland Mitigation Bank, CMSWS had difficulties in determining the future demand for credits in each watershed that lead to periods where one watershed may have had an excess of credits while another may have had none. In order to solve this problem CMSWS applied for and received a special authorization from USACE-Wilmington District that now allows them to sell credits amongst the three watersheds. Erin Shanaberger stated securing and managing conservation easements for bank sites is one of CMSWS's major challenges in implementing mitigation banks. Due to the dense populations associated with urban and suburban areas, projects can sometimes involve large numbers of property owners. It can be challenging to keep up with current owners as property is constantly sold and new owners may not know of or understand the conservation easement on the property. Some property owners may not agree to an easement leading to a fragmented site that results in decreased restoration value.

The urban and suburban environment of Charlotte causes further challenges for the design of mitigation sites. Impervious surfaces like concrete and asphalt prevent stormwater from infiltrating into the ground leading to runoff entering surrounding water systems at more extreme volumes and speeds. A project manager shared that they have begun to better understand how to design mitigation practices in an urban environment through trial and error as some projects and project components that were not properly designed to handle these periods of above average stormwater runoff degraded or failed.

Appendix

Figure 3. City of Durham's Third Fork Creek Watershed Improvement Plan (City of Durham, 2023)

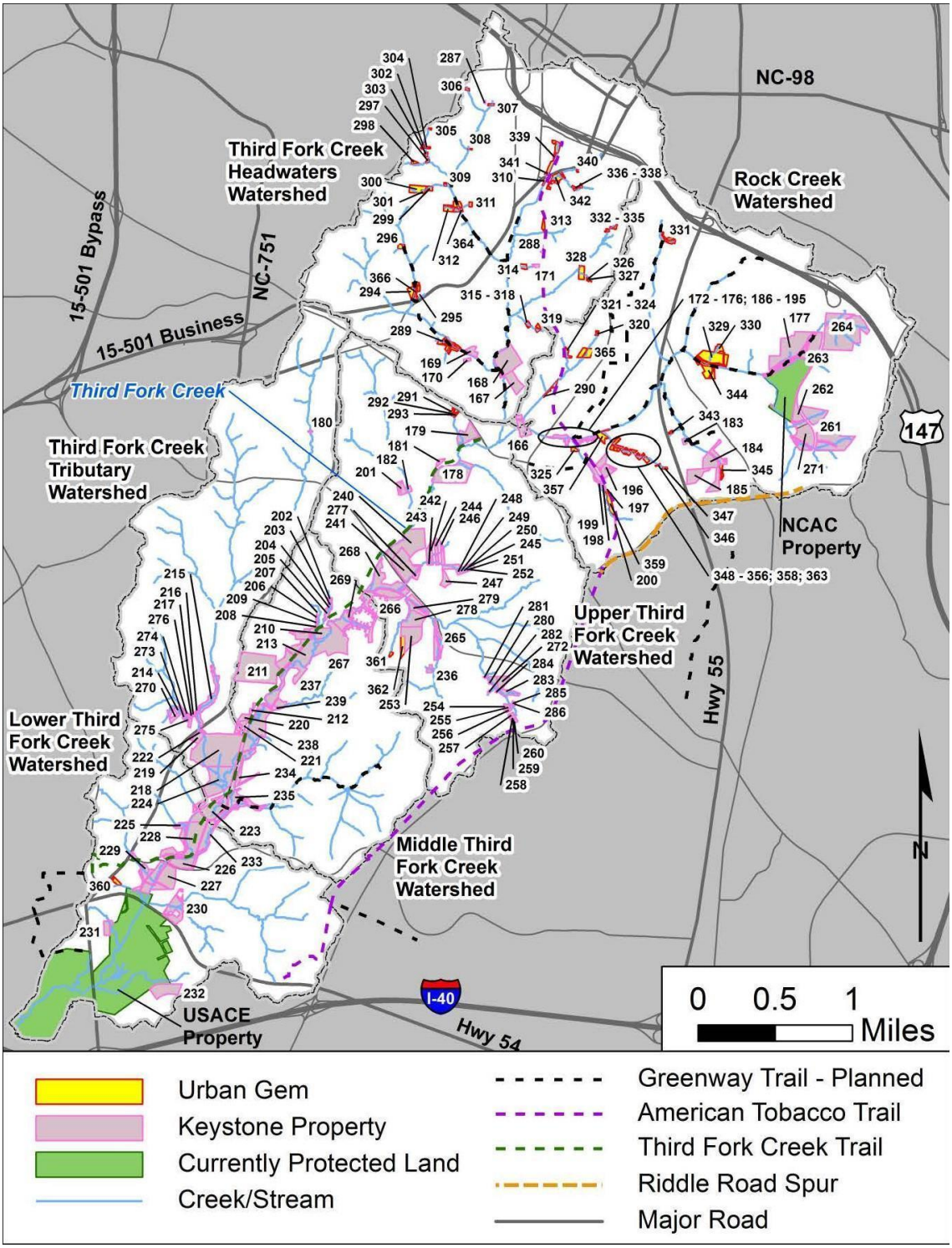

Figure 4. City of Durham's Ellerbe Creek Critical Area Protection Plan (City of Durham, 2023)

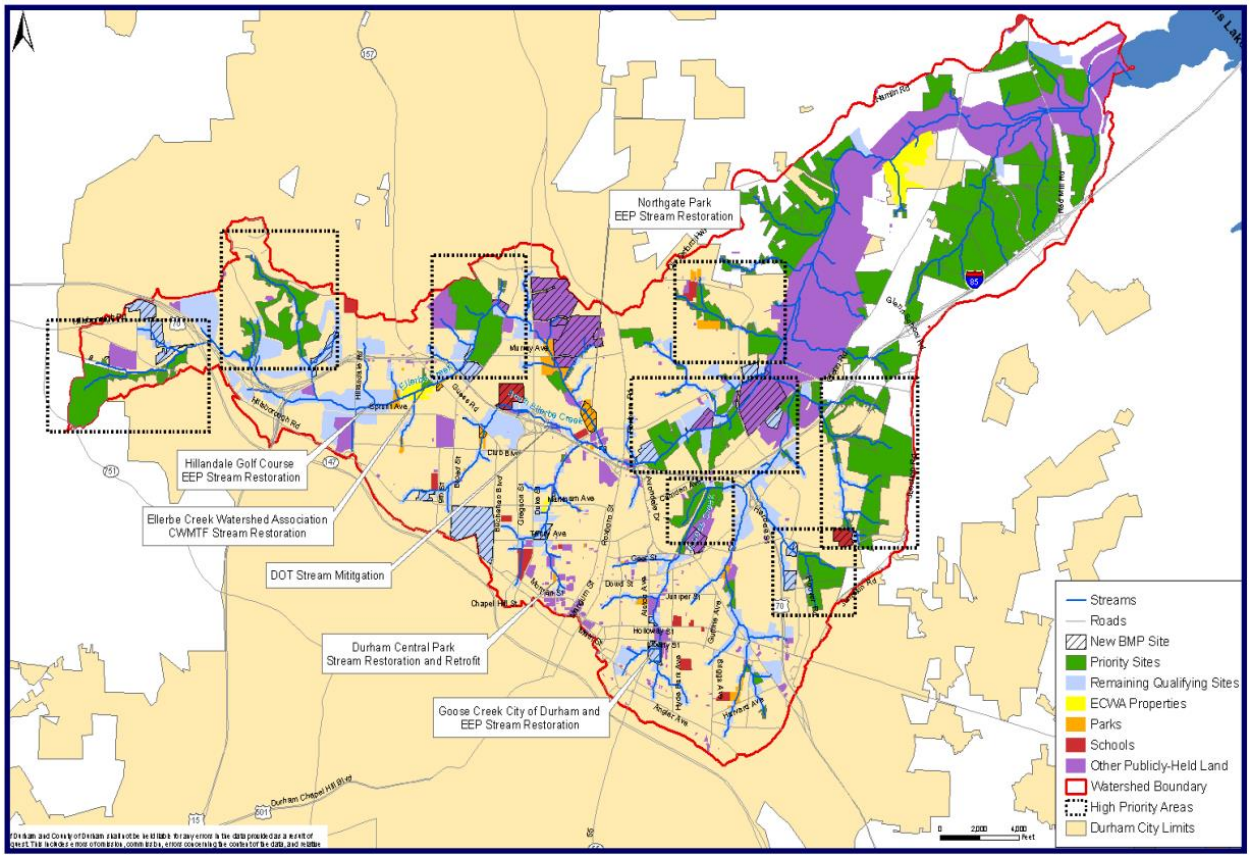

Figure 5. The timeline for bank and ILF program approval (Kihslinger et al., 2020)