Fire Protection Water Sources for Nantucket

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Abstract

Fire hydrants on Nantucket Island are concentrated in the urban center, but many other areas are left unprotected, and alternative water source records are incomplete. A robust platform that incorporates all water source data could benefit the Nantucket Fire Department (NFD). This project aimed to recommend a mobile firefighting application for the NFD, locate and characterize water sources, and make recommendations to promote fire safety. We recommended a user-friendly application that was best suited for the NFD's unique challenges. We also identified and mapped over 800 pools as potential alternative water sources and over 2,000 homes unprotected by hydrants. With this data, we recommended sprinkler regulation and water main infrastructure upgrades.

Acknowledgements

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Executive Summary

Firefighting on Nantucket

In the United States, the severity of fires has been increasing, necessitating fire departments to have access to multiple reliable water sources. Fire hydrants are the most reliable water source for firefighting, but many rural and suburban areas are left unprotected. These areas could benefit from alternative water sources, as well as a system to map and organize these sources. Many towns and fire departments utilize Geographic Information System (GIS), a spatial database, to map and characterize various water sources. Mobile firefighting applications work in conjunction with GIS data to promptly provide information about water sources to responders.

On Nantucket, an island located 30 miles off the coast of Cape Cod, Massachusetts, the Nantucket Fire Department (NFD) faces unique firefighting challenges. As the only department on the island, Nantucket's location makes it difficult for the NFD to request mutual aid from neighboring departments. Additionally, the island experiences a population spike from 18,000 in the winter to 65,000 in the summer months. The sudden increase in population, along with poorly maintained roads in remote parts of the island, can significantly delay emergency responses during the busy season.

About one in seven fire calls on Nantucket originate from areas unprotected by hydrants. To fight fires in these remote areas, the NFD could benefit from access to private and alternative water sources, such as pools, dry hydrants, and natural bodies of water. Given the importance of water sources to firefighting, the NFD must have access to reliable information on each source's location and quality. The NFD currently uses Rover, a mobile application specialized in sending alerts for incidents and tracking hydrants, but the locations of alternative water sources are not recorded on this application. This project aimed to recommend a mobile firefighting application for the NFD, locate and characterize water sources, and make recommendations to promote fire safety on the island.

Firefighting Applications

We identified four viable candidates for the NFD to consider through our initial research into water source tracking applications. We chose two of these to move forward into the final stage of research: Rover and Active911. We compared these two applications in Table 1.

Table 1. *Comparison between Rover and Active911.*

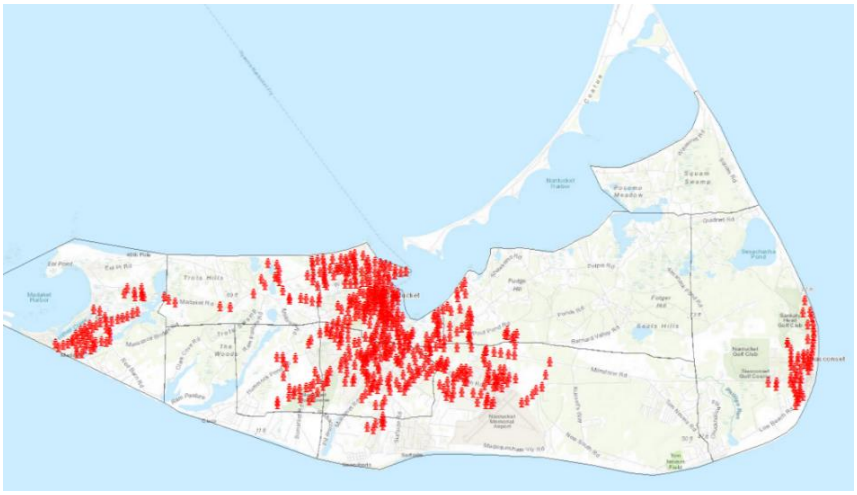
Rover	**Active911**
Pros • Currently used by the NFD • Provides text message alerts	***Pros*** • Flexible water source tracking • Some offline capability • In-app navigation
Cons • No offline capabilities • Alternative water source icons are not available, only hydrants	***Cons*** • Fewer management capabilities • Unfamiliar to the NFD

We recommend Active911 to help the NFD improve its fire response and water source tracking capabilities. Active911's offline capabilities, in combination with excellent alternative water source tracking, led to our conclusion that it is the best fit for the needs of the NFD.

Firefighting Water Sources

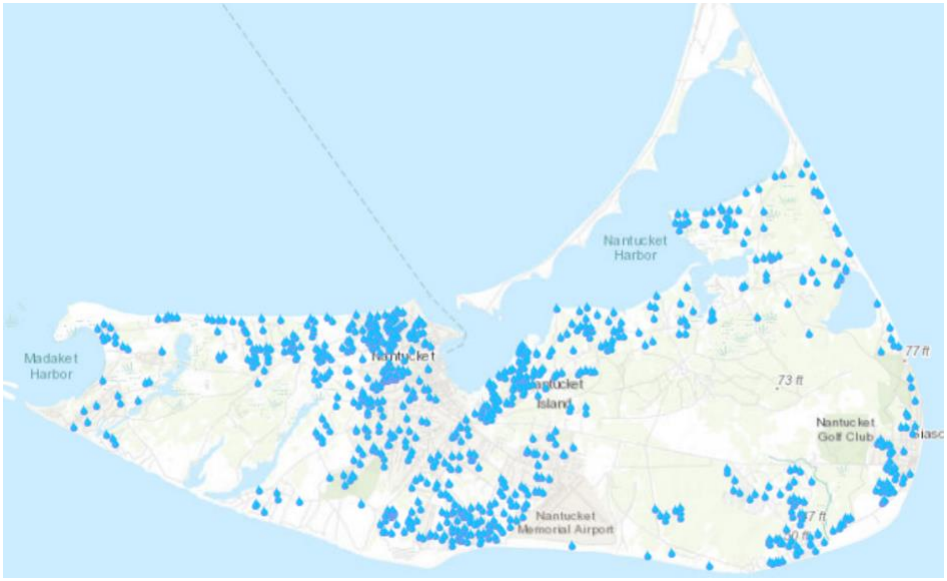
Hydrants are the most reliable water source for firefighting, but they are limited to three primary regions, leaving much of the island unprotected. According to town records, the island of Nantucket contains 592 fire hydrants. They are grouped in Town, Madaket, and Siasconset, as seen in Figure 1. A detailed district map can be found in Appendix D.

Figure 1. *Map of hydrants on Nantucket, marked in red.*



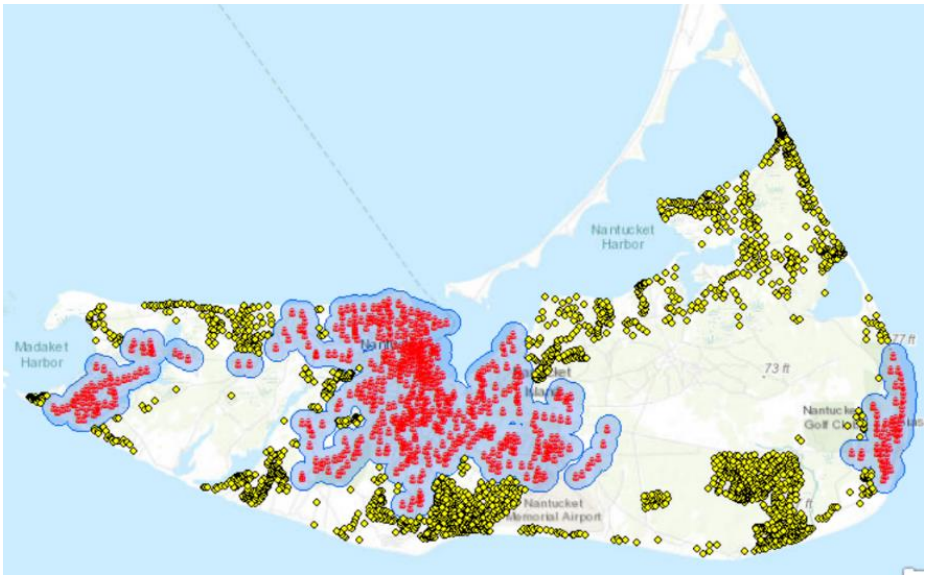
Pools, dry hydrants, ponds, and other alternative water sources are common on the island, but few are consistently reliable for fighting fires. When hydrants are not readily available, the NFD uses alternative water sources, such as swimming pools. We located 852 pools on Nantucket, as shown in Figure 2. However, to effectively draft from a body of water, a fire apparatus must be within 20 feet. We found that only 27 pools, equating to less than 4%, fit this criterion. Additionally, vertically oriented obstacles, such as fences and hedges, are not easily visible via satellite imagery.

Figure 2. *Map of pools on Nantucket, marked in blue.*



Many homes lay unprotected outside of the hydrant buffers; most of these homes are in Surfside, Pocomo, and Tom Nevers. The NFD's fire engines carry a maximum length of 1,000 feet of hose to connect to hydrants. Homes or structures further than 1,000 feet from a hydrant are considered unprotected. We located 2,129 unprotected homes on Nantucket, as shown in Figure 3

Figure 3. *A map of unprotected homes on the island, marked by yellow diamonds.*



The 2020 call data has shown that one in every seven fire calls originate outside of the hydrant buffers. With data provided by the NFD, we created a map of fire calls from 2016 to 2020, with EMS and inspection calls omitted. By comparing unprotected homes with this call data, we found that 13.8% originated from unprotected properties during the five years. When the NFD responds to these calls, they must either utilize alternative water sources or make multiple trips to the closest hydrant using tanker trucks.

Recommendations

- ***We recommend that the Town of Nantucket use available funds to extend water mains and install new fire hydrants in unprotected areas.*** Hydrants are the most reliable water source on Nantucket, and expanding their usage is the surest way to ensure water supply for emergencies all over the island.
- ***We recommend that the Town of Nantucket consider requiring sprinkler systems in newly constructed homes.*** Sprinklers contain fires with less water and damage and reduce the need for alternative water sources in areas without nearby hydrant access.
- ***We recommend that the Town of Nantucket and the Nantucket Civic League consider additional measures for fire protection for recent and new housing construction.*** Areas with new construction outside the hydrant district will benefit from fire protection infrastructure, such as additional dry hydrants and alternative water sources.
- ***We recommend that the Town of Nantucket implement regulations or incentives for future construction of private swimming pools.*** Changes in local regulations could require dry hydrants and clear paths with 20 feet of the driveway for future pools to be accessible by the NFD.

Future Work

- ***Conduct site visits to each pool to determine whether it is accessible and can serve as an alternative water source.*** Although we mapped the pools on Nantucket as potential water sources, their viability for firefighting remains uncertain until they are physically checked.
- ***Enter the alternative water sources deemed accessible into the application the NFD chooses.*** The locations of the alternative water sources should be input as markers, along

with the attributes we recorded and any further information gathered through future work and site visits.

- ***Populate the application with other relevant markers.*** Additional markers, such as beach access points or buildings with specific pre-plans, can aid firefighters in quickly preparing for emergencies in particular locations.
- ***Provide training for the NFD on its chosen application.*** Since the application needs to be regularly updated with water sources, the NFD should be able to populate and utilize the application without aid in the future.
- ***Research the projected population growth on Nantucket.*** Future efforts could research and recommend specific hydrant and water main expansions based upon where future housing developments are expected.

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After outlining sections as a team and writing components of this paper individually, members of the team separately reviewed and commented on each section. The team then collaboratively edited and revised each section. All information shown in the appendices was also a group effort.

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Chapter 1: Introduction

Although the number of fires has decreased in the United States since 1980, deaths and monetary loss caused by fires have increased by 24.1% and 74.5%, respectively, since 2010 (NFPA, 2019; U.S. Fire Administration, 2021a). As the severity of fires increases, so does the need for fire departments to have access to reliable water supplies. The most common and reliable water source used for firefighting is hydrants; there are numerous hydrants found in highly populated areas and fewer in less populated areas of towns (Firefighter Nation Content Directors, 2015). Due to the lack of fire hydrants in less populated areas, fire departments must have access to alternative water sources. These alternative sources include pools, ponds, lakes, rivers, and more (Walter, 2012). Departments that use many different types of water sources need a system to map and organize these sources.

Historically, fire departments have relied on rudimentary methods of locating water when responding to a fire. These include physical maps, diagrams, and the local knowledge of firefighters themselves (National Wildfire Coordinating Group, n.d.). Expanding the water supply beyond a hydrant district—a cluster of hydrants connected by underground water mains—increases the complexity of locating water, creating a need for a singular system that can store data from many sources and promptly provide firefighters the necessary information. Developments in technology have allowed digitized systems to compile data from multiple information sources and continuously be updated and accessed (Active911, 2020; IamResponding, 2021).

Many fire departments utilize digitized databases and applications to map and categorize different water sources. Spatial databases, such as Geographic Information System (GIS), are widely used to map potential water supplies and aid firefighters in efficiently locating water sources during an emergency (Shadin & Tahar, 2015). Fire departments can use GIS data in conjunction with existing user-friendly mobile applications, such as IamResponding, Rover, First Due, and Active911, to map water sources and their individual characteristics to assist with fire response (Nunavath & Prinz, 2016; Shadin & Tahar, 2015). Fire departments that encounter challenges in locating water sources can benefit from using these applications to effectively prepare for and respond to emergencies.

Fighting fires on the island of Nantucket, situated 30 miles off the coast of Cape Cod, Massachusetts, poses unique challenges to the Nantucket Fire Department (NFD). The NFD is the sole fire department on the island, making it difficult to receive mutual aid should a fire become unmanageable. The department has two water tankers that can be driven to a scene, but due to narrow roads, not all streets are accessible by the tankers. Along with a population spike from approximately 18,000 to 65,000 during the summer months, these challenges significantly impact the NFD's response time and resource allocation (Campanelli et al., 2017). In 2020, about one in seven calls originated from areas unprotected by hydrants. Private and alternative water sources could assist the NFD in fighting fires in these areas, but these sources are not mapped on a singular platform (Chief Stephen Murphy, personal communication, April 6, 2021). A potential improvement to the NFD's fire response is to compile the island's water sources into a single database.

This project aimed to recommend a mobile firefighting application for the NFD, locate and characterize water sources, and make recommendations to promote fire safety on the island. The team researched and recommended firefighting applications that fit the NFD's needs and utilized GIS to locate, assess, and compile both current and unmapped water sources.

Chapter 2: Background

This chapter will discuss general challenges faced by fire departments worldwide and how those challenges specifically extend to the Nantucket Fire Department (NFD). First, we discuss the importance of firefighting and common challenges faced by fire departments in remote areas, as well as how the problems that the NFD faces parallel those challenges. We then analyze the various water supplies used to combat fires and how the NFD utilizes water sources. Finally, we highlight the technological solutions that fire departments worldwide use and how the NFD can utilize these technologies.

2.1 Fighting Fires in Remote Areas

This section will cover the importance of firefighting and the challenges faced by fire departments worldwide. It will also cover how these challenges uniquely affect Nantucket and the NFD.

In the United States, there are many human, wildlife, and financial consequences resulting from fires. Fire departments respond to fire emergencies throughout the country every 24 seconds (Ahrens & Evarts, 2020). While the number of house fires is in decline, the danger posed is still severe. In 2019 alone, fires caused over 20,000 civilian injuries and deaths, in addition to $14.8 billion in property damage (Ahrens & Evarts, 2020). Furthermore, forested areas, grasslands, and shrublands are at high risk for wildfires. As reported by the United States Environmental Protection Agency (EPA), wildfires have increased in number and severity since 1983. There is an average of 72,000 wildfires each year (US EPA, 2016), illustrating the importance of effective firefighting strategies across the country.

To understand how firefighting can be affected by the landscape of remote areas, one must first understand the specific challenges that geographic features present. Mutual aid is the ability to call upon nearby allies to assist in fire response and allows any department to multiply its resources during times of need. Mutual aid allows for responses to larger and more complex incidents, shorter response times, and access to specialized resources (Stephens & Coutier, 2019). The annual National Fire Protection Agency (NFPA) Fire Experience survey notes the prevalence of mutual aid in the United States. The NFPA found that in 2018, fire departments made 1.32 million calls to fires, while 1.51 million were responses solely for mutual aid (NFPA,

2019). In conjunction with a growing proportion of mutual aid calls since 1980, this data demonstrates the utility of outside help.

While providing mutual aid on islands, the restriction of traveling to the island via air or water presents a challenge in promptly transporting firefighting equipment and personnel. A variety of methods provide solutions to this problem, usually depending on the distance between departments. For example, fireboats from the nearby towns of Bristol and Portsmouth helped extinguish a fire extending across three homes on Prudence Island, Rhode Island in 2021 (Doiron et al., 2021). In Hawaii, the Intrastate Mutual Aid System project has identified the Hawaii Air National Guard as the primary method of moving fire protection resources among islands (Oliviera, 2012). The mutual aid response on an island is dependent on location as well as existing nearby transportation options.

Nantucket poses fire prevention challenges like other remote locations, as well as unique challenges of its own. Nantucket, an island community located in Massachusetts, United States, cannot quickly receive mutual aid from other departments when combating fires. It takes between thirty minutes and an hour to reach Nantucket from Martha's Vineyard or Cape Cod by ferry. Figure 4 demonstrates the isolated location of Nantucket relative to Martha's Vineyard and the mainland. Nantucket has only received mutual aid once from other departments in the past 15 years and must rely solely on water sources found within the island (Sean Mitchell, personal communication, March 3, 2021).

Figure 4. *Nantucket's geographic location relative to Cape Cod and Martha's Vineyard. Nantucket is in the bottom right of the map.*

The lack of access to water sources due to insufficiently sized and maintained roads can present a challenge for fire departments. Privately owned and maintained roads in remote areas can often be too narrow, poorly managed, or even impassable for emergency vehicles, such as fire engines (Cocks et al., 2012). These private ways generally must be maintained by the owner, but some locations allow towns to make repairs under certain conditions. For example, Massachusetts General Law states a municipality may still make "temporary repairs on private ways" under certain conditions, including "public necessity" (Mass. Gen. Laws 2021). Even with this ability, it can still be difficult for a municipality to track, manage, and fund repairs on large areas of private roads (Cocks et al., 2012).

Privately owned roads make up most streets on Nantucket, and many of these are either in poor condition or narrow (Lippert et al., 2016). These qualities pose challenges for the NFD since some roads are inaccessible by their fire engines and other emergency equipment. Figure 5 shows one of the NFD's fire engines on a narrow road en route to a call. An emergency vehicle becoming restricted on the way to a call will impede the NFD's ability to respond promptly and effectively.

Figure 5. *A Nantucket Fire Department engine on a narrow road in Nantucket.*

Nantucket's population fluctuates significantly throughout the year, resulting in a higher strain on the NFD during the summer. A previous study estimated the yearly population of

Nantucket and identified population growth and loss trends. Through analysis of solid waste production as well as ferry, airport, and traffic data, the study concluded that Nantucket's population spikes to around 65,000 during the summer and drops to a low of approximately 18,000 people during February (Campanelli et al., 2017). In addition to the population spiking, the NFD experiences a rise in fire calls during the summer. The number of EMS calls received by the NFD increases along with fire calls, further limiting the amount of available personnel. As shown in Figure 6, the number of fire emergency calls is generally proportional to the island's population; the calls peak at approximately 230 in July as the population spikes, with the least number of calls in February with about 85.

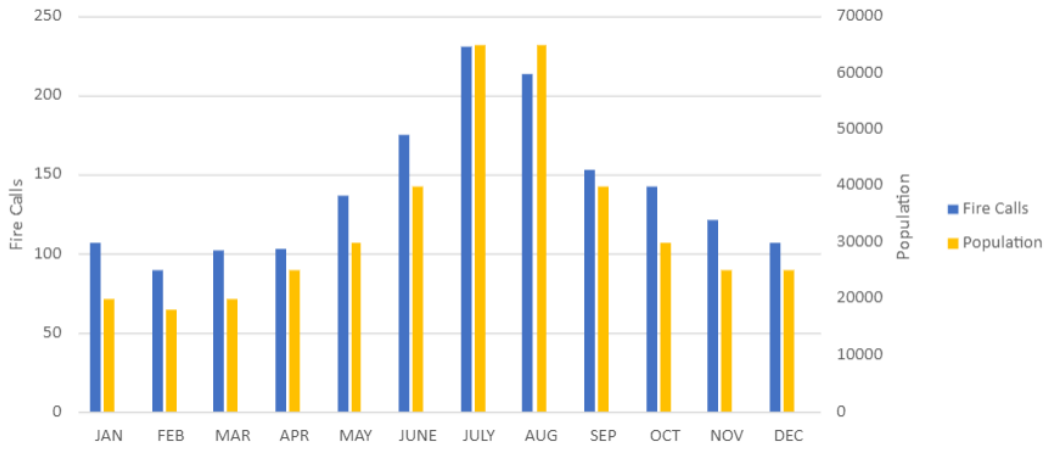

Figure 6. *Nantucket's average population and fire emergency calls over the past five years (2016-2020) by month.*

The population fluctuation and rise in fire call frequency pose a problem for the limited staff of the NFD (Chief Stephen Murphy, personal communication, February 12, 2021). To manage the population and fire call increase and help maintain Nantucket's fire safety, the NFD staffs 36 personnel. However, only three to six people are on active duty at any given time for the entire island; there are usually three people on duty during most of the year and at least four during the busy summer season. This number has remained stagnant over the past few years because it is difficult for the NFD to recruit new members due to the high cost of living on Nantucket (Sean Mitchell, personal communication, March 3, 2021). The NFD currently possesses the following vehicles: seven engines, one ladder, and two tankers (Cape Cod Fire Department, 2021). As the population grows in the summer, the relative size of the department

decreases. Since resources are more likely to be stretched thin during the summer, a lack of available personnel or equipment may delay the response to a large fire. Similarly, the increase in population causes an increase in traffic from both residents and tourists. These spikes sometimes cause delays when the NFD responds to calls in the summer, resulting in a slower and less effective response (Sean Mitchell, personal communication, March 3, 2021).

The NFD must be better prepared to efficiently utilize resources, especially during the summer months when the island's population spikes. Being able to identify a suitable water source for fires rapidly is of utmost importance. If the department can improve the speed at which they locate water sources for fighting fires, they can better protect the population of Nantucket.

2.2 Water Supplies for Firefighting

In this section, we will describe the different water sources commonly used in urban, rural, and suburban areas, as well as the different types of alternative water sources that can be used for firefighting. It will also discuss the water sources available for use by the NFD.

Municipal water sources, such as fire hydrants, are the most utilized water supply for fighting fires in urban areas (NFPA, 2019). Figure 7 demonstrates the mapped hydrants in the Town District of Nantucket.

Figure 7. *Map of fire hydrants in downtown Nantucket, Massachusetts. The red and brown symbols indicate fire hydrants and houses, respectively.*

Fire departments in remote areas use municipal fire hydrants and alternative water sources to fight against fires. Hydrants are most commonly found in urban areas, while they are more sparse in rural and suburban areas as homes become spaced further apart (NFPA, 2019). Figure 8 is a map of the suburban Cliff District of Nantucket Island, which shows the sparsity of hydrants in less densely populated areas. Due to the lack of hydrants in rural and suburban areas, many fire stations respond to fires with tanker trucks that store water in large tanks to supply the fire engines. Tankers are limited to carrying a fixed volume of water, and responders must replenish by driving to and drafting from the closest reliable water source when the water runs out. The most common alternative water sources found in rural areas include ponds, lakes, bays, rivers, streams, and swimming pools (Walter, 2012).

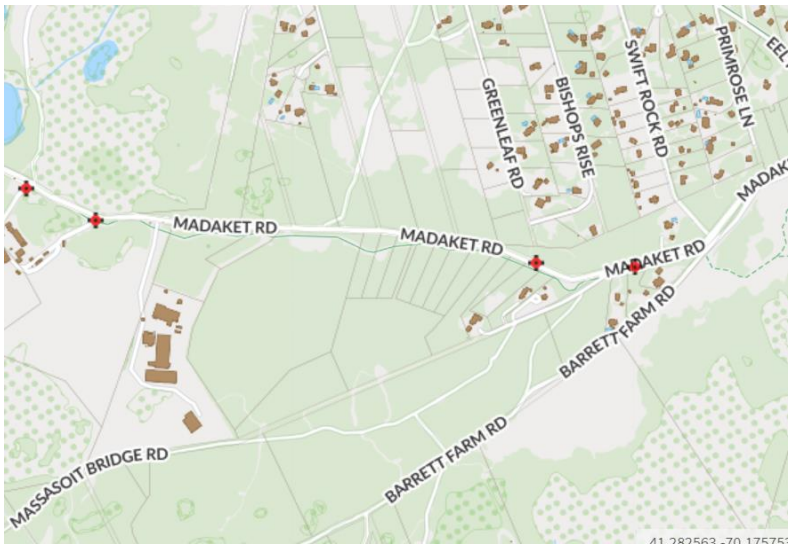

Figure 8. *GIS map of fire hydrants in the Cliff District of Nantucket, Massachusetts.*

Although fire hydrants are the main water source for firefighting and can be easily found in most towns, keeping track of alternative water supplies in case of failure or inaccessibility of hydrants can aid firefighters in quickly adapting their response plans. In an emergency, consideration of the fire's size and location are critical to identifying alternative water sources as larger fires require a greater volume of water. Furthermore, a water source's volume, accessibility, and reliability over time are paramount to selecting appropriate water sources (Buchanan, 2002). For example, some lakes or ponds that can serve as alternative water sources during the summer may have frozen over during the winter.

Natural bodies of water tend to be much more difficult to collect water from than hydrants and may not be efficient in an emergency, especially if there are more accessible water sources nearby (Wang & Shih, 2018). When drafting water from an alternative source, the pumps used by fire departments can only provide suction for about 20 feet of hose. If the trucks cannot get within this distance, the pumps cannot provide enough suction to draft water (Chief Stephen Murphy, personal communication, February 12, 2021). Pools can be a beneficial resource to fight fires in remote areas if they are accessible by the trucks; firefighters can use the water from residential or public pools to save a neighboring house along with water from a tanker truck (Walter, 2012). However, many pools are in the backyards of properties, and trucks often cannot get within the necessary distance to draft water. On the other hand, in-ground water tanks are typically situated in locations accessible to the fire department. Tracking these alternative water supplies can assist firefighters in assessing other potential water sources in the area and selecting the most suitable one.

Aside from fire hydrants, Nantucket mainly relies on ponds, in-ground tanks, and swimming pools as alternative sources to provide water for fighting fires. Hydrant systems utilize ponds as a water supply, which protect densely populated areas such as downtown Nantucket (Town and County of Nantucket, 2021). Due to a lack of hydrants in the rural and suburban areas, the fire department often uses its two tanker trucks to transport water to fires in those unprotected areas (Chief Stephen Murphy, personal communication, February 12, 2021). However, if the roads leading to those unprotected areas are inaccessible or poorly maintained, they can pose a significant problem for the responders trying to access water sources or reach the scene of a fire. The NFD must find nearby, substantial water sources that its trucks can quickly access to collect water and extinguish fires. If that is not an option, the fire department can use private water sources, such as pools and in-ground tanks, to collect the necessary water to put out a fire. These alternative sources are less reliable, as they are not as well documented or substantial in volume as local ponds (Chief Stephen Murphy, personal communication, February 12, 2021).

2.3 Technological Solutions & Databases for Firefighting

This section covers how databases can characterize private and municipal water sources for emergency responders to use when extinguishing fires in various locations. Databases with

geographic information about water sources help fire departments plan for and react to calls quickly and efficiently (Shadin & Tahar, 2015). This section also covers how the NFD uses these databases and the department's technological challenges.

A Geographic Information System (GIS) is a type of database that digitally stores spatial data and displays data points with their respective geographic associations. GIS has many features to help analyze geographical data, such as finding patterns, combining datasets, making measurements, predicting scenarios and statistics associated with location, and visualizing data as maps (Bernhardsen, 2002). GIS maps of towns and cities often show the locations of residential areas, buildings, and roads, as well as fire hydrants and other water sources.

Mapping water sources is beneficial for emergencies, especially in remote areas that lack water sources (Shadin & Tahar, 2015). GIS is commonly used for modern firefighting worldwide to track water sources as it is much more efficient than paper documents and maps. Potential water sources, including fire hydrants, swimming pools, tanks, and natural bodies of water, can be entered into GIS along with their location, size, and quality as some of the factors that can help determine whether the source is viable in an emergency. Depending on the factors that affect the amount of water needed for a given fire emergency, such as the fire's location, rate of growth, intensity, and duration, firefighters can use the database for finding the most appropriate water source for the scenario (Buchanan, 2002). Many GIS maps already include the locations of fire hydrants. However, additional information, such as hydrant conditions and private water source characteristics, can provide extra support to emergency responders who need to take swift action. Many towns and cities already have GIS data that maps municipal water systems with details about the sizes of tanks, the number of pumps, reservoirs, and topology of specific areas. The town and fire department can use GIS maps to identify areas where they can add valves for new fire hydrants into water mains, especially in high-risk or isolated areas (Jolly et al., 2014).

Furthermore, since GIS data is highly compatible with other software, there are various existing mobile applications designed for firefighters that utilize local GIS data to show a variety of relevant information. Many of these applications have robust features that vastly improve a department's fire response. Some of the most useful features include organizing mutual aid, storing pre-plans, displaying global positioning system (GPS) routing to the scene of an emergency, mapping and tracking hydrant and alternative water sources, scheduling, and

documenting incident reports (Jolly et al., 2014; Nunavath & Prinz, 2016; Shadin & Tahar, 2015). When organizing mutual aid, many applications allow cross-communication between departments using the same application. Most applications allow for map markers to depict water sources and store characteristics or notes about each source. Some applications have built-in GPS routing or utilize an Application Program Interface (API) for Google Maps to route the responder to the scene when an alert arrives. Finally, many of these applications provide a centralized location to store and complete paperwork, such as scheduling shifts, planning overtime, and filing incident reports after an emergency.

GIS-based applications can further assist fire departments by quickly identifying municipal water sources that are out of service and communicating with the appropriate local departments to resolve the issue. They can also provide firefighters with live information about the alternative water sources that fire departments can use in place of inoperative fire hydrants (Shadin & Tahar, 2015). Applications such as these assist in communication by helping fire departments communicate with other emergency services to transmit information about ongoing emergencies and keep firefighters connected (Huang et al., 2007). Some popular existing applications used by fire departments include IamResponding, Active911, Rover, and First Due.

The NFD currently relies upon Rover to relay hydrant, water source, and call data between the department and their dispatch system. Dispatch uses the town's GIS maps to locate the nearest hydrant to the emergency. Then, dispatch passes the hydrant information to Rover, which sends the call information to firefighters through text messages. Private water sources are currently not mapped or recorded on Rover; their locations are primarily within the memory of the firefighters on the island and may be forgotten over time or during high-stress situations (Sean Mitchell, personal communication, March 3, 2021).

With all these challenges in mind, a previous study from 2016 set out to improve the response of the NFD, specifically by optimizing the response time to calls in the area. Through GIS-driven research, the group concluded that by renovating and reopening one of NFD's satellite stations, improving the dispatch system, hiring more staff, and purchasing a dynamic deployment vehicle that could navigate the narrow streets, the NFD could reduce its average response time by about 30% (Lippert et al., 2016). While this study showed that these methods would improve the response time of the NFD, especially for EMS calls, it did not consider the

importance of having reliable data about water sources used during an emergency. Although the NFD has an effective fire response system, quickly locating and supplying water sources can further enhance that response.

Chapter 3: Methodology

This project aimed to recommend a mobile firefighting application for the Nantucket Fire Department (NFD), locate and characterize water sources, and make recommendations to promote fire safety on the island. To accomplish this goal, we implemented the following research objectives:

1. Research and recommend an application that the NFD can use to determine viable water sources in a fire emergency.
2. Assess the water supply currently known by the NFD, including hydrants and private water sources.
3. Locate and map unrecorded private and alternative water sources on Nantucket Island accessible by the NFD for fire emergencies.
4. Compile water sources and their respective characteristics into a single database.
5. Identify areas on the island unprotected by reliable water sources.

This chapter reviews the methods we used to recommend a firefighting application, assess the current state of Nantucket's water supply, map the unrecorded alternative water sources, organize this information into a single database the NFD can use to improve its firefighting response capabilities, and identify unprotected homes to make recommendations to improve fire prevention on the island.

3.1 Recommend Firefighting Application

We first gathered a list of existing applications that assist in optimizing firefighting efficiency. The purpose was to determine a firefighting application that best fulfilled the NFD's needs. The following questions guided our search for an application that fits these needs:

1. What are the critical features required in an application during a fire response?
2. What is the relative priority of each feature or requirement?
3. What qualities and capabilities does each application have compared to other applications?
4. What method can be employed to compare the different applications and identify the most suitable one for the NFD?

Through a series of interviews, we compiled a list of the key features Chief Stephen Murphy, the chief of the NFD, wanted in an application. Using those features, we began researching firefighting applications based on what other fire departments use and compiled all their characteristics into one location to compare between applications easily. We chose to quantify each application's capabilities and the relative importance of each capability. We analyzed nine applications and their critical features to create a decision matrix, shown in Appendix A.

We rated each application with respect to each capability on a scale of 0 to 3, where 0 meant the application lacked that specific capability, 1 meant the application performed that capability poorly, 2 meant the application adequately performed the capability, and 3 meant the application excelled at the capability. When rating each category, we used information from the application's websites to determine how each application's capability should be rated. We also assigned each category a weight between 1 and 5 to quantify the importance of specific features and capabilities. The weights of each category were determined through interviews with the NFD. For example, we gave the ability to map hydrants and alternative water sources both the maximum weight of 5 because that was a top priority for the NFD. The mutual aid capability was given a weight of 1 since it is infrequent due to the island's location. We multiplied each application's rating per category by each category's respective weight and summed up the totals to get a score for each application.

We presented the first matrix to Chief Murphy, along with questions about the multipliers of each capability to reassess the relative priority of each feature for the NFD. The full interview protocol can be found in Appendix B. Using Chief Murphy's feedback, we reevaluated the weights assigned to each capability, narrowed down the applications to four in Appendix C, and acquired free trials for each of those four applications. With the free trials, we were able to gain knowledge about each application's user interface and capabilities. Then, with this data and experience using the applications, we revised the rankings in the decision matrix and presented the new matrix to Chief Murphy for his final decision. Concurrently, we began assessing the current water supply known by the NFD.

3.2 Assess Current Water Supply

To assess the NFD's current water supply, we identified which water sources, including hydrants and bodies of water, were mapped on the town's Geographic Information System (GIS) maps and analyzed the characteristics of these water sources. The purpose of this assessment was to check which water sources the town already had on file and what recorded characteristics would be helpful for firefighting. We assessed the currently mapped water supply by gathering information from the NFD and Nathan Porter, the town's GIS coordinator. The GIS map layers of water sources that we received from Nathan Porter documented bodies of water such as rivers, ponds, and lakes, as well as fire hydrants. After the group compiled and mapped the various known water supplies used by the NFD, we then cataloged the different characteristics of each water source. These characteristics include:

- ***Location:*** This provides responders with the location of each source so responders can easily find it in relation to a fire call.
- ***Total volume available:*** This is useful for determining how much water firefighters can draft from a source and whether the amount will be enough for a specific fire emergency. Although the volumes of water sources are usually rough estimates, they still provide information about the relative size of each source.
- ***Volumetric flow rate (gallons per minute):*** This lets responders know how quickly they can draft from a supply, which can be helpful in urgent fire calls.
- ***Ease of access:*** Information about accessibility, such as narrow roads or inconvenient drafting locations, provides more insight into how long it may take to get to a water source or draft from it.
- ***Last evaluation:*** The date of the source's previous evaluation suggests how reliable a particular source may be.
- ***Connection type*****:** The type of connection is vital so that responders in tanker trucks can bring the correct hose connections for the hydrant.

We determined these key characteristics by interviewing and meeting with Chief Murphy and Fire Prevention Officer Sean Mitchell of the NFD; these interview questions can be found in Appendix B.

3.3 Review Unmapped Alternative Water Supplies

Next, we reviewed unmapped private and alternative water supplies. The purpose was to create GIS layers of unmapped sources that can serve as potential water supplies for fires outside the hydrant district. We met with Chief Murphy to determine which alternative and private water sources were viable for the NFD. These alternative water sources include:

- Private and public pools
- Dry hydrants
- Drafting points of bodies of water

To locate the pools, we used Google Earth satellite imagery and drew district lines on the island to split it up into ten districts, as shown in the map in Appendix D. The district lines were drawn based on major neighborhoods of Nantucket, as opposed to an existing district map of the island. We surveyed each district and placed a map marker on each pool's location to prevent overlap or duplication. We measured the surface area of each pool by using the measure feature on Google Earth, which provided rough estimates for our final database. We also checked the accessibility of each pool by measuring the distance from the nearest driveway to the closest point of the pool. We concurrently entered the data into GIS layer containing the pools on Nantucket to record their individual locations and attributes using ArcMap.

This method presented several limitations in our ability to analyze pools. The two-dimensional nature of satellite imagery only enabled us to determine the pool surface area but not volume. While the area can give a sense of size, volume is the better metric for how much water each pool contains. Additionally, since elevation changes and vertical objects such as fences and shrubs are challenging to see, many of our accessibility measurements could take a path through a solid object. Finally, since the most recent satellite photography is from 2019, the data does not reflect changes since then. Due to these limitations, our mapped GIS data will need to be updated regularly.

To determine the location of the dry hydrants and drafting points, we consulted with Chief Murphy. Once we collected the viable private and alternative water sources, we recorded each type of source in separate GIS layer files and compiled them into a database to hold the location and attribute data for all of Nantucket's water supplies.

3.4 Create Water Supply Database

We used the mapped pool, hydrant, and alternative water source data collected from the previous sections to create a water supply database and compiled them within a single GIS map. The purpose of the compilation of water sources was to create a single access point for all water source information. The database included the NFD's existing data on their primary water sources, as well as the additional private and alternative water sources that were previously undocumented. Additionally, we added relevant information about each water source's characteristics to the database, such as those listed in section 3.2. By compiling the alternative water sources with the town's GIS data, we created a single platform that contained the locations and characteristics of each water source, making it more straightforward for the NFD and other organizations on Nantucket to access the data. We shared this map with the town so that other interested groups can access it in the future.

3.5 Map Unprotected Areas

Finally, we used GIS to create a map of areas on Nantucket protected by hydrants. The purpose of mapping these protected areas was to create a clear visualization of locations on the island outside of the hydrant buffer. We created the hydrant buffers as a GIS layer displaying the areas of the island within a 1,000-foot radius of a hydrant. We marked each home outside the hydrant buffer, along with its address, on a separate GIS layer. Additionally, the NFD has been cataloging their incoming fire calls as per state regulations, over the past five years. This data allowed geocoding of their fire calls, or locating specific places based off street address, zip code, state, and country, using complex geographic algorithms. We used Google Earth's geocoding algorithm to locate where fire calls took place and then exported the locations into a GIS layer. We then compared the locations of fire calls and unprotected homes to identify areas with a high concentration of calls but do not have reliable water sources nearby.

Chapter 4: Evaluation of Firefighting Applications

This chapter presents an evaluation of the top mobile firefighting applications that the Nantucket Fire Department (NFD) could use to improve fire response. We will also present the findings from our interviews with NFD firefighters about the top two applications: Active911 and Rover.

Table 2 lists the nine firefighting applications and rankings of their performance concerning the most essential criteria for the department. As shown, only four applications addressed these criteria adequately, so our analysis focused on Active911, First Due, IamResponding, and Rover. For a complete matrix of all the criteria considered for each application, refer to Appendix A.

Table 2. *Initial decision matrix with all nine applications considered, along with their respective rankings for each capability.*

Application	**Water Source Tracking Customizability**	**Alternative Source Tracking**	**Hydrant Tracking**	**GPS Directions**	**Offline Capability**
Active911	3	3	3	3	3
First Due	3	3	3	3	3
IamResponding	3	3	3	3	0
Rover	3	2	3	3	0
Rapid Response	2	2	3	3	0
Rhodium Incident Management Suite	1	1	2	0	3
Alertfind	0	0	0	0	0
ESO	1	0	1	0	0
PSTrax	1	0	0	0	0

One of the features strongly considered was offline capability due to the lack of reliable cell service on the island. Figure 9 shows cell coverage on Nantucket Island sourced from Opensignal, an application that collects cellular data from users to map the quality of service

across the island. The best cell coverage is near the Town District in the center of the island, but it quickly deteriorates as one moves into the island's outskirts. Without the ability to access data offline, Rover and IamResponding become unusable if cell service fails. However, the NFD is located near the center of the island and could use these applications at the station before heading to a call. Active911 and First Due both work offline, allowing responders to access preloaded data in areas with poor service.

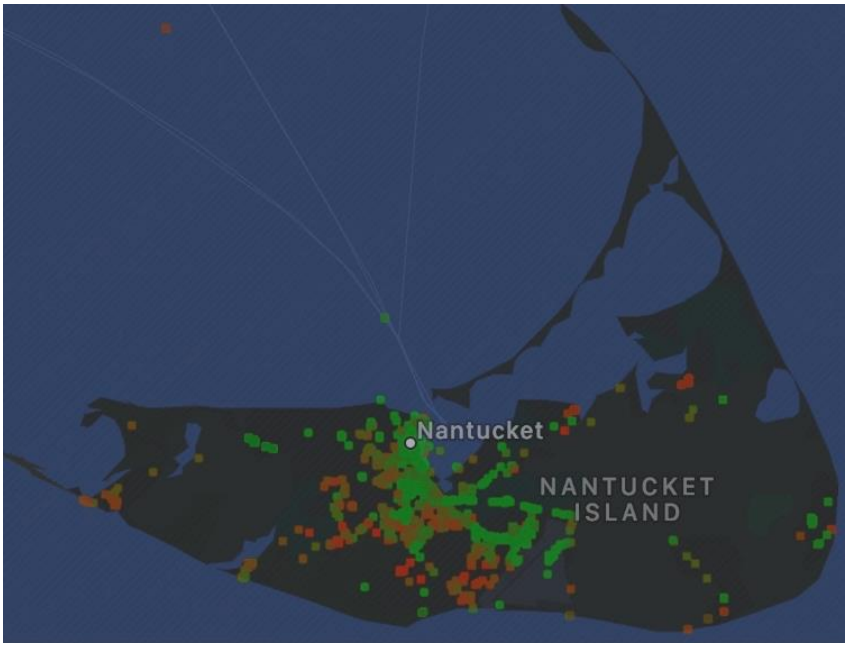

Figure 9. *Cell coverage on Nantucket. The gradient from green to red represents excellent to inadequate cell coverage, respectively (Opensignal, 2021).*

The features tested through the free trials of Active911, IamResponding, and Rover were evaluated and entered into Table 3. Upon completing the demonstrations, we confirmed that IamResponding and Rover lacked offline water source tracking capabilities. It is also important to note the differences in price between the applications. IamResponding, Active911, and Rover are approximately the same price, while First Due was far more costly. As shown in Table 3, all these applications would be suitable for the NFD. Chief Murphy decided to move forward with Active911and Rover due to their ability to integrate with Emergency Reporting, an application that the department will use for records management and incident reporting. Emergency Reporting assists departments in limiting human error and time spent on paperwork. For a

complete matrix with all criteria considered for each of the four applications, refer to Appendix C.

Table 3. *The final decision matrix with the top four applications and their respective rankings for some of the most important capabilities.*

Application	Price	Alternative Source Tracking	Offline Capability	Customer Service	Users
Active911	$875	3	3	3	300,000
First Due	$2000	3	3	1	5,000
IamResponding	$800	3	0	3	400,000
Rover	$960	2	0	2	25,000

Rover can map fire hydrants and categorize them by their different flow rates delineated by the different colors shown in Figure 10. Hydrants are the only available map markers in Rover, so mapping alternative water sources is not as effortless as other applications. Rover also does not allow the user to input custom data for each hydrant and instead has required preset fields for new markers, such as flow rate and test date.

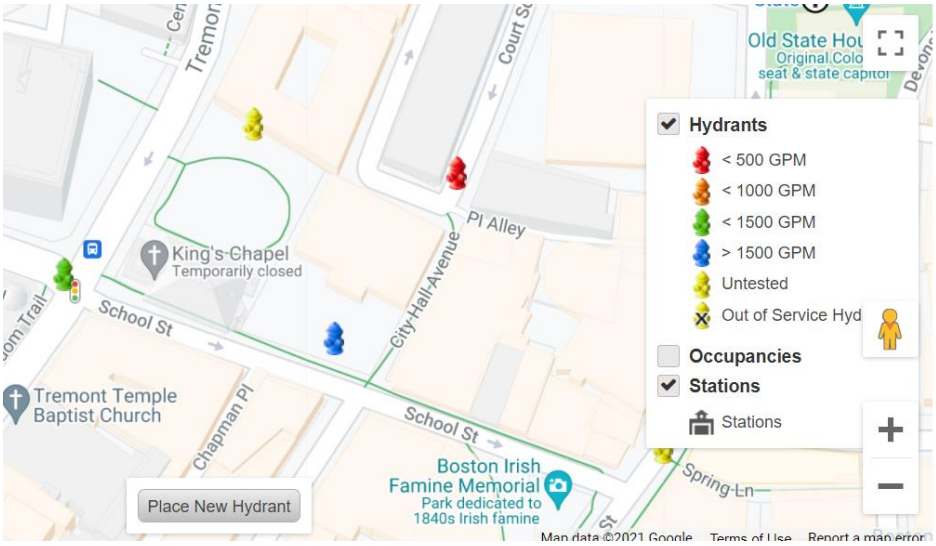

Figure 10. *Rover's hydrant tracking capabilities. Users can add a new hydrant by clicking the button on the bottom left, and hydrants are color coordinated by flow rate.*

In Active911, there are many different map markers and color options to define the different types of water sources. For example, a red hydrant marker can denote a hydrant with a higher flow rate, and a faucet marker can indicate a pool or other alternative water source. Within each map marker, the user can input different attributes that can be seen by clicking on the source, such as the red hydrant in Figure 11. Map markers with various icons can indicate other critical locations, such as beach access points for EMS calls.

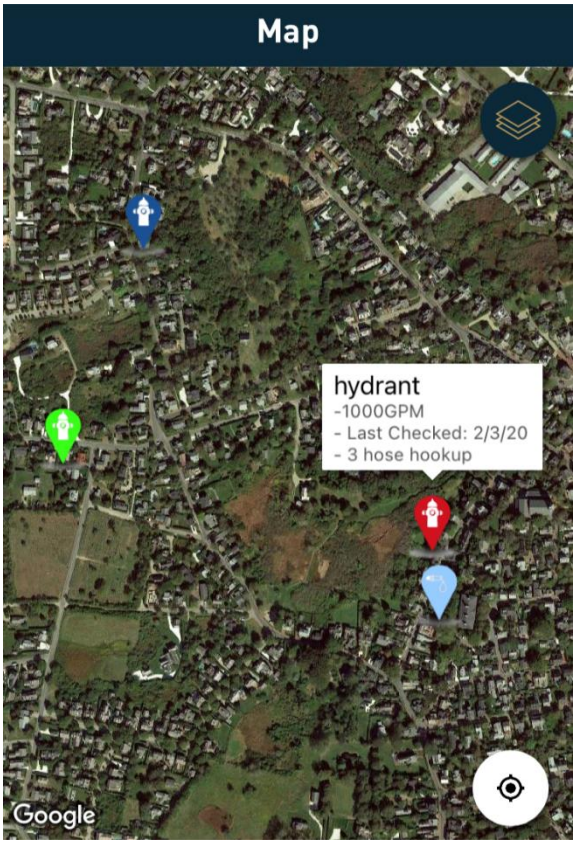

Figure 11. *Active911's water source tracking capabilities. This map shows both hydrants (hydrant symbol) and pools (faucet symbol). Accessing information about each source is completed by pressing down on individual markers.*

If it is not clear where the nearest water source to the location of a call is or if a fire requires multiple viable water sources, users can hold their finger down on the location of a fire scene. The application will provide the distances of the nearest sources. As seen in Figure 12, a dark gray target marks the address, and the closest source found was the green hydrant. The nearest water source feature searches all varieties of sources.

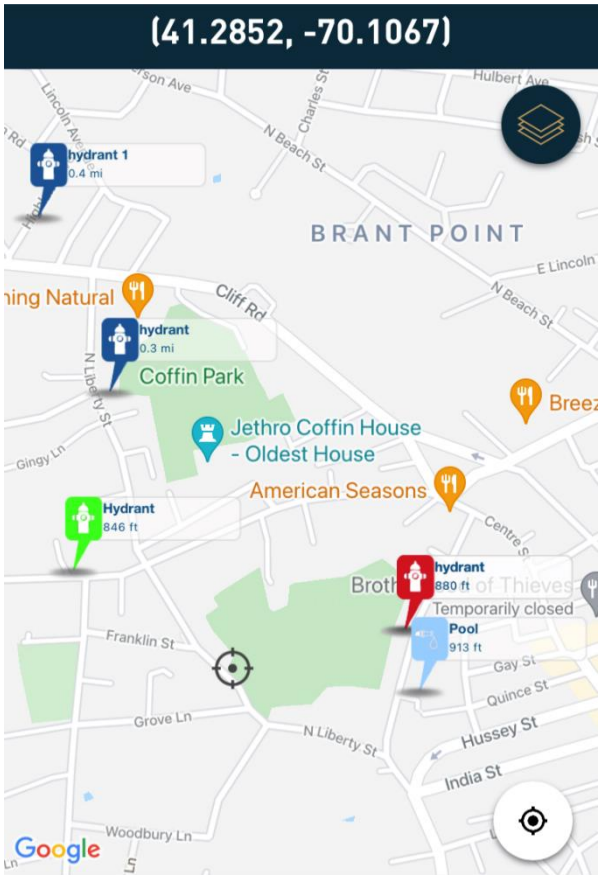

Figure 12. *Active911's capability of displaying the distance to water sources. By pressing down on the screen, the user places a marker (dark gray), and the program computes the distances to each hydrant, allowing users to determine the closest water source.*

In addition to source tracking, GPS routing is a capability favored by the NFD. While Rover relies on external destination applications, such as Google Maps and Apple Maps, GPS routing to the scene can be done within the Active911 application or externally in Google Maps or Apple Maps. In the example situation shown in Figure 13, an emergency is occurring at Worcester Polytechnic Institute (WPI), and a firefighter is responding to the call by opening the application and updating their status.

Figure 13. *Active911's GPS directions. In this situation, a firefighter has received the alert for a nearby fire and has indicated they are responding. Shown also is the navigational route to the scene.*

Another capability of Active911 is its ability to integrate with Emergency Reporting, as well as interfacing with the dispatch system through Simple Mail Transfer Protocol (SMTP). When dispatch receives a call, an alert is sent to Active911 through SMTP, as shown in Figure 14, and firefighters can begin their response procedure. Once the NFD resolves the emergency, the information can be sent directly to Emergency Reporting through an Application Program Interface (API). The alerts tab allows firefighters to set their status, view who else is responding via the log tab, and view the location and address of the alert.

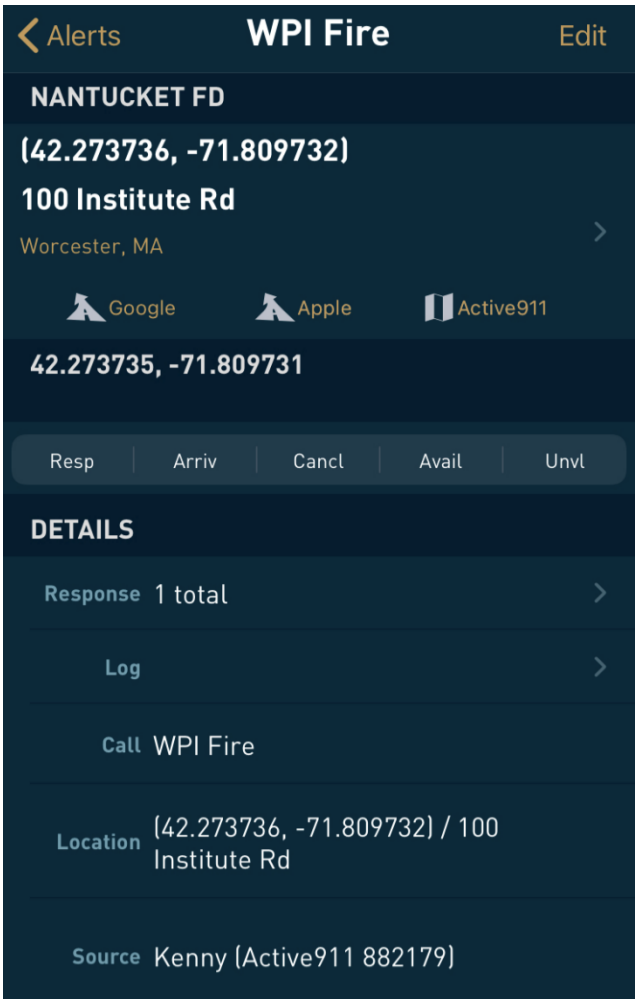

Figure 14. *Active911 receives an alert through SMTP. Each responder can set their status and click a link to redirect to either Google Maps, Apple Maps, or navigate with Active911's integrated navigation.*

Interviews with four NFD firefighters revealed that the firefighters found Active911's water source tracking capabilities highly informative and user-friendly; the interview questions can be found in Appendix E. The firefighters noted the current Rover application did not have as much information regarding hydrants as Active911 and is primarily used to receive call location notifications. On investigating the NFD's firefighting procedure, we found that dispatch sends the information to a separate application called ProPhoenix during fire responses. This application then relays a link to Google Maps to the scene of the emergency for the responders. The firefighters stated that Rover and ProPhoenix have restricted source tracking capabilities,

necessitating the department to rely on dispatch for directions and hydrant information. For more in-depth interview notes, refer to Appendix F.

It is noteworthy to mention limitations in the application research process. In some cases, information about the water source tracking capabilities was limited. In addition, the free trials were not standard amongst the final four applications. IamResponding and Rover only gave single person free trials, making it difficult to understand how users interact within these applications. Active911 provided a full free trial as the application would be used in the department, while First Due did not have a free trial of any capacity.

Chapter 5: Assessment of Water Supply

This chapter presents an analysis of the current water supply utilized by the Nantucket Fire Department (NFD) and alternative water sources that can be accessed for future fire responses. We will also present the areas of the island that are left unprotected by a lack of reliable water sources, as well as the fire call data recorded by the NFD over the past five years.

5.1 Current Water Supply

In the following chapters, we will be referring to these districts defined in Figure 15. This map was designed to identify the neighborhoods of the island that are dense in water sources or left unprotected during fire emergencies. In addition, the mapped data presented in this chapter is shown in Appendix G by district.

Figure 15. *Custom district map of Nantucket.*

Nantucket's hydrant district is limited to areas with underground water mains, leaving large areas of the island unprotected by a reliable water source. Hydrants provide an adequate

water flow rate with effectively no limitation on volume. Figure 16 shows the 592 hydrants on Nantucket concentrated in Town, Siasconset, and Madaket, and Table 4 shows the number of hydrants by district.

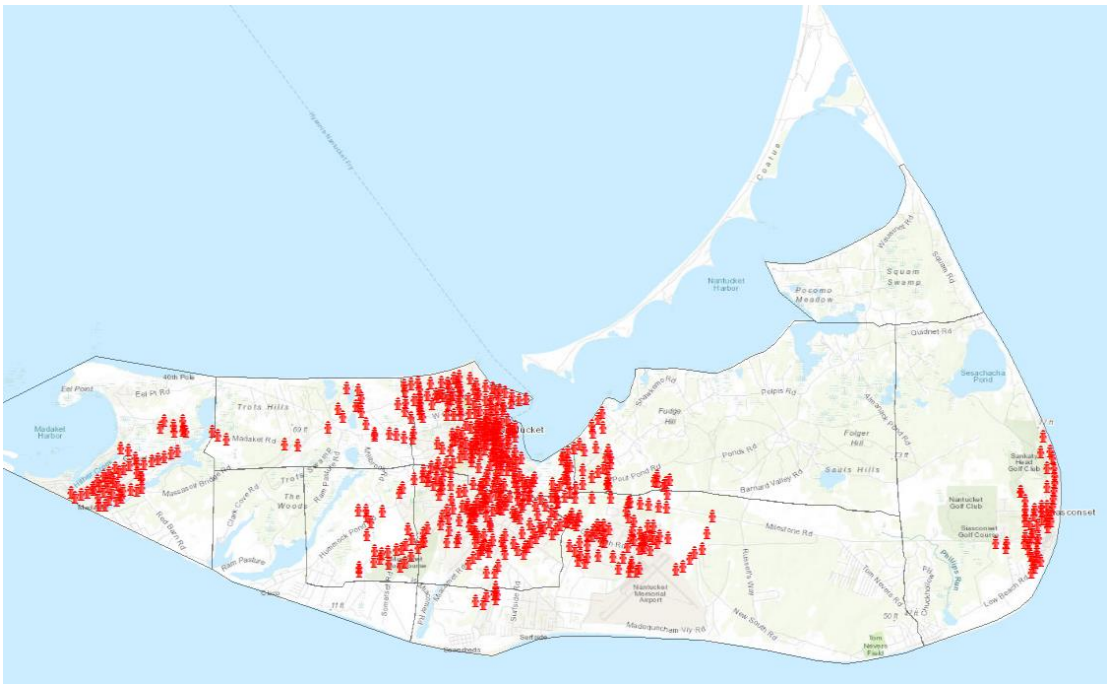

Figure 16. *Map of hydrants on Nantucket marked in red.*

Table 4. *Number of hydrants by district.*

District	Hydrants
Madaket	54
Cliff	24
Hummock	0
Mid Island	26
Town	210
Naushop	116
Surfside	82
Monomoy	30
Pocomo	0
Siasconset	50

The GIS hydrant layer also includes an attribute table, which allows the NFD to access additional characteristics of each hydrant, along with the associated location. The town, NFD, and water company can use the additional data when populating a water source tracking application and managing hydrant maintenance. Attributes such as hydrant manufacturer, connection type, and installation date are listed. However, these fields are far from complete, with many empty entries. It is only possible to check this information in person by inspecting each hydrant, so we could not verify or update the attributes while working remotely. With hydrants being added and removed, the hydrant data we received from the town is only a representation of the database as of early 2021.

5.2 Alternative Water Supply

Pools, dry hydrants, ponds, and other alternative water sources are common on the island, but few are consistently reliable for fighting fires. This section summarizes the alternative water sources on Nantucket and discusses their reliability and usefulness for firefighting. There are 852 pools total on Nantucket, as shown in Figure 17; Table 5 lists the number of pools by district.

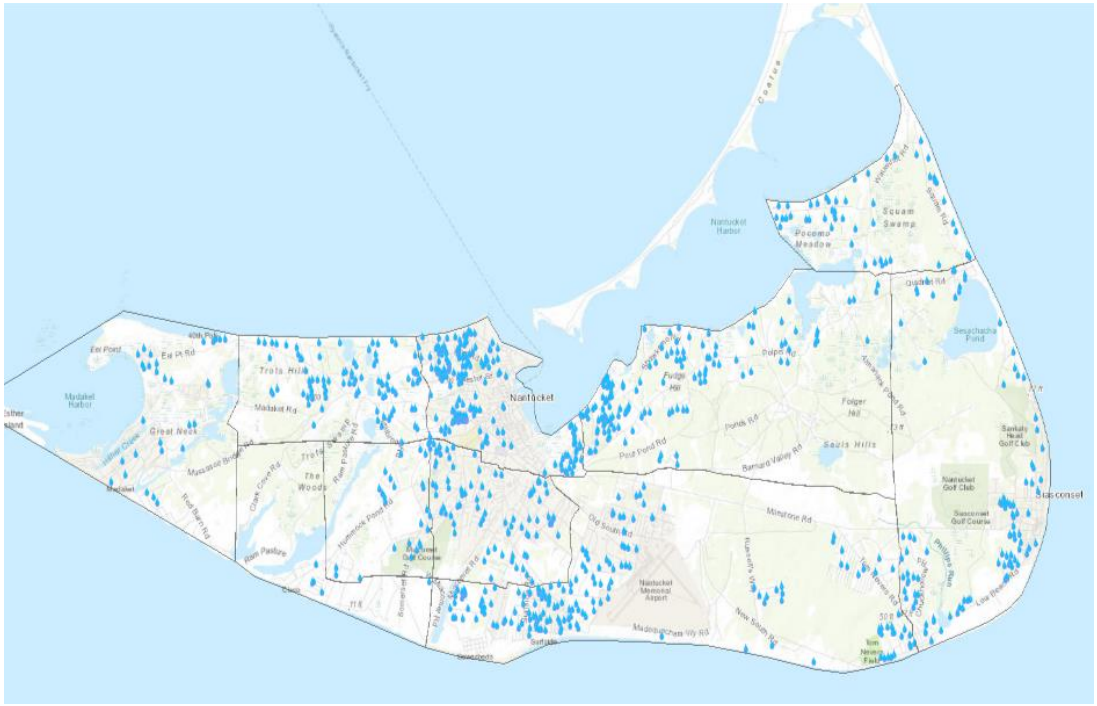

Figure 17. *Map of pools on Nantucket, marked in blue.*

Table 5. *Number of pools by district.*

District	Pools
Madaket	30
Cliff	88
Hummock	5
Mid Island	27
Town	176
Naushop	81
Surfside	172
Monomoy	125
Pocomo	50
Siasconset	97

Since pools must be within 20 feet of a driveway to be accessible by the NFD, there are only 27 pools usable for firefighting based on our initial distance estimates shown in Figure 18. Of these 27 pools, 9 of them lay outside the hydrant buffer. Since tankers and engines are too heavy to be driven on lawns of properties, most pools are inaccessible to the NFD, but brush trucks used for fighting wildland fires may be able to access some of these pools because of their lighter build. Due to large areas of conservation land on the island, many homes are in the Wildland Urban Interface (WUI). WUI is the transition region between unoccupied areas and human development (U.S. Fire Administration, 2021b). Residential homes located on conservation land present challenges for fighting wildland and structure fires simultaneously. While less accessible pools do not assist in common structure fires, brush trucks can better protect homes in the WUI by drafting from these pools.

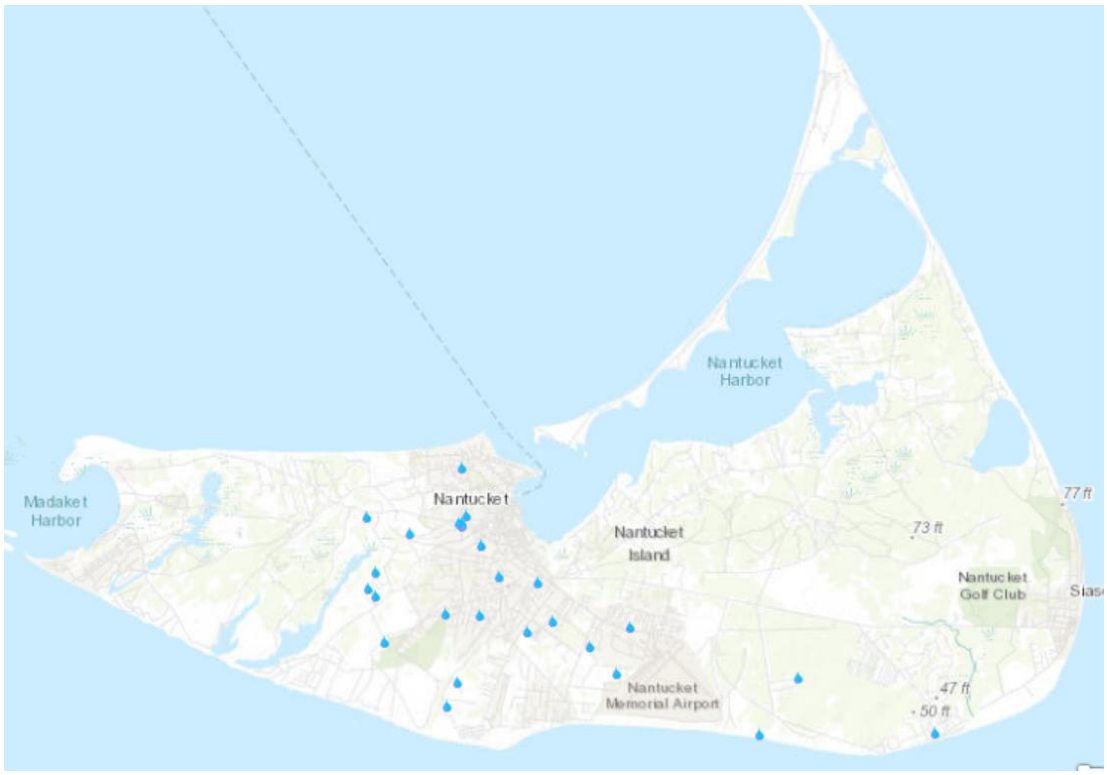

Figure 18. *Map of pools on Nantucket that are accessible by the NFD.*

In addition to the locations, the GIS pool layer includes an attribute table with relevant information about each pool, as shown in Table 6. Some of these attributes, such as area and distance, are approximations based on 2D satellite imagery due to the team working remotely. Although volume would be a more practical value for determining how much water a given pool can provide in an emergency, satellite imagery cannot accurately measure the depth of pools, leaving surface area as the only dimension that satellite data can estimate. The town also does not currently have any record of the volumes of each pool. The driveway distances are also initial estimates, and in some cases, the neighboring homes' driveways may provide more access than that of the current address. The accessibility attribute provides a space to input any important notes about each pool that may affect their accessibility, such as being under construction or seasonally available. Finally, the last tested and next tested rows provide an opportunity for the NFD to enter testing dates to keep track of and schedule the testing of pools.

Table 6. *Pool attributes and descriptions.*

Pool Attribute Table	
Position	X and Y position, in feet, of each pool in 1983 Massachusetts island coordinates.
Address	Address of each pool based on Massachusetts's GIS district map and Google Maps.
Area	Surface area of each pool, in square feet.
Distance	Approximate distance from the driveway of the address to each pool, in feet.
Accessibility	Notes on the status of each pool's accessibility.
Last Tested	Last date each pool was checked and tested.
Next Tested	Next date each pool is scheduled to be checked and tested.

There are seven dry hydrants the NFD is aware of on the island, four of which have been tested previously. These dry hydrants are non-pressurized pipes that allow the NFD to draft from a water source more efficiently, whether from a pool or natural body. Of the four tested, three are class B, with the fourth being a class C. Class B refers to a flow rate of 500 to 999 gallons per minute (GPM), while class C is less than 500 GPM. As shown in Figure 19, there are a total of six dry hydrants that lay outside of the hydrant buffer. The tested dry hydrants can serve as reliable water sources to protect some of the homes that hydrants do not cover.

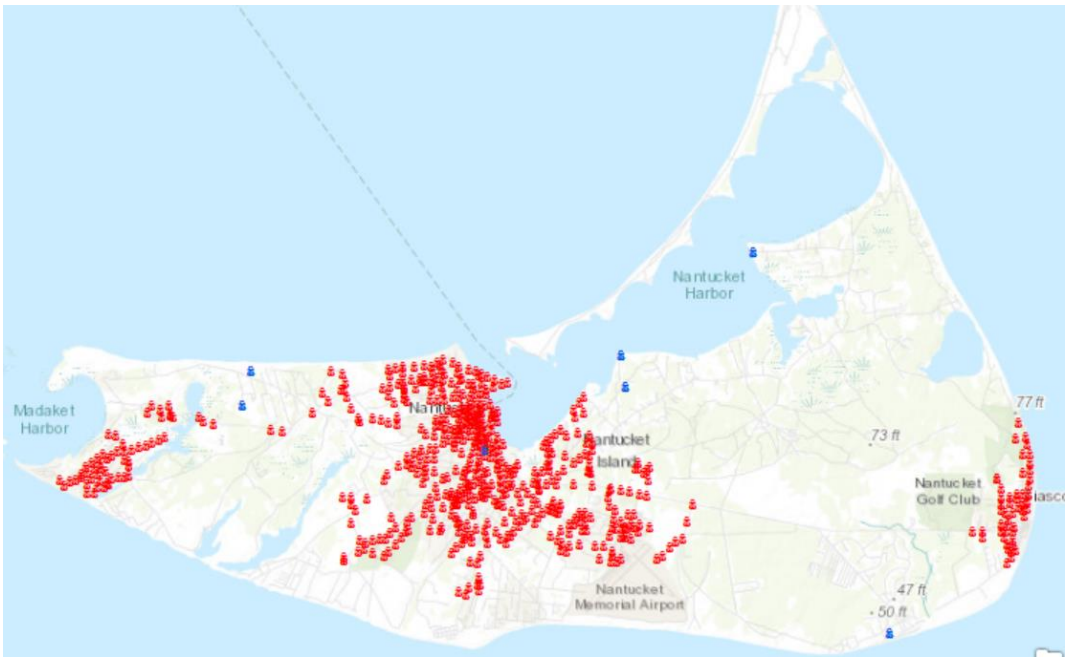

Figure 19. *Dry hydrants, marked in blue, in relation to hydrants, marked in red.*

On Nantucket, there are many natural bodies of water, as shown in Figure 20, but few are reliable for fire protection purposes. Some of these bodies of water already have dry hydrants to provide water to trucks quickly, but if there is not a dry hydrant, the NFD needs to draft the water directly from the pond or lake, which may be more difficult. The trucks need to get within 20 feet from the water's edge to draft from a body of water. Since most of the land around the lakes and ponds is marshy and full of vegetation, the trucks may not be able to get close enough. Additionally, the land around these bodies of water is protected as conservation land or privately owned, making it even harder for the town to create better access points for the NFD. Another drawback of drafting water from lakes or ponds is that the NFD does not know definitively how much water they will be able to draft from that point.

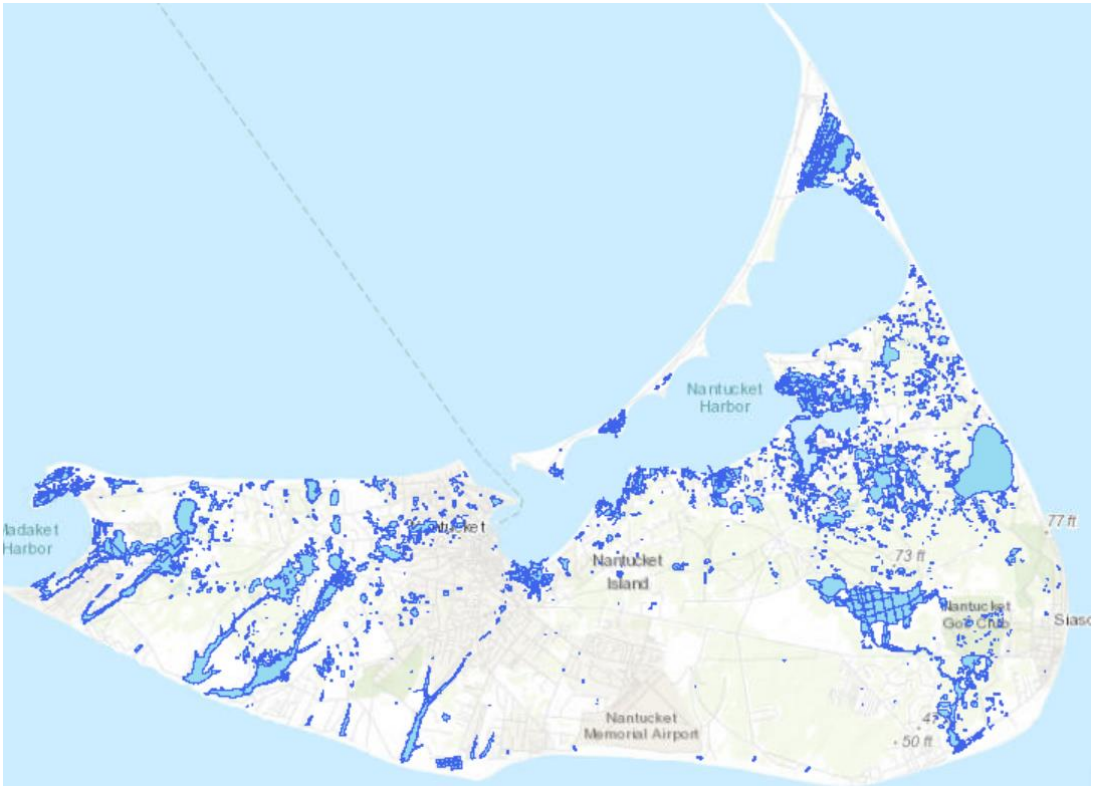

Figure 20. *Map of the bodies of water on Nantucket, including lakes and ponds.*

5.3 Unprotected Areas & Homes

Each fire hydrant on Nantucket protects homes within a 1,000-foot radius, limited by the length of hose the truck carries. Figure 21 shows a map of the protected zone each fire hydrant provides.

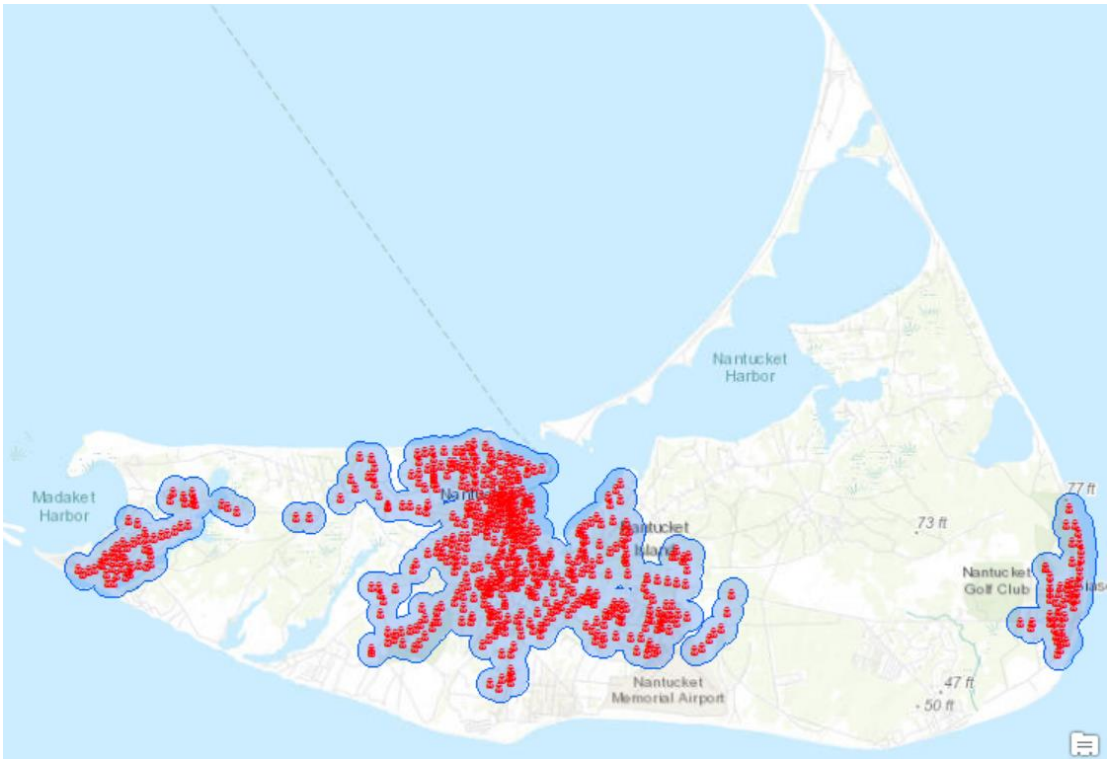

Figure 21. *Map of protected areas; hydrants are marked in red, and the 1,000-foot radii hydrant buffers are shaded in blue.*

We located a total of 2,129 unprotected homes on the island that are not within the 1,000-foot radius hydrant buffers, as shown in Figure 22. Table 7 the number of unprotected homes there are in Nantucket by the district. When the NFD responds to fire calls located at these unprotected homes, they need to use alternative water sources or tanker trucks. Some isolated areas of the island require tanker trucks to make multiple trips miles away from the scene to the nearest hydrant. For example, a fire call from the northern tip of Pocomo would require the NFD to travel to the closest hydrant in Siasconset to refill their water supply, a round trip of approximately five miles.

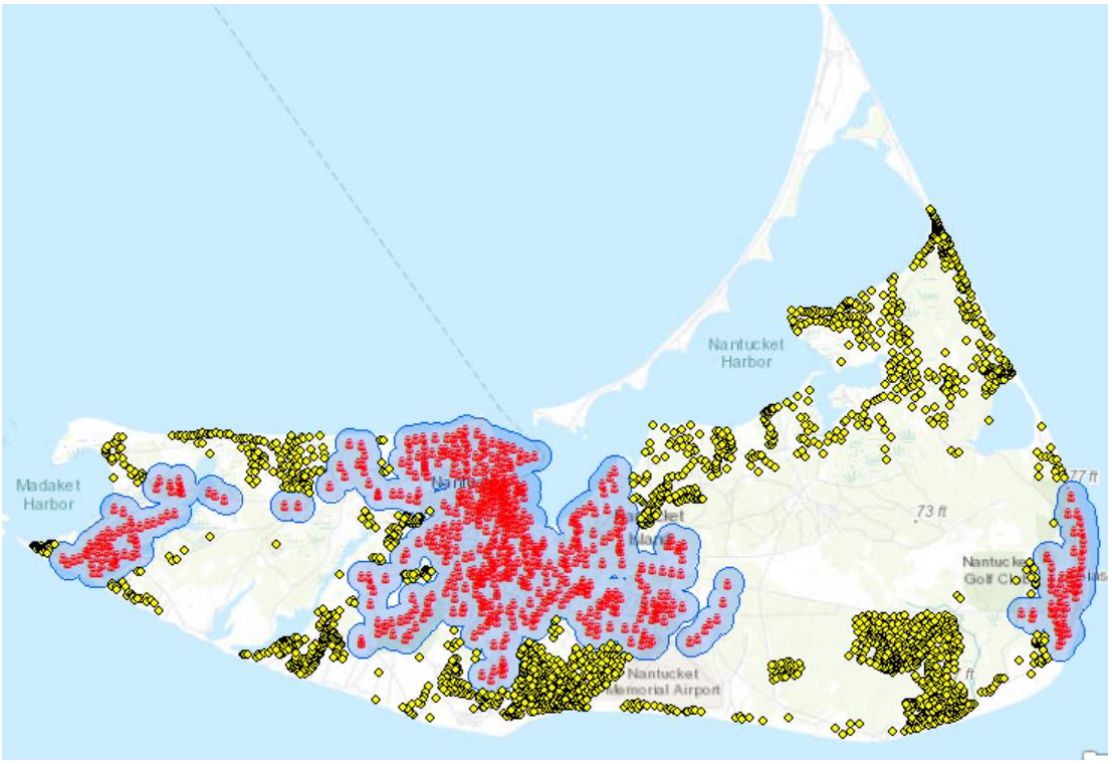

Figure 22. *A map of unprotected homes on the island, marked by yellow diamonds.*

Table 7. *Number of unprotected homes by district.*

District	Unprotected Homes
Madaket	102
Cliff	144
Hummock	99
Mid Island	110
Town	5
Naushop	50
Surfside	885
Monomoy	247
Pocomo	260
Siasconset	227

An important metric for understanding the significance of unprotected homes is the frequency of calls to the fire department made outside of the hydrant buffers. Figure 23

demonstrates the call data locations over five years from 2016 through 2020. Appendix H contains the individual yearly fire call layers. Throughout the past five years, the Town District has had the greatest number of calls. Upon further investigation, almost every house in the densest part of the Town District had a fire call between 2016 and 2020. However, it is important to note that fire calls are not a one-to-one ratio to actual fires; these calls include every response by the NFD that was not EMS or an inspection, and some were for false alarms.

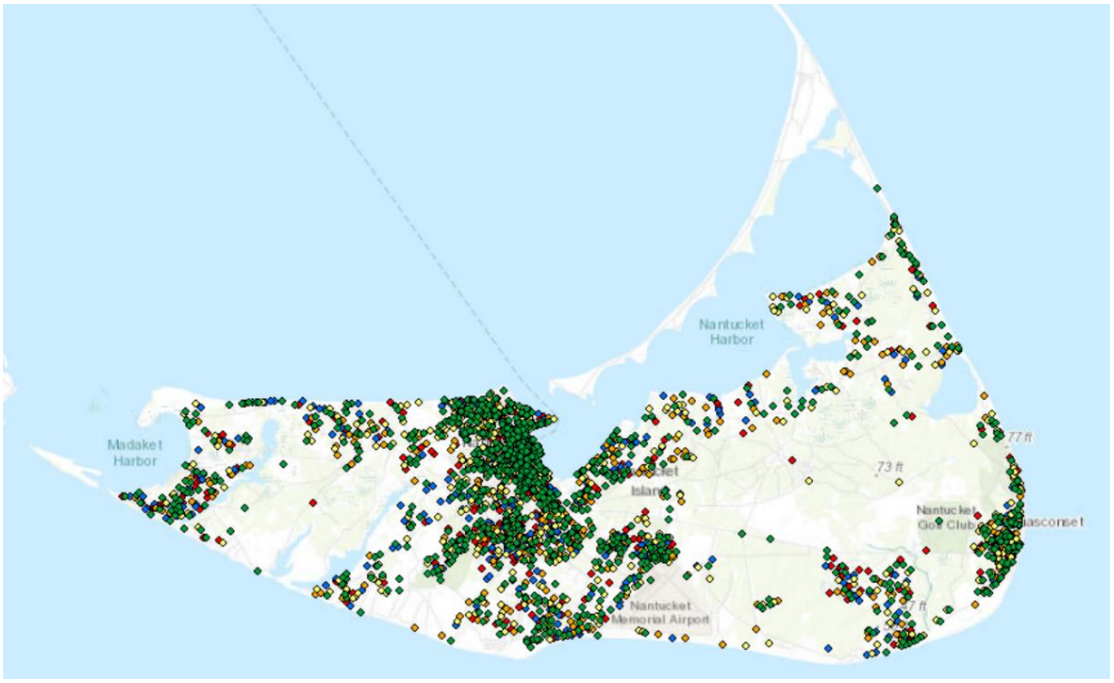

Figure 23. *2016-2020 geocoded fire call data; each year is represented by color, with 2016 as red, 2017 as blue, 2018 as orange, 2019 as yellow, and 2020 as green.*

Since the density of fire calls is directly proportional to housing density, for more suburban areas such as the eastern side of Surfside, the calls are sparse compared to the urban Town District and the residential neighborhoods of Siasconset. We can directly compare the fire calls with the building layer, as seen in Figure 24. The darker the area, the closer the buildings are to each other. Thus, the Town District being compact and densely populated suggests the relationship between fire call and building density. Additionally, despite the relatively brief scope of the data, there appeared to be no relationship between calls moving towards or away from certain areas in the previous five years. The areas with high building density consistently produced more fire calls per year than less dense areas, regardless of new housing developments.

The fire call data also confirms the hydrant district's strategic placement to cover the most fire call dense areas of Nantucket.

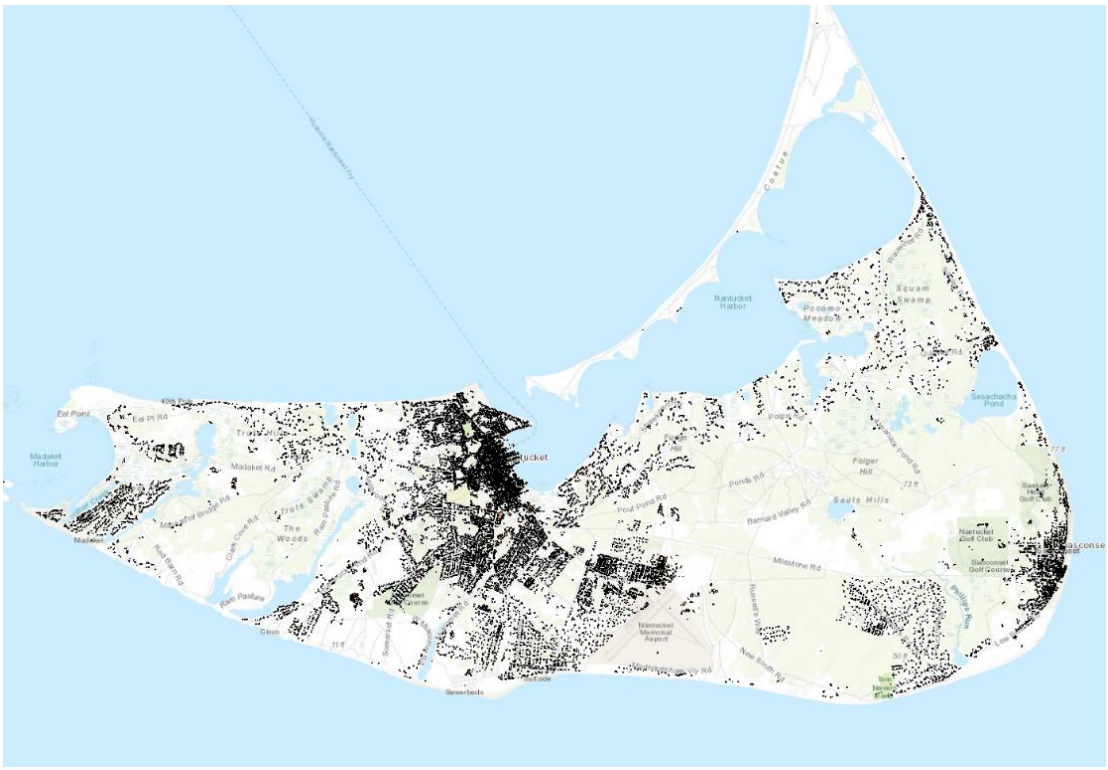

Figure 24. *Map of structures on Nantucket, marked by 2D black shapes.*

It is important to note that the geocoded fire call data works by identifying the centroid of a property, which can be inaccurate for suburban and rural areas. For urban areas, the location of the household is almost always in the centroid of the property. However, the exact positions of the calls lose accuracy in areas with large properties. In addition, the algorithm is susceptible to errors and could not geocode approximately 400 calls over all four years due to insufficient data entry or algorithmic faults. While these missing fire calls are less than 1% of the total fire call volume, they introduce the unlikely possibility that the algorithm missed calls within a community.

While most of the fire calls come from the Town District, one out of seven calls come from outside of the hydrant buffers. This number equates to 244 fire calls from addresses unprotected by hydrants in 2020. While this represents a relatively small portion of all calls, it reflects a danger to life and property on the island. Figure 23 shows some concentrations of fire

calls around Surfside's southern and eastern areas, which are also in the unprotected areas shown in Figure 22. The lack of reliable water sources for firefighting presents a challenge to the island now and in the future.

Chapter 6: Recommendations & Conclusions

This chapter presents recommendations for the Town of Nantucket and the Nantucket Fire Department (NFD) based on the findings discussed in the previous chapter. First, we state our recommendation for a mobile firefighting application to improve the NFD's fire response. Next, we propose infrastructure upgrades to improve fire protection on the island. We also discuss how town rules and regulations can be adjusted for new construction to encourage future homeowners to better protect their homes and the island. Finally, we conclude by suggesting future efforts that can build upon the findings and recommendations from this project.

6.1 Recommendations

We recommend the mobile application Active911 to help the NFD improve its fire response and water source tracking capabilities. Compared to the other researched applications, Active911 provides the most important features the NFD requires in a firefighting application. These features include:

- Practical user interface
- Customizable water source tracking
- Internal and external navigation
- Integration with Emergency Reporting
- Offline capabilities

We believe that Active911 would meet all the NFD's needs and improve its productivity, response, and performance.

We recommend that the Town of Nantucket use available funds to extend water mains and install new fire hydrants in unprotected areas. Fire hydrants are the most reliable water supply for the fire department. Expanding the water main to allow for more hydrants to be installed in unprotected areas would limit the need for alternative sources and aid the NFD's fire response. Some areas, such as the southwestern side of Surfside and the neighborhood along the border between Surfside and Siasconset (also known as Tom Nevers), are dense in fire calls but completely unprotected by fire hydrants, as shown in Appendix H and Appendix I. Although some of these areas have pools and dry hydrants available for use during a fire emergency, there is no guarantee that these alternative sources will provide an adequate supply of water to contain a fire.

We recommend that the Town of Nantucket and the Nantucket Civic League consider additional measures for fire protection for recent and new housing construction. The Co-President of the Nantucket Civic League, Peter Morrison, suggested that many of the problems the NFD faces are rooted in a lack of fire prevention infrastructure. In addition to the currently unprotected neighborhoods on the island, new construction is likely in areas outside the hydrant district, such as Siasconset, Pocomo, and Surfside. As shown in Appendix H, there are large clusters of calls coming from areas unprotected by fire hydrants. The NFD must quickly access alternative water sources or transport water in tanker trucks to put out fires in these higher risk areas, which can significantly delay their fire response. By analyzing census data, the Nantucket Civic League can identify developing areas on the island in need of improved fire prevention. In tandem with the neighborhood associations from these areas, the Civic League can recommend preventative measures and infrastructure improvements that will increase protection for these homes and aid the NFD in carrying out a more efficient response.

We recommend that the Town of Nantucket consider requiring sprinkler systems in newly constructed homes. Sprinkler systems provide targeted and timely fire suppression, effectively controlling 96% of fires that set them off. They also reduce water consumption by 90% compared to fires put out solely by fire departments and significantly decrease the deaths and damage typically caused by fires (NFPA, 2017). California began requiring residential sprinklers in new homes in 2010, reducing the death rate by 80% and property loss by 71% (California Fire Sprinkler Coalition, 2011). Scottsdale, Arizona also implemented a similar bylaw and conducted a 15-year study of the city's fire risk afterward. The fire losses in incidents without sprinklers were more than 20 times greater than those with sprinklers, and 90% of fires were contained by a single sprinkler (Scottsdale Report, 2013). Residential sprinklers reduce insurance rates for homeowners by about 10% (NFPA, 2017), further incentivizing sprinkler installation for new homeowners. The NFD can influence bylaws on the island by demonstrating the benefits of sprinklers for both firefighters and homeowners. Sprinklers would be especially beneficial to homes outside the hydrant district, giving the NFD more time to respond and reducing the need for alternative water supply. A potential bylaw could require new homes to install residential sprinklers to reduce fire risk on the island. In the meantime, the NFD and Nantucket Civic league can use the list of unprotected homes and begin contacting the

homeowners to demonstrate the risk to their property. They can use the map of unprotected homes to encourage residents of these homes to install residential sprinkler systems.

We recommend that the Town of Nantucket implement regulations or incentives for future construction of private swimming pools. By working collaboratively with the town's building and assessor departments, the NFD and the Nantucket Civic League could demonstrate the importance of alternative water sources on the island and having accessible dry hydrants on pools. The town could pass a bylaw that would require all newly installed pools to have clear paths to a dry hydrant within 20 feet of the property's driveways. Currently our estimates suggest only about 3% of pools on the island are accessible by the NFD; installing these dry hydrants would provide more alternative water sources for firefighting and help protect homes in areas unprotected by hydrants but dense in pools. If the town cannot pass a bylaw, they could offer incentives, such as property tax discounts, for those who install a dry hydrant for their pool.

6.2 Future Work

In this section, we suggest additional efforts that could support the NFD's mission to protect the island. Due to the limitations of working remotely, some findings of this project can be expanded to be more useful for the NFD. Additionally, some of our recommendations can be further researched and implemented to improve the NFD's fire response and decrease fire risk on the island. Our suggestions for future work include:

- ***Conduct site visits to each pool to determine whether it is accessible and can serve as an alternative water source.*** Although we mapped the pools on Nantucket as potential water sources, their viability for firefighting remains uncertain in most cases. Either the NFD or other future work can assess the accessibility of the pools on the island.
- ***Enter the alternative water sources deemed accessible into the application the NFD chooses.*** The locations of the alternative water sources should be input as markers, along with the attributes we recorded and any further information gathered through future work and site visits.
- ***Populate the application with other relevant markers.*** Besides water source locations, additional markers, such as beach access points or buildings with specific pre-plans, can aid firefighters in quickly preparing for emergencies in particular locations.

- ***Provide training for the NFD on its chosen application.*** Since the application needs to be regularly updated with water sources as they are added and removed, the NFD should be able to populate and utilize the application themselves in the future.
- ***Research the projected population growth on Nantucket.*** As mentioned in Section 6.1, extending the water mains to unprotected areas with new construction would allow for more hydrants. Future efforts could research and recommend more specific hydrant and water main expansion locations based upon where future housing developments are expected to appear.

6.3 Conclusion

The goal of this project was to recommend a mobile firefighting application for the NFD, locate and characterize water sources, and make recommendations to promote fire safety on the island. With Active911, the NFD can have a reliable platform to compile and access water supplies for use during a fire response. Since not all areas of the island are protected by hydrants, the NFD relies on alternative sources or traveling to the nearest hydrant. While this study has not identified new reliable sources, the ability to quickly locate potential water sources during an emergency will help improve the NFD's fire response. Due to Nantucket's lack of reliable water sources in unprotected areas and poorly maintained roadways, our recommendations for infrastructure upgrades could enhance fire prevention for the future of the island. These upgrades could help contain fires, giving the NFD more time to respond during the summer months when population and fire calls increase. The Town of Nantucket could also further improve the NFD's fire response by providing the island with more water supplies for firefighting. By expanding the water mains or requiring dry hydrants for new pools, the NFD will have access to additional reliable water sources. While remote work hampered our ability to characterize the alternative water sources fully, we hope the work we have completed through this project will benefit not only the NFD, but the greater Nantucket community in the years to come.

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Appendix A: Initial Application Decision Matrix

Application	Total	Water Source Tracking Customizability	Alternative Source Tracking	Hydrant Tracking	Ease Of Use
Multiplier		**5**	**5**	**5**	**5**
Active911	**147**	3	3	3	3
First Due	**140**	3	3	3	3
IamResponding	**136**	3	3	3	3
Rover	**128**	3	2	3	3
Rapid Response	**93**	2	2	3	3
Rhodium Incident Management Suite	**91**	1	1	2	3
Alertfind	**77**	0	0	0	3
ESO	**73**	1	0	1	2
PSTrax	**47**	1	0	0	2

Application	Updatability	GPS	Offline Capabilities	Asset Tracking	Response Tracking
Multiplier	**5**	**4**	**4**	**3**	**3**
Active911	3	3	3	3	3
First Due	3	3	3	3	3
IamResponding	3	3	0	3	3
Rover	3	3	0	3	3
Rapid Response	3	3	0	0	0
Rhodium Incident Management Suite	3	0	3	2	1
Alertfind	3	0	0	3	3
ESO	2	0	0	3	3
PSTrax	2	0	0	2	0

Application	Documentation & Customer Service	Mutual Aid	Incident Tracking	Management
Multiplier	**3**	**1**	**1**	**1**
Active911	3	3	2	2
First Due	1	3	2	1
IamResponding	3	3	2	3
Rover	2	3	3	2
Rapid Response	1	1	1	3
Rhodium Incident Management Suite	3	0	1	3
Alertfind	2	2	3	3
ESO	2	2	3	3
PSTrax	1	0	0	3

Multiplier Field	Application Field
0 = Not Applicable	0 = Does not Exist
1 = Low Importance	1 = Poor
2 = Slight Importance	2 = Okay
3 = Some Importance	3 = Works Well
4 = High Importance	
5 = Very High Importance	

W.S. Tracking Customizability & Fields: Ability to add descriptions of individual water sources into each map marker, as well as changing the icon of the source, making it easily identifiable.

Alternative Source Tracking: Ability to track alternative water sources such as pools, dry hydrants, natural bodies, and other sources besides hydrants.

Hydrant Tracking: Hydrant mapping abilities.

Ease of Use: How easy the application is to learn and use.

Updateability: How easily someone can update the application by adding new water sources or removing old ones.

GPS Directions: Ability to provide navigation for responders to the scene of a call.

Offline Capabilities: Ability for the application to display information offline.

Asset Tracking: Ability to show where trucks are in relation to the scene during a response.

Response Tracking: Ability for firefighters to show their response status during emergencies.

Customer Service & Documentation: Tech support and online documentation in case of any issues or a system outage.

Mutual Aid: Ability to provide mutual information and connect to other departments' systems.

Incident Tracking: Ability to keep track of past fire incidents and document their details.

Management Capabilities: Ability to help with scheduling, planning, and communication between responders.

Appendix B: Application Research Interview Protocol

Interview topic: Choosing an application based on the application decision matrix.

Format: Semi-structured interview

Interviewee: Member of the Nantucket Fire Department (NFD)

Roles

- 1 person to ask scripted questions.
- 1-2 people to ask follow-up questions and take notes.

Script

Hello Mr./Mrs. NFD member,

We are students from WPI working with you, the Nantucket Fire Department, to find a system to provide real-time data on water sources to use during fire responses across the island of Nantucket. We are focusing on setting up a suitable preexisting application that can serve as a platform for finding water sources and planning fire responses efficiently. In addition, we will be locating water sources that may be currently unmapped or are not officially recorded by the NFD to input into the selected application. From this interview, we hope to learn more about how the fire department currently locates water sources while on calls, what you would like to see in a system that locates water sources and receive feedback on the application decision matrix we have created. With your permission, we would like to record this interview. If you would like, we can provide a copy of our final report upon completion.

Questions

1. General Questions
    a. How long have you been a member of the Nantucket Fire Department (NFD)?
    b. What is your role within the NFD?
    c. What is the motivation for the NFD to find a new system to locate water sources? How does this affect your role within the department?
2. Private and Alternative Water Sources

a. What does the NFD currently use to locate water sources when away from municipal fire hydrants? Does the NFD use the town GIS maps?
b. What works well and what needs improvement within this system?
c. How does new information on these water sources reach the fire department?
d. If a water source is changed or removed, how is this change updated from the fire department's perspective?
e. Could you point out areas of the island that pose a significant challenge because of the difficulty of finding alternative water sources?

3. Firefighting Applications
   a. Are there any other criteria than what is already on the decision matrix you would like us to consider when ranking these firefighting applications?
   b. Are there any criteria listed on the matrix that are not applicable or important to the NFD?
   c. Would you be willing to categorize the criteria into "essential," "nice to have," and "not important," and explain why?
   d. Are there any applications that we have not considered that you would like us to consider?

Appendix C: Final Application Decision Matrix

Application	Total	Price	Alternative Source Tracking	Offline Capabilities
Multiplier		**5**	**5**	**4**
Active911	**163**	2	3	3
IamResponding	**152**	2	3	0
First Due	**147**	1	3	3
Rover	**142**	2	2	0

Application	Documentation & Customer Service	Users	Incident Tracking	Maintenance Records
Multiplier	**3**	**2**	**1**	**1**
Active911	3	3	2	2
IamResponding	3	3	2	3
First Due	1	1	2	1
Rover	2	2	3	2

Multiplier Field	Application Field
0 = Not Applicable	0 = Does not Exist
1 = Low Importance	1 = Poor
2 = Slight Importance	2 = Okay
3 = Some Importance	3 = Works Well
4 = High Importance	
5 = Very High Importance	

Price Range	
3	$0-500
2	$500-1,000
1	$1,000-2,000
0	$2,000+

Application	Users	Price
Active911	300,000	$875
IamResponding	400,000	$800
First Due	5,000	$2,000
Rover	2,000	$960

It is important to note that not all the columns in the matrix are presented. However, it has all the same categories as the initial decision matrix shown in Appendix A, as well as a couple of additional ones, such as price and number of users. Columns where rankings for all four applications were equivalent were collapsed, but the total score was still calculated from every column, both visible and hidden.

Appendix D: Nantucket District Map

Appendix E: Application Feedback Interview Protocol

Interview topic: Feedback on firefighting applications

Format: Semi-structured interview

Interviewee: Member of the Nantucket Fire Department (NFD)

Roles

- 1 person to ask scripted questions.
- 1 person to ask follow-up questions and take notes.

Script

Hello Mr./Mrs. NFD member,

We are students from WPI working with you, the Nantucket Fire Department, to find a system to provide real-time data on water sources to use during fire responses across the island of Nantucket. We are focusing on setting up a suitable preexisting application that can serve as a platform for finding water sources and planning fire responses easily. In addition, we will be locating water sources that may be currently unmapped or are not officially recorded by the NFD to input into the selected application. For this interview, we aim to discuss any thoughts you have on your current system and gain insight into potential new solutions. With your permission, we would like to record this interview. If you would like, we can provide a copy of our final report upon completion.

Questions

1. General Questions
    a. How long have you been a member of the Nantucket Fire Department (NFD)?
    b. What is your role within the NFD?
2. Emergency Reporting
    a. The two applications under consideration are Rover and Active911, which both have integration with Emergency Reporting. When a call comes, the CAD system will send the information into ER, and an incident report will be populated.
3. Spotted Dog/Rover (Current System)

    a. How often do you use the Spotted Dog application?
    b. What features do you like about it?
    c. What features do you dislike?
    d. Is there anything that you feel is missing from this application?
4. Demonstration of Active911
    a. Receiving/Responding to alerts
    b. Chat communication
    c. Road directions to emergency
    d. Is there anything that you feel is missing from this application? Is there anything we missed?
5. Feedback on Active911
    a. What are your initial impressions of Active911?
    b. Can you see yourself using Active911 regularly on calls?
    c. Do you believe that Active911 easily integrate with the NFD?
    d. What features do you like about it?
    e. What features do you dislike?
    f. Is there anything that you feel is missing from this application?
6. Additional Comments
    a. If there are any last thoughts or final comments, please let us know.

Appendix F: Application Feedback Interview Notes

Major Takeaways

- Rover's primary use is that it provides external navigation through Google Maps.
- Rover's hydrant map takes a long time to load, which is not ideal in emergencies.
- The firefighters would like to have both navigation and water source markers on the same map.
- The updateability of the application is extremely important.
- Identifying water sources without the need to rely on dispatch would be helpful.
- There was a concern for location tracking of off-duty firefighters.
- The ability to add pre-plans would be beneficial.

Spotted Dog/Rover (Current system)

- Not everyone in the department has or uses the application.
- Used to communicate the directions to the scene, but the responders rely on dispatch for hydrant and road closure information.
- Usually, responders know where the call address is located and use Rover to double-check the location and directions.
- It takes a long time to load information, and the hydrant map must reload when switching out of the application to external navigation.
- It is challenging to update or add markers, which requires contacting Rover.
- Satellite imagery would be more helpful to find driveways for trucks and access points in different areas.
- Rover does not provide dispatch notes or information about the call.
- Departments use Rover for shifts, overtime, scheduling, and training.

Active911

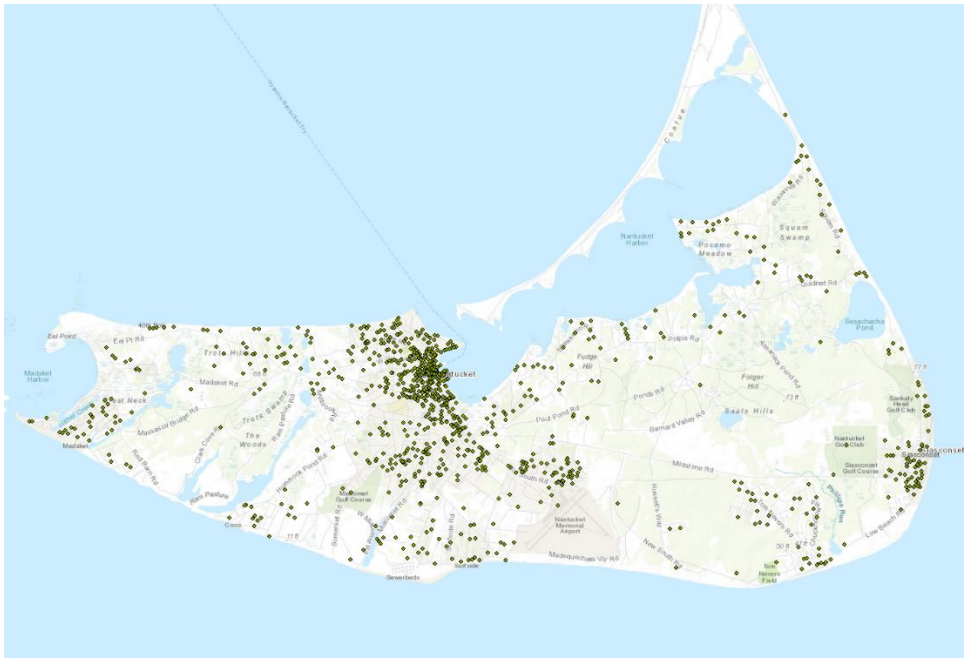
- Active911's feature to find the closest water sources to a call is useful.
- It has both internal and external navigation, but it is not crucial since most firefighters already know the island well.
- It is very user-friendly, which is beneficial for those who are not tech-savvy.

- Easy to do everything in a single app, which keeps it simple during an emergency.
- Allows responders to identify hydrants quickly through the app, rather than relying on dispatch.
- Easy to add, remove, and update hydrants and alternative water sources.
- Alternative water sources and other map markers can have other icons and colors to distinguish them easily.
- Has in-app communication for responders to make different groups.
- There is an option to turn off location while off-duty, so the department can still use the application for communication.
- Has the ability to add pre-plans by uploading documents to specific markers.
- Offline capabilities will be helpful in more remote parts of Nantucket.
- It is not focused on management, such a shift scheduling, which would be a useful feature.
- The water company could get access in order to add or edit hydrants.
- Active911 could have a station readout on a TV.

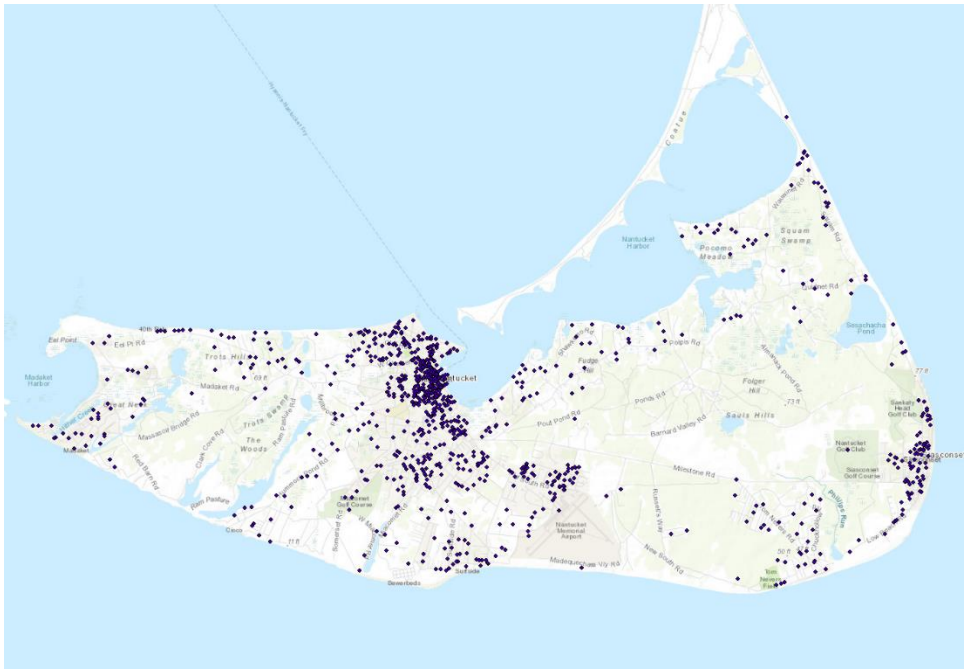
Appendix G: GIS Layer Data by District

District	Hydrants	Dry Hydrants	Pools	Fire Calls (2020)	Unprotected Homes
Madaket	54	0	30	85	102
Cliff	24	2	88	80	144
Hummock	0	0	5	11	99
Mid Island	26	0	27	24	110
Town	210	1	177	881	5
Naushop	116	0	81	195	50
Surfside	82	0	172	154	885
Monomoy	30	2	125	100	247
Pocomo	0	1	50	54	260
Siasconset	50	1	97	180	227
Total	**592**	**7**	**852**	**1764**	**2129**

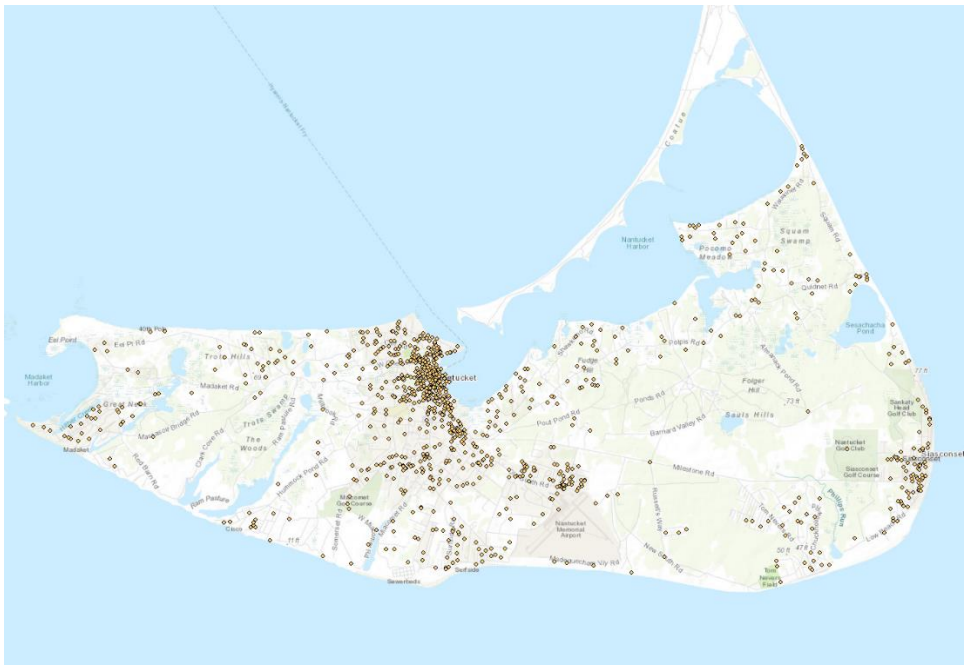
Appendix H: Geocoded Fire Call Data, 2016–2020



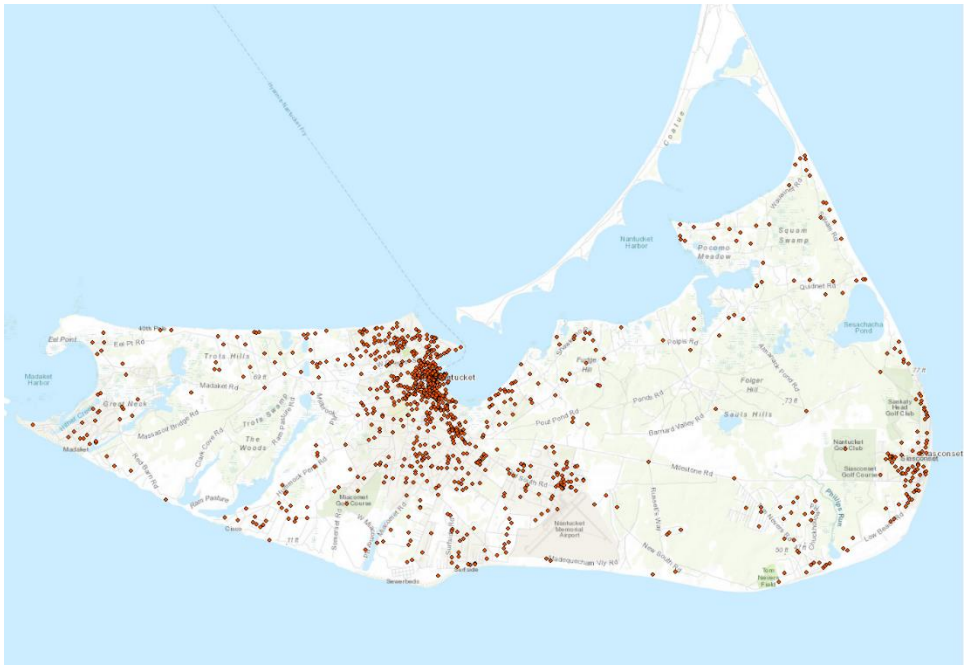
2016



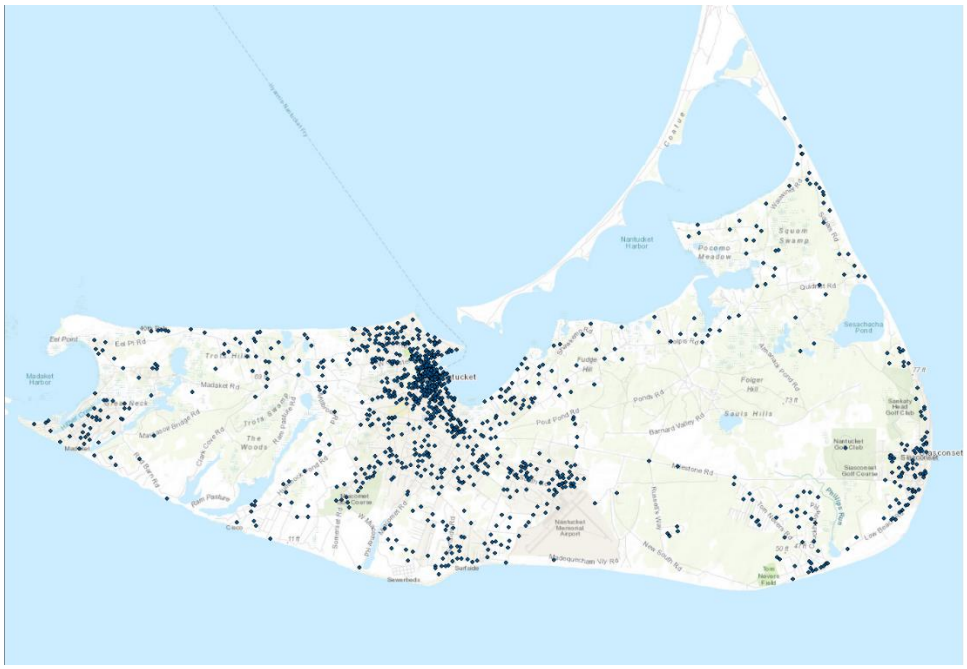
2017



2018

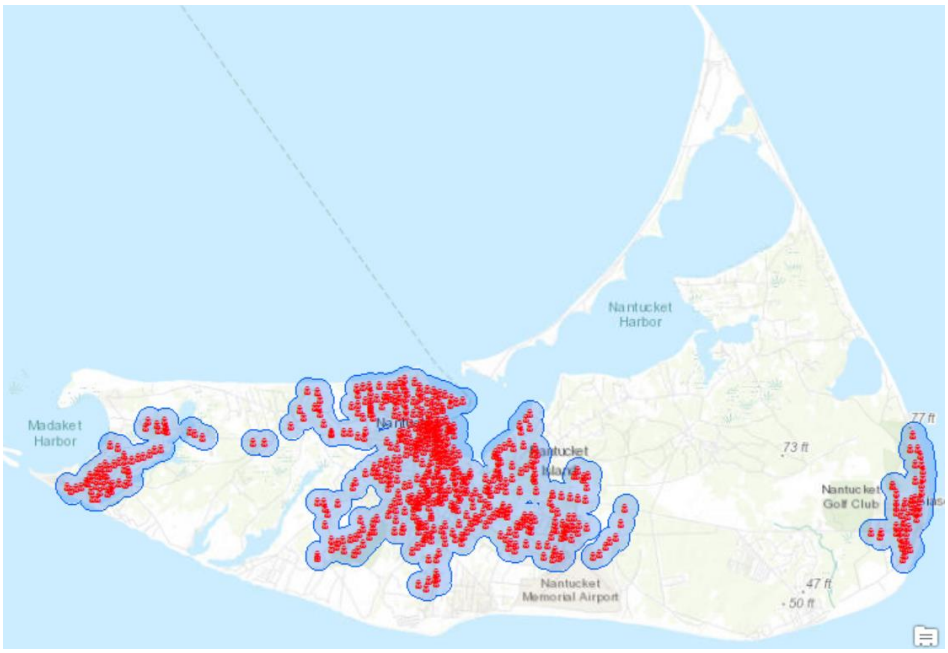


2019

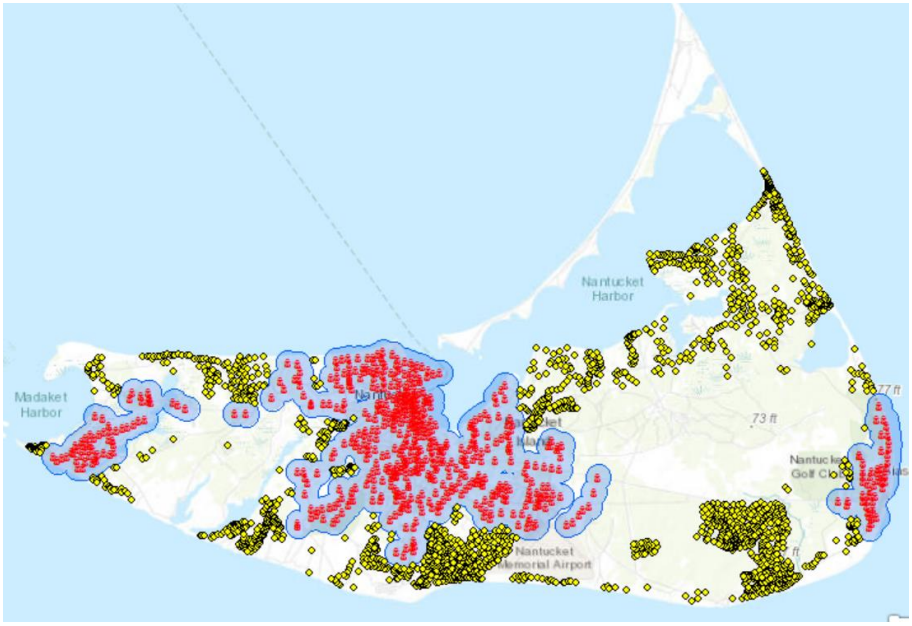

Nantucket Harbor
Squam Swamp
Madaket Harbor
Madaket Rd
Sesachacha Pond
Fudge Hill
Folger Hill
Sauris Hills
Barnard Valley Rd
Ponds Rd
Polpis Rd
Milestone Rd
Nantucket Memorial Airport
Sankaty Head Golf Club
Nantucket Golf Club
Siasconset Golf Course
The Woods
Cliff Rd
Low Beach Rd

2020

Appendix I: Map of Protected Areas & Unprotected Homes



Map of protected areas; hydrants are marked in red with the 1,000-foot radii shaded in blue.



A map of the unprotected homes that are not within 1,000 feet of a hydrant, marked by yellow diamonds.