Future Flood Mitigation in Charlotte-Mecklenburg

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Abstract

This case study examines the successes of flood mitigation planning in Charlotte-Mecklenburg, beginning with their locally created future conditions flood risk maps, and followed by complementary risk reduction strategies informed by these maps. Charlotte-Mecklenburg's future conditions maps, known locally as Community Maps, were created in 2000, because after repeated flood losses in the region, residents and local officials realized the need for better data to help "stop the bleeding." This thesis takes a critical look at existing national level flood mitigation mapping and regulations, and compares them with Charlotte-Mecklenburg's local strategies. It also looks at what ingredients have allowed Charlotte-Mecklenburg Storm Water Services to achieve this success and where there is still room for improvement. Finally, this paper offers lessons and recommendations for national policy as well as other local communities to help improve flood management across different levels of government.

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1.0 Introduction

1.1 United States History of Flood Management

Globally, and in the United States, floods are one of the costliest natural disasters in terms of lives lost, property damaged, and people affected (Stromberg, 2007). In the United States, federal involvement and spending on flood management has been steadily increasing since 1879, after several major floods occurred in close succession in the lower Mississippi Valley (Wright, 2000). Flood management paradigms have evolved in recent years in the United States, with much contention, and still, flood-related costs continue to rise for all levels of government. Since its conception, flood control efforts, primarily managed by the US Army Corp of Engineers (USACE), have invested heavily in engineered solutions, such as levees and dams, to physically move flood waters and control rivers. Only as recently as 2012 did the USACE make an explicit statement that, "the current trajectory of funding water resources projects is not sustainable" (Berginnis, 2019, p. 3), referring to the need for complementary non-structural projects in increasing flood resilience.

In spite of widespread reluctance in the mid-1800s to nationalize flood management, even as state and local governments became increasingly overwhelmed with rising flood costs, Congress finally passed the first Flood Control Act of 1917. This explicitly dedicated funds for flood control, primarily in the form of constructing a levee system. This "levee-only" approach was modified after it failed to protect over 246 lives and major damages during the Great Flood of 1927 (Wright, 2000). The Flood Control Act of 1936 was intended to increase coordination between the Department of Agriculture, which would be responsible for reducing stormwater runoff to reduce flood risk, and USACE, which would be responsible for engineered solutions downstream. This was unsuccessful due to an undefined plan of action to coordinate the two agencies. Following this, the main approach to flood control continued to rely on built and engineered projects. Even as new tools and approaches have been added to the arsenal of flood mitigation strategies, an over reliance on engineered solutions continues to date. However, as early as 1938, the idea of preventing further encroachment in floodplains had been suggested (Wright, 2000). Engineers involved with the Tennessee Valley Authority floodplain management were among the first in the country to start estimating potential storm magnitudes and analyzing the hazards facing flood prone areas. This type of maximum and expected potential flood hazard analysis was intended to guide local land use planning, and by the 1960s, regulating floodplain development became an accepted flood mitigation strategy across the United States. Still, as costs associated with floods continued to increase with more development, two other major changes in flood control efforts included in the introduction of federal construction regulations to allow buildings to better withstand flood damages, and the creation of the National Flood Insurance Program (NFIP) in 1968 (Wright, 2000).

Costs continued to overwhelm municipalities in flood prone areas, and in an effort to relieve the pressure on disaster relief funding, the NFIP was created (NRC, 2015). The Federal Insurance Administration (FIA) was formed along with the NFIP and they adopted several of the floodplain mapping standards that are still widely used today (Wright, 2000). Until the establishment of NFIP, only a relatively small number of metropolitan areas had undertaken or requested floodplain maps for regulatory measures. National floodplain mapping at large scale really began with the NFIP, and national flood hazard maps are known as Flood Insurance Rate Maps (FIRM). Since the beginning, the FIA was overwhelmed with the demands of national flood mapping. The first maps were oversimplified with floodplain boundaries that conveniently followed prominent map features, such as roads, or simply created boxes to show floodplain boundaries. Flood Disaster Protection Act of 1973 mandated flood insurance for given circumstances, and suddenly maps needed to be much more accurate.

In order for communities to participate in the NFIP, they had to adopt basic land use regulations and take some responsibility of reducing local flood risk. This served to increase the number of communities with formalized land use regulations (Wright, 2000), and laid the groundwork for floodplain regulations to become a common tool for flood mitigation.

In 1978, the Federal Emergency Management Agency (FEMA) was established and the NFIP program became a part of FEMA (NRC, 2015). Also in 1978, $35 million was authorized across 100 NFIP-participating communities to purchase over 1,000 properties that had been repetitively damaged (Wright, 2000). This became the first example of property acquisition by a federal agency in service of flood cost mitigation. By the 1980s, FEMA had converted flood hazard maps to a digital format for quicker updating as development was constantly changing flood conditions.

It is in this context of national flood management, history of inter-agency collaboration challenges, evolving flood mitigation tools, and an overburdened flood mapping program used primarily for setting insurance rates, that Charlotte-Mecklenburg developed local flood risk maps and several complementary strategies toward local flood mitigation.

1.2 Current State of Flood Management in the US

85% of the Presidential Disaster Declarations in the last 50 years have been for flood events (Cigler, 2017). While the national government spends a significant amount of money on extreme weather events, 90% of that spending is on response and recovery after an event, rather than preventative measures to minimize damages before the event (Cigler, 2017). FIRMs continue to pose major issues for planners as they lead to uninformed floodplain regulations, haphazard property acquisitions, and worse, overlooking other flood mitigation strategies altogether.

Pralle (2018) discusses how FEMA's flood maps are so intertwined with flood insurance costs that they often overlook the more important discussion of risk mitigation. FEMA's flood hazard maps are primarily used to set flood insurance rates by geographic area and any changes to these maps significantly affects insurance premiums for people added or removed from the Special Flood Hazard Areas (SFHAs). While these maps are also used locally by jurisdictions to inform flood regulations, their powerful influence on insurance costs is what ends up driving discussions around mapping. Insurance costs are already unaffordable for many people, but Pralle points to further issues with the process of mapping that lead to greater inequity. FIRMs may be challenged by property owners or local governments if an engineer can show enough evidence that the FEMA designation for a property is incorrect. Wealthier owners and developers, with greater resources, are often able to show maps to this effect and successfully waive their flood insurance requirements. Low-income residents do not have the resources to challenge these maps and end up having to pay higher premiums. This unfair burden on lower-income residents leads to an upward wealth redistribution. According to Pralle (2018), politics can also drive greater subsidies for powerful developers.

Additionally, when conversations around flood hazard get caught up in insurance costs, it is difficult for jurisdictions to use these maps for more productive risk reduction policies and programs, that may even lead to more equitable long-term solutions. Pralle cites criticism of the NFIP for inadvertently encouraging people to remain in harm's way by sending a "distorted market signal that underestimates the true cost of living in a flood-prone area" (Pralle, 2018, 230). More holistic regulations and policies based on accurate flood hazard and risk maps can serve to reduce long term risk by removing structures in the floodplain or building them to higher resilience standards.

Lastly, Pralle criticizes FIRMs for their inadequate representation even of current flood hazard, let alone future flood risk. She reiterates how FEMA maps are often very out of date, based on historic data rather than future modeling, and follow development rather than precede it (Pralle, 2018, p. 231). FEMA prioritizes mapping areas that are more developed, leaving greenfields and underdeveloped areas unmapped. It follows then that unregulated development continues to occur in unmapped areas, increasing the flood risk over time.

As the risks of flood damage continue to increase with climate change and urban development patterns, one of the most effective solutions to reducing flood risk is property acquisition (Mach et. al, 2019). Also known as voluntary buyouts in the United States, when the government purchases a home, demolishes it, and restricts any future development on that property, they effectively remove any risk of flood damages on that property. In 1993, the FEMA officially began funding property acquisition through the Hazard Mitigation Grant Program (HMGP) (ELI and UNC, 2017). The idea behind home buyouts is simple: by purchasing a property in a flood-prone area and converting that land to natural uses with no built structures, the inhabitants of a high-risk area are moved out of that area. However, in order to effectively move people out of high-risk areas, the municipality has to be able to accurately identify such areas, and this is difficult to do with incomplete or outdated data, which is often all that is available to most communities. Additionally, the notable weakness of federal buyout funding is that it is only available after a disaster. There is little to no funding available from federal sources for preventative measures. Lastly, most of these funding sources require restoring the damage to its pre-disaster state. This is problematic because its pre-disaster state will inevitably be damaged the same way by the next flood.

For good reasons, buyouts have been controversial, unpopular, and problematic in most jurisdictions. Buyouts are unpopular among local officials for fear of reduced tax base (Flavelle, 2018); unpopular among moving residents because of the long and complicated process, and long-term social and economic impacts; unpopular among remaining residents because of the perceived reduction in safety with potentially abandoned adjacent land (Harvey, 2017); controversial in terms of how truly *voluntary* they are (De Vries, 2012); and lastly, problematic because their voluntary nature causes a “checkerboard” effect of non-contiguous land, which is far less useful for future flood mitigation.

Managed retreats are a more strategic way of conducting buyouts. Programs such as LA SAFE and New Jersey’s Blue Acres programs use data and a higher level of detailed information than that provided by FIRMs to acquire high-risk, contiguous areas of land. The benefits of buyouts done well include safer families, reduction of repetitive loss, and benefit to adjacent properties from the new public amenity and added flood protection.

Harvey’s (2017) thesis for the Department of Urban Studies and Planning at MIT compares two buyout programs in NYC and New Jersey. It explains the importance of buyouts as a flood mitigation strategy in the US: buying out and demolishing homes from floodplains can serve as a relief to the family living there as well as reduce future costs to the state of repairing a flood prone property. Buyouts funded by national dollars are required to be voluntary. However, this often leads to partial buyouts and the checkerboard effect, which has negative results on remaining scattered residents and on the ability to effectively use vacant land for further flood mitigation. The New Jersey Blue Acres program prioritizes buyouts in clusters of homes to acquire contiguous land, whereas the New York Rising program simply maximized the number of buyouts regardless of their spatial relationships. Using risk maps allows a community to proactively identify higher-risk and higher priority buyout areas. Even if it is still voluntary, the community is informed and ready to respond to buyout requests in high priority areas more efficiently.

1.3 Charlotte-Mecklenburg's Flood Management Context

Geography

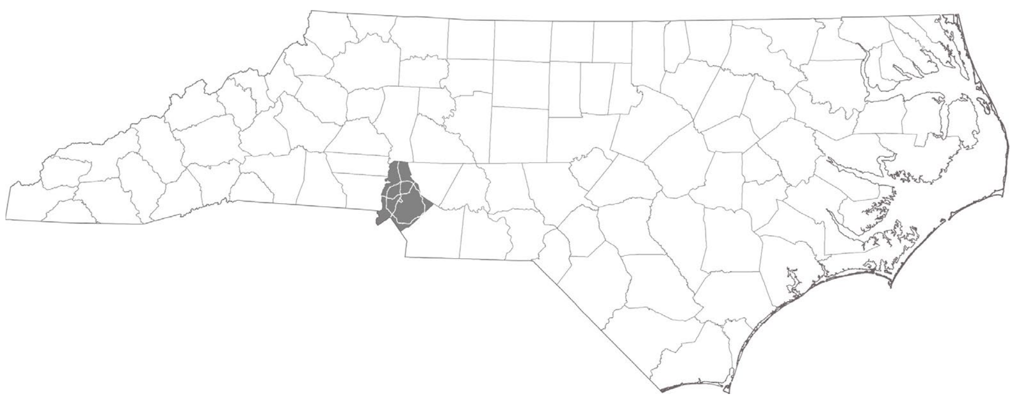


Figure 1: Mecklenburg, North Carolina

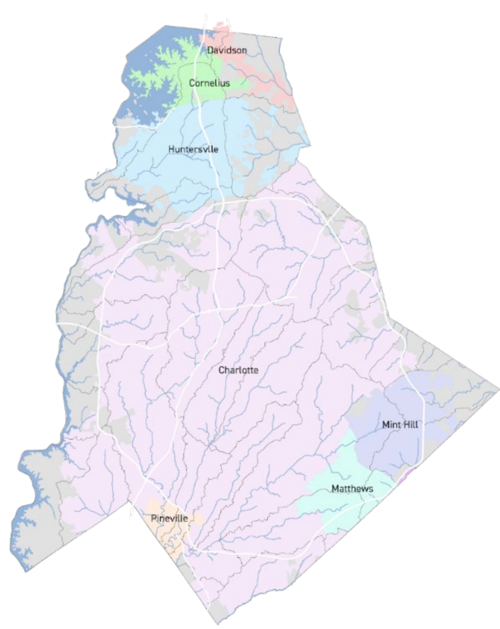


Figure 2: Mecklenburg County Municipalities, overlaid with channels and watersheds (Mecklenburg County GIS).

Every flood underscores the need for better data, and the inadequacy of FEMA's floodplain maps as a tool for flood regulations and policies. The increasing frequency of flood events due to climate change makes the question of how local governments respond, adapt, and mitigate flood risk ever more critical. While the majority of costs associated with floods are incurred by the national government, state and local governments have far greater influence and ability to mitigate those costs.

Mecklenburg County and the City of Charlotte, North Carolina, have been no exception to this increasing vulnerability to floods, and their hilly landscape has seen many riverine floods that have caused significant disturbance to lives as well as major economic loss. Though Mecklenburg County is far inland from the east coast and not overly susceptible to sea level rise, its hilly landscape does experience significant fluvial (overflowing river banks) and pluvial (flash floods from inadequate drainage) flooding, as well as channel erosion and degradation (CMSWS, 1997, p. 2-2). The natural landscape of the County is mostly gentle hills, not mountainous and not flat. The western two thirds of the County drain into Catawba River Basin, while the eastern one third drains to Yadkin/Pee Dee.

Most of Mecklenburg County's land area is also the City of Charlotte. The rest of the County is divided into the smaller towns of Cornelius, Davidson, Huntersville, Matthews, Mint Hill, Pineville, and unincorporated areas. As such, most flood regulations are managed between the City of Charlotte and Mecklenburg County.

Stormwater Planning

Since the late 1990s, the Charlotte-Mecklenburg region has succeeded in creating major improvements to its flood management and planning. The success of this region can be defined in terms of lives saved, economic losses avoided, and environmental benefits. For example, Tropical Storm Danny, a storm that dropped 8 to 12 inches of rainfall in Charlotte (Pasch, 1997), caused three deaths in 1997 (AECOM, 2015). On the other hand, Tropical Storm Fay in 2008 poured over 11 inches (AECOM, 2015. p7) but had no reported deaths. Hurricane Florence in 2018, a Tropical Depression when it passed over Charlotte, also met with no deaths or major injuries in Charlotte or Mecklenburg, according to the Charlotte Observer (Portillo, 2018). Charlotte-Mecklenburg's in-house Losses Avoided Tool, discussed in section 2.3 of this thesis, calculates nearly $30 million dollars in losses avoided so far, thanks to flood mitigated structures between 1997 and 2013 (Scanlon, 2021b). Over 700 families have been relocated out of floodplains thanks to their local buyout program. Finally, environmental benefits are plentiful as Charlotte-Mecklenburg has been in the process of a major stream restoration project for the 3,000 miles of streams across the county. Stream restoration improves water quality, slows down water flowing to the channel, often increases the capacity of a channel, and reintroduces natural landscapes along rivers. This project not only increases flood resilience, but is a major benefit to the environment and public health.

There is no single silver bullet solution to mitigating flood impacts. Like most complex problems, this one needs a complex solution too. The two initial steps that set Charlotte-Mecklenburg up to address flooding more holistically were consolidating all stormwater management under one entity, the Charlotte-Mecklenburg Storm Water Services (CMSWS), and implementing a stormwater utility fee (SUF) across the region between 1993 and 1994. Consolidating all of their stormwater management allowed CMSWS to plan across jurisdictional boundaries, at the watershed level. Flood mitigation planning is most effective at the watershed level, rather than within municipal boundaries, especially when cities are as small as the majority of those in Mecklenburg County. Uncoordinated, and sometimes even contradictory planning efforts can leave cities unable to manage floods. Since most of the streams that run through the county also originate in the county, this consolidation allowed CMSWS to manage streams right from their very source. Further, CMSWS as a single stormwater management entity, was able to implement flood mitigation programs more holistically, such as complementing future conditions flood risk mapping with regulations and buyouts and implementing gauges for a notification system that also collects data for mapping.

Complementarily, the generation of sustainable local revenue source through the SUF meant the region was less beholden to restrictions placed on federal disaster recovery funding. The SUF is paid by residential and non-residential property owners, based on the percentage of impervious land on their property. It took almost two years of stakeholder discussions and public meetings before the SUF was approved and implemented, but it now provides nearly $100 million in revenue per year (Canaan and Scanlon, 2021). This allows CMSWS to fund floodplain mapping updates, buyouts, and all other stormwater related programs, without any restrictions from the federal government.

Following two very close flood events, 1995's Tropical Storm Jerry and 1997' Hurricane Danny, Charlotte-Mecklenburg decided they needed to "stop the bleeding," (Canaan, 2020a) which meant, instead of trying to control stormwater, removing people from the path of floodwaters and preventing people from living in high risk areas in the future. While the 1995 and 1997 floods caused an estimated $20 million and $60 million in losses (Canaan, 2013), respectively, the storms were not declared presidential disasters and Mecklenburg County and the City of Charlotte did not qualify for much federal aid because the storm damages were not deemed widespread enough (Canaan, 2021). This put the entire burden of recovery on local funding sources, becoming the impetus to create more resilient funding sources and flood mitigation programs in the region.

In 2000, Charlotte-Mecklenburg was one of the first geographies in the United States to develop future conditions risk maps (Sellers, 2020). Referred to locally as Community Maps, they use planned *future* development to predict *future* flood risk. This is in contrast with FEMA's flood hazard maps, known as FIRMs, which use current development to create current floodplain boundaries. FEMA maps can become outdated even by the time they are released, as new developments can be constructed during the time it takes FEMA to release new maps. Additionally, Charlotte-Mecklenburg's Community Maps use more advanced technology to survey topography and include a flood depth layer, as will be discussed in section 2.2 of this thesis. While Charlotte-Mecklenburg still subscribe to FIRMs in order to set flood insurance rates, local planning and regulation is now based on their own Community Maps. This thesis will explore how these maps have improved flood mitigation planning in Charlotte-Mecklenburg.

CMSWS Structure

Within Mecklenburg County, the cities are responsible for managing the smaller, man-made streams that drain less than 1 square mile of land, while the county is responsible for everything that drains more than 1 square mile as well as the named streams: Little Sugar Creek, Briar Creek, and McDowell Creek (CMSWS, n.d.(b)).

CMSWS was created in 1993 and has since consolidated all stormwater related projects and regulation in the County (CMSWS, n.d.(b)). This includes:

- Surface Water Improvement and Management Initiative (SWIM)
- Flood Information and Notification System (FINS) and the rain gauge network
- Naturalization of channels
- Flood Preparedness and Safety
- Floodplains and Maps
- Floodplain Development
- Drainage and Maintenance
- Buyout Program
- RetroFIT Floodproofing Grant

The Community Floodplain Maps were first launched in 2000, and in 2010 they set about a new project to create 3D maps (CMSWS, n.d.(c)). These maps serve several purposes (Canaan, 2020a):

1. New Development: not only does it keep new development from happening in flood prone areas, it also allows them to set appropriate regulations around new construction.

2. Buyout planning: they have created plans for community buyouts which allows them to proactively reach out to high risk communities about buyout options and not leave a checkerboard effect.
3. Information and transparency: each address is given a flood risk assessment that is freely available for anyone to see. A more detailed assessment is available on request.

1.4 Research and Methodology

Charlotte-Mecklenburg has been credited with forward-leaning policies and programs around flood management (Sellars, 2020) and officials from Charlotte-Mecklenburg have been invited to share the ingredients of their success with flood risk management around the nation on topics such as buyouts and local flood risk maps. They are doing something right.

In this thesis, I explore the relationship between the local flood risk mapping that CMSWS initiated 20 years ago and flood mitigation planning, such as floodplain regulations and home buyouts, to understand how Community Maps have been leveraged to prevent human, economic, and environmental costs. Additionally, I dig into what motivated and what ingredients allowed Charlotte-Mecklenburg to create future conditions floodplain maps, work that may seem redundant with FEMA's floodplain mapping, while other jurisdictions have been unable, or chosen, not to. This research will expectedly allow other municipalities to learn from some best practices adopted by Charlotte-Mecklenburg; contribute to the larger discussions in academia around flood risk management at the local government level; and will also be legible to the general public, allowing them to be better informed in advocating for flood mitigation projects in their regions.

I find that a public will, combined with effective local governance, communication and engagement of multiple stakeholders, and a local source of revenue, produced flood maps and data that better reflect local conditions and predict future flood risk. These maps, in turn, inform better flood mitigation strategies, such as local flood regulations, buyout, and retrofit programs, as well as create more transparency for residents and other stakeholders.

Methodology

The main methods of my research include interviews, GIS data analysis, comparing FEMA's and Mecklenburg County's floodplain regulations, and first-hand interaction with online tools and services available through Charlotte-Mecklenburg Storm Water Services and the City of Charlotte website.

Interviews with Charlotte-Mecklenburg Storm Water Services (CMSWS) staff. I interviewed several staff members multiple times to understand the events leading to the creation of Community Maps and their impact on broader flood mitigation planning in the region. CMSWS includes both City of Charlotte and Mecklenburg County staff that work closely together. Dave Canaan is the Director for the county while Kruti Desai is the Program Manager for the City of Charlotte. Each of the flooding programs has a point of contact listed with an email address on the CMSWS website, allowing inquiries to be personal and direct. Further, two GIS specialists who work for the CMSWS are also listed with email addresses on their website. I conducted semi-structured interviews with the county Director, a GIS specialist, and two Project Managers listed under the floodplain development and the buyout program. The questions and notes from these interviews are included in the Appendices.

- Dave Canaan, the County Storm Water Services Director, was the main interviewee to provide information on what events led to the maps. I spoke with him over Zoom four times and exchanged several emails. Canaan has worked at CMSWS for over 27 years and led a lot of the discussions around new floodplain maps. He also shared simplified excel sheets to show the costs of mapping. Unfortunately, notes and other documents from stakeholder and public meetings in 1999 only exist in printed format and are located in the physical county offices, which are closed due to COVID-19. This meant that I was unable to gain access to any such documentation and relied on the interviews for information about public engagement.
- James Scanlon, the GIS Analyst at CMSWS, was the second interviewee, whom I also interviewed over Zoom three times. He generously shared multiple unpublished datasets and provided unpublished results of the Losses Avoided Tool analysis for this thesis.
- David Goode, a Project Manager at CMSWS, spoke with me over Zoom about the City of Charlotte's floodplain regulations and their relationship with the Community Maps.
- David Love, also a Project Manager at CMSWS, in a Zoom interview, provided me with information on the Buyout and RetroFIT programs and how they leverage the Community Maps for prioritization and implementing the appropriate mitigation projects.

GIS data analysis. I used GIS data available online and provided by James Scanlon, to understand the differences in mapping input variables and outputs between FEMA floodplain maps and Charlotte-Mecklenburg's Community Maps. Datasets include:

- 1999 FEMA floodplains and floodways
- Community Floodplains and Encroachment Areas
- Building footprints from 2000
- High water marks (HWM) from past storm events
- Land use
- And other base layers such as highways, jurisdiction boundaries, rivers, and watersheds.

Floodplain regulation documents. I compared minimum floodplain regulations required by FEMA for NFIP-participating communities and the City of Charlotte's floodplain regulation ordinances to study how Community Maps affect development and buildings in the region.

First-hand use of online tools and services. CMSWS and the City of Charlotte offer interactive Community Maps and other tools for understanding flood risk by individual property online. They also provide applications for services for flood mitigation improvements, such as through the RetroFIT program. I explored these first-hand by navigating through as much of these as I could before needing to input my personal details. This helped me assess the ease of use and acquiring information online for residents.

1.5 Literature Review

Over a decade ago, the National Research Council (NRC, 2009) published a book that takes a critical look at floodplain mapping practices in the United States, how they could be improved, and the benefit-cost analysis of improving them. The report concludes that the benefits outweigh the costs of improved accuracy in floodplain mapping.

Flood maps used by most jurisdictions around the United States are created by the National Flood Insurance Program (NFIP), which is administered by FEMA. These maps, though called Flood Insurance Rate Maps (FIRMs) and created for setting flood insurance rates, are also used for disaster mitigation, land use planning, and emergency response planning (NRC, 2009). Communities participating in the NFIP must use these maps to calculate flood insurance rates and adopt minimum floodplain regulations based on FEMA's floodplain boundaries. However, these maps primarily communicate flood hazard, not complete risk. Mark Fleischhauer differentiates between hazard, "any potential threat to something that people value, including one's life, health, environment or lifestyle," (Fleischhauer, 2008, p. 275) and risk, as incorporating individual, social, or biophysical vulnerability due to the probability of a disaster impacting people and structures occupying static hazardous zones. As static and unnuanced hazard maps, these do not provide enough useful information to create responsive flood regulations appropriate for a variety of risks across floodplains. Without much federal incentive for communities to exceed these minimum regulations, and without any dedicated funding for local mapping, most communities continue to use FIRMs and simply adopt the minimum regulations.

Another issue with FIRMs is that they are essentially never up to date. Wilson (2018) cites that 63% of communities are using FIRMs that are five or more years old, and many municipalities use maps that were created over forty years ago. In general, this is due to a combination of how complicated the mapping process is, local opposition, and inadequate funding (Wilson, 2018). FIRMs can sometimes be outdated as quickly as six months after they are adopted by a community, depending on how fast development conditions in that area are changing. FIRMs also simply do not account for changing man-made or natural conditions such as development or climate change, erosion, or hydrologic trends.

Other flaws of the current mapping include its technical methodology. FIRMs use current conditions of topography, soils, vegetation, and surface permeability, as determined by engineers and surveyors, in establishing the Base Flood Elevations (BFE) at various cross-sections of a stream or river. BFEs help set insurance premiums as well as become the regulatory basis for setting the minimum finish floor heights of structures built in floodplains, as required by FEMA. However, the BFEs are still largely estimated, not accurately modeled or calculated, in spite of better technology available to do so. Based on the NRC (2009) report, the largest benefit can be gained by improving topographic data and producing accurate BFEs. The level of uncertainty generated by current elevation surveys is around ten times greater than what FEMA itself considers acceptable. Newer technologies, such as LiDAR (light detection and ranging), are now available and used in North Carolina to more accurately scan and model topography. New engineering modeling methods are also available to determine flood depths (NRC, 2009). Further, to determine actual flood risk, finish floor elevations must be determined for the structures in floodplains. Damages to structures can be proportional to the depth of flooding so an accurate risk assessment would require knowing the elevation of a structure's finish floor relative to the BFE. If a structure is adequately raised above the BFE, it is at far less risk of being damaged. However, FEMA does not have this data for most communities that participate in the NFIP, so actual risk in communities remains unknown (NRC, 2009).

Finally, one of the other major problems with FIRMs is that they offer cleanly defined boundaries for what is considered a Special Flood Hazard Area (SFHA) based on the 1% annual chance flood, what area has a 0.2% annual exceedance probability (AEP), and everything else, which includes a lower than 0.2% AEP or an undetermined risk. This shows nothing of flood depths, and can be falsely interpreted as an exact extent of flooding from a 1% or 0.2% flood event. Worse, it can be interpreted as the areas outside of the 0.2% floodplain having no flood risk at all. And yet, during Hurricane Harvey, 40% of flooded structures in Houston were not mapped in either of these floodplains (Grigg, 2019). These clearly drawn floodplain boundaries often give residents and businesses outside of them a false sense of safety from flood risk.

Burby (2001) summarizes the US experience with flood insurance and floodplain management starting when the NFIP program began, walking through the major amendments made to date. He explains how the FIRMs, used to set flood insurance rates and to set flood mitigation regulations, are, in fact, inadequate for the latter. 2.3 million of the then 6.6 million built structures within the 1% AEP floodplain were constructed after FIRMs in their area had been created. This means that a FIRM's designation of SFHA did not deter developers from building in those areas (Burby, 2001). NFIP sets minimum regulations for communities participating in the program to discourage construction in floodways and SFHAs, such as allowing fill only up to a cumulative increase of 1 foot of water elevation across a site. Burby estimates this rule caused flood levels to increase by over three feet in Charlotte, North Carolina. Further issues with the floodplain mapping by FEMA include the fact that only 7,000 of the 45,000 flooded buildings in Houston during Tropical Storm Allison were shown in the 1% AEP floodplain. Lastly, repetitive loss and grandfathered properties in the floodplains lead to ineffective floodplain management as their insurance rates are heavily subsidized, compared to the costs, and a disproportionate amount of insurance claims are paid out to repetitive loss properties. Burby also credits the NFIP for keeping flood losses from being as high as they would be without the program, however, he offers several recommendations for mapping to be more appropriate for floodplain management.

Burby (2001) suggests that the NFIP program would benefit from more detailed mapping with up to date information, no assumption or allowance for fill in floodplains, mapping upstream flood hazards, and providing enough details in maps to be used for land use planning. He offers further suggestions for complementing better mapping with broader floodplain management strategies, minimizing development in floodplains, up to 3 feet higher margin of error in finished floor elevation requirements relative to base flood elevations, retrofitting and relocating repetitive loss properties in the floodplains, and better on-site stormwater detention.

Graber (2016) presents a case study of Canarsie, New York, that gives life to the issues highlighted above with FIRMs. Zone A on a FIRM is the designation for high-risk areas. Residents in this zone are charged higher insurance premiums and jurisdictions generally have stricter regulations within this zone. By 2013, Canarsie's FIRMs were 30 years old and only showed 24 or so structures in Zone A. The updated Preliminary FIRMs proposed by FEMA in 2013 expanded Zone A to include 5,000 structures. According to Graber (2016), FEMA estimated insurance premiums in this zone to go up as high as $9,500 a year, which is especially unaffordable for a neighborhood where the median household income is $55,000. Further, building code regulations, such as a higher habitable floor, would make renovations or new builds in this zone cost-prohibitive.

This case study spotlights the impact on human lives of poor FEMA mapping and the dependence of local regulations on those maps. Better mapping technology and data could have led to more preventative measures in advance of Hurricane Sandy. Today, after NYC Department of Planning's resilience planning in Canarsie, solutions identified involve keeping attached family units (which are the predominant housing type in this neighborhood) in Zone A with architectural modifications to allow the lowest floors to flood. While these solutions will help residents in the short run, these structures will continue to flood and cause major disruptions in the lives of those who live here. Further, the unaffordable increase in insurance premiums based on these new maps could cause displacement of current Canarsie residents. This points to a need for a complementary buyout and relocation program. If it is so unsafe to live here, residents should have comparable options where it is safer and affordable for them.

Criticism of FIRMs as tools for flood regulations is abundant in available literature. However, as Burby (2001) indicates, improvements to flood management require work at the federal and local government levels. The process of decision- and policy-making at the local government level varies greatly across municipalities because of different value systems and government capacities and resources.

Prevailing debates on the most efficient, just, and effective decision-making include arguments made by Davidoff (1965) and Lindblom (1959). Their articles instigated a vibrant and influential discussion, as will be discussed here. Etzioni's (1986) adaptation of Lindblom's initial argument sets the stage for the Charlotte-Mecklenburg case study.

Davidoff (1965) started a long continuing discussion on advocacy and pluralism in planning. He called for greater democracy in the field of urban planning through representing and advocating for plural viewpoints, especially the underprivileged. Pluralism in planning, according to Davidoff, is a prerequisite for a just society. Accepted widely now is that adequate representation of a multitude of interest groups makes for better public policy. Davidoff's theories have evolved from advocacy in planning to community planning. In his article, he states that public participation should not take the form of reacting to a proposed plan or program, but should instead have a role from the beginning of the planning process, including setting goals and creating proposals.

Clavel (1994) built on Davidoff's framework to study the evolution of the advocate planner. In his article, he suggests that the original concept of the advocate planner was created outside of public office and has since come to be accepted in government positions as well as outside. While originally it was hard to accept that planners in City Hall might be interested in amplifying the voices of the underrepresented, communities have since come to accept just planners, even if they are paid by broader constituencies, outside of poor communities.

Lindblom (1959) offers a theory on how change happens in planning and policy. "Muddling through" is the theory of small steps, minor adjustments, and reactionary change in developing policies, programs, and plans. Instead of sweeping ground-up change, he makes a case for the greater usefulness and effectiveness of evolving and adjusting using small changes over time. This normative statement has been highly contested in the last sixty years. Following literature has supported, contested, modeled and simulated the incremental decision-making process. Rationalism is impossible, according to Lindblom, with humans and our inability to definitively rank our preferences, especially against others' preferences. While Lindblom claims that the process of incremental change allows for more efficiency and fewer irreversible mistakes in policy making, contesting literature, such as Bendor (1995), claims that incremental policy changes are, in fact, just as prone or more to making mistakes. As the process for zooming out to challenge high level assumptions and incorporate new technologies is foregone, policy changes only consider recent actions and a small range of information, ultimately leading to narrow-minded decisions. Incremental policy change may work in certain cases with a homogenous group of decision-makers, but with conflicting perspectives, decisions are objectively worse in this process.

Etzioni (1986) reviews the theories around the mixed scanning method of decision-making. Where Lindblom, and to some degree, Davidoff, promote a form of incremental planning, Etzioni presents the case that incremental planning misses opportunities for innovation and the ability to reexamine the fundamental framework of planning. Rationalism, he agrees with Lindblom, is the other extreme of incrementalism, which is simply not possible with the resources and capabilities available in decision-making. Etzioni offers mixed scanning, as a third option that combines both. He argues this allows for higher level framework thinking followed by lower level incremental decisions. Etzioni draws from examples of other literature, including pointing to higher courts and federal agencies making more fundamental decisions, while lower courts and local governments operating under those make incremental decisions.

Rationalism is best carried out at a centralized higher level of government and does not encourage public debate, especially once a decision is adopted. Incrementalism allows for pluralism and consensus-building to make decisions, but fails to step back and reexamine if the wrong path has been started down. Etzioni ends with one of two hypotheses that says rationalism may not be suited even for highly centralized decision making, incrementalism may reinforce the weaknesses inherent in pluralism without a fundamental framework to work within, and mixed-scanning may just be the balance where fundamental frameworks are revisited from time to time with incremental decisions made within those frameworks.

For effective mixed-scanning methodology to create better policies, there needs to exist good data and it must be available to everyone. Transparency of data with stakeholders and the public not only serves to create more accurate data, it also equips everyone with the knowledge to sustain a healthy public debate, as Williams (2020) shows. She offers ways in which data can be used to "do no harm, respond to the needs of those on the margins of society, expose unjust practices, and ultimately help educate us about our world so we can make better decisions" (Williams, 2020, p. 10). Using first hand experiences of three case studies, she demonstrates the importance of co-creating data and making it accessible to everyone. This not only creates more accurate and less biased data, but garners more trust among various interest groups and empowers the public to use the data creatively on their own. In the first case, her team builds their own dataset and visualization of the informal mutatu public transportation system in Nairobi. Working closely with mutatu drivers allowed them to create a more useful map that has since informed policy changes and allowed better leveraging of the informal sector for everyone's benefit. Further, the open data has allowed the Institute of Transportation and Development Policy to better plan their Bus Rapid Transportation system.

Williams' book points to the significance of process in mapping, data collection, and data management. The accuracy and reliability of data is important to empower the public and decision-makers to make better decisions. Greater transparency, collaboration, and early involvement of people with a variety of agendas is critical for producing the best data with the greatest amount of trust among all parties. Additionally, she highlights the benefits of making data openly accessible to everyone so that it may be checked and used for further work.

2.0 Charlotte-Mecklenburg Flood Mitigation Planning

2.1 How Charlotte-Mecklenburg Got Here

Why was Mecklenburg able to create community risk maps and thus improve their flood risk management in 2000? Section 1.3 discusses the two initial actions, consolidation of stormwater services for the entire county under one agency, and the implementation of a stormwater utility fee (SUF), In addition to these two actions that staged the subsequent flood mitigation success in the region, it took a combination of several other events and variables to ensure the implementation and success of Community Risk Maps in Mecklenburg: public memory, local champions, early stakeholder engagement, and a sustainable local funding source.

Often, a few years after a flood event, a critical mass of the public has forgotten the losses and damages caused by the flood (McEwen et. al., 2016). Because it takes years to make a meaningful change to a jurisdiction’s flood mitigation strategies and practices, the effort loses momentum as public memory fades. The proximity of Tropical Storm Jerry in 1995 and Hurricane Danny in 1997 in Mecklenburg kept the memories of loss fresh in the public’s mind, creating a longer sustained drive to develop more resilient flood risk management strategies (Canaan, 2020a). Further, because neither of these floods was declared a Presidential Disaster, federal funding for recovery was limited, placing a larger recovery burden on Mecklenburg county and the other local jurisdictions. The added cost burden of the two disasters made the public even more inclined to support drastic changes to flood risk management.

Dave Canaan, interviewed extensively for this thesis, is the current Director of the CMSWS and has worked there for over 27 years. That long term commitment to flood mitigation work by him and others at CMSWS has meant continuity and lasting institutional memory. He has been creative and proactive in his approach to finding new solutions. After the 1995 and 1997 floods, a Board of Commissioners meeting was held with flood survivors present. Survivors showed up in large numbers with buckets and brooms to send a visual message demanding change and better levels of service (Canaan, 2020c). During this time, the prevailing wisdom around flood management included cutting down trees and channelizing rivers. As discussions about revamping the mapping system began, Canaan was insistent that they needed to “stop the bleeding,” (Canaan, 2020a) in other words, they could not have the same losses and damages flood after flood. Upon recognition of the benefits of natural channels and floodplains, aggressive changes were made, such as cutting 70% of the staff that was employed to channelize rivers and cut vegetation. The savings from this and additional seed money from grants gave way to new mitigation strategies.

The process began with a stakeholder group, consisting of engineers, developers, environmental advocates, and flood survivors (Canaan, 2020c). Collaboration across county and city departments continued to increase. The first resistance came from the engineering community, who were skeptical of the science behind the mapping. So they were invited to analyze, critique, and create their own, but they found no major discrepancies. The bigger resistance came from the community of developers because of the cost increases they would face when needing to build to higher flood standards. New maps indicated a two- to four-foot rise in flood elevation across parts of the county (Canaan, 2013). However, thanks to the early involvement of advocates and engineers, government officials had support from many stakeholders. The engineering community evoked their code of ethics to say that having seen this data, they could not ethically continue to build to lower standards (Canaan, 2020c). Thus, developers would have to comply with stricter standards, either by official regulations, or by engineers refusing to build to lower standards. Canaan insists that the engineering community was instrumental to the adoption of the new floodplain maps and the development of higher building standards.

One of the other major barriers communities face in implementing higher standards and reserving more land for flood waters, instead of development, is the expected loss in tax base. However, one of the advantages of this particular geography is that only 5% of the land is in the floodplain (CMSWS, n.d.(c)). This means that even if all of that land is bought out and reserved for natural drainage, 95% of the county will still be developable. Additionally, Canaan says they have actually seen an increase in some property taxes due to higher values of properties now adjacent to new greenways (Canaan, 2020a). This tax increase offsets some of the loss in tax base.

Today, after each flood, CMSWS collects data on how many homes and businesses have flooded and what the estimated damages have been. However, they then also discuss what *did not* flood to shine a light on the successes of flood management so far. According to Canaan, one of the reasons for CMSWS' continued success is the fact that they make sure to publicly credit government officials, even for decisions made before their terms. Generously crediting elected officials for the success of this program, even if a program pre-dates the official, is part of what sustains the public and financial support for flood management projects (Canaan, 2020c).

2.2 Community Maps Compared to FEMA Maps

Charlotte-Mecklenburg is still a participating member of NFIP and thus still uses FEMA's Flood Insurance Rate Maps (FIRMs). However, locally this means they effectively have two floodplains and two floodways. The FEMA floodplain and floodway are used to determine flood insurance and to ensure compliance with federal regulatory minimums, and the Community Floodplain and Community Encroachment Areas are used for further regulatory purposes and to guide broader flood mitigation strategies. A combination of different input variables and new underlying assumptions makes Community Maps very different from FIRMs. This section will explain the major differences between FIRMs and Charlotte-Mecklenburg's Community Maps.

Table 1: FIRMs vs Community Maps Comparison Overview

	FIRMs	**Community Maps**
Input variables	- Existing development - Engineering surveys for topography data	- Projected future development - LiDAR technology for topography data
Rainfall quantities	NOAA Atlas 14 average rainfall estimates for the future	NOAA Atlas 14 estimates with an 8% error margin
Coverage	Prioritizes highly developed/urban areas	Maps all areas, including greenfields
Maintenance	Some maps haven't been updated for as much as 40 years.	Updated every 8 years.
Permissible surcharge	0.5 - 1 foot cumulative surcharge allowed	0.1 foot cumulative surcharge allowed

Map Input Variables

The major difference between FEMA's FIRMs and Charlotte-Mecklenburg's Community Maps is that the former approximates current flood hazard while the latter predicts a future flood risk. The technical differences between the maps stem from different input variables, such as land use and infrastructure information, topographic and bathymetric data, and hydrologic data such as the amount of rainfall that has a 1% chance of falling in 24 hours. The ways in which Charlotte-Mecklenburg has improved its mapping is by using better elevation data, modeling future land use conditions, and using higher future rainfall estimates.

First, FEMA's elevation data is created using field surveys or scaling United States Geological Survey (USGS) topography data (NRC, 2009, p. 17), and is often outdated. LiDAR data, used by Mecklenburg for their community flood maps, is a newer laser scanning technology that creates accurate 3D models of current topography. Topographic and bathymetric data is the largest predictor of flood risk

(NRC, 2009), so by using more accurate technology, Community Maps are already far more reliable in calculating the flood risk across Mecklenburg county. Second, FEMA uses existing land use conditions to create their maps, which can sometimes be outdated as soon as the maps are created. For example, if a major new development has been constructed since the mapping process for an area began, by the time the map is released, the flood maps are already inaccurate. FEMA maps for various jurisdictions are decades old, using land use patterns that have evolved significantly. Specifically, for Mecklenburg County in 1999, when the community flood mapping effort was proposed, the then-effective FEMA maps for the area had been created in the 1970s. North Carolina, by contrast, uses future land use planning and market predictions to input a modeled full build-out of the watershed (Canaan, 2020a). This allows them to estimate future flooding based on development that is planned or predicted in the county, rather than existing or historic flooding. This is a forward-looking approach that helps Charlotte-Mecklenburg plan for the coming flood risk across the county.

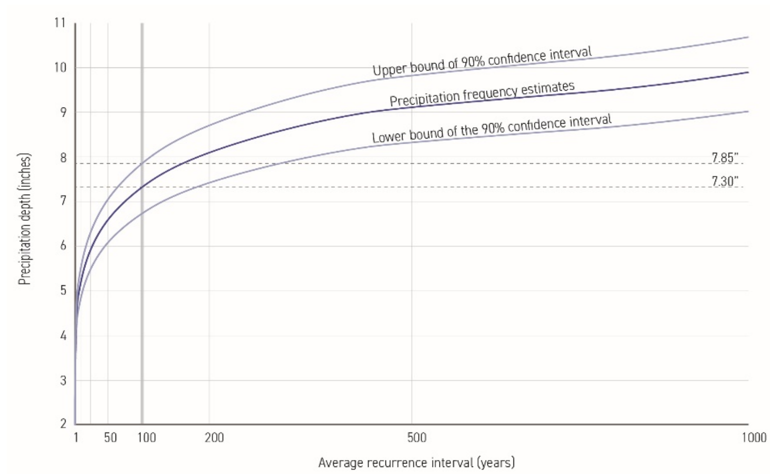


Figure 3: 24-hr Precipitation Frequency Estimate. Adapted from NOAA Atlas 14, Vol 2, Ver 3 (Canaan, 2018)

FEMA maps use NOAA's estimated rainfall amount that has a 1% chance of falling in a 24-hour period to model flood hazard. For the Charlotte-Mecklenburg area, NOAA predicts that in a 24-hour period, there is a 1% chance of 7.30 inches falling. This estimate has a 90% confidence interval with a +/- 8% uncertainty around it. Community Maps, unlike FEMA maps, conservatively use the upper uncertainty limit, 7.85 inches of rainfall in 24 hours. This effectively makes the floodplains deeper and wider as it is accounting for a larger amount of rainfall with a 1% chance. These are three specific ways in which Mecklenburg's flood maps are more accurate and useful for future planning than FEMA's.

Two other, non-technical, ways in which FEMA maps differ from Community Maps are the land areas prioritized for mapping and maintenance. FEMA has to prioritize areas for mapping because it is creating maps for the entire United States. Thus, national floodplain mapping prioritizes highly developed and urban areas because those tend to be at highest risk and incur the greatest losses from flooding. A greater number of people live in these areas and are impacted by floods, and more development directly causes more flooding due to higher levels of impervious land. However, this means that greenfields and open spaces are deprioritized. Charlotte-Mecklenburg maps the entire county, including undeveloped and underdeveloped areas. Especially for regulatory purposes this is extremely important because these open spaces act as a level of protection against floods and adding too much impervious land here would increase flood risk substantially. Lastly, as mentioned in the literature review, FEMA maps can be as old as 40 years in parts of the United States. They were over 30 years old in the Charlotte-Mecklenburg region when Community Maps were produced. CMSWS updates Community Maps every 8 years, making the information available much more relevant and accurate.

The Floodway

So far, the differences in FEMA and Community Maps explained apply to the entire floodplain. There is one other major difference in the way CMSWS maps the Community Floodway, known locally as the Encroachment Area, compared to FEMA's floodway. A floodway, as defined by FEMA is a stream or channel, and some area of land adjacent to it, that must be reserved for floodwaters to flow through. In the floodway, development must be regulated so the level of the water cannot increase above some determined amount. With a floodplain and floodway boundary drawn, the area between those two boundaries is known as the "flood fringe." Community Maps define the floodway in the same way as FEMA but use a different level of acceptable floodwaters to draw the floodway boundary (CMSWS, 1997).

In order to determine the boundary of a floodway, FEMA and CMSWS perform an encroachment analysis. First the flood levels (BFEs) and extents of a 1% chance storm are determined. Then, the encroachment analysis is performed by gradually removing flood water storage area from the floodplain, in other words, by adding development in the floodplain from the outer edges moving closer and closer to the water channel and letting the BFE rise. A "surcharge value" is the maximum amount the BFE is allowed to rise due to development inside the floodplain. FEMA uses a surcharge value of 1 foot in most of the United States, which means only as much development is allowed in the floodplain as would raise the BFE by 1 foot, and no more. In Charlotte-Mecklenburg, FEMA's surcharge value is more conservative, at 0.5 foot. In the case of the Community Maps, CMSWS decided that only a 0.1 foot rise in BFE, or surcharge, is acceptable (CMSWS, 1997). They performed the encroachment analysis with a 0.1 foot maximum cumulative surcharge, which created a much wider floodway boundary than FEMA's. This meant a greatly reduced flood fringe available for development, and increased the land area reserved for flood waters.

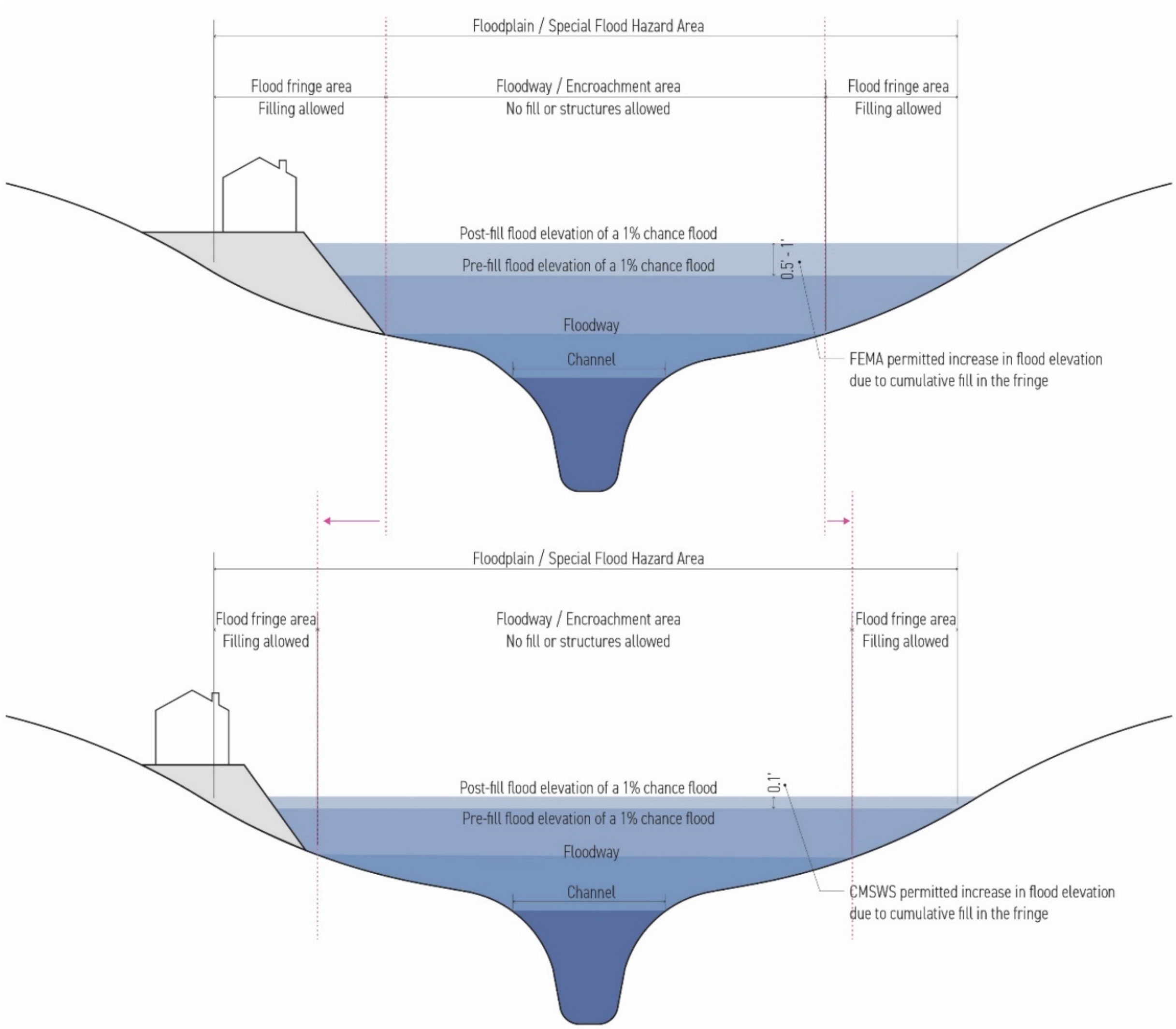


Figure 4: FEMA allows a 0.5 – 1 foot surcharge, while CMSWS only allows 0.1 foot (Mecklenburg County, 1997)

Map Outputs

Table 2: Comparison of FIRM vs Community Map floodplain areas and number of structures in 2000 (Mecklenburg County, County GIS Data Portal, 2021)

	FEMA Map (1999)			**Community Map (current)**		
	Floodway	**Floodplain**	**Flood fringe**	**Floodway**	**Floodplain**	**Flood fringe**
Area (square mi.)	10.7	29.5	18.9	17.6 (+65%)	30.5 (+3.3%)	13.9 (-26%)
Number of structures	1,191	8,574	7,383	2,619	7,638	5,019

Figure 5: Spatial comparison of FEMA Maps in 1999 (Scanlon, 2020) and Community Map floodplains (Mecklenburg County GIS, 2019a-b)

In addition to impacting future development regulations, Community Maps reveal a much higher number of built structures at risk for flooding than the 1999 FEMA maps. GIS data comparing 1999 FEMA maps and the Community Flood Maps shows a 65% increase in land area in the floodway and a 3.3% increase in the total 1% AEP floodplain. Overlaid with the building footprints dataset from 2000 (Mecklenburg County GIS, 2018), this shows a nearly 100% increase in structures built in the floodway (including accessory structures). The flood fringe showed fewer structures in the Community Maps compared to the fringe in the 1999 FEMA maps, of course, because the area of the flood fringe, i.e. where fill is allowed, decreased by 26%. Another way to look at the flood fringe data is that only 2,904 of the 4,121 structures in the flood fringe according to FEMA maps were allowed to stay there based on the lower surcharge calculations used for Community Maps. Based on CMSWS' calculations, 1,300 future structures would be built in floodplains, at risk of flooding if they continued to use FEMA maps (Canaan, 2013). There is 65% more land area in the floodway and 26% less acceptable fill area in the floodplain. This means a lot of land in the county is no longer available for development in the future, and a lot of structures already in the floodplain and floodway are at a much greater risk than previously known.

By using better technology, more conservative rainfall predictions and margins of error, and a lower acceptable level of risk, CMSWS' Community Maps paint a very different picture of flood risk in Mecklenburg County compared to their preceding FEMA maps. Community Maps go even further and map flood depths rather than static lines that misleadingly show an area as binarily hazardous or not. Incorporating potential flood depths allows for more nuanced planning strategies as the solutions appropriate for less than 6 inches of flooding are different than those needed for greater flood depths.

2.3 Uses of Community Maps

Community Maps are not only a significant technical upgrade to FEMA maps, they also help improve other flood mitigation planning efforts. More accurate flood risk maps help inform many of CMSWS' other programs, however, the biggest complementary strategies to the maps are floodplain development regulations, property acquisitions, the RETROfit program, and improved communication and transparency with the public and developers.

Floodplain Regulations

Equipped with the more accurate data and flood risk, the CMSWS began changing flood regulations and future land use planning to mitigate flood risk. NFIP requires participating communities to adopt, at a minimum, a model set of floodplain regulations for any construction in floodplains. Charlotte-Mecklenburg does participate in NFIP but exceeds the minimum regulations significantly. The primary tools they use include regulating a much larger area than required by NFIP, elevated habitable floors, and floodable construction under the flood protection elevation.

Charlotte-Mecklenburg's philosophy on floodplain management is that floodplains are meant to flood (CMSWS, n.d.(c)). This means that as impervious areas grow with increasing development across the county, more runoff will need to be drained, thus floodplains must be wider. Because the county uses *future* land use conditions to determine floodplains, they map the amount of floodplain as will be required to accommodate a predicted full build-out of the watershed; this, as opposed to mapping how much area is needed for flood waters based only on current land uses. Community Floodplains have 3.3% more land area than FEMA floodplains, as shown in Table 2, and Charlotte-Mecklenburg uses Community Floodplains for all regulatory purposes.

Development is allowed in this regulatory Community Floodplain, however, the amount of fill permitted in the flood fringe is restricted by modeling how much fill will increase the floodway by 0.1 foot. FEMA draws a floodway, but allows fill in the floodplain up to the point of a 0.5 foot increase in water level (CMSWS, 1997). Effectively, this means that the land area in the Community Encroachment area, where regulations are stricter, is much wider; and the land area available for development between the floodway and the floodplain, known as the flood fringe, is 26% *smaller* in the Community Maps compared to FEMA maps. No water level increase is allowed in floodways so any proposed project inside the community encroachment area must prove that the water level will rise by a maximum of 0.00 feet in order to receive a building permit (Goode, 2021).

Future conditions mapping also results in greater average depths of flooding. CMSWS models flood levels by depth, unlike FEMA, and the Community Maps find, a two- to four-feet increase in base flood depths in areas across the county (Canaan, 2013). Community Base Flood Elevation (CBFE) is thus much higher than FEMA Base Flood Elevation (BFE). For regulation purposes, construction in the flood fringe is required to have habitable finish floors raised to the CBFE *plus* another foot of freeboard to account for errors in modeling (Mecklenburg, 2015). Compared to FEMA's maps in 1999, this means a finish floor elevation requirement of three- to five-feet higher in many areas around the county.

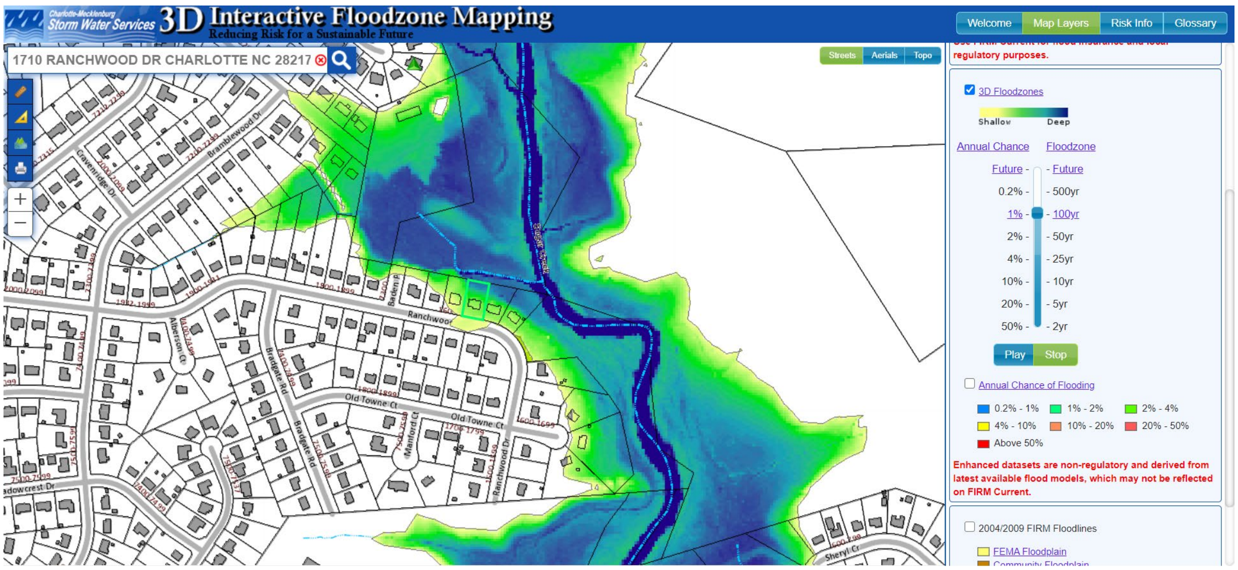
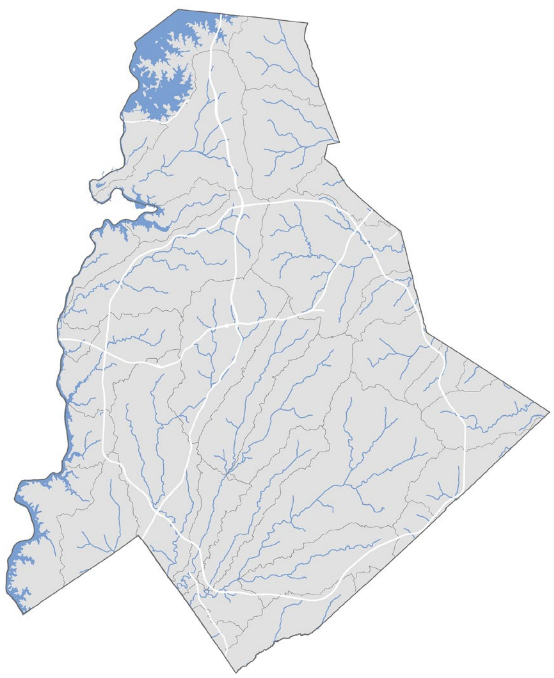


Figure 6: Screen capture of Community Map in a residential area in Charlotte (CMSWS, n.d.)

In addition to regulating construction in floodplains to a much higher standard, land use planning is also influenced by community flood maps. Most significantly, the Greenway Master Plan for Mecklenburg County Parks and Recreation complements flood mitigation. At the time when increasing floodplains and regulations within floodplains would have cost the developers' community, the planning department offered density bonuses if the county could purchase the vacated floodplain areas for greenways. This offset the cost to the developers, allowing them to build at higher density next to greenways, and allowed the collective benefit of using the floodplains as an additional amenity for residents (Canaan and Scanlon, 2021).

The first official Greenway Master Plan for this region was created in 1980 and only planned 73 miles of greenway along 14 corridors (Mecklenburg County, 2008). The 1999 update to the Master Plan made flood mitigation an explicit goal along with habitat conservation, recreation, alternate transportation, and protection of water supply (Mecklenburg County, 2015). The latest update, released in 2015, focuses on county-wide connectivity, calling for the trail network to increase by 268 miles over the next 30 years from the current 215 miles of completed trails. The planning and building of the greenways works complementarily with floodplain regulations and buyouts.



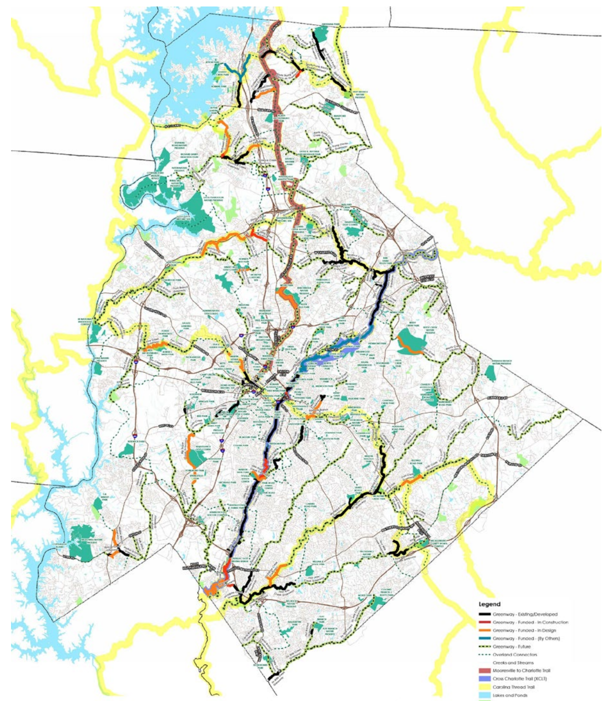


Figure 7 (left): Mecklenburg County Watersheds and Major Waterways (Mecklenburg County, 2021)

Figure 8 (right): Mecklenburg County Park & Recreation Adopted Greenway Master Plan (Mecklenburg County, 2020)

Local building regulations and land use planning have thus been shaped by the community flood maps in Charlotte-Mecklenburg: floodways are difficult to obtain a building permits for due to the requirement of demonstrating a zero foot increase in water levels, the total area of floodways and floodplains has increased compared to FEMA maps, buildings in the floodplains must at times have habitable floors three to five feet higher than what FEMA maps allowed, and the overall area protected for open space and flood storage has increased along with the Greenway planning.

Buyouts

Regulating future development was one critical step toward mitigating future risk based on Community Maps, however, there were still over 2,000 structures already built in the Community Floodplains, which needed a different flood mitigation strategy. The most effective way to protect people and property already at risk, of course, to physically remove people from harm's way. FEMA's buyout eligibility is highly restrictive and the program has very limited use. Buyouts funded by FEMA dollars or other federal funding, such as the Department of Housing and Urban Development (HUD), need to meet repetitive loss criteria and the entire process can take up to five years to complete. Additionally, federally funded buyouts have to be purely voluntary; there may not be any semblance of coercion on the government's side to encourage people to leave high risk areas.

In 1999, buyouts in Mecklenburg county were almost entirely funded using federal dollars. However, after the first 300 homes, the "low-hanging fruit" (Canaan, 2020a) had all been bought out. Because federal funds must prioritize property buyouts across the nation, once the highest risk properties in the county had been bought out, fewer and fewer funds were granted to Charlotte-Mecklenburg for buyouts, because properties in the rest of the United States were at higher relative risk and thus higher priority for funding (Canaan, 2020a). CMSWS invested in creating a sustainable local funding source, as a portion of the SUF revenue, to fund further buyouts starting in the early 2000s. By 2012, CMSWS was able to fully fund acquisitions that were not eligible for federal funding (CMSWS, n.d.(d)).

While the future conditions mapping is not directly responsible for the success of the buyout program, the continuously evolving and improving mapping program has helped the county develop risk scores for each property by address, as part of the Risk Assessment and Risk Reduction plan. These scores are based on a variety of non-regulatory factors determined by the mapping program, such as flood depths and finish floor elevations. Higher risk properties are on higher priority for buyouts, and the county is also able to weigh contiguous properties more highly (Goode, 2021). Through a combination of these priorities, each year, CMSWS staff is able to lay out a budget for $6 to $10 million out of the stormwater utility fee revenue, and then begin to work with communities (Love, 2020). Negotiating with everyone in a contiguous neighborhood can take years before the last person is willing to sell, but the county approaches families in the years when they have not been heavily flooded to give them room to weigh their options and reach a conclusion about selling their property. Additionally, information from the local mapping also helps decide whether an acquisition is the most cost-effective strategy for a property, or if their flood risk might be better mitigated using the Retrofit program, which helps property owners finance home elevation or wet floodproofing as alternatives to buyouts.

As of 2019, CMSWS had bought out 700 households and restored 200 acres of land to open space (Sellers, 2019). The median property value prior to the mitigation project was $62,500, based on the raw data linked to the Losses Avoided Tool[1], indicating much lower valued homes than the median home value in 2019 in Mecklenburg county, $252,000 (Martin, 2019). The buyout program has spent $81 million on 446 mitigated structures, and avoided cumulative losses totaling $30 million to date (Scanlon, 2021b). This

[1] This is a GIS tool, developed in-house for internal CMSWS use, which James Scanlon shared with me over email.

includes the most recently mitigated structures as of December 2020, which have not encountered any storms and thus have not yet avoided any losses. Further, CMSWS estimates future savings of up to $300 million from purchased homes (Sellers, 2019). While most cities avoid flood acquisitions fearing a lower tax base, Mecklenburg county finds that restoring floodplains has the added advantage of creating an outdoor amenity, thereby raising property values around bought out properties (Canaan and Scanlon, 2021). Of course, this is possible in large part because of the proactive nature of their buyouts and the pairing of the buyout program with the Greenway Master Plan. Unlike other cities that pursue buyouts as a flood mitigation strategy using federal funds, Mecklenburg county is able to reach out to high risk property owners to recommend and encourage buyouts. While buyouts are still voluntary in Mecklenburg, having more information and receiving it between flood events, when families have time to think and plan ahead, has meant the program has seen an 85% success rate on households taking a buyout offer after going through the appraisal process (CMSWS, n.d.(d)).

Families may also approach the county to volunteer for buyouts. In such a case, CMSWS is able to use their risk scoring to determine if the property is in the buyout plan and work with the property owner to either purchase the home, or offer alternatives. Additionally, the Quick Buy program was also developed for owners who choose to sell immediately after a flood and do not want to spend the time and money on repairs to their damaged property. Home acquisition through the Quick Buy program can be completed in a matter of months (Canaan, 2020a).

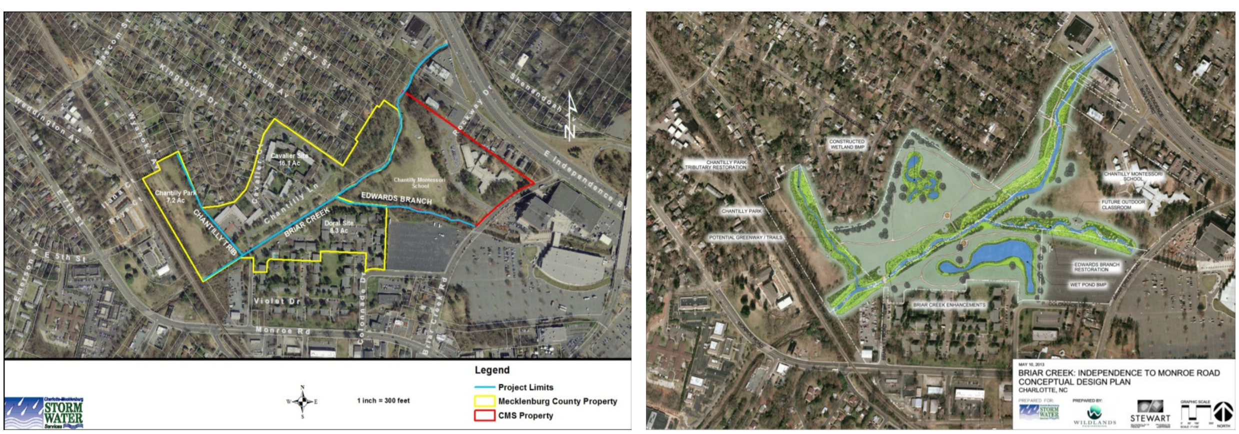


Figure 9: An example of a strategic buyout of properties that were repeatedly flooded. Doral and Cavalier apartments were bought out in 2008. Images from (Goode and Earley, 2018)

As a part of Charlotte-Mecklenburg's Risk Assessment and Risk Reduction (RA/RR) plan (AECOM, 2012), a Losses Avoided Tool (LAT)[2] was developed to assess the cost-effectiveness of mitigation projects, track the realized benefits of implemented projects, and estimate long-term future savings. Although this tool does not provide a cause and effect analysis of economic benefits resulting from the Community Maps, most mitigated projects have benefited from the data provided by these maps.

The tool was created by a team of two dedicated staff members at CMSWS, who are GIS experts (Scanlon and Canaan, 2020), using Python Scripts and can be run in a basic desktop version of ArcMap. Inputs include high water marks (HWM) data post storm, information on mitigated projects, and multi-storm frequency storm information.

A mitigated project includes acquired and elevated properties. The three input datasets are collected as follows. First, since HWMs are difficult to determine at a building that may have been removed, a complicated extrapolating/interpolating process is outlined in the LAT User Guide (CMSWS, 2020). Essentially, the county uses a combination of stream gauges, door-to-door surveys, aerial imagery, and modeling techniques to create an HWM dataset after each storm. Next, a database is maintained of any information relating to mitigated projects, such as its cost, type, and pre-project value. Finally, the multi-storm frequency water surface information is provided by the Flood Insurance Study at the County and is used to calibrate the water surface elevations after a storm. Once the depth of flooding has been determined at mitigated projects, depth damage curves are used to estimate the savings.

[2] In-house CMSWS GIS Losses Avoided Tool.

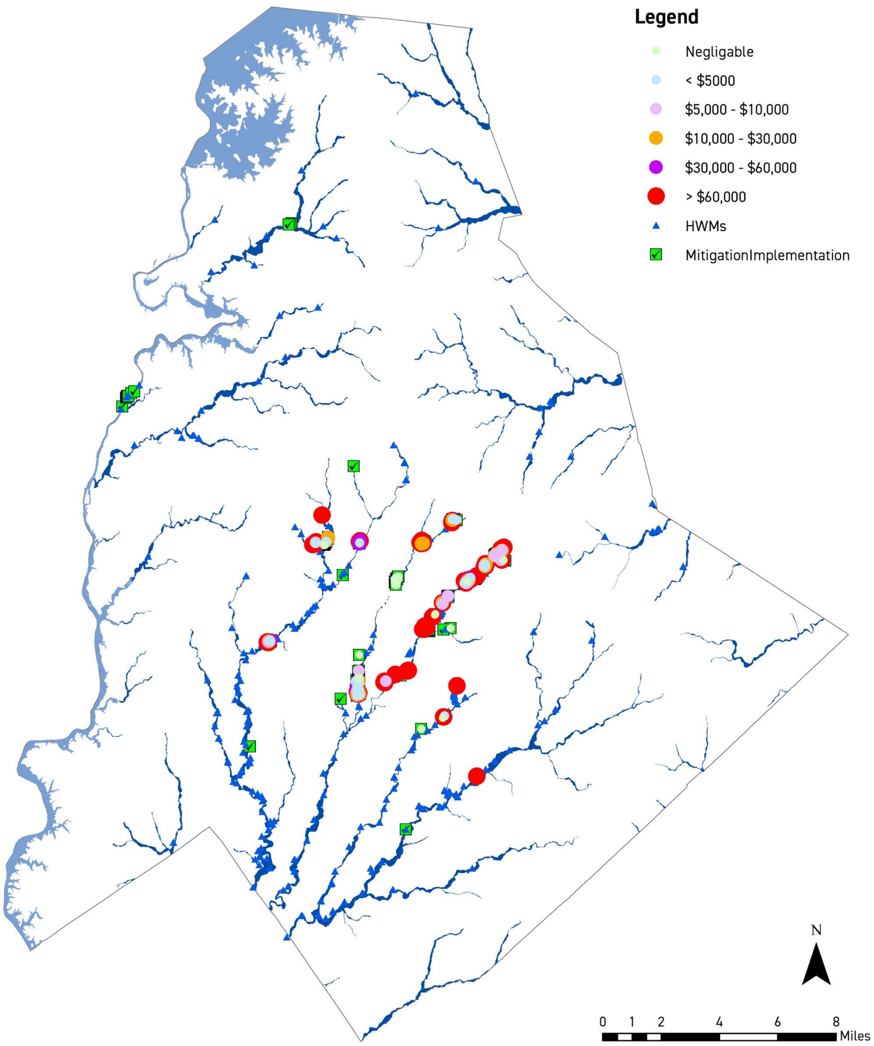


Figure 10: Results of the Losses Avoided Tool in ArcMap

This tool can be used to look at savings from mitigated projects during a single storm event, or all storms to date. Additionally, it can estimate long-term benefits. The county was able to share raw data and the LAT with me for projects up to 2013 and I was able to replicate their process to see losses avoided until 2013. James Scanlon (2021a) also shared the latest figures from the LAT as of December, 2020, finding $81 million spent on 446 mitigation projects, with cumulative losses avoided totaling $30 million to date.

RetroFIT Program

Often, buyouts may not be the most cost-effective flood mitigation solution for a property because the damage to a property might be minimal. For example, shallow flooding may flood a basement and utilities and cause power outages in a household, but the damage to property may not be high enough to warrant demolition. Such conditions raise the need for a different program to address the properties still remaining in flood risk areas and offer lower-cost solutions. In 2014, the North Carolina legislature permitted Mecklenburg county to use their SUF to fund a new RetroFIT program. This program grants funds to properties with low to medium flood risk to mitigate the risk using solutions such as (CMSWS, 2015): structure demolition, elevation, relocation, wet and floodproofing, abandoning basement and filling, and protecting mechanical/electrical/service equipment

I found one particular property that is identified by the Community Mapping tool as a “low” risk for flooding. Under the risk reduction suggestions, options such as buyouts and wet floodproofing are available. On the RetroFIT program website, I searched the same address and received an immediate indication that this property is, in fact, eligible for RetroFIT funds. The next window allowed me to select possible solutions I would like to apply for funding for.

Such a program offers mitigation strategies for different levels of flood risk. The online interface is fairly simple to understand and follow the steps for, but CMSWS also periodically reaches out to eligible property owners to provide information on their RetroFIT options.

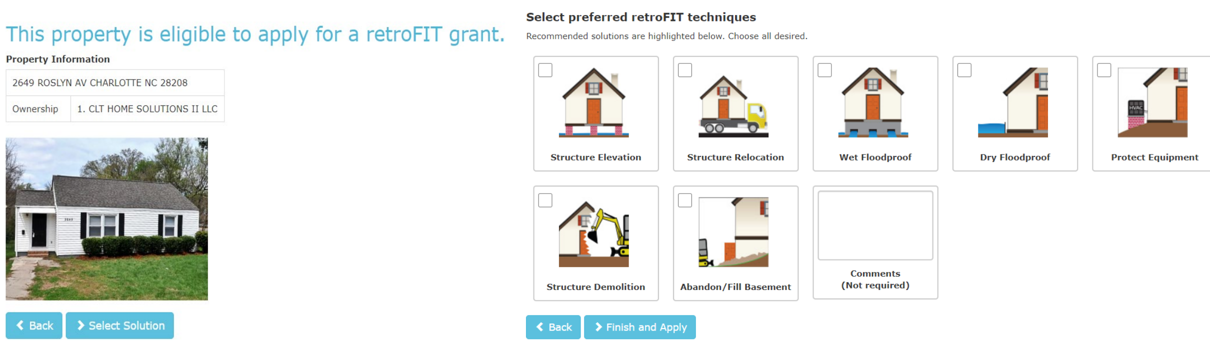


Figure 11: User interface example of RetroFIT program (City of Charlotte, 2021)

Communication and Transparency

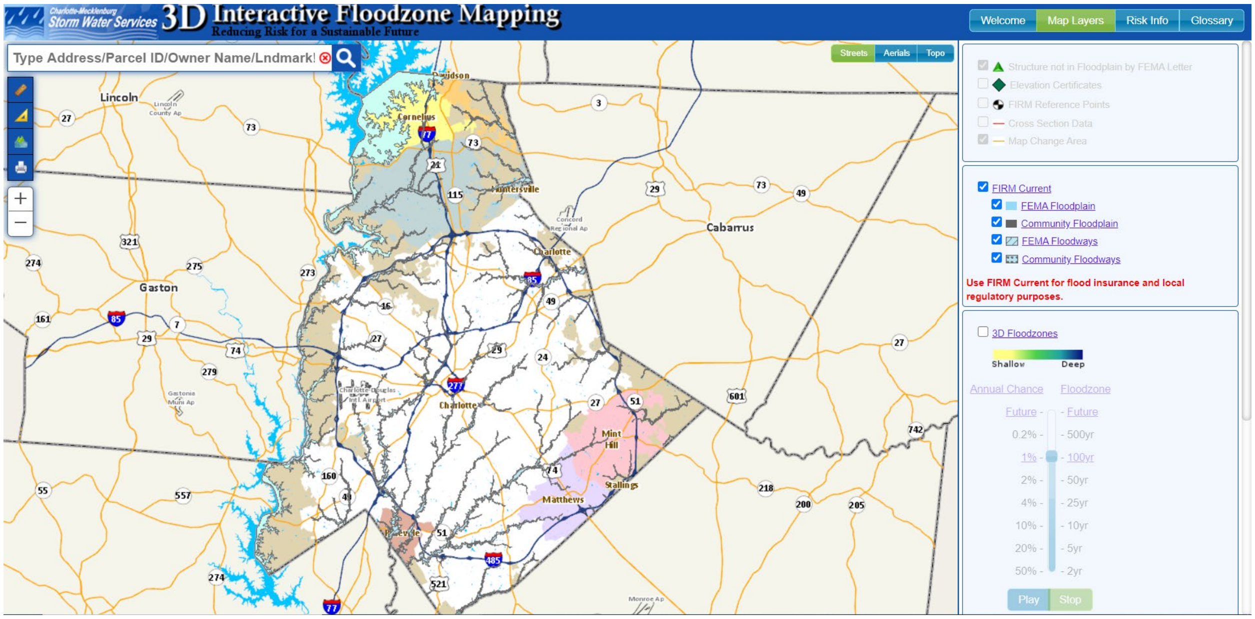


Figure 12: Screen capture of interactive Community Maps website

In addition to better-informed flood regulations, increasing land preservation, removing people from high risk areas, and creating economic savings, Community Maps in Charlotte-Mecklenburg are accessible to the general public, as seen through the screen captured images in this section. With an interactive and easy user interface, the 3D Floodzone Map allows the public to navigate to their address or a property and access a very comprehensive amount of information on that property. Property owners and potential buyers can see if a property is classified as a low, medium, or high risk for flooding. This tool also shows a property's flood protection elevation and the depth of flood risk in their area. Further, this tool offers a set of risk reduction actions a property owner can take responding to the particular type and level of risk for that property.

The map tool also has additional features such as the FEMA boundaries, allowing users to find their basic FIRM information on the same website instead of having to navigate to official digital FIRMs.

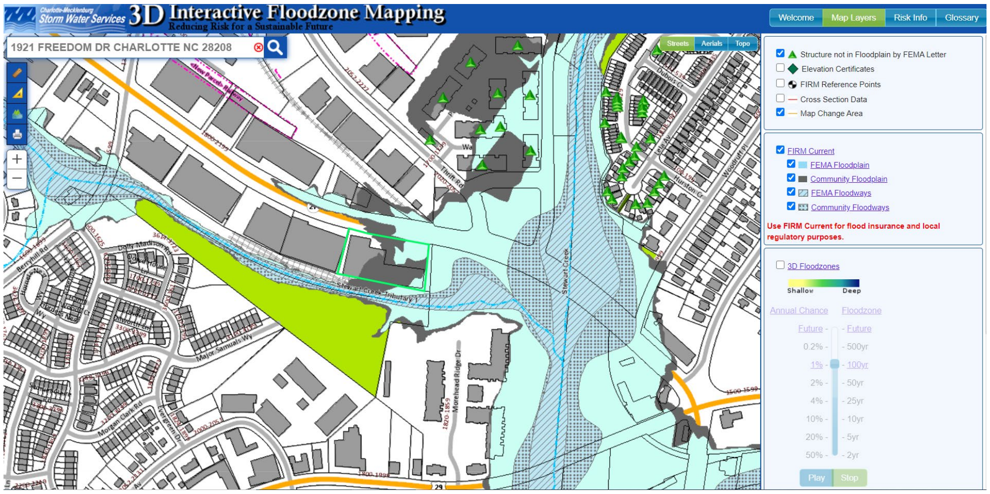


Figure 13: Current map layers at 1921 Freedom Drive (CMSWS, n.d.(a))

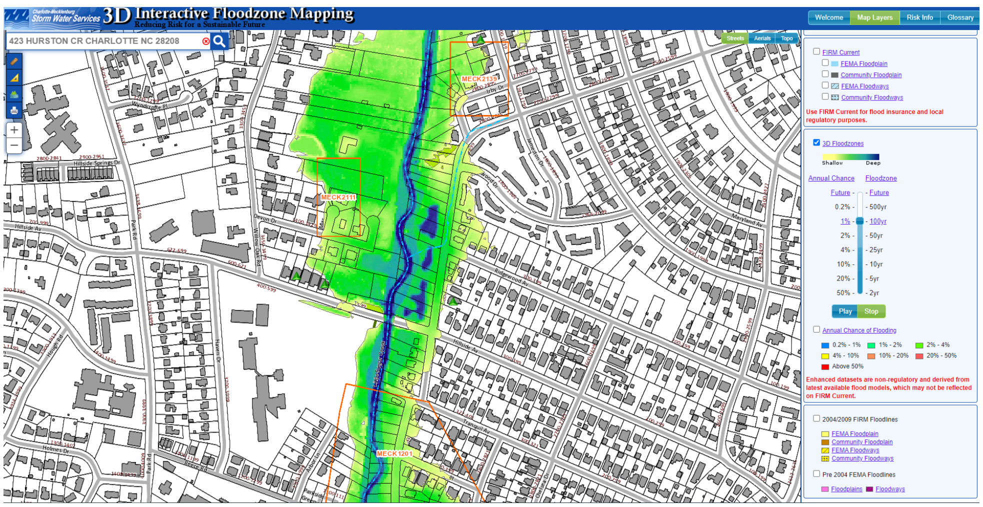


Figure 14: Flood depths at 3000 Westfield Road (CMSWS, n.d.(a))

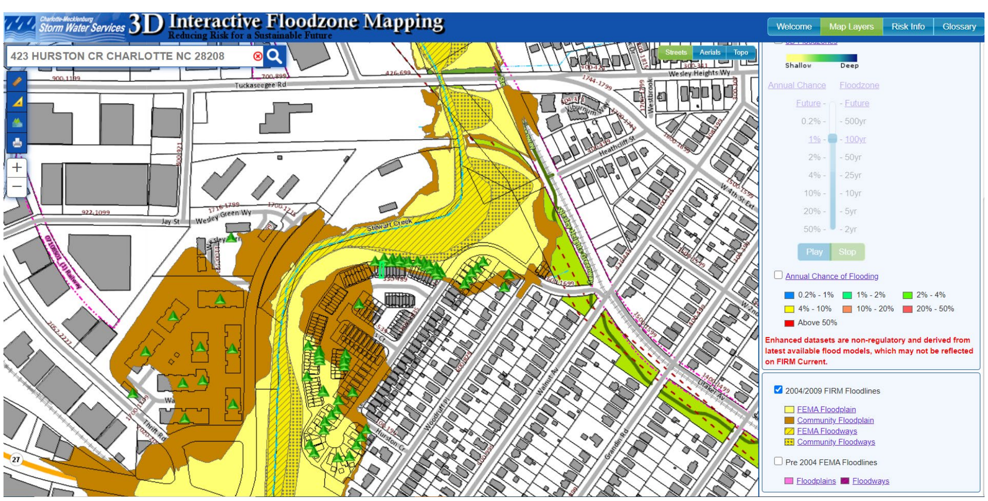


Figure 15: Old FEMA map layers at 423 Hurston Circle (CMSWS, n.d.(a))

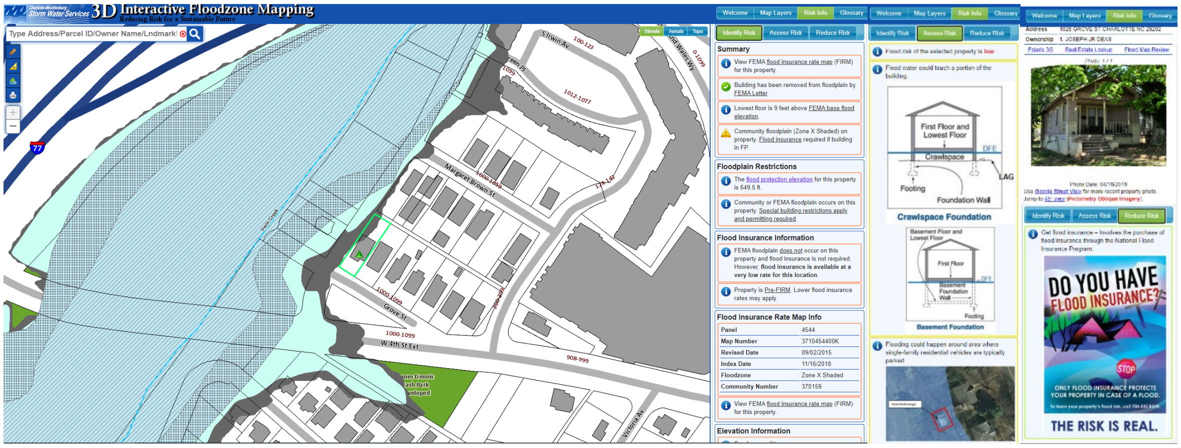


Figure 16: Low risk at 1026 Grove Street (CMSWS, n.d.(a))

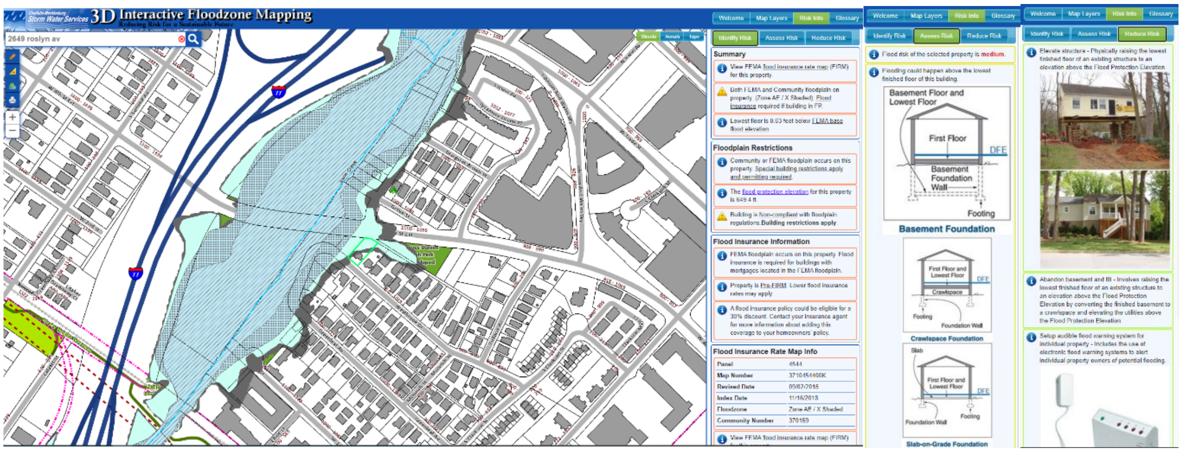


Figure 17: Medium risk at 1020 Westbrook Drive (CMSWS, n.d.(a))

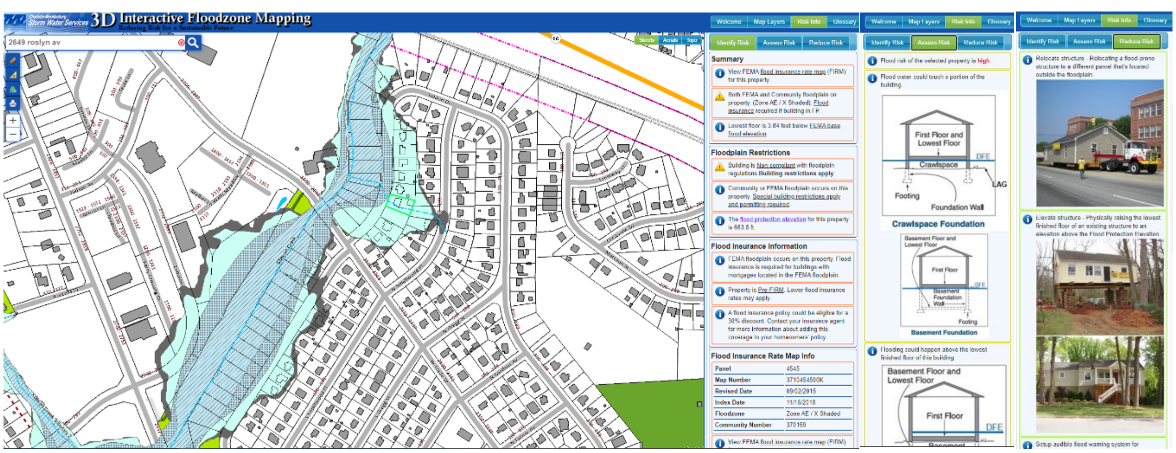
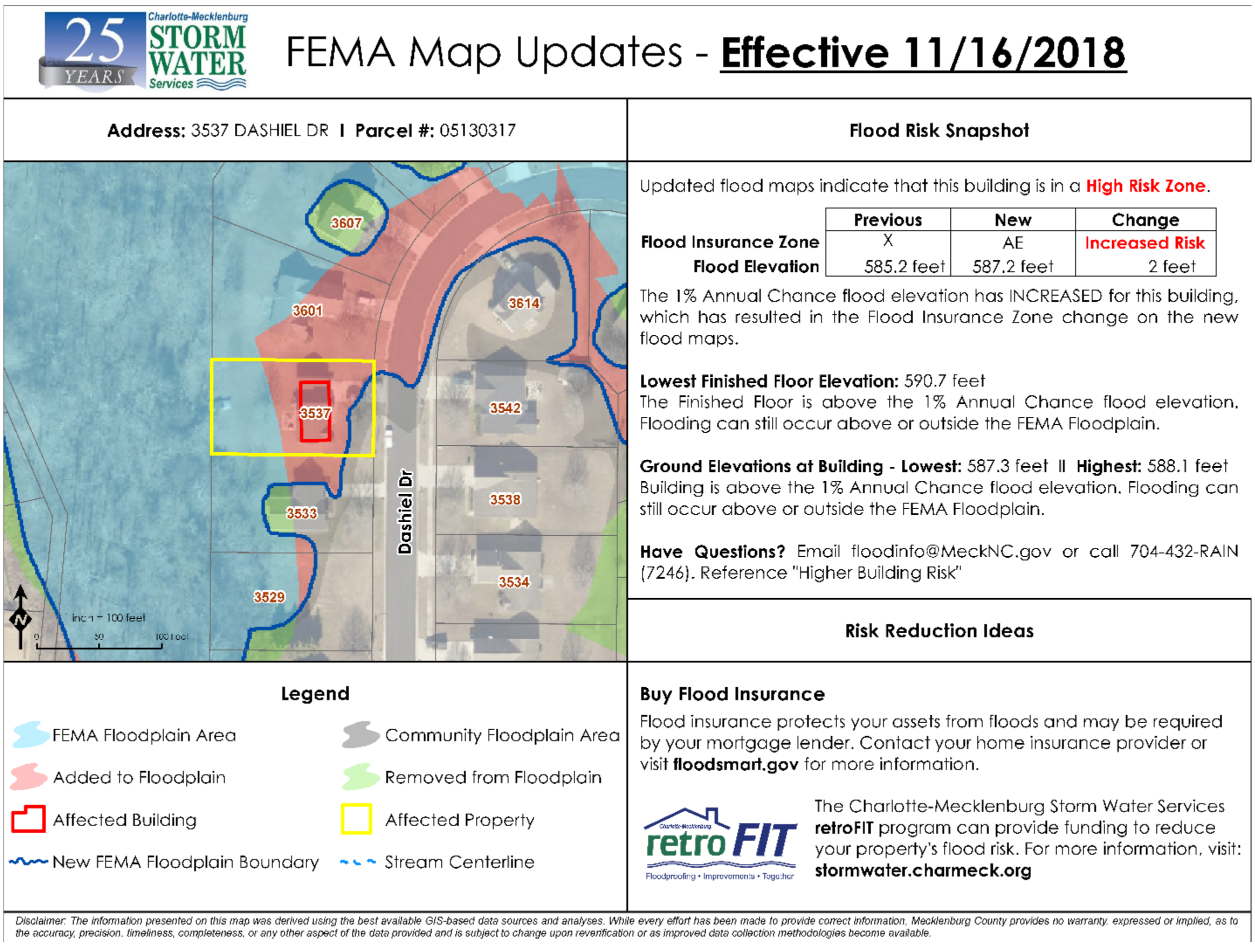


Figure 18: High risk at 827 Seldon Drive (CMSWS, n.d.(a))

In addition to the friendly interface website, CMSWS also mails home a personalized report to every property owner whose property is affected by a map change. With each map update, if a property's risk goes up or down, its owner will receive a report as shown in Figure 19, indicating the change and offering a customized set of mitigation options available to that owner. Reaching out with a printed report is helpful, especially for folks who do not find online information accessible, but also because most people are not monitoring the online site and may not be aware of any change to the known risk on their property. CMSWS also relays this information in public meetings and stakeholder meetings when appropriate.


FEMA Map Updates - **Effective 11/16/2018**

Address: 3537 DASHIEL DR I **Parcel #:** 05130317

Flood Risk Snapshot

Updated flood maps indicate that this building is in a **High Risk Zone**.

	Previous	New	Change
Flood Insurance Zone	X	AE	**Increased Risk**
Flood Elevation	585.2 feet	587.2 feet	2 feet

The 1% Annual Chance flood elevation has INCREASED for this building, which has resulted in the Flood Insurance Zone change on the new flood maps.

Lowest Finished Floor Elevation: 590.7 feet
The Finished Floor is above the 1% Annual Chance flood elevation. Flooding can still occur above or outside the FEMA Floodplain.

Ground Elevations at Building - Lowest: 587.3 feet II **Highest:** 588.1 feet
Building is above the 1% Annual Chance flood elevation. Flooding can still occur above or outside the FEMA Floodplain.

Have Questions? Email floodinfo@MeckNC.gov or call 704-432-RAIN (7246). Reference "Higher Building Risk"

Risk Reduction Ideas

Buy Flood Insurance
Flood insurance protects your assets from floods and may be required by your mortgage lender. Contact your home insurance provider or visit **floodsmart.gov** for more information.

The Charlotte-Mecklenburg Storm Water Services **retroFIT** program can provide funding to reduce your property's flood risk. For more information, visit: **stormwater.charmeck.org**

Legend
FEMA Floodplain Area
Community Floodplain Area
Added to Floodplain
Removed from Floodplain
Affected Building
Affected Property
New FEMA Floodplain Boundary
Stream Centerline

Disclaimer: The information presented on this map was derived using the best available GIS-based data sources and analyses. While every effort has been made to provide correct information, Mecklenburg County provides no warranty, expressed or implied, as to the accuracy, precision, timeliness, completeness, or any other aspect of the data provided and is subject to change upon reverification or as improved data collection methodologies become available.

Figure 19: Sample Letter to Resident (Scanlon, 2021c)

<u>Overall Benefit-Cost</u>

The price of creating Community Maps was funded by CMSWS. It cost $2.86 million to map the Community Floodplains for nearly 363 miles of stream. Updating and maintaining maps also costs approximately $7,800 per mile (Canaan, 2020b). This thesis does not calculate the trickle-down costs of mitigation projects that resulted from mapping because there is no counterfactual for which of the downstream projects might have happened anyway, such as modifications to floodplain management and regulations and buyout programs. The Losses Avoided Tool (LAT) provides an incomplete but meaningful picture of the economic cost of mitigated projects and the benefits gained in terms of losses avoided.

However, the numerous benefits of mapping also include that local jurisdictions are no longer guessing and making uninformed decisions about acceptable risk around how much flood risk is acceptable to the community, how much land preservation is necessary to keep from exceeding that risk level, and which properties are at highest risk and therefore highest priority to mitigate. The maps have allowed for swifter and more cost-effective decision making around flood mitigation. Further, clear communication and increased transparency through online maps have allowed people to build more trust in their local government and make better decisions for themselves.

3.0 Planning Implications

3.1 Discussion of Lessons Learned

Twenty years and still evolving, this case study underscores the complex nature of flood management, and shows that an effective solution requires a long-term commitment. There have been several occasions of major change in the approach to flood mitigation in Mecklenburg county since the early 1990s, each with their own challenges. One, the stormwater utility fee was implemented throughout Mecklenburg County in 1993, but the stakeholder engagement prior to adopting the fee lasted over two years, with understandable resistance from property owners. Without a local funding revenue, the subsequent initiatives and programs that CMSWS implemented could not have been possible. Two, there was also a major reorganization of structures around the same time, consolidating storm water services for all the municipalities in Mecklenburg county under one agency. Three, after the 1995 and 1997 floods, residents demanded better service for their stormwater fee and the local governments felt the same need due to a lack of federal aid for recovery (Canaan, 2020c). Because they already had a local funding source, CMSWS was able to take more drastic measures in 1999, such as creating their own future conditions risk maps. Four, when federal buyout funding ran out for the highest at-risk properties in the county, CMSWS laid off nearly 70% of their maintenance staff to start the buyout program (Canaan and Scanlon, 2021). The maintenance staff was primarily serving to remove vegetation from floodplains to allow water to flow into the channels more quickly. However, with the paradigm shift in the county that floodplains were meant to flood, and natural vegetation in fact helps with flood mitigation, CMSWS made the difficult decision to redirect resources from maintenance to buyouts. Five, when developers opposed stricter floodplain regulations, the engineering community fought back, and the planning department negotiated density bonuses in exchange for purchasing the floodplains that would become available for the Greenway Master Plan. These are all examples of major changes in flood management in Mecklenburg county over the last thirty years, and they highlight the need for an openness to change course and to repeatedly engage with multiple stakeholders to reach a suitable solution.

The mapping and subsequent floodplain management process used by CMSWS has been critical to achieving flood mitigation success and this case study offers lessons learned for the Mecklenburg region as well as other jurisdictions around the United States. However, CMSWS' flood mapping is not perfect. Two major areas of future improvement include incorporating climate change data and prioritizing flood mitigation planning based on a social and economic vulnerability assessment. Other challenges that CMSWS will have to contend with include staying up to date with modeling technology as they continuously evolve. CMSWS is already working on 2D vector modeling of floods to better assess velocity damage due to flooding. So far, CMSWS has been on the leading edge of flood risk mapping and mitigation, but they will also hopefully be able to overcome any loss in institutional memory after long-serving members of the agency have left, the ups and downs of funding stability, and the public and political will to continue to invest in new technologies and flood mitigation planning.

CMSWS' success can be attributed in large part to them challenging existing assumptions at the federal level behind flood mitigation planning and policy making. By recreating the maps and data used to plan flood mitigation, they have created a more fundamental shift in their planning process. Further, they have upgraded their data and technology to work with better information. Finally, they have built their planning process to include better communication and transparency with non-governmental stakeholders to build more robust strategies.

Areas for improvement

While CMSWS is doing a lot of things well and has seen meaningful success in flood mitigation over the last twenty years, there are also various areas for improvement within their risk assessment program. Two specific ways in which flood mapping and mitigation planning can be improved in Mecklenburg county include accounting for climate change and conducting a social vulnerability assessment.

As a comparison, the City of Cambridge has created a Climate Change and Vulnerability Assessment (CCVA) report (City of Cambridge, 2015) where the goal is to model and estimate future flood and heat risk for the city. The report looks at the predictions for sea level rise and increased rainfall due to climate change in the years 2030 and 2070. Further, the report goes beyond a future risk assessment to evaluate physical, social, and economic vulnerability.

Climate change is an imminent danger to all municipalities but is not accounted for in CMSWS' flood mitigation planning. The City of Cambridge partnered with the Boston Water and Sewer Commission (BWSC), MassDOT, the Massachusetts Department of Conservation and Recreation (DCR), and the City of Boston to share data and employ the latest available technology to model future climate change. Of course, future predictions include large margins of error, but even so, the CCVA reports a substantial increase in 24-hour 1% chance rainfall amounts. By 2030, the rainfall amount is expected to increase from 8.9 inches to 10.2 inches in 24 hours. By 2070, the city estimates 11.7 inches of rainfall in the same time period. This amounts to a 15% increase in rainfall by 2030 and total of 31% increase by 2070. CMSWS' Community Maps use the upper limit of the margin of error in NOAA's rainfall estimates, which is 8%

higher than the rainfall amounts used for FEMA flood mapping in Mecklenburg county, however, 8% could be a significant underestimation of future rainfall in the region. Incorporating climate change predictions in future conditions mapping is critical to a more accurate understanding of future flood risk.

As of 2015, Mecklenburg had produced a Multi-Jurisdictional Hazard Mitigation Plan that identified various types of hazards facing the county, including floods, winter storms, droughts, wildfires, landslides, and levee and dam failures of the major structures in the county. This report also includes a vulnerability analysis that looks at where repetitive loss properties are located, what areas are most dense within the county, and what infrastructure and assets are at high-risk of failure or damage. Vulnerability of built structures is broken down by building type, with residential buildings at highest economic loss risk. This document is yet another step in the right direction for CMSWS to be able to prioritize flood mitigation planning. However, this vulnerability assessment lacks a nuanced understanding of relative risk to different populations and spatial areas. The CCVA report, in contrast, layers data on vulnerable populations, defined by income levels and age group, to identify people at greater risk from the same natural disaster than others. This report also maps the buildings by use that could cause the greatest potential damage to critical facilities and the greatest economic losses. By assigning a score based on qualitative indicators, the CCVA is able to offer a clear prioritization for mitigation projects in the city. CMSWS could benefit from such a vulnerability analysis to protect their most at-risk populations and properties.

Challenging existing frameworks within policy-making

CMSWS used a version of the mixed scanning method (Etzioni 1986) to change the course flood mitigation efforts were on in the region in 1999. However, the process used by CMSWS to rethink flood mitigation strategies was more fundamental and rationalized than Etzioni's example makes room for. Etzioni cites the example of a federal agency, such as FEMA, setting the fundamental framework for policy making, and local agencies, like CMSWS, making only incremental changes within this framework. Arguably, the version of mixed scanning used by CMSWS for policy change was a more fundamental challenge to FEMA's assumptions and methods.

Until 1999, certainly, FEMA built the groundwork and Mecklenburg county used FEMA maps and NFIP regulations to manage their floodplains. Between 1999 to 2000, however, there was an intentional "zooming out" to look at the broader framework the county was operating in. After repeated losses and little financial help from the federal level, CMSWS consolidated its functions, created a stakeholder group with a variety and sometimes conflicting interests, and sat down to examine how to "stop the bleeding" (Canaan, 2020a). The result of this process, described in section 2.1, was to change the underlying framework itself. Community Flood Maps were created with new technology and new assumptions. They were mapped with a lower level of acceptable risk to the community and thus changed subsequent decisions that were based on spatial risk data.

Since the City of Charlotte and Mecklenburg county are still participants of the NFIP, they continue to use FIRMs for insurance purposes, so they have not completely undone the original framework of decision-making. And yet, even with effective FIRMs, local regulations, buyouts, and other flood mitigation strategies are now based on the Community Maps. While Charlotte-Mecklenburg's floodplain regulations may read similarly to FEMA's, their outcome is meaningfully different because of the new areas being regulated as well as the new local criteria of acceptable risk. A purely incremental form of decision-making perhaps might have continued to use FEMA maps for all flood mitigation decisions; building standards would have only increased marginally and fewer properties would have been bought out each year.

Mixed scanning is a combination of changing the fundamental framework and incrementalism in policy making. The community future conditions maps changed the framework for the county, and the policies and programs that followed were incremental. Since the beginning of the process in 1999, stakeholders ranging from engineers, developers, environmental advocates, to flood survivors have all been a part of the planning process. This plurality of planning, as Davidoff (1965) suggests, is essential to sustainable policy changes, and is a key feature of incremental planning.

Gathering, using, and documenting better technology and data

Accurate and reliable data based on the best available technology is an important prerequisite for informed debate and effective policy-making. Keeping up to date with new technology at the federal level is extremely difficult because of the sheer scale of FEMA's floodplain mapping program. With the federal agency barely keeping pace with updating maps for localities, they do not have the resources to upgrade their technology and change the way mapping is done, nor the capacity to employ local expertise in data collection. With creative funding and stakeholder buy-in, Charlotte-Mecklenburg was not only the first to create future conditions mapping using the latest technology, they continue to update their maps every eight years and upgrade their methodology with new technology and better data.

LiDAR scanning and new modeling techniques, coupled with future development conditions and NOAA's predictions of rainfall increase, CMSWS' maps increased flood elevations by two to four feet across the county and widened the floodplain by 45% on average compared to FEMA floodplains. Further, the region increased its standards for acceptable risk and modeled the developable flood fringe by capping floodwater surcharge at 0.1 foot, in contrast with FEMA's blanket 0.5 to 1 foot surcharge across the US.

This revealed a more accurate future flood risk, doubling the number of existing structures from the FEMA floodway to the Community Encroachment Area. Having accurate data on the future flood risk has allowed Charlotte and Mecklenburg to plan development more strategically, raise standards for building in at-risk areas, and prioritize how to remove people from harm's way. CMSWS has shown the need and value of better data to inform planning.

Another important cautionary lesson from this case study is that CMSWS stops short of overreliance on data to solve all flooding issues. They do not ignore other programs and policies that do not directly derive from the Community Maps, such as naturalization of channels, emergency notifications, and drainage maintenance. It is not enough to rely on this data alone to guide flood management, and one of the strengths of CMSWS is their ability to use the data as one tool, rather than the end all of flood mitigation planning.

Planning holistically and collaboratively

While using up-to-date data and technology are critical, they alone cannot improve flood mitigation. In the case of Charlotte and Mecklenburg, they found the "best dancing partners" (Canaan, 2020c) for the maps to be floodplain regulations and the buyout program. On the one hand, the city and county can regulate future development to reserve land for floodwaters, as well as regulate new buildings in the flood fringe to be built to safer standards. On the other hand, they can mitigate existing risk by removing people from the highest risk areas through the buyout program, and retrofit or floodproof, as needed, in lower risk areas. Of course, other jurisdictions may not find these two tools of flood mitigation to be their best solutions, but better data can inform a more holistic planning approach everywhere.

Transparency with the general public and collaboration with stakeholders from early stages of planning is key to successful flood mitigation. Had engineers and advocates not been in the early planning rooms with CMSWS staff, privy to new preliminary data in 1999, perhaps a united front in opposition to the developers may not have formed. With powerful developers resisting higher standards, public officials may have caved, as they often do, but with the support of engineers and advocates, they were able to increase local standards. Additionally, with a clear and easy-to-use interface for flood risk maps, the public continues to stay informed of levels of risk in their area and possible solutions available to them. Transparency and clear communication also created a level of trust among the population for CMSWS. This trust manifests itself, for example, in the well above average success rate of the buyout program; with over 85% of property owners taking the buyout offer after going through the appraisal process.

No one flood mitigation program can be successful in isolation, programs need to complement each other, and allowing a single agency to oversee all strategies has created a more effective overall flood mitigation plan for CMSWS. Further, transparency and communication have led to more trust and lasting change.

3.2 Recommendations for other stakeholders

One of the biggest takeaways from this case study for other communities is that local planning can meaningfully supplement national flood mitigation efforts to reduce flood risks. The future conditions maps created by CMSWS were the first of their kind in the US, and helped CMSWS plan where development should be allowed or restricted, where buyouts or property improvements were needed to reduce the risk to existing families and properties, and to provide complete information to the public so they could modify their individual behavior toward reducing their own flood risk. However, there are, of course, many reasons this case study cannot simply be applied exactly in this way to a different geography. First, this case study would offer the most for other areas that are also hilly and inland, with primarily riverine and shallow flooding instead of coastal flooding. Second, not every jurisdiction can legally implement a stormwater utility fee, depending on state regulations, so funding challenges will vary based on location. Third, Charlotte-Mecklenburg has the rare advantage of most of their streams originating within county boundaries, meaning they are the cause, and therefore the solution, for their own flooding problems (Canaan and Scanlon, 2021). Fourth, having a specialized agency focus on all storm water related issues worked really well for Charlotte-Mecklenburg, but there are also advantages to interdisciplinary departments managing interrelated issues, such as drainage and land use planning. Finally, only 5% of the county's land is in floodplains, which means even if no development were allowed in floodplains, this is a relatively low area to give up from the tax base. Other places may not be able to afford stricter regulations if their floodplains are a much larger percentage of their available land. However, while it is important to recognize how different communities and conditions will require different approaches, there are elements of the path taken by Charlotte-Mecklenburg that offer new considerations for other communities as well and this final section offers some recommendations for national level policies and agencies as well as other local communities.

Recommendations for National Agencies

Provide financial and capacity building resources to smaller levels of government. FEMA cannot keep up with the demand for maintaining and updating flood maps for all of the United States every five years, as is expected. Currently, FEMA allows communities to create their own future conditions mapping, but only in addition to FEMA's own existing conditions maps, and all decisions related to the future conditions mapping are left up to individual communities (NRC, 2009). This leaves almost no incentive or resources for communities to develop future conditions maps. Instead, FEMA needs to form more partnerships with state and/or county governments, build capacity, and have the smaller governments produce their own maps and lead mitigation planning in their regions. At the very least, FEMA should provide financial assistance and incentives for local jurisdictions to create and update regional floodplain maps to account for future conditions. Where technical expertise is needed, FEMA should also provide capacity-building trainings to local engineers and decision-makers.

Maintain oversight and coordination at federal level. Federal oversight of flood mitigation strategies and mapping across the United States because stormwater does not follow political boundaries. As such, the federal government can provide the macro level assessment of flood mitigation efforts within river basins, as well as coordination and standardization of data so upstream and downstream municipalities may be able to share their data more easily. Specifically, USGS can require and enforce consistent data collection methodology and documentation of metadata across the United States, as well as coordination and data sharing with USGS datasets.

Shift national paradigm to support floodplain restoration. A shift from highly engineered solutions to more nature-based solutions is already taking place around the United States. However, agencies like the Environmental Protection Agency (EPA) and FEMA should set more explicit goals and change the underlying philosophy behind floodplains to reserve appropriate land areas for floodwater storage and flow.

Improve buyout funding and processes. HUD, FEMA, and other national agencies should offer more and different types of grants for mitigating risk faced by existing structures in floodplains. This can include funding for retrofitting, elevating, or floodproofing. Grants should also be more flexible in their use so high-risk properties can be acquired proactively instead of only after repetitive losses. Further, the buyout process right now has to go through several rounds of approvals at various levels of government, causing a single buyout to take as many as five years. This process should be streamlined, allowing state or local agencies more autonomy to process requests more quickly.

Recommendations for state and local governments

Consolidate stormwater management across an appropriate geography. Having multiple jurisdictions managing parts of a watershed can be ineffective, or worse, counterproductive. However, national level management of watersheds will not have the granular information and knowledge to shape the best flood mitigation strategies. Storm water planning is best performed at a watershed scale. Where political boundaries do not align with watersheds, states or counties can be more effective in flood mitigation planning than city governments, so that a watershed is not managed by many different jurisdictions. Consolidating stormwater management services under one organization can allow coordinated and holistic planning, with fewer redundancies and reduced unnecessary bureaucracy.

Engage various stakeholders at all stages of planning. Stakeholders should vary in their interests and agendas. The public, especially those who have been affected by flooding, will provide localized knowledge and help create more accurate data. Having developers, engineers, elected officials, business owners, and residents (homeowners and tenants) of a region participate in planning will mean a slower process, but it will also mean a more well thought through plan with everyone's expertise contributing to a more equitable and long-lasting solution.

Communicate data in a variety of user-friendly ways. In order to effectively engage stakeholders, clear visual and verbal communication must be offered through a variety of media. CMSWS' interactive floodplain map website offers a complete and legible tool for stakeholders to use. However, this information must also be disseminated in print form and in person at public meetings, and in multiple languages, to reach the greatest number of residents.

Create future conditions flood maps. Looking at future flood risk means being able to plan for the future, not just for today. These maps can help prioritize problem areas that need assistance as well as guide future land use planning. Future conditions should also consider climate change, in addition to future land development. Developing future conditions flood risk maps should involve collecting LiDAR elevation data, maintaining building elevation certificates, incorporating future land use projections, using climate change predictions for rainfall data, and periodic evaluation of flood mitigation projects, among others.

Create a holistic risk reduction plan for multiple hazards with a social vulnerability focus. Community Maps will guide spatial planning, buyouts, and floodplain building regulations, but there are many more tools available for flood mitigation. Jurisdictions must consider and weigh combinations of all of these options for what is best suited for their region and the disasters facing them. Flood mitigation will also be well served through a multi-hazard mitigation plan. Depending on the natural disasters that commonly affect a region, planning for multiple disasters at once may lead to greater cost effectiveness and efficiency in implementation. However, such a plan must account for social vulnerabilities to ensure historically neglected populations are served equitably.

Set up a stormwater utility fee, where possible. This requires public support and state permission in most jurisdictions, but where possible, and done equitably, a stormwater utility fee can become a reliable local funding source that will allow for more freedom in spending compared to federal funds. Otherwise, ear-marking funding for stormwater services from local tax revenues could also offer a local funding source.

When possible, dedicate funding for an in-house technical expert team. Having dedicated staff to manage and update data will help information stay current and relevant. This can often take one or more people working on this full-time. CMSWS has two full-time people working in the GIS department and is able to keep maps updated and run frequent analyses on costs and benefits of mitigation projects, losses avoided after each storm, and share data with other departments such as for land use planning.

4.0 References

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5.0 Appendix

5.1 Dave Canaan Initial Interview over Zoom

August 12, 2020
1.5 hour semi-structured online interview
Dave Canaan is the Director at Mecklenburg County Storm Water Services and has worked here for over 27 years (at the time of this interview). He is trained as Civil Engineer and has worked for the US Geological Survey and Ogden Environmental.

<u>Semi-structured questions:</u>

General

1. What is your current title at SWS?
2. How long have you been with the county's SWS?
3. Have you worked in flood management anywhere else?
4. What are the most common flood types mecklenburg deals with: riverine, rainfall/shallow, coastal?

Risk Maps

5. How have the risk maps, implemented in 2000, been an asset to flood planning in Mecklenburg County?
   a. Were you part of the conversations around implementing local risk maps?
      i. If so, what were the pros and cons weighed then and what do you see as the benefits/drawbacks of the maps now?
   b. What specific programs and policies have the maps been able to inform? And in what way?
   c. How do various city officials vs county residents use the maps? Other users?
   d. Do you have more info on the science behind these and how they're different from FEMA maps? If not, who would know more of the technicalities behind the maps?
      i. Do they use NOAA and USGS? How do those agencies collaborate?
      ii. What are the input variables: elevation, surfaces (absorption rates?), finish floor elevations, man-made hydraulic structures, future conditions/climate change etc.?
      iii. What are the outputs: areas of flooding, flood depths, structures endangered, probabilities?
      iv. What is some of the missing data? Room for improvement in input and output variables?
      v. How often are they updated?

Buyouts

6. Buyout strategies seem to have been significantly informed/shaped by these maps -- can you point to specific ways in which this is true or not true?
   a. Is there data available on flood damages/repetitive loss on properties that have been bought out? Also data on the cost of the buyout (+relocation)?
   b. Is there a running/long term check in process for bought out/relocated folks?
   c. How long do buyouts take in the county now? How long for the quick-buy program?

   d. Are there plans / after the buyout photos you can share of entire neighborhoods that have been bought out and are now being used as amenities?
   e. How have buyouts affected the tax base and revenue?

Other

7. What are some of the other policies and programs (other than risk maps) you have seen that have reduced damages and recovery costs?

Impact

8. What buckets of the city/county budget do various disaster recovery services come from?
9. What is the funding/revenue/budgeting structure for SWS?
   a. What are the components of total revenue?
   b. How is the revenue distributed across the various services SWS provides?
10. What have been the costs of the risk maps (initial and running)?
11. Have you seen/quantified a reduction in damages and recovery costs in the last 50 years after major storm events? A difference in federal aid that you have applied for and received?
    a. Risk to people and communities
    b. Economies
    c. Ecosystems
    d. Social well-being

5.2 Dave Canaan Second Interview over Zoom

September 23, 2020
1 hour semi-structured online interview

<u>Semi-structured questions:</u>

Losses Avoided

- You had mentioned a Losses Avoided Tool and I was wondering if there is someone I could talk to to get figures on $$ spent on buyouts by year, estimated flood damages avoided by year, actual flood damages incurred (# of structures flooded, # of people affected etc), and anything else the LAT has data on.

- Show the difference in number of structures (residential and otherwise) that were *not* in FEMA floodplains in 2000 but *were* in the community floodplains (including those that have been bought out by now): are there records of historic maps available? From what I can see online, the FEMA FIRMS look pretty similar to the CMSWS community maps today but I'm guessing FEMA has updated their maps based on the community mapping recently.

Costs of mapping

- The partner leverage excel doc that you shared shows costs of mapping for miles of streams and a break down of FEMA contributions and partner contributions. Who does "partner" refer to?
- Also, those are the costs of *creating* the maps for those miles of stream, right? What are the maintenance/updating costs of community flood maps (ie how much does SWS spend on upkeep of these maps every 8-10 years)?
- And does the stormwater utility fee or some other funding source pay for that?

Factors contributing to the creation of Community Floodplain Maps

- As you had mentioned, having two back to back storms in '95 and '97 was an important factor because it created an appetite for drastic measures among the public. But what else did it take?
- Do you have any info on how big the GIS team was at the time of initial mapping/how big that department is now?
- Who, other than you, were the biggest champions of creating future conditions mapping? Which other technical experts, city officials, state/federal partners, and local champions were required to make these maps a reality?
- Other than cost, what were there barriers/opposition to the mapping?
- When was the stormwater fee first implemented and did it help pay for the mapping?
- Am I missing any factors that were needed to make this happen?

Doral Cavalier Apts

- Was there something that the community floodplain maps revealed that made this buyout possible and a priority?
- In general, what are the ways in which the community floodplain maps complement the buyout program beyond what FEMA maps could have done?
- Also, I understood that the buyout program’s success came partially from the fact that the county isn’t reliant on federal funds for buyouts (since those have a lot of strings attached) but use the stormwater utility fee to fund buyouts. So how come FEMA funds were able to be used for these buyouts?

5.3 James Scanlon and Dave Canaan Interview over Zoom

October 13, 2020
1 hour semi-structured online interview
James Scanlon is a GIS Analyst for Mecklenburg County with experience in flood hazard mapping, risk assessment, mitigation and planning projects. Scanlon has worked with Mecklenburg County since 2013.

Semi-structured questions:

Maps/Data

- LAT -- figures on $$ spent on buyouts by year, estimated flood damages avoided, actual flood damages incurred (# of structures flooded, # of people affected etc), **by year** since 2000 (any raw version of data is fine too, I'm happy to run analyses myself)
- I want to show the difference in number of structures (residential and otherwise) and area of land (ideally overlaid with land use type) that were *not* in FEMA floodplains in 2000 but *were* in the community floodplains (including those that have been bought out by now):
    - Are there records of **historic flood maps** (community & FEMA) available? From what I can see online, the FEMA FIRMS look pretty similar to the CMSWS community maps today but I'm guessing FEMA has updated their maps based on the community mapping post 2000.
    - Future land use map/GIS as of 2000
    - Current land use map/GIS in 2000
- Do you have any info on how big the GIS team was at the time of initial mapping/how big that department is now?
- (Do the community flood maps use LiDAR data?)

Other

- Process documentation -- public/stakeholder meeting notes/records from the beginning of the mapping process? Who attended, comments that were made etc.
- Flood regulation changes that have been made since the new maps.

5.4 David Love Buyout Interview Over Zoom

December 1, 2020
1 hour semi-structured online interview
David Love is a Project Manager at Mecklenburg County and has worked there since 2007.

Semi-structured questions:

Are there more updated figures than those on
https://charlottenc.gov/StormWater/Flooding/Pages/FloodplainBuyoutProgram.aspx

How do community maps help the buyout program be more proactive? Are there short- & long-term buyout plans?

Dave Canaan said this is seen as a finite project -- what are the foreseeable goals for completing this project?

What is the step-by-step process for a buyout in high risk areas? How long does it take? What kind of campaigning/informing is done to encourage high risk property owners to sell?

What about when a property owner just approaches the city but is not on high priority?

What are average buyout values from the last year? Is this enough for families to relocate within the city?

Are there additional services offered to help a family relocate after the buyout?

What revenue sources fund buyouts? Is it entirely the stormwater utility fee? How much is budgeted for buyouts each year? How much has actually been spent each year? How many properties on avg per year? Final number?

I found the following using GIS datasets available online. Number of structures is calculated using only 2000 building footprints -- is it correct that there are more footprints in the FEMA '99 floodplain than in the Community Maps floodplain?

		Area (square miles)	**Number of Structures (all types)**
FEMA maps effective in 1999	Floodway	10.7	799
	Floodplain	29.5	5,359
	Flood fringe	18.9	4,121

Community Map -- 2004 future conditions	Floodway	17.6 (+65%)	1,604
	Floodplain	30.5 (+3.3%)	4,574
	Flood fringe	13.9 (-26%)	2,904

Relationship with greenway/other urban planning?

5.5 David Goode Flood Regulations Interview over Zoom

December 2, 2020
1 hour semi-structured online interview.
David Goode is a Project Manager at Mecklenburg County Storm Water Services and has worked there since 2005.

Semi-structured questions:

What is your title and how long have you worked at SWS? Have you done similar work in other jurisdictions?

How are floodplain building regulations in Char-Meck meaningfully different from NFIP minimum requirements?

How have building regulations changed since the Community / future conditions maps were developed in 2000?

How have community maps informed land use planning? Are there Future Land Use Plans available from 2000 vs now?

What are the specific tools used to regulate development and buildings? (runoff rates/detention area requirements, cut/fill, FFE, foundation types, other?)

How do these regulations compare to peer cities?

These are my notes from reading through Charlotte's regulations and CFR44 -- is my understanding of them correct?

	Charlotte	CFR 44
Flood protection elevation	100-year (SFHA): All resi new and substantial improvement: CBFE + 1' Nonresi: follow resi or floodproof to CBFE+1' 500-year: 1' above 0.2% flood elevation and all new critical facilities must be outside of SFHA (p26 #11))	SFHA: lowest floor (inc basement at BFE) Floodway: allowed after encroachment review shows no adverse effects of development in floodway.

Building in the flood fringe	SFHA construction: max surcharge of 0.1’ in the comm encroachment area Community Encroachment Area: no encroachments, IFDPs, new construction, substantial improvement, or other Development unless Floodway Engineering Analysis can prove a max increase to community base flood of 0.1’ FEMA floodway: ^same except no increase (0’) to FEMA BFE	1’ surcharge allowed while discharging a 1% flood -- newer analysis shows the amount of fill FEMA allows which should theoretically increase the floodway elevation by 1’ in a 100year storm is actually closer to 2.3’ in CM. So community encroachment area has been widened relative to FEMA floodways on average by 45%
Buildings up to Flood Protection Elevation	Enclosed areas below FPE designed to flood and equalize hydrostatic pressure -- only used for parking and minimal storage/maintenance equipment.	Nonresi: ^ or watertight and only structural components need to be able to withstand hydrostatic/hydrodynamic loads & buoyancy

5.6 James Scanlon Interview on GIS data

February 1, 2020
1 hour online interview, unstructured.

Latest figures on losses avoided?

Methodology