GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

FINAL REPORT

International Association of Fire Fighters
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Washington, DC 20006

MANITOWOC FIRE RESCUE DEPARTMENT

MANITOWOC, WISCONSIN

January 2019

Dedication

This Report is Dedicated to the Citizens of Manitowoc, Wisconsin, who Deserve the Most Efficient and Effective Fire, Rescue, and Emergency Medical Services Available.

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Executive Summary[1]

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Manitowoc Professional Firefighters (MPFF), IAFF Local 368, to provide information and resources to decision makers in the City of Manitowoc regarding the importance of maintaining adequate resources consisting of fire stations, apparatus, and personnel to meet emergency incident demand throughout the city.

Recently, the Manitowoc Fire Rescue Department (MFRD) has discussed modifying the department's current deployment configuration by relocating fire stations and resources. Potentially MFRD may merge two stations together, which may result in Fire Stations 2 and 4 being closed and apparatus from those stations being moved to a new fire station.[2] Currently, both Stations 2 and 4 maintain one engine and one medic unit which are cross-staffed (Cross-staffing is a practice whereby firefighters staff several types of emergency response vehicles simultaneously in a work period) by a crew of three firefighters.[3] The Local believes the new fire station would only deploy one engine company and one medic unit, each staffed with two dedicated firefighters. This would reduce the overall daily staffing level by two firefighters.

Currently, MFRD operates apparatus that are not staffed to provide for effective, efficient, and safe emergency operations required by the National Fire Protection Association (NFPA®) Standard 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations and Special Operations to the Public by Career Fire Departments* and the Occupational Safety and Health Administration's (OSHA) rules and regulations. MFRD's fire suppression apparatus are staffed with three firefighters. Staffing apparatus below the minimums set by industry standards has been shown to result in crews being less efficient in completing critical fireground tasks. The smaller the crew size, the more tasks an individual must complete, which contributes to the delay in initiating fire attack and containing fire, which contributes to diminished efficiency in stopping fire loss.

Inadequate staffing levels on fire suppression apparatus expose civilians and firefighters to increased risk. It also further drains fire department resources and stresses the emergency response system by requiring additional apparatus to respond from farther distances. This

[1] Analysis was performed based on the typical daily staffing level as of August 2018. At that time the typical daily staffing was 14 firefighters. As of January 2019, the department's typical daily staffing level is now 12 firefighters.
[2] Potential locations are the 700 block of North 18th Street or the intersection of North 18th Street and Nagle Avenue.
[3] Cross-staffing is a practice whereby firefighters staff several types of emergency response vehicles simultaneously in a work period. The type and scope of the emergency (e.g., structure fire, technical rescue, EMS call) dictates which type of emergency apparatus responds. Cross-staffing leaves frontline suppression apparatus potentially unstaffed and creates the possibility of personnel begin out of the station and unavailable when an incident occurs.

document will discuss the importance of maintaining safe and effective staffing levels and the impact on service when these levels are not met. This document also examines the department's incident demand levels and response capabilities in comparison to NFPA 1710 performance objectives.

Background

MFRD provides fire suppression, technical rescue (including confined space, water, ice, high-angle, trench and collapse rescue), vehicle extrication, HAZMAT, emergency medical services (EMS) first response and transport at the advanced life support (ALS) level, and interfacility transfers. In addition to emergency responses, the department performs other services for the City of Manitowoc such as fire prevention and safety programs, which include fire-safety inspections and a wide range of public education. Currently, MFRD operates four fire stations and deploys three cross-staffed engine/medic companies, one medic unit, a cross-staffed engine/ladder company, and several pieces of reserve and specialty apparatus which are staffed by the previous identified companies.

MFRD provides emergency and non-emergency medical services for the City of Manitowoc and contracted municipalities.[4] MFRD's EMS response boundary covers approximately 142 square miles (a third of Manitowoc County) with an estimated population of 43,100. MFRD performs interfacility transfers from two hospitals located within city boundaries (Holy Family Memorial Hospital and Aurora Medical Center – Manitowoc County) to eleven hospitals located outside of the city. Medic 1 executes the majority of the interfacility transfers which can last for at least two hours. If the MFRD does not have any medic units available for response, the Two River's Fire Department will then be called to perform medical transports. The citizens of Manitowoc should expect longer response times when relying on responses from Two River's Fire Department to respond to an emergency within the city.

Additionally, another result of insufficient staffing and resources is the department frequently has to call in off-duty MFRD firefighters and/or volunteer departments[5] to staff fire stations, respond to ongoing incidents, or respond to simultaneous incidents when the department experiences high call volumes. The department does not currently have a policy stating the conditions under which off-duty MFRD firefighters should be called in. Typically, however, if there are 5 or fewer firefighters available to respond to an emergency, (usually occurring when three or more apparatus are on-assignment at the same time or if there is a confirmed structure

[4] Town of Centerville, Village of Cleveland, Village of Francis Creek, Village of Kellnersville, Town of Manitowoc Rapids, Town of Manitowoc, and Town of Newton.
[5] Volunteer departments include Silver Creek, Newton, Branch, Whitelaw, Rockwood, Francis Creek, Town of Two Rivers, and Cleveland Fire Department. Volunteer departments located within MFRD's medical response boundary do not perform medical transport.

fire), off-duty MFRD firefighters[6] will be asked to respond. Volunteer departments are also requested to respond when there is a confirmed structure fire. Dependent upon personnel availability and the extent of the fire, volunteer firefighters either assist with fireground operations or staff MFRD stations. Off-duty MFRD firefighters and firefighters from volunteer fire departments do not carry personal protective equipment (PPE) so if called to assist with fire suppression, they must first report to a fire station to don gear and board apparatus, greatly increasing the time it takes to arrive on the incident scene.

MFRD's reliance on responses from volunteer fire department resources presents a fireground safety issue. MFRD and the surrounding volunteer fire departments self-contained breathing apparatus (SCBA) are not consistently compatible. By not having compatible SCBA, firefighters may experience issues providing safe breathable air in the event of an unexpected firefighter rescue, which would lead to an increase probability of injury and/or fatality for firefighters.

When the cross-staffed medic units respond to a medical incident, all three firefighters from the engine company transfer to the medic, placing the engine out of service. Cross-staffing medic units with an engine company removes critical fire suppression apparatus from service and greatly reduces the department's ability to respond with the necessary resources to an emergency.

Analysis and Methods

Using Geographic Information Systems (GIS), analysis was performed to evaluate how different staffing and deployment configurations change the department's response capabilities. Using historical traffic patterns,[7] analysis was performed to examine the department's ability to meet industry standard response requirements such as 4-minute initial unit arrival, the establishment of a minimum of four personnel on scene within 4 minutes, 8-minute ALS response capabilities, and the assembly of personnel for low- and medium-hazard structure fires.[8]

Analysis also examined the department's past workload and response performance. MFRD provided computer-aided dispatch (CAD) data for all emergencies responded to from January 1, 2015 to December 31, 2017. The CAD data contain, but are not limited to, information about the type of the emergency incident, the responding apparatus, time the call was received, dispatch time, en route time, time of arrival on scene, clear time, and on-assignment time (definitions provided on the following page). The workload analysis examined the CAD data to evaluate the

[6] Off-duty MFRD firefighters are compensated for a minimum of two hours at time and half when called in.
[7] Historical traffic data contained in ESRI's StreetMap Premium, version 17.2.
[8] Low-hazard structures are typically a two-story single-family dwelling without a basement and with no exposures. Medium-hazard structures consist of open-air strip shopping center and three-story, garden style apartment buildings.

department's historical response capabilities and determine the possible need for additional resources.

The department's workload was evaluated using several parameters, including the total number of incidents and apparatus responses per year, when the highest volume of incidents and apparatus responses occurred throughout the day, the total number of hours each apparatus was engaged on assignment, the number of hours apparatus were engaged at the same time (whether responding to the same incident or to different incidents), and the travel time of the first arriving apparatus. Also, an examination of the department's interfacility transfers was performed to determine the number of responses and the number of hours spent on these assignments. All of these factors were examined to determine how the potential changes in staffing and deployment may affect MFRD's response capabilities and how performance may be improved through the implementation of recommended staffing and deployment enhancements.

Key Definitions

As stated above, an examination of the department's historical call volume data (January 1, 2015 to December 31, 2017) was completed to evaluate the department's response capabilities and performance. The following definitions were created to identify terminology used in the department's CAD reporting system and specific characteristics used to evaluate the department's performance.

Incident: refers to an emergency to which fire department mobile and personnel resources are dispatched to intervene and mitigate. An incident may require a single or multiple apparatus to respond.

Response: refers to an individual unit, or units, being dispatched and traveling to the scene of an incident.

Travel Time: refers to the time interval that begins when a unit is en route to the emergency scene and ends when the unit arrives at the scene.[9]

Key Findings

- MFRD's fire suppression apparatus are staffed with less than four personnel. Apparatus not staffed with a minimum of four firefighters do not meet the company staffing objectives outlined in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program* and NFPA 1710. Because units are not staffed with four, firefighters must rely on supplemental personnel arriving later before making entry into

[9] NFPA 1710 §3.3.53.7 (2016)

environments that are immediately dangerous to life and health (IDLH), such as structure fires, in order to meet objectives outlined in industry standards and OSHA rules and regulations.

- NFPA 1710 requires a minimum of four firefighters on each suppression apparatus and also requires that the first arriving apparatus be on scene within a 4-minute travel time to 90% of incidents.[10] Additionally, the OSHA "2 In/2 Out" Regulation[11] requires that a minimum of four personnel be on scene before firefighters may enter a building. This Regulation states a minimum of two firefighters must be positioned outside of the structure before two firefighters can enter the building to perform interior firefighting. Currently, the department is capable of assembling a minimum of four firefighters on 26.5% of city roads within 4 minutes, assuming all units are available to respond immediately upon dispatch. Pursuant to implementing staffing and deployment, recommendations (including staffing all suppression apparatus with a minimum of four firefighters and the discontinuation of cross-staffing[12]) the department would likely be able to assemble a minimum of four firefighters on 67.5% of city roads within 4 minutes of travel

- NFPA 1710 requires a minimum of 14 firefighters and 1 command officer to arrive on the scene of a fire occurring in a typical 2,000 square foot residential structure within 8 minutes of travel to 90% of incidents. Currently, the department is **not** capable of assembling a minimum of 15 firefighters on any portion of city roads within 8 minutes of travel. The current daily staffing level of fourteen firefighters restricts MFRD's ability to respond appropriately to a low-hazard structure fire to meet NFPA 1710 low-hazard alarm response requirements. Pursuant to implementing staffing and deployment recommendations, the department would likely be able to assemble a minimum of 15 firefighters within 8 minutes of travel on 56.2% of city roads.

- NFPA 1710 requires a minimum of 26 firefighters and 1 incident commander with an aide to arrive on the scene of a medium-hazard structure fire within 8 minutes of travel to 90% of incidents, for a total of 28 responders. Currently, the department is **not** capable of assembling a minimum of 28 firefighters on any portion of city roads within 8 minutes of travel. The current daily staffing level of fourteen firefighters restricts MFRD's ability to respond appropriately to a medium-hazard structure fire to meet NFPA 1710 low-hazard

[10] Percentages (response capabilities for both existing and potential configurations) given in this document are based on a desire to cover one hundred percent of all road segments within a fire department's total response area. These percentages are used as a proxy for the percentage of incidents covered, as it is impossible to predict where all of a jurisdiction's future emergencies will occur. Therefore, the emergency response capabilities as are presented herein are represented by the portion of all road segments able to be reached within the specified time parameters.
[11] 29 CFR 1910.134.
[12] Detailed in Table 9 on page 73.

alarm response. Pursuant to implementing staffing and deployment recommendations, the department would likely be able to assemble a minimum of 28 firefighters within 8 minutes of travel on 12.6% of city roads.

- From January 1, 2015 and December 31, 2017, MFRD frontline apparatus responded to 17,077 incidents and performed 18,639 responses. The department experienced an 11.5% **increase** in incidents and 11.8% **increase** in responses in 2017 compared to 2015. The highest volume of incidents and apparatus responses took place between the hours of 7:00 a.m. and 9:00 p.m.

- In 2017, for 51.2% of the total annual hours, one or more apparatus were on assignment at the same time. Based on this finding, over 50% of the time, MFRD did not have the available resources required to meet the department's own definition of an initial alarm response to a structure fire. [13] In these instances, MFRD would have to rely on calling in off-duty firefighters and/or volunteer departments to provide the necessary resources and personnel to mitigate the incident.

- In 2017, the department experienced a 38.1% **increase** in the number of hours one or more apparatus were on assignment at the same time compared to 2015.

- In 2017, for 7.5% of the total annual hours, three or more apparatus were on assignment at the same time. When three or more apparatus are engaged on assignment at the same time, the department will likely have 5 or fewer firefighters available to respond to an emergency resulting in the department calling in off-duty MFRD firefighters and/or resources from volunteer departments to respond to an incident or staff MFRD's fire stations.

- In 2017, the department experienced a 150% **increase** in the number of hours three or more apparatus were on assignment at the same time compared to 2015.

- From January 1, 2015 to December 31, 2017, the average travel time of the first arriving apparatus was 4 minutes and 29 seconds and the 90th percentile travel time was 7 minutes and 14 seconds. There was a 9.2% **increase** (23 seconds longer) in the average and a 14.3% **increase** (1 minute longer) in the 90th percentile travel times in 2017 compared to the average and 90th percentile travel times in 2015.

[13] MFRD's initial alarm assignment to a confirmed structure fire is three engine companies, one ladder company, and one medic unit.

IAFF Recommendations

- MFRD should staff all fire suppression apparatus with a minimum of four firefighters to meet the minimum staffing objectives stated in NFPA 1500 and NFPA 1710.

- MFRD should stop the practice of cross-staffing the ladder company and medic units with engine companies to ensure the department has the appropriate resources available to respond to all type of emergencies.

- MFRD should increase daily staffing to ensure the department's initial alarm response to a fire occurring in a low-hazard structure is responded to by a minimum of 15 firefighters, in accordance with NFPA 1710 requirements.

- Due to the high number of CAD entries with missing en route or arrival on-scene times, the department should make an effort to improve CAD recordings of time stamps in order to facilitate future analysis.

- Due to the extreme weather and natural disasters the city experiences such as tornados and strong winds, winter storms (snow and ice), extreme temperatures, floods, wildland fires, landslides, and hazardous materials incidents, MFRD should evaluate its ability to respond to natural disasters and ensure the department is equipped with the necessary resources to respond to all types of incidents, even those that may occur less frequently, but have the potential for significant loss.

- MFRD should routinely perform risk and hazard assessments, along with a review of system demand, to identify the potential threats to the community so that stakeholders and decision makers can make informed decisions on how to best mitigate, or at least minimize, these threats.

Executive Summary Conclusion

MFRD's fire suppression apparatus are staffed with less than four firefighters. Apparatus not staffed with a minimum of four firefighters do not meet the minimum staffing objectives outlined in NFPA 1500 and NFPA 1710. Fire suppression resources are not deployed adequately for the arrival of the first arriving company within 4 minutes of travel to 90% of incidents. MFRD's response capabilities do not meet objectives included in the industry standard NFPA 1710 which directs the assembly of 15 firefighters to a low-hazard structure fire within 8 minutes of travel to 90% of incidents.

The potential the department may merge two stations together resulting in Fire Stations 2 and 4 being closed and apparatus being relocated to a new fire station will reduce the department's response capabilities. The reduction in daily staffing from fourteen to twelve firefighters will greatly restrict the department's ability to respond with the appropriate personnel and resources to all types of emergencies. It will also increase the frequency of the number of times the department has to rely on off-duty MFRD firefighters and/or volunteer personnel. Currently, off-duty MFRD firefighters and/or volunteers are requested during periods of high call volume, when there is a confirmed structure fire, or if there are less than five firefighters available to respond (typically occurring when three or more apparatus are on-assignment at the same time). Off-duty and volunteer firefighter response times are unpredictable and typically longer as these personnel must come from different distances (i.e. work or home) to the fire station to gather the necessary equipment and then respond to the emergency.

Low staffing levels result in the department's emergency response capabilities being significantly limited. Staffing apparatus to meet the minimum staffing level objectives outlined in industry standards and staffing the ladder and medic companies with dedicated crews will increase the department's ability to establish a minimum of four personnel at emergency incidents and to assemble effective response forces at low-hazard structure fires.

A fire department should be designed to adequately respond to a number of emergencies occurring simultaneously in a manner that aims to minimize the loss of life and the loss of property that the fire department is charged to protect. Any proposed changes in staffing, deployment and station location should be made only after considering the historical location of calls, response times to specific target hazards, compliance with departmental Standard Operating Procedures (SOPs), existing industry standards, including NFPA 1500 and NFPA 1710, and the citizens' expectations of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames to make a difference in their emergency.

The provision of fire protection and EMS response are essential services that governments must provide. However, in order for these services to be effective and efficient, they must be staffed and positioned appropriately to address emergencies in an equitable manner, as they occur. The findings in this report will provide the department and city officials with information on how the department's present response capabilities compare to industry standards and how the lack of resources negatively affects the MFRD's ability to appropriately respond to incidents in the City of Manitowoc. This information will demonstrate why the department must stop the practice of cross-staffing apparatus and increase resources to ensure it can meet demand.

Risk Assessment

A significant part of planning for future fire department strategies is knowing the risks in the community. As such, risk characteristics within the City of Manitowoc were examined for this report.

The Manitowoc Fire Rescue Department is located in Manitowoc, Wisconsin, in Manitowoc County. MFRD is responsible for responding to approximately 18 square miles in the City of Manitowoc. Manitowoc, WI had a 2016 estimated population of 33,183 residents.[14]

In addition to the general population, it is important to identify distinctive groups within the population that can drive emergency services demand. A vulnerable population is defined as a group of people who are unable to anticipate, cope with, resist, and recover from the impact of a disaster. According to the U.S. Census Bureau, 2012 - 2016 American Community Survey 5-Year Estimates, 25.7% of Manitowoc's population was in a vulnerable category based on age. This category consists of persons under the age of 5 (5.9%) and persons 65 years of age and older (19.8%) but does not include the special needs population. These groups may be unable to care for themselves or have multiple health issues. Additionally, 14.1% of the population was living at or below the poverty line.[15] These are people who generally lack the means to properly maintain residences which can lead to an increased risk for fire. Typically, people living within these demographic characteristics are at an increased risk for medical complications and fire-related injury or death.

The risk assessment also examined housing characteristics. Based on 2012 - 2016 American Community Survey 5-Year Estimates, there were 16,037 housing units, with the majority being single family residences (66.7%), followed by multifamily (30.9%), and the remainder being mobile homes (2.4%). Of these structures, 61.9% were of pre-1970 construction and 30.3% were built in 1939 or earlier.[16] Typically, when there are high numbers of older buildings constructed before many current fire codes were developed, there is an increased demand on emergency services.

In addition, the city is also at risk for natural disasters. The Manitowoc County 2014 Hazard Mitigation Plan[17] prepares county and city officials to response to tornado and strong winds, winter storms (snow and ice), extreme temperatures, floods, wildland fires, landslides, and hazardous materials incidents. Wisconsin is located on the northern edge of the nation's most

[14] https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml
[15] Ibid.
[16] https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF
[17] http://www.co.manitowoc.wi.us/media/3118/hazard-mitigation-plan.pdf

frequent zone of tornadoes. Wisconsin's tornado season runs from the beginning of April through September. Tornadoes have been known to cause personal property damages, deaths, and injuries. The City of Manitowoc also experiences arctic air masses and high winds causing very low temperatures and wind chills during the winter months. The city has average annual snowfall totals of 37.5 inches. Due to the extreme cold and snowfall, MFRD may encounter issues locating and/or connecting to fire hydrants. In cases like this, there will be delays in the department's ability to establish a water source. Extreme cold, snow, and ice will complicate fire department operations in several ways (FEMA Special Report: Fire Department Preparedness for Extreme Weather Emergencies and Natural Disasters April 2008)[18]:

- Roads are less passable or altogether impassible from heavy snow and ice on the roadway or from broken water mains that flood and then freeze
- Snow and ice present operational hazards to on-scene personnel (slips, falls)
- Equipment and apparatus will be more susceptible to damage (pumps freezing, etc.)
- Improvised heating systems may cause more fires or carbon monoxide poisoning, placing additional service demands on the fire department
- The risk of hypothermia for both firefighters and civilians increases.

Fire department personnel must take precautions to limit exposure to extreme cold. This often is accomplished by rotating crews more often and providing heated rehabilitation areas. It also is recommended that personnel have an extra change of dry uniforms and protective clothing. An extended cold spell may cause bodies of water to freeze that do not normally do so. There is a greater potential for ice rescue calls. Fire departments should prepare for ice rescue operations with the proper equipment and training to reduce the risk of injury and enhance unit effectiveness.[19]

Due to the treacherous and threatening conditions to which these potential hazards expose the public, MFRD must be equipped with the necessary resources to respond to all types of disasters.

[18] https://www.usfa.fema.gov/downloads/pdf/publications/tr_162.pdf
[19] Ibid.

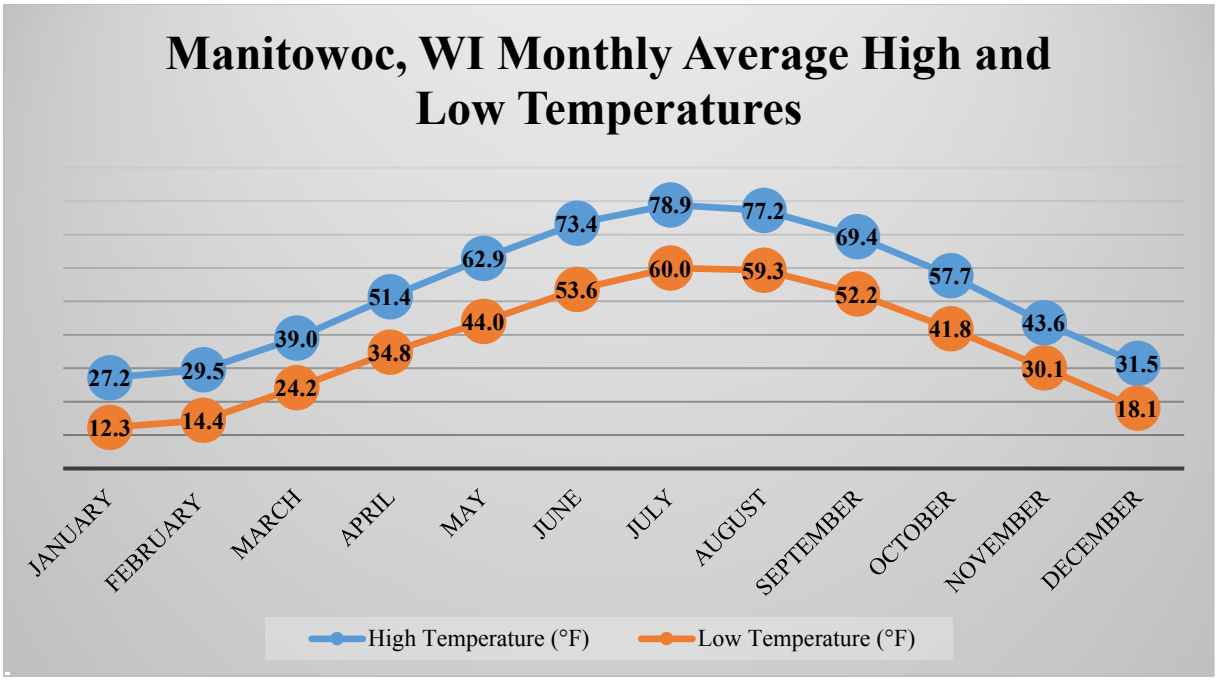


Chart 1: Manitowoc, WI Average Monthly High and Low Temperatures. Chart 1 depicts the average monthly high and low temperatures in Manitowoc, WI. In the winter months, Manitowoc has average monthly temperatures in the high 20s to low 30s. Manitowoc also frequently experiences wind chills in the single digits and below.

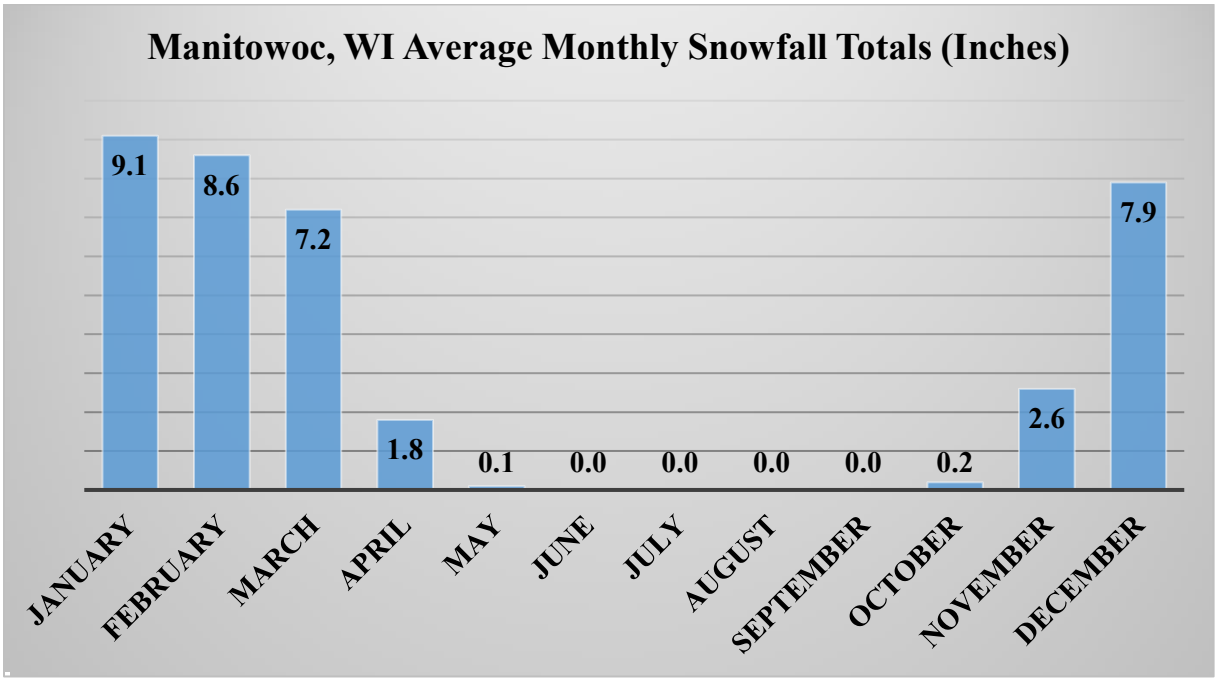
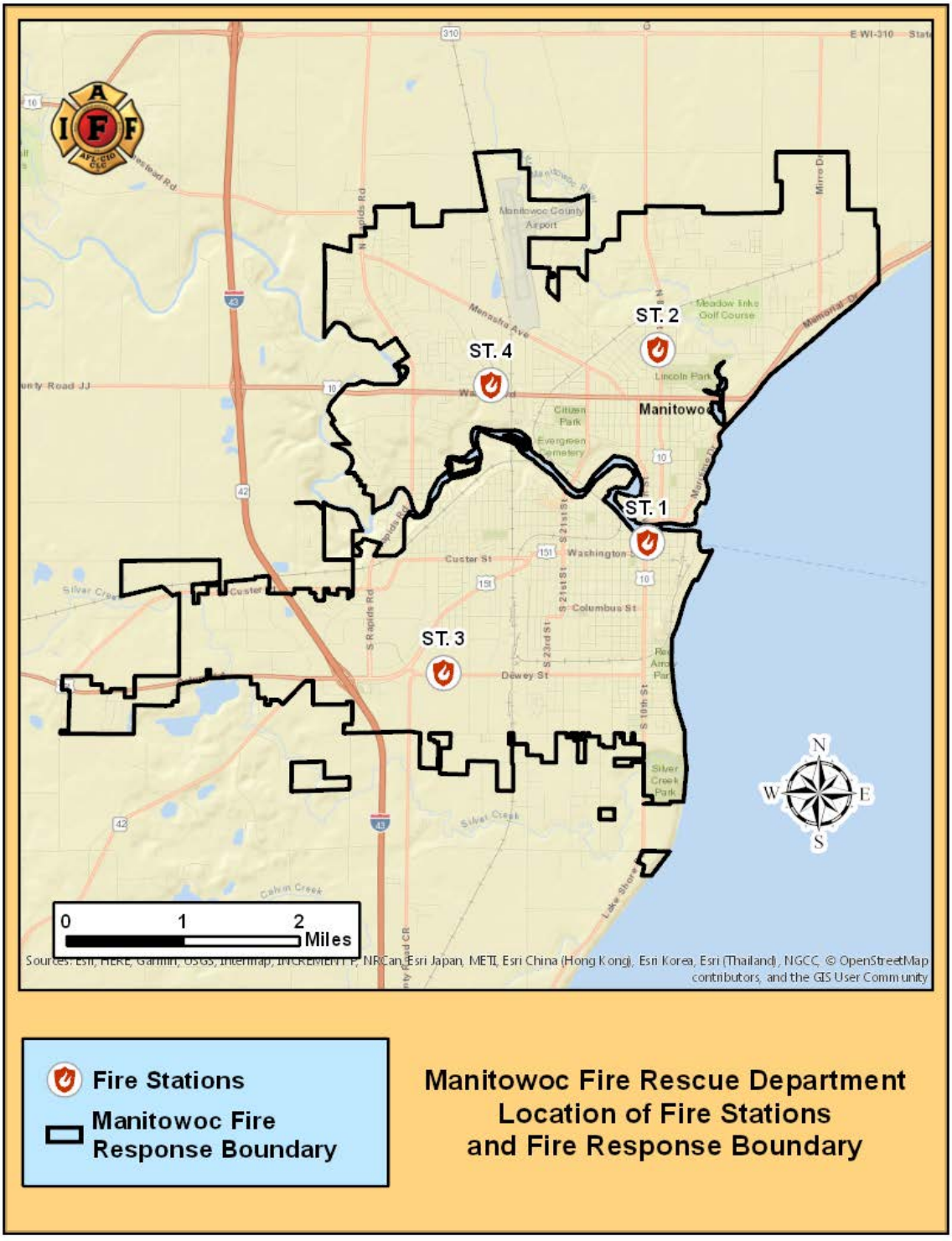
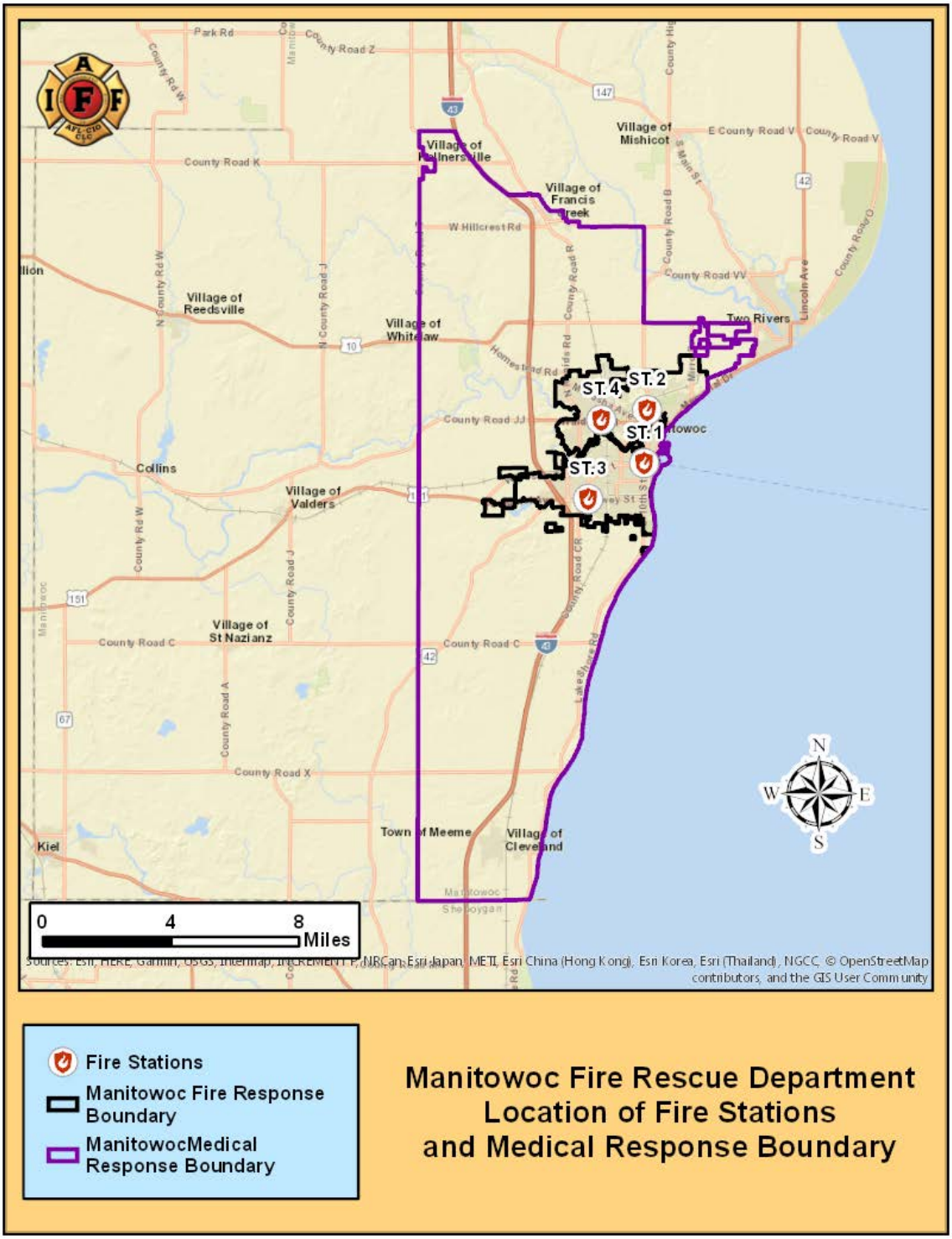


Chart 2: Manitowoc, WI Average Monthly Snowfall Totals (Inches). Chart 2 depicts the average monthly snowfall totals (inches) in Manitowoc, WI. The city has an average annual snowfall total of 37.5 inches.

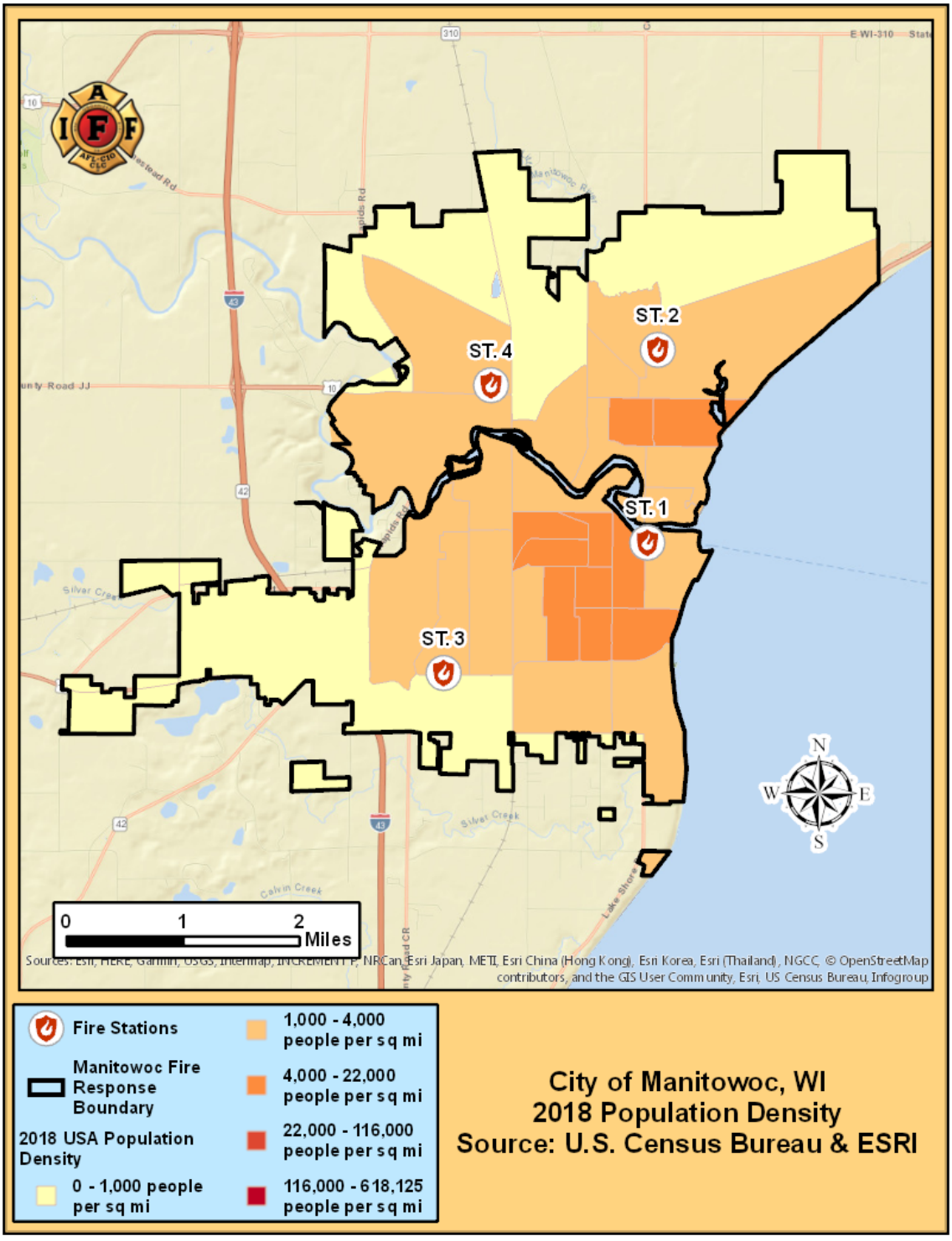
The citizens of Manitowoc should expect delays in response during times of inclement weather. Roads can quickly become impassible due to snow and ice on the roadways, greatly increasing the time it takes MFRD's apparatus to arrive on scene. The limited resources and practice of cross-staffing apparatus also contribute to longer response times. Due to the combination of inclement weather and insufficient fire department resources, citizens of Manitowoc should expect longer response times in the winter months compared to the summer months.



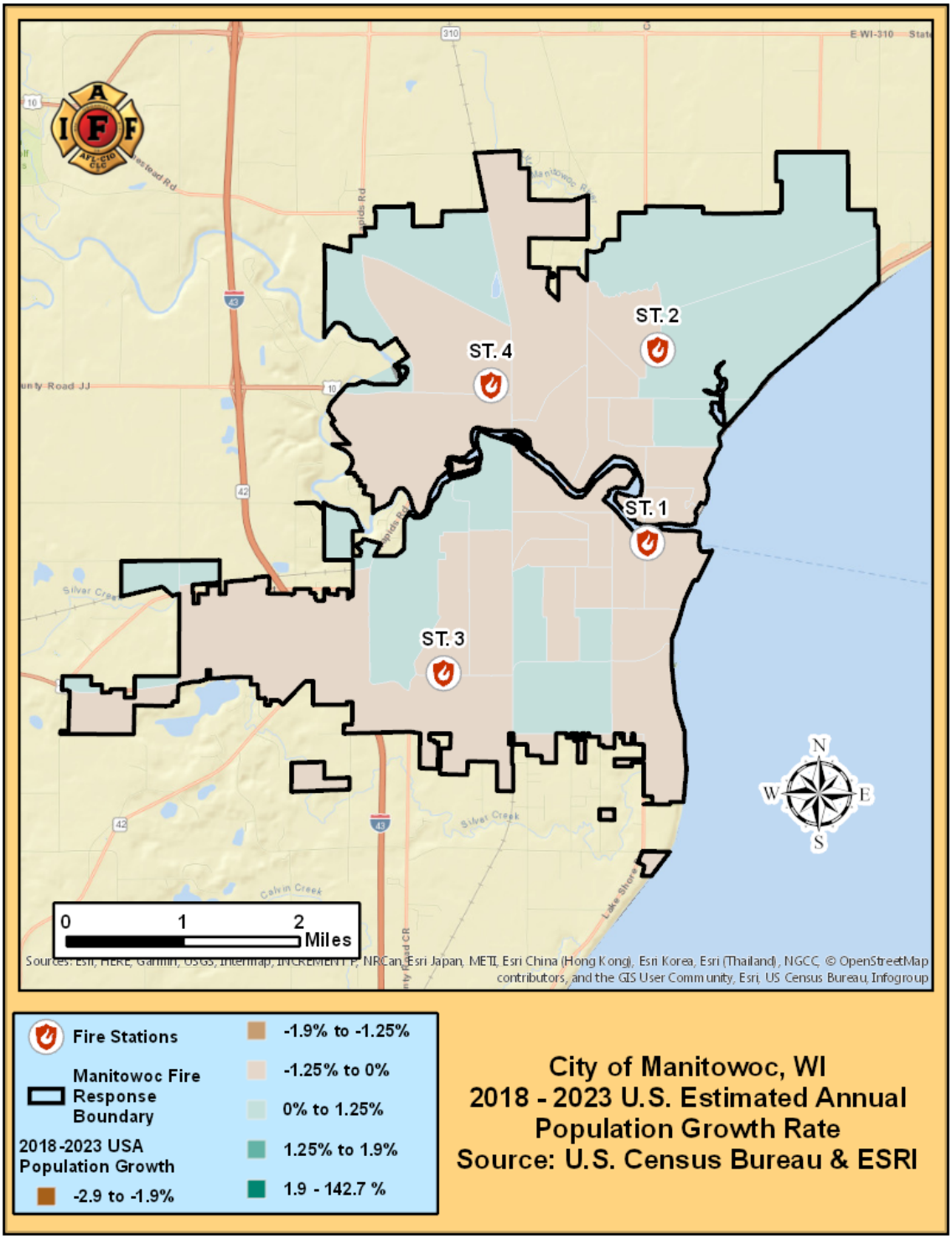
Map 1: Location of Fire Stations and Fire Response Boundary. Map 1 depicts the current locations of MFRD's fire stations and the fire response boundary.



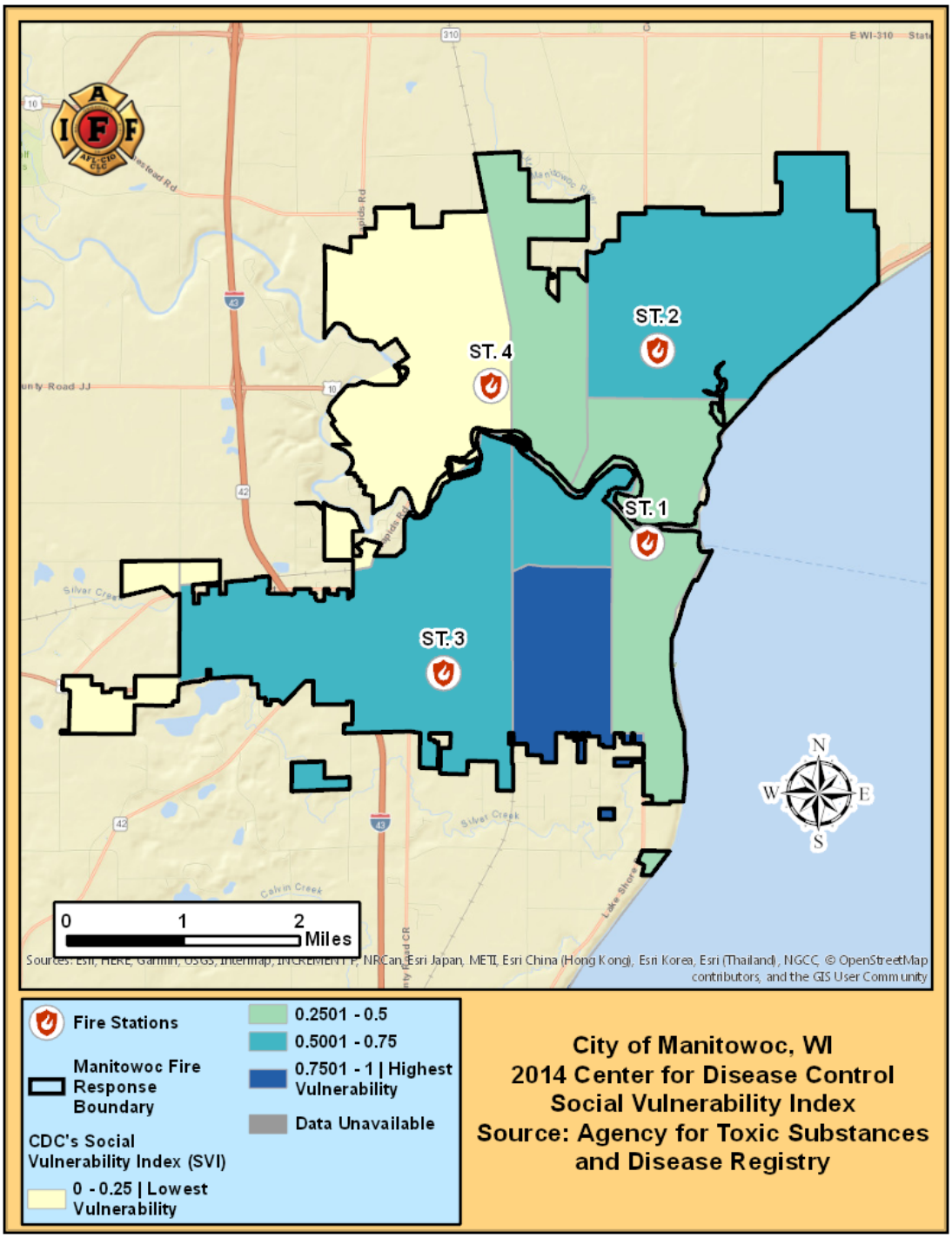
Map 2: Location of Fire Stations and Medical Response Boundary. Map 2 depicts the current locations of MFRD's fire stations and the medical response boundary.



Map 3: 2018 Population Density. Map 3 depicts the City of Manitowoc's population density in 2018. Areas with a high population density are likely to have a high volume of emergency incidents, resulting in a larger demand placed on the department in these areas.

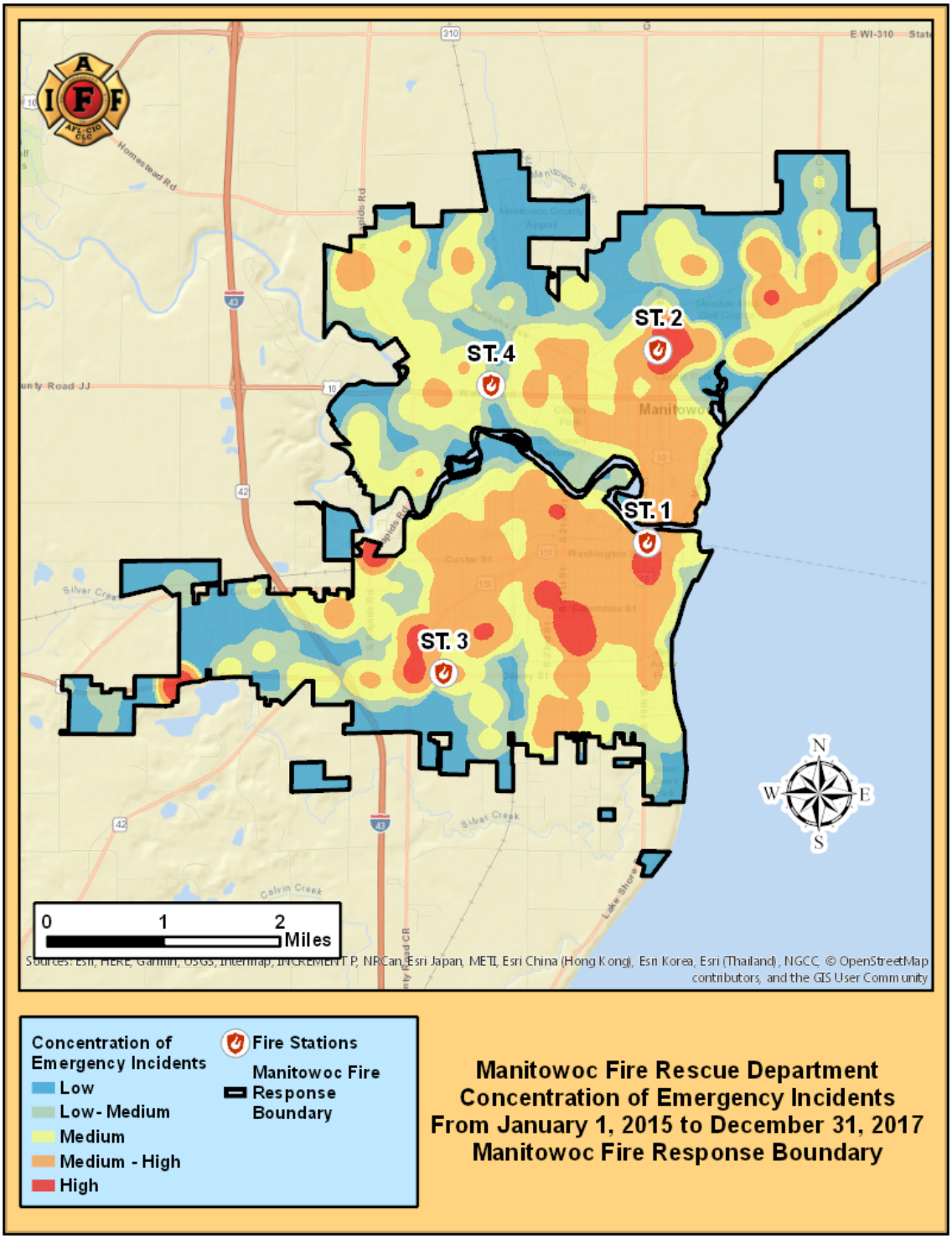


Map 4: 2018 – 2023 Estimated Annual Population Growth Rate. Map 4 depicts the City of Manitowoc's estimated annual population growth rate from 2018 – 2023. Areas that have a high estimated population growth rate will likely experience an increase in emergency services requests. Typically, as population increases, so does demand.

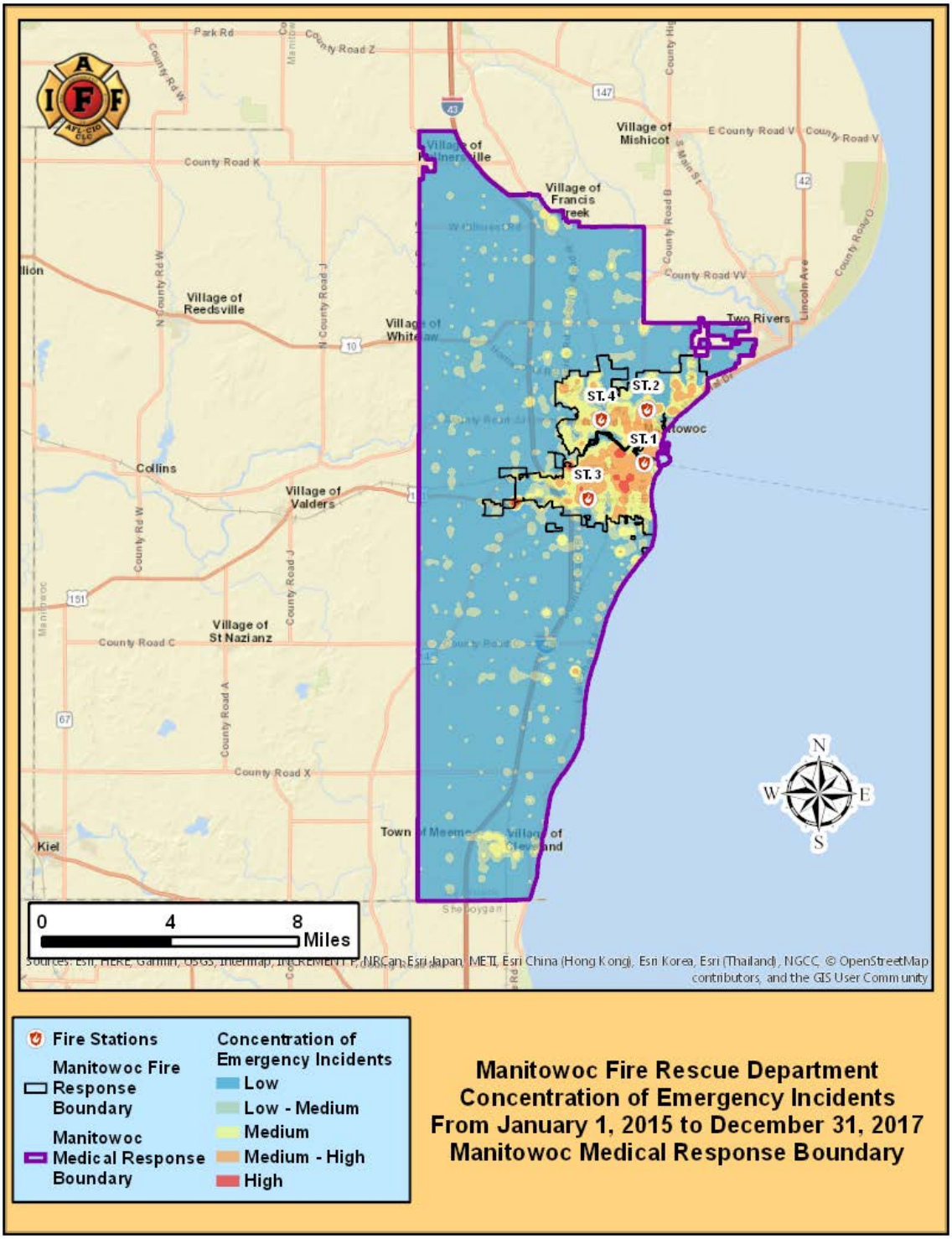


Map 5: 2014 Center for Disease Control (CDC)'s Social Vulnerability Index (SVI). Map 5 depicts the social vulnerability index[20] score per census tract in the City of Manitowoc. An SVI score is determined by examining factors such as socio-economics, housing composition, residents with disabilities, minority status, languages spoken, and housing and transportation. An SVI score assists in identifying areas in the community that will most likely need assistance before, during, and after a hazardous event. The closer the SVI score is to 1, the higher the vulnerability.

[20] https://svi.cdc.gov/Documents/FactSheet/SVIFactSheet.pdf



Map 6: Concentration of Emergency Incidents, All Incident Types from January 1, 2015 to December 31, 2017, Manitowoc Fire Response Boundary. Map 6 depicts the concentration levels of emergency incidents from January 1, 2015 to December 31, 2017 within MFRD's fire response boundary. The highest concentrations of emergency incidents were located southwest of Fire Station 1, north of Fire Station 2, and west of Fire Station 3. Additional resources should be positioned at fire stations that experience a high concentration of emergency incidents to ensure timely, safe, and effective response.



Map 7: Concentration of Emergency Incidents, All Incident Types from January 1, 2015 to December 31, 2017, Manitowoc Medical Response Boundary. Map 7 depicts the concentration levels of emergency incidents from January 1, 2015 to December 31, 2017 within MFRD's medical response boundary. The highest concentrations of emergency incidents were located within MFRD's fire response boundary and the southern part of the EMS response boundary near the Town of Meeme and Village of Cleveland.

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Fire Suppression Operations

The business of providing emergency services has always been labor intensive and remains so today. Although new technology has improved firefighting equipment and protective gear and has led to advances in modern medicine, it is the firefighters who still perform the time-critical tasks necessary to contain and extinguish fires, rescue trapped occupants from a burning structure, and provide emergency medical and rescue services.

A small flame can quickly burn out of control and become a major fire in a short period of time. This is because fire grows and expands exponentially as time passes. In the time frame of fire growth, the temperature of a fire rises to above 1,000° Fahrenheit (F). It is generally accepted in the fire service that for a medium growth rate fire,[21] flashover--the very rapid spreading of the fire due to super heating of room contents and other combustibles—can occur. Assuming an immediate discovery of a fire, followed by an un-delayed call to 9-1-1, and dispatch of emergency responders, flashover is likely to occur within 8 minutes of fire ignition. However, studies conducted by the Underwriters Laboratory (UL) and the National Institute of Standards and Technology (NIST) have proved that, due to new building construction materials and room contents that act as fuel, flashover may occur much sooner.

At the point of flashover, the odds of survival for unprotected individuals inside the affected area are virtually non-existent. The rapid response of an appropriate number of firefighters is therefore essential to initiating effective fire suppression and rescue operations that seek to minimize fire spread and maximize the odds of preserving both life and property.

This section will explain fire growth and the importance of fire department response to a low-hazard structure fire. A low-hazard structure fire is defined as a fire that occurs in a typical, 2,000 square foot, single-family residential home with no basement or exposures.

[21] As defined in the *Handbook of the Society of Fire Protection Engineers*, a fast fire grows exponentially to 1.0 MW in 150 seconds. A medium fire grows exponentially to 1 MW in 300 seconds. A slow fire grows exponentially to 1 MW in 600 seconds. A 1 MW fire can be thought-of as a typical upholstered chair burning at its peak. A large sofa might be 2 to 3 MWs.

Fire Growth

The Incipient Phase

The first stage of any fire is the incipient stage. In this stage a high heat source is applied to a combustible material. The heat source causes chemical changes to the material's surface which converts from a solid and begins to release combustible gases. If enough combustible gases are released the material will begin to burn freely.

This process is exothermic, which means that it produces heat. The heat being generated raises the temperature of surrounding materials, which in turn begin to release more combustible gases into the environment and begins a chemical chain reaction of heat release and burning. At this point the fire may go out if the first object completely burns before another begins or the fire can progress to the next stage, which is called the Free Burning Phase.

The Free Burning Phase

The second stage of fire growth is the "free" or "open burning" stage. When an object in a room starts to burn, (such as the armchair in Figure 3, following page), it burns in much the same way as it would in an open area. In this phase of the fire, oxygen in the air is drawn into the flame and combustible gases rise to the ceiling and spread out laterally. Simultaneously, the materials that are burning continue to release more heat, which heats nearby objects and materials to their ignition temperature, and they begin burning as well. Inside a room, unlike in an open area, after a short period of time confinement begins to influence fire development. The combustible gases that have collected on the ceiling will eventually begin to support fire and will begin to burn. Thermal radiation from this hot layer begins to heat the ceiling, the upper walls, and all the objects in the lower part of the room which will augment both the rate of burning of the original object and the rate of flame spread over its surface.

When this occurs, the structure fire reaches a critical point: either it has sufficient oxygen available to move on to the next stage or the fire has insufficient oxygen available to burn and it progresses back to the incipient stage. However, since structures are not airtight, there is a low likelihood of the fire depleting the available oxygen. During this stage of fire growth, toxic chemicals released by the fire and high heat are enough to burn people in the immediate area and disorient and/or incapacitate people in the structure. Without rapid response and intervention by an adequately staffed fire department, the fire will likely spread to the rest of the structure.

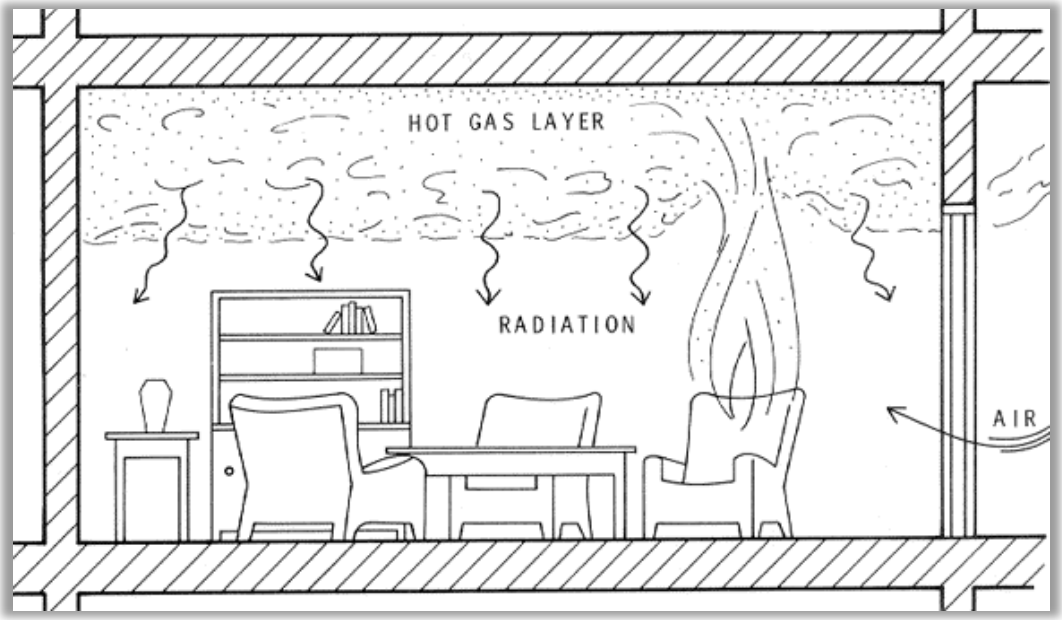

Figure 1: Fire Growth in a Compartment.[22] Figure 1 depicts the growth of fire in a compartment, which is an enclosed space or room in a building. In a compartment the walls, ceiling, floors, and objects absorb radiant heat produced by the fire. Unabsorbed heat is reflected back to the initial fuel source, which is depicted by the armchair above. This reflected heat continues to increase the temperature of the fuel source and therefore the rate of combustion. Hot smoke, combustible gases, and super-heated air will then rise to the ceiling and spread at first laterally across the ceiling, but later downward towards other fuel sources and the floor of the compartment. As this toxic, super-heated cloud touches cooler materials, the heat is conducted to them, thus increasing their temperature and eventually leading to pyrolysis, which is the process where a fuel source begins to release flammable vapor. This release of flammable vapor leads to further fire growth and eventually flashover. Flashover is the point at which all exposed fuel sources in a compartment ignite.

If there is sufficient oxygen, then the fire will continue to grow and the heating of the other combustibles in the room will continue to the point where they reach their ignition temperatures more or less simultaneously. If this occurs, all combustible materials in the room will spontaneously ignite. This transition from the burning of one or two objects to full room involvement is referred to as flashover. [23]

Flashover

Flashover, when it occurs, is the most significant event during a structure fire. As combustible gases are produced by the two previous stages, they are not entirely consumed and are therefore available fuels. These available fuels rise and form a superheated gas layer at the ceiling that continues to increase, until it begins to bank down to the floor, heating all combustible objects regardless of their proximity to the burning object. In a typical structure fire, the gas layer at the

[22] Image courtesy of University of California at Davis Fire Department
[23] J.R. Mehaffey, Ph.D., Flammability of Building Materials and Fire Growth, Institute for Research in Construction (1987)

ceiling can quickly reach temperatures of 1,200˚ F and higher. With enough existing oxygen at the floor level, flashover occurs, which is when everything in the room ignites at once. The instantaneous eruption of flames generates a tremendous amount of heat, smoke, and pressure. The pressure generated from this explosion has enough force to push fire beyond the room of origin and into the rest of the structure, as well as through doors and windows.

As has been noted, at the time of flashover, windows in the room will break. When these windows break, as a result of the increased pressure in the room, a fresh supply of air from the outside of the building is available to help the fire grow and spread. Based on the dynamics of fire behavior in an unprotected structure fire, any decrease in emergency unit response capabilities will correlate directly with an increase in expected life, property, and economic loss.

The Importance of Adequate Staffing: Concentration

NFPA 1500 and 1710 both recommend that a minimum acceptable fire company staffing level should be four members responding on, or arriving with, each engine and ladder company responding to any type of fire.

A prime objective of fire service agencies is to maintain enough strategically located personnel and equipment so that the minimum effective response force can reach a reasonable number of fire scenes before flashover occurs.[24] Of utmost importance in limiting fire spread is the quick arrival of sufficient numbers of personnel and equipment to attack and extinguish the fire, as well as rescue any trapped occupants and care for the injured. Sub-optimal staffing of arriving units may delay such an attack, thus allowing the fire to progress to more dangerous conditions for firefighters and civilians

Staffing deficiencies on primary fire suppression apparatus negatively affects the ability of the fire department to safely and effectively mitigate emergencies and therefore correlate directly with higher risks and increased losses, both physically and economically. Continued fire growth beyond the time of firefighter on scene arrival is directly linked to the time it takes to initiate fire suppression operations. As indicated in Table 1, responding companies staffed with four firefighters are capable of initiating critical fire ground operational tasks more efficiently than those with crew sizes below industry standards.

[24] University of California at Davis Fire Department website; site visited June 7, 2004.
< http://fire.ucdavis.edu/ucdfire/UCDFDoperations.htm >

Engine Company Duties					Ladder Company Duties			
Fireground Tasks	**Advance Attack Line**	**% Change**	**Water on Fire**	**% Change**	**Primary Search**	**% Change**	**Venting Time**	**% Change**
4 Firefighters	0:03:27		0:08:41		0:08:47		0:04:42	
3 Firefighters	0:03:56	12% Less Efficient	0:09:15	6% Less Efficient	0:09:10	4% Less Efficient	0:07:01	32% Less Efficient
2 Firefighters	0:04:53	29% Less Efficient	0:10:16	15% Less Efficient	0:12:16	28% Less Efficient	0:07:36	38% Less Efficient

Table 1: Impact of Crew Size on a Low-Hazard Residential Fire.[25] Table 1 compares and contrasts the efficiencies of suppression companies in the completion of critical tasks for fire control and extinguishment. The smaller the crew size, the more tasks an individual must complete as a team member, which contributes to the delay in initiating fire attack and contributes to diminished efficiency in stopping fire loss. Currently, MFRD staffs all engine companies with 3 firefighters and cross-staffs Ladder 1 with the crew assigned to Engine 1.

First-arriving companies staffed with four firefighters are more efficient in all aspects of initial fire suppression and search and rescue operations compared to two- or three-person companies. There is a significant increase in time for all the tasks if a company arrives on scene staffed with only three firefighters compared to four firefighters. According to the NIST Report on Residential Fireground Field Experiments, four-person crews are able to complete time critical fireground tasks 5.1 minutes (nearly 25%) faster than three-person crews. The increase in time to task completion corresponds with an increase in risk to both firefighters and trapped occupants.

With four-person crews, the effectiveness of first-arriving engine company interior attack operations *increases* by 12% to 29% efficiency compared to three- and two-person crews respectively. The efficacy of search and rescue operations also *increases* by 4% to 28% with four-person crews compared to three- and two-person crews. Moreover, with a four-person company, because the first-in unit is staffed with a sufficient number of personnel to accomplish its assigned duties, the second-in company does not need to support first-in company operations and is therefore capable of performing other critical fireground tasks that are likely to improve safety and outcomes.

At the scene of a structure fire, the driver/operator of the first engine company on the scene must remain with the apparatus to operate the pump. This leaves one firefighter to assist the operator in securing a water source from a hydrant and two firefighters to deploy a hoseline and stretch it to the fire. After assisting the operator, the third firefighter should begin to assist the other two firefighters with advancing the hoseline into the building and to the location of the fire. Before initiating fire suppression, the supervising officer of the first arriving engine company is also

[25] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.

responsible for walking around the building to assess the situation, determine the extent of the emergency, and request any additional resources necessary to mitigate the fire.

Similarly, the driver/operator of the first arriving ladder company must remain with the apparatus to safely position and operate the aerial device while the other three firefighters also perform critical fireground tasks such as ventilation and search and rescue. Due to the demands of fireground activities, a fire attack initiated by companies with only three or fewer firefighters is not capable of effecting a safe and effective fire suppression and/or rescue operation until additional personnel arrive.

Insufficient numbers of emergency response units, or inadequate staffing levels on those units, exposes civilians and firefighters to increased risk. It also further drains already limited fire department resources and stresses the emergency response system by requiring additional apparatus to respond from further distances. Failing to assemble sufficient resources on the scene of a fire in time to stop the spread and extinguish the fire, conduct a search, and rescue any trapped occupants puts responding firefighters and occupants in a dangerous environment with exponential risk escalation such that it is difficult to catch up and mitigate the event to a positive outcome.

The Importance of Crew Size to Overall Scene Time

Studies have shown that the more personnel that arrive on engine and ladder truck companies to the scene of a fire, the less time it takes to do all aspects of fire suppression, search and rescue, and other critical fireground activities. As dispatched units arrive with sufficient numbers of firefighters, the overall time on the scene of an emergency decreases since critical fireground tasks can be completed simultaneously rather than in sequence. This also results in the decrease of on-scene risk levels. In other words, the more firefighters available to respond and arrive early to a structure fire, the less time it takes to extinguish the fire and perform search and rescue activities, thus reducing the risk of injury and death to both firefighters and trapped occupants and reducing the economic loss to the property.

Overall Scene Time Breakdown by Crew Size		
Scenario	**Total Time**	**Efficiency**
4-Person Close Stagger	0:15:44	
3-Person Close Stagger	0:20:30	23% Less Efficient
2-Person Close Stagger	0:22:16	29% Less Efficient
4-Person Far Stagger	0:15:48	
3-Person Far Stagger	0:21:17	26% Less Efficient
2-Person Far Stagger	0:22:52	31% Less Efficient

Table 2: The Relationship between Crew Size and Scene Time.[26] Table 2 displays how companies staffed with larger crew sizes will be on the scene of an emergency for a shorter time than smaller sized companies. This lag on scene could be translated to mean that emergency resources will be unavailable longer to address other emergencies that may arise. Currently, MFRD staffs all fire suppression apparatus with 3 firefighters.

As Table 2 shows, units that arrive with only two firefighters on an engine or ladder truck are on the scene of a fire almost 7 minutes longer than units that arrive with four firefighters on each crew. Responding units arriving with only three firefighters on an apparatus are on the scene of a fire 5 to 6 minutes longer than units that arrive with four firefighters on each apparatus. In addition to crew size, the time between the arriving crews matters to overall effectiveness and total on scene time.

In the NIST study on the low hazard residential fire, close stagger was defined as a 1-minute time difference in the arrival of each responding company. Far stagger was defined as a 2-minute time difference in the arrival of each responding company.[27] [28] The results show a consistent pattern of units arriving with four firefighters in a close stagger or far stagger will decrease the overall time at the scene of the emergency compared to units that arrive with two or three firefighters and are more efficient in fire suppression tasks as well.

[26] Ibid.
[27] Ibid.
[28] One-minute and two-minute arrival stagger times were determined from analysis of deployment data from more than 300 U.S. fire departments responding to a survey on fire department operations conducted by the International Association of Fire Chiefs and the International Association of Firefighters.

Physiological Strain on Smaller Crew Sizes

The same NIST study also examined the relationship between crew size and physiological strain. Two important conclusions were drawn from this part of the experiments.

- Average heart rates were higher for members of small crews.
- These higher heart rates were maintained for longer durations.[29]

In 2017 alone, 53% of all firefighter fatalities were related to overexertion.[30] There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events.[31] Smaller crews are responsible for performing a number of task that are designed to be performed by multiple people and frequently in teams of two. This means that firefighters on smaller crews are required to work harder than larger crews to accomplish multiple tasks. Additionally, as discussed earlier, firefighters on smaller crews will also be working longer than larger sized crews. Working harder and longer in high heat and dangerous, stressful environments increases the likelihood of firefighters suffering an injury, or worse dying, as a result of overexertion.

Charts 3 and 4, on the following pages, highlight the cardiovascular impact on firefighters based on crew size for the first arriving engine and truck company. The heart rates of firefighters of crew sizes ranging from 2 to 5 firefighters were measured as they participated in the NIST study. The study was able to conclude that not only do smaller crews work harder and longer than larger crews, their heart rates are also more elevated for longer periods of time as well. This increases the risk of firefighters suffering an injury or death from overexertion. A firefighter suffering a medical emergency on the scene of a working fire, EMS, or rescue incident negatively impacts outcomes and increases the risk to the community, the citizen requiring assistance, and the firefighter.

[29] Averill, J.D. et al. (2010). Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.
[30] Fahy, R.F., LeBlanc, P.R., Molis, J.L. (June, 2018) Firefighter Fatalities in the United States-2017. NFPA.
[31] Albert, C.A., Mittleman, M.A., Chae C.U., Lee, I.M., Hennekens, C.H., Manson, J.E. (2000) Triggering Sudden Death from Cardiac Causes by Vigorous Exertion. N Engl J Med 343(19):1355-1361

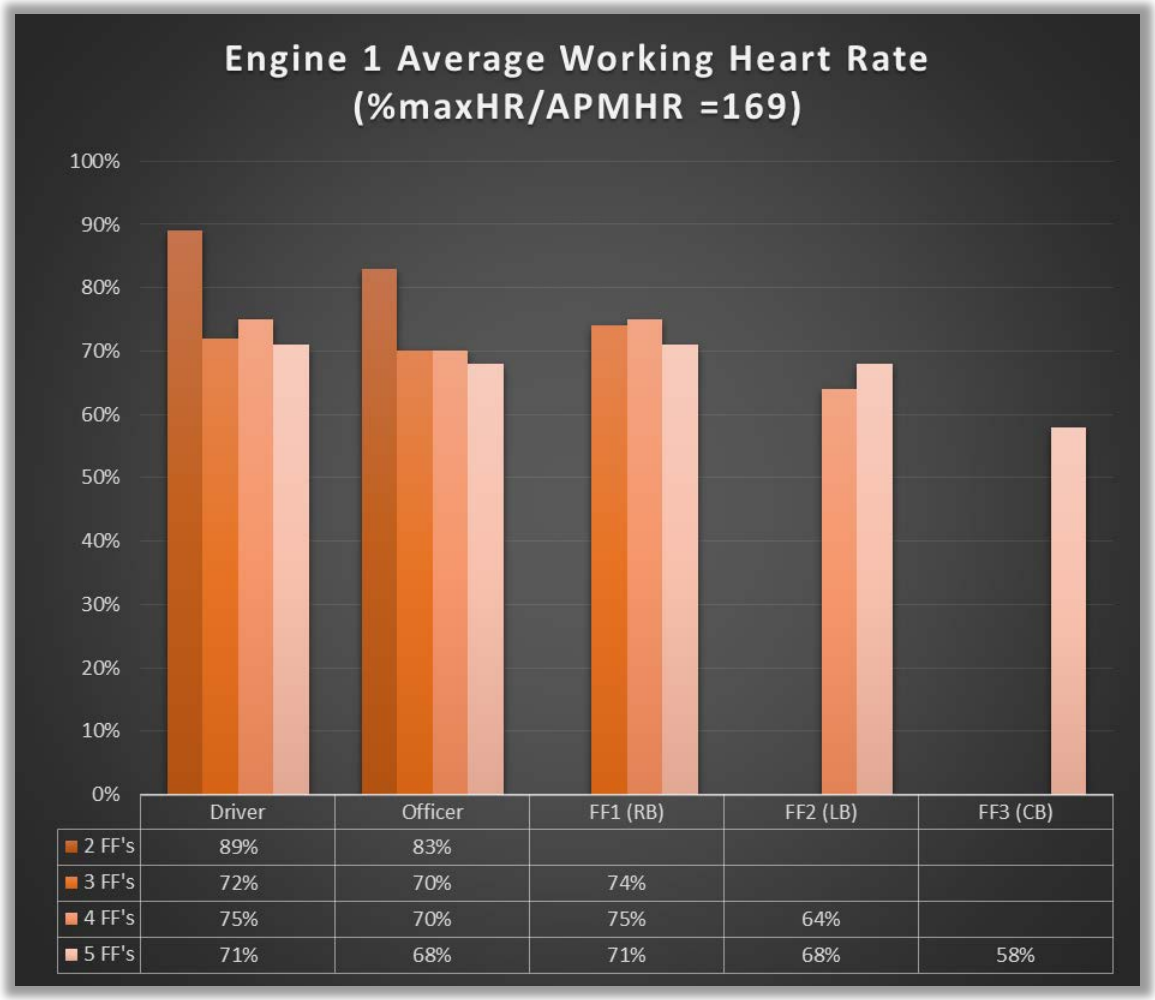

Chart 3: Average Peak Heart Rate of First Engine (E1) with Different Crew Sizes by Riding Position.[32] In Chart 3, heart rates are expressed as a percent of maximal age-predicted maximal HR. The average heart rates for firefighters on the first engine company were above 80% of age-predicted maximum values when only 2 firefighters were working. When staffing was at 2 firefighters, the driver of the apparatus had an average peak heart rate of nearly 90% of the age-predicted maximum. This is largely due to the number of additional tasks the driver must perform to prepare the engine to pump water to the fire and then join the officer to stretch hose to the fire. As can be seen, the larger the crew size, the lower the heart rate.[33] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

[32] Riding position for Chart 3 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3- Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[33] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

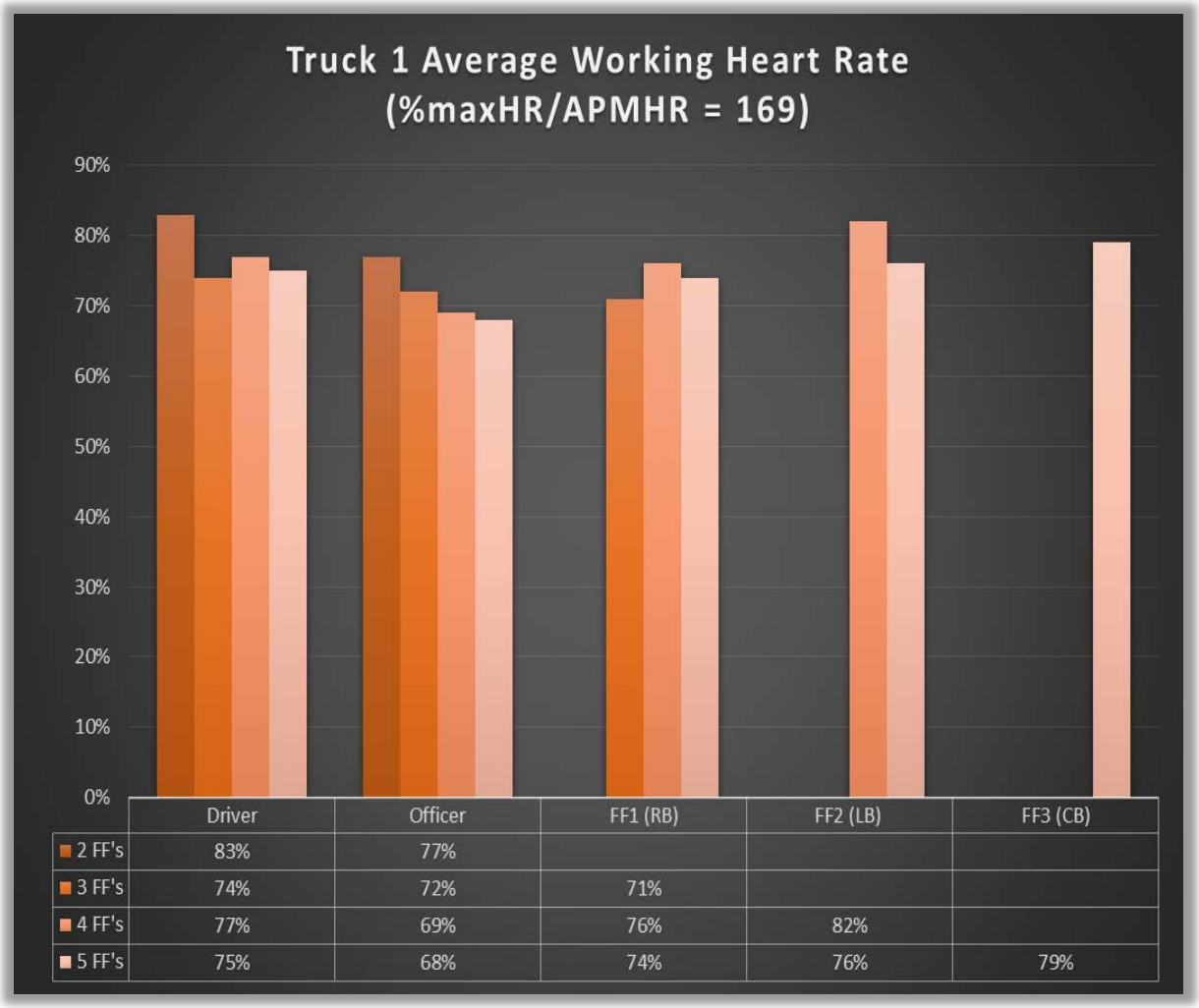

Chart 4: Average Peak Heart Rate of First Truck (T1) with Different Crew Sizes by Riding Position.[34] In Chart 4, heart rates are expressed as a percent of maximal age-predicted maximal HR. The average heart rates for firefighters on the first truck company were above 80% of age-predicted maximum values when only 2 firefighters were working.[35] Decision makers could potentially reduce their liability for firefighter injury and death by ensuring staffing is compliant with the minimum recommended industry standards of four firefighters per apparatus.

[34] Riding position for Chart 4 are as follows: Driver, Officer, Firefighter 1-Right Bucket (RB) seat, Firefighter 2-Left Bucket (LB) seat, Firefighter 3- Center Bucket (CB) seat. A fire company that is staffed with 2 will consist of a Driver and an "Officer."

[35] Smith, D.L., Benedict, R. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. April, 2010. Pp 5-7

The Importance of a Rapid Response

Uncontained fire in a structure grows exponentially with every passing minute. Any delay in the initiation of fire suppression and rescue operations, such as the 5- to 7-minute delay that results from smaller sized crews of firefighters, translates directly into a proportional *increase* in expected property, life, and economic losses as is shown in Table 3, following page. It warrants emphasizing that if a structure has no automatic suppression or detection system, a more advanced fire may exist by the time the fire department is notified of the emergency and is able to respond. Fires of an extended duration weaken structural support members, compromising the structural integrity of a building and forcing operations to shift from an offensive to defensive mode.[36] As with inadequate staffing, this type of operation will continue until enough resources can be amassed to mitigate the event.

In the NIST study on the low-hazard residential fire, researchers also used fire modeling to mark the degree of the toxicity of the environment for a range of growth fires (slow, medium, and fast). Occupant exposures were calculated both when firefighters arrive earlier to the scene, and when arriving later. The modeling proved that the longer it takes for firefighters to rescue trapped occupants, the greater the risk posed to both the firefighters and occupants by increasing atmospheric toxicity in the structure.

[36] According to the NFPA, "it's important to realize that every 250 GPM stream applied to the building can add up to one ton per minute to the load the weakened structure is carrying."

Rate Per 1,000 Fires			
Flame Spread:	**Civilian Deaths**	**Civilian Injuries**	**Average Dollar Loss per Fire**
Confined fires (identified by incident type)	0.00	10.29	$212.00
Confined to object of origin	0.65	13.53	$1,565.00
Confined to room of origin, including confined fires by incident type [37]	1.91	25.32	$2,993.00
Beyond the room, but confined to floor of origin	22.73	64.13	$7,445.00
Beyond floor of origin	24.63	60.41	$58,431.00

Table 3: The Relationship between Fire Extension and Fire Loss.[38] Table 3 displays the rates of civilian injuries and deaths per 1,000 fires, as well as the average property damage. Following the far-left column from top to bottom, each row represents a more advanced level of fire involvement in a residence. Typically, the more advanced the fire, the larger the delay in suppression. Assuming an early discovery of a fire, companies staffed with larger crew sizes help to minimize deaths, injuries, and property loss. This highlights why a 5- to 7-minute delay in suppression activities by smaller sized crews results in higher economic losses to a residence.

OSHA's "2 In/2 Out" Regulation

The "2 In/2 Out" Regulation is part of paragraph (g)(4) of the United States Occupational Safety and Health Administration's (OSHA) revised respiratory protection standard, 29 CFR 1910.134. The focus of this important section is the safety of firefighters engaged in interior structural firefighting. OSHA's requirements for the number of firefighters required to be present when conducting operations in atmospheres that are immediately dangerous to life and health also covers the number of persons who must be on the scene before firefighting personnel may initiate an interior attack on a structural fire. An interior structural fire (*an advanced fire that has spread inside of the building where high temperatures, heat and dense smoke are normally occurring*) would present an IDLH environment and, therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside needed to fight the fire, must be present before firefighters may enter the building.[39] [40] This

[37] NFIRS 5.0 has six categories of confined structure fires, including cooking fires confined to the cooking vessel, confined chimney or flue fire, confined incinerator fire, confined fuel burner or boiler fire or delayed ignition, confined commercial compactor fire, and trash or rubbish fire in a structure with no flame damage to the structure or its contents. Homes include one- and two-family homes (including manufactured housing) and apartments or other multifamily housing. These statistics are national estimates based on fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies. National estimates are projections. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Property damage has not been adjusted for inflation.

[38] National Fire Protection Association, NFPA 1710 (2016), Table A.5.2.2.2.1 (b) Fire Extension in Residential Structures, 2006-2010.

[39] According to NFPA standards relating to fire fighter safety and health, the incident commander may make exceptions to these rules if necessary to save lives. The Standard does not prohibit fire fighters from entering a burning structure to perform rescue operations when there is a "reasonable" belief that victims may be inside.

[40] Paula O. White, letter to Thomas N. Cooper, 1 November 1995 (OSHA)

requirement is mirrored in NFPA 1500, which states that "a rapid intervention team shall consist of at least two members and shall be available for rescue of a member or a team if the need arises. Once a second team is assigned or operating in the hazardous area, the incident shall no longer be considered in the 'initial stage,' and at least one rapid intervention crew shall be required."

NFPA Standard 1710 also supports the OSHA Regulation by requiring a minimum of four personnel on all suppression apparatus. Portions of the 1710 Standard recommend that "fire companies whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with **a minimum of four on-duty members**,"[41] while "fire companies whose primary functions are to perform the variety of services associated with truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul and salvage work… shall [also] be staffed with **a minimum of four on-duty members**."[42] For either fire suppression company, NFPA 1710 states that in jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other pertinent factors as identified by the authority having jurisdiction, these companies shall be staffed with a minimum of five or six on-duty members.[43]

[41] NFPA 1710, § 5.2.3.1 and §5.2.3.1.1.
[42] NFPA 1710, § 5.2.3.2 and §5.2.3.2.1.
[43] NFPA 1710, § 5.2.3.1.2, §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

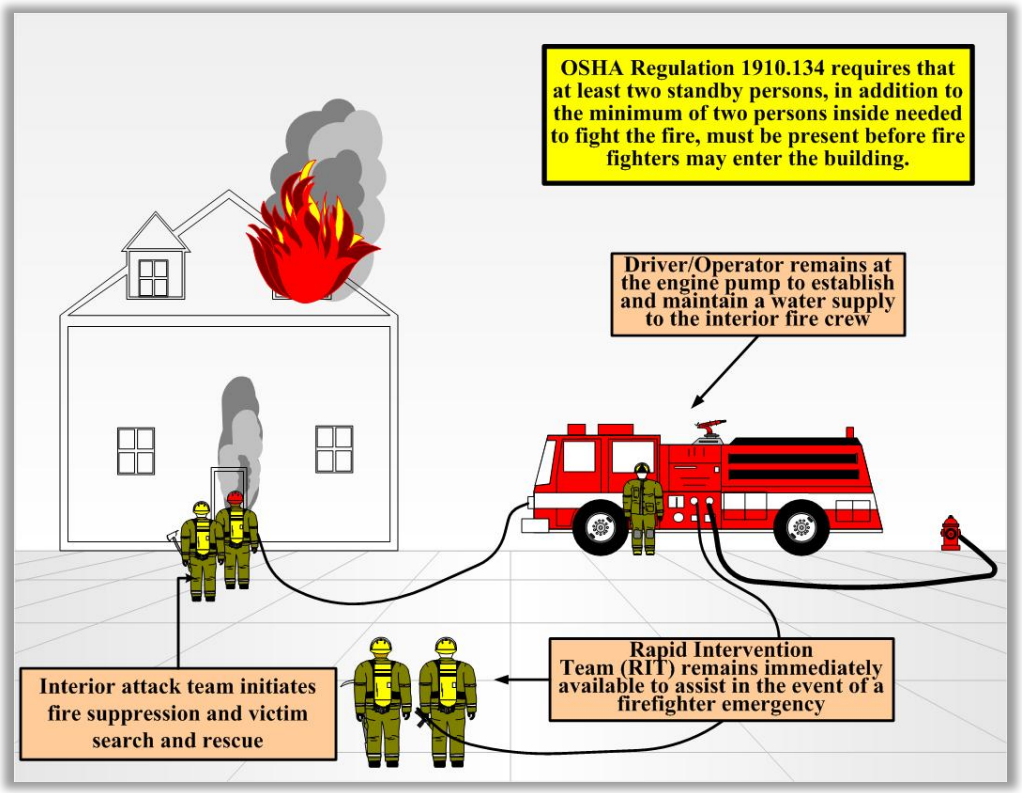

Figure 2: The OSHA "2 IN/2 Out" Regulation. Figure 2 depicts the number of firefighters required to meet OSHA regulation 1910.134, which demands one firefighter outside for every firefighter inside. The firefighters outside can support a secondary attack line and facilitate the rescue of trapped or disabled firefighters should the need arise. In this scenario, the driver/operator of the apparatus is not counted towards the total number of firefighters. Currently, MFRD staffs all fire suppression apparatus with 3 firefighters.

A number of incidents exists in which the failure to follow the "2 In/2 Out" Regulation have contributed to firefighter casualties. For example, in Bridgeport, Connecticut in July 2010, two firefighters died following a fire where the National Institute of Occupational Safety and Health (NIOSH) later found that although a "Mayday" was called by the firefighters, it wasn't responded to promptly as there was no incident safety officer or rapid intervention team (RIT) readily available on scene. In a second case, two firefighters were killed in a fire in San Francisco, California in June 2011. The initial RIT was re-assigned to firefighting duties, and the back-up RIT did not arrive on scene until after the victims were removed.

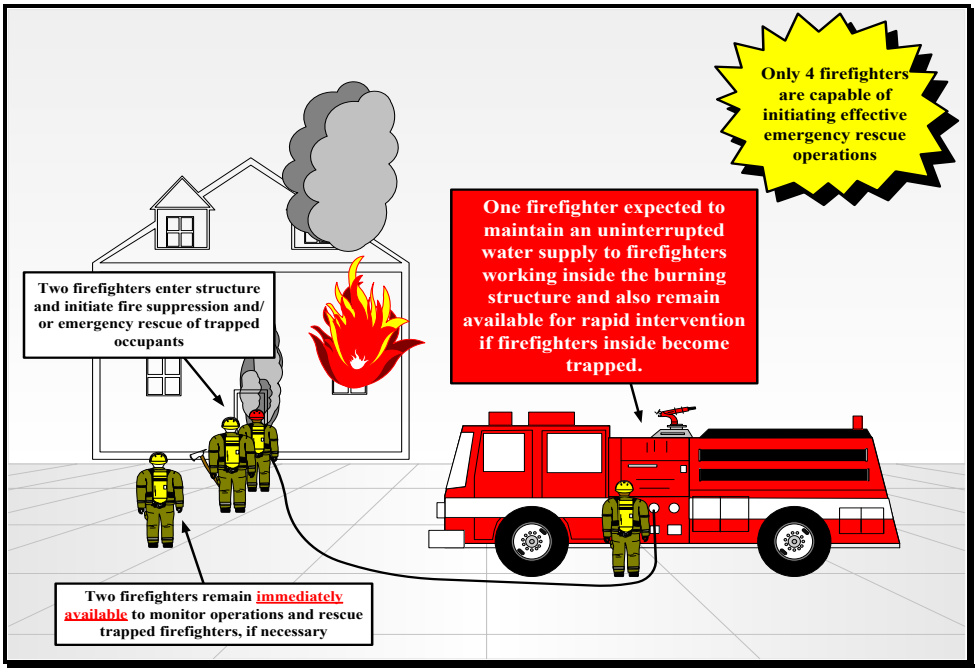

Figure 3: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of 4 personnel and operates under emergency conditions. In this case, the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter must be dressed in personal protective equipment (PPE) and be ready to participate in rescue if the need should arise.

When confronted with occupants trapped in a burning structure and a single fire company is on scene, only a company staffed with four firefighters is able to initiate emergency search and rescue operations in compliance with the "2 In/2 Out" Regulation. As indicated in the previous graphic, this requires the complete engagement of every firefighter from the first-in fire company, staffed with four, to participate in the effort, and means that the driver-operator of the apparatus must tend to the pump to ensure the delivery of water to the firefighters performing the initial attack and search and rescue operations and be prepared to make entry with the remaining firefighter should the crew operating inside become trapped.

Regardless, when there exists an immediate threat to life, only a company of four firefighters can initiate fire suppression and rescue operations in compliance with "2 In/2 Out" Regulation, and in a manner that minimizes the threat of personal injury. In crews with fewer than 4 firefighters, the first-in company must wait until the arrival of the second-in unit to initiate safe and effective fire suppression and rescue operations. This condition underlines the importance and desirability of fire companies to be staffed with a minimum of four firefighters and stresses the benefit of four-person companies and their ability to save lives without having to wait for the second-in company to arrive.

Initial Full Alarm Assignment

Single-Family Dwelling Initial Alarm Assignment Capability, as outlined in NFPA Standard 1710, recommends that the "fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents and that the initial full alarm shall provide for the following:

Assignment	*Required Personnel*
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

Table 4: NFPA 1710, §5.2.4.1.1. Table 4 is the breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA 1710, requires a minimum contingent of 15 fire suppression personnel. NFPA 1710 also requires that supervisory chief officers shall be assisted by a staff aide[44] which will increase on-scene staffing to 16 personnel required to arrive at the scene of a structure fire within 8 minutes of travel. Although not specifically discussed in the standard, an industry best practice is to have a second uninterrupted water supply which requires a second dedicated engine pump operator. This second, dedicated pump operator brings the total count of firefighters to 17.

[44] NFPA 1710, § 5.2.2.2.4 and § 5.2.2.2.5

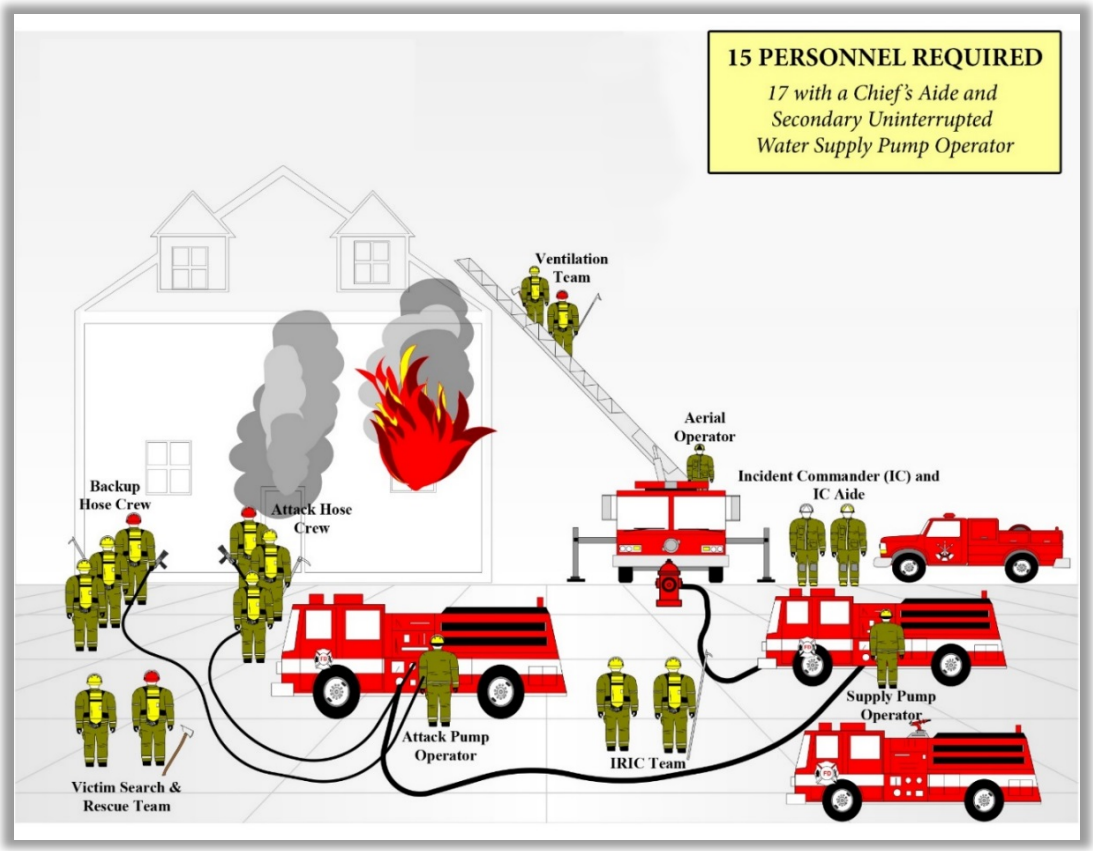

Figure 4: Initial Full Alarm Assignment Deployed Within 8 Minutes. Figure 4 depicts the full alarm assignment discussed in NFPA 1710, with an additional firefighter to act as the incident commander's aide, and another additional firefighter to act as a pump operator for a supply apparatus.

In addition, NFPA 1710, §5.2.4.5.2 states, "The fire department shall have the capability for additional alarm assignments that can provide for additional command staff, members, and additional services, including the application of water to the fire; engagement in search and rescue, forcible entry, ventilation, and preservation of property; safety and accountability for personnel; and provision of support activities…" Currently due to a lack of resources, MFRD is not capable of dispatching additional alarm assignments. MFRD must rely on calling in off-duty firefighters and/or volunteer personnel to provide additional resources. This places citizens and firefighters at an increased risk of injury or death.

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. Each stage of fire extension beyond the room of origin directly increases the rate of civilian deaths, injuries, and property damage. Fire growth is exponential, growing in a non-linear manner over time. Extending the time for crew assembly by waiting for additional crews to arrive causes on-scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, firefighter injury or death, and increased property loss.

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High-Rise Operations

Although this section specifically addresses fire response to high-rise buildings, it is important to note that the discussion can be extrapolated to large area buildings such as manufacturing centers, warehouses, grocery stores, schools, and other structures with a high fire load and populations.

Overview of High-Rises

High-rise buildings were once found exclusively in urban cities. However, today they are commonly found in small and mid-sized suburban communities as well. Many high-rise buildings in suburban areas are newer, shorter, and protected by automatic sprinkler systems, although this is not always a guarantee. NFPA 101, Life Safety Code, 2015 Edition and the International Code Council's International Building Code both define a high-rise structure as a building more than 75 ft. (23 m) in height, measured from the lowest level of fire department vehicle access to the bottom of the highest occupied floor. High-rises, which are described in NFPA 1710 §A.3.3.28 as high-hazard occupancies, represent an extraordinary challenge to fire departments and are some of the most challenging incidents firefighters encounter.

High-rise buildings may hold thousands of people above the reach of fire department aerial devices and the chance of rescuing victims from the exterior is greatly reduced once a fire has reached flashover. The risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above grade level.[45] This is especially true once firefighters are operating above the reach of aerial ladders on truck companies. In these situations, the only viable means of ingress or egress is the interior stairs. Therefore, a sound fire department deployment strategy, effective operational tactics, and engineered fire protection systems cannot be separated from firefighter safety. As in any structure fire, engine company and truck company operations must be coordinated.

High-rise buildings present a unique threat to the fire service. Multi-floor fires such as the Interstate Building Fire, One Meridian Plaza Fire, World Trade Center collapse, Cook County Administration Building Fire, and Deutsche Bank Building Fire each represented serious challenges to the operational capabilities of a modern fire department. According to the NFPA, between 2009 and 2013, there were an estimated 14,500 reported high-rise structure fires per year that resulted in average annual losses of 40 civilian deaths, 520 civilian injuries, and $154

[45] Klaene, B. and Sanders, R. (2007). Structural Firefighting: Strategies and Tactics- High-Rise. Jones and Bartlett 2007.

million in direct property damage. Office buildings, hotels, apartment buildings, dormitories and health care facilities accounted for almost three-quarter (73%) of these high-rise fires.[46]

Although the frequency of fires in high-rise structures is low, they pose a high consequence of loss with regards to injury, loss of life, and property damage. Even if a department does not respond to high-rise buildings at present, it may in the future as urban sprawl continues and/or jurisdictional border restrictions and population growth require taller buildings to meet residential needs.

High-Rise Firefighting Tactics

As has been stated, in a high-rise fire the risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above ground level. As the level of the fire floor gets higher, firefighters are required to carry more equipment further and must rely more on the building's standpipe system. A standpipe system is a piping system with discharge outlets at various locations usually located in stairwells on each floor in high-rise buildings that is connected to a water source with pressure supplemented by a fire pump[47] located in the building and/or a fire apparatus with pumping capabilities.

A fire in a high-rise building can threaten occupants and responding firefighters. Because of the amount of time it takes firefighters encumbered with equipment to access the involved floors, the fire may have expanded well past the area of origin. This means that firefighters can encounter a large volume of fire and darkened conditions when they arrive on the involved floors. This can be further complicated if the building is not equipped with a sprinkler system. Additionally, open-layout floor plans such as office buildings with cubicle farms can challenge both the standpipe's flow capacity and fire department resources regarding search, rescue, and hoseline deployment. The most effective way to extinguish a high-rise fire is by mounting an offensive attack as early as possible, because in the vast majority of historic high-rise fires, the best life safety tactic is extinguishing the fire. Good high-rise firefighting tactics and firefighter/occupant safety cannot be separated. As with a residential structure fire, the first arriving suppression apparatus should be on the scene within four minutes of travel time. However, when responding to any high-hazard buildings or structures, which include high-rises, first responding fire apparatus should be staffed with five to six firefighters per NFPA 1710, upon the determination of the AHJ.

Similar to residential structure fires, there are several critical tasks that must be accomplished. However, unlike residential firefighting in a 2,000 square foot residence, firefighters working at a high-rise fire must travel upwards of more than three stories and carry additional equipment

[46] Ahrens, Marty. (2016), High-Rise Building Fires. NFPA.
[47] Structural Firefighting Strategy and Tactics 2nd Edition. Klaene B., Sanders R. NFPA 2008

beyond the normal requirements. Additionally, as it takes longer to assemble an effective response force and to access the fire floor, firefighters are likely to encounter a large volume of fire and will therefore have an extended fire attack. Because of this, it is necessary to establish an equipment supply chain to transport equipment and resources up and down the building.

Search and Rescue

Search and rescue are critical fireground tasks that comprise a systematic approach to locating possible victims and removing those victims from known danger to a safe area. In a residential structure fire, searches are normally conducted by a crew of two firefighters, supplemented by an attack or ventilation crew. However, high-rise structures pose challenges regarding search and rescue that are not typically encountered in residential housing. For commercial high-rises and wide-area structures, large open areas and cubicle farms require additional search and rescue teams so that thorough searches can occur over a larger area than found in most residences. In addition to these larger areas, search and rescue can be further complicated because conscious victims may retreat to areas in an attempt to find shelter from heat and smoke. These areas may differ from places where they are typically seen by coworkers, making locating them difficult if they are unaccounted for.

In residential high-rises, apartments typically lack two exits and usually share a common hallway for egress. Doors left open by victims fleeing fire can allow fire and smoke to spread into the hallway and impact escape attempts. Firefighters will be slowed in their search since they will be required to force their way into numerous apartments to search for victims. For this reason, regardless of commercial or residential, it is essential for there to be multiple search and rescue teams operating per involved floor to quickly locate victims in large surface areas. It is also necessary for additional search and rescue teams to search the floors above the fire and the highest floor of the building, due to how fire and smoke spread to the rest of the building. Search and rescue teams should also be supplemented with evacuation management teams to assist injured or disabled victims down the stairwells so searching can continue. Because of the larger search area, NFPA 1710 requires a minimum of four firefighters for searching and a minimum of four firefighters for evacuation management teams.

Fire Extinguishment

Fire extinguishment is a critical factor, since the intensity and size of the fire will determine the extent to which combustion gases are heated and how high they will rise inside the building. Building suppression systems, both active and passive, can impact fire growth, occupant safety, and firefighter safety and effectiveness. Such features include active fire detection and automatic sprinkler systems that are designed to either extinguish the fire or contain it until firefighters arrive.

Once firefighters are on scene, they will complete a series of fire confinement and extinguishment tasks. Firefighters access the structure, locate the fire, locate any avenues of spread, place hoselines, and establish a water supply. Once a water supply is established, water should be placed at the seat of the fire or in the compartment containing the fire to extinguish it. Unlike residential structure fires where hoselines can be stretched from the fire apparatus into the structure, high-rise structures require the use of standpipe systems to combat fire. This requires firefighters to carry multiple sections of hose to the affected floors and connect into the system to fight fire. Minimally, firefighters must deploy two hoselines to the involved floor and one hoseline to the floor above the fire. The third hoseline supports a number of critical tasks in the suppression effort. Principally, it is used to protect search and rescue teams, but also to stop the spread of fire as a result of conduction and convection through exposed pipes, metal framing, and ventilation systems.

Ventilation[48]

Ventilation affects both search and rescue and fire extinguishment. Ventilation may be implemented at any time during the operation, but it should be coordinated with suppression and interior rescue activities. Ventilation is used to channel and remove heated air, smoke, fire gases, and other airborne contaminants. Applying proper ventilation at the right time and place is key to firefighter and occupant safety. Venting at the wrong time or place can draw active fire toward fresh air, which will injure or kill anyone in its path. In instances of high-rise fire suppression, adequate and appropriate ventilation is important to keep stairways free of smoke and noxious gases for victims who are evacuating.

Because of the size of high-rise buildings and high-hazard structures in general, a larger number of firefighters is required for a ventilation team than would be for a residential structure. NFPA 1710 requires a minimum of four firefighters to be assigned to ventilation.

Support

Similar to residential structure fires, there are several critical tasks that must be accomplished. However, unlike residential firefighting in a 2,000 square foot residence, firefighters working at a high-rise fire must travel upwards of more than three stories and carry additional equipment beyond the normal requirements. Additionally, as it takes longer to assemble an effective firefighting force and to access the fire floor, firefighters are likely to encounter a large volume of fire and will therefore have an extended fire attack. Because of this, it is necessary to establish an equipment supply chain to transport equipment and resources up and down the building.

[48] Due to varying differences in building designs, occupancy levels, evacuation procedures, etc., the NIST High-Rise Report marked ventilation complete as time stamps rather than actual tasks to be performed and completed. Both Positive Pressure Ventilation (fans) and Roof Ventilation were marked as occurring one minute after Fire Out.

As has been discussed, fire suppression in a high-rise or high-hazard structure requires the establishment of a supply chain to shuttle equipment to different locations. Additionally, with increased resources and personnel, there is an increased need for additional supervision and accountability.

One critical support variable in high-rise fire operations is the availability of reliable elevators. If firefighters can safely use the elevators to move people and equipment, fire-ground logistics may be significantly improved. When the fire is located several floors above ground level, there is a strong inclination to use the elevators. However, fire service access elevators[49] may not be available in all buildings. Therefore, adequate stairways are necessary for firefighters to transport equipment and reach the fire floor for suppression.

Moving supplies and staff up 10, 20, 30, or more stories is an arduous task. If it is not properly managed, firefighters may be exhausted and unable to fight the fire or rescue trapped occupants. Additionally, joint use of stairways by firefighters moving upward and occupants attempting to evacuate may increase the overall evacuation time of the occupants, as well as delay the firefighters' efforts to begin critical tasks such as fire suppression or search and rescue operations. As such, it is important to have multiple firefighters to help carry equipment upstairs and manage resource distribution.

To accomplish the critical fireground tasks associated with high-rise firefighting and meet the minimum staffing objectives for task completion, NFPA 1710 recommends the following company sizes for the first arriving unit(s) on the scene within four minutes of travel time for response to high-hazard structures:

- In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[50]

- In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members.[51]

As indicated by the tasks that must be accomplished on a high-rise fireground, understanding the required resources is critical. The number of firefighters needed to safely and effectively combat a high-rise fire may be large. Although an offensive fire attack is the preferred strategy whenever conditions and resources permit, a defensive attack that limits operations to the outside of a

[49] A fire service elevator is engineered to operate in a building during a fire emergency and complying with prescriptive building code requirements and the American Society of Mechanical Engineers (ASME) A 17.1 safety standard for elevators.
[50] NFPA 1710. §5.2.3.1.2
[51] NFPA 1710. §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

building and generally results in more property damage must be considered when risks to firefighter safety are too great and benefits to building occupants are negligible. The offensive vs. defensive decision is based on a number of factors: fireground staffing available to conduct an interior attack, a sustained water supply, the ability to conduct ventilation, and risk vs. benefit analysis regarding firefighter and occupant safety. Table 5, following page, displays the minimum number of firefighters required to arrive as part of the initial full alarm assignment to a high-rise fire.

Assignment	*Required Personnel*
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters (1 for each line)
Rapid Intervention Crew (RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters (2 per team)
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

Table 5: Number of Firefighters for an Initial Full Alarm to a High-Rise Fire. Fighting fire in high-rise structures poses many unique obstacles and challenges other than are found in a residential structure fire. Hose cannot be deployed directly from fire apparatus and needs to be carried, with other equipment, to the location of the fire. Search and rescue is impacted by large areas and accessibility concerns. Additionally, because of delays in access, firefighters are likely to encounter a high volume of fire which will necessitate a supply chain to equip ongoing suppression efforts. A single alarm response to a high-rise building minimally requires 43 responders, consisting of 36 firefighters, 1 incident commander, and 6 officers.

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Fire Department EMS Operations

In recent years, the provision of emergency medical services has progressed from an amenity to a citizen-required service. More than 90% of career and combination fire departments provide some form of emergency medical care, making fire departments the largest group of prehospital EMS providers in North America. In many fire departments that deliver prehospital care, EMS calls can equate to over 75% of total call volume.

There are six main components of an EMS incident from start to finish.[52] These are (1) detection of the incident, (2) reporting of the incident to a 9-1-1 center, (3) response to the incident by the appropriate emergency resources, (4) on scene care by emergency response personnel, (5) care by emergency personnel while in transit to a medical care facility, and (6) transfer of the patient from emergency response personnel to the medical care facility. Not all EMS events will necessitate all six components, as when a patient refuses treatment, or is treated at the scene and not transported.

In an analysis of data from over 300 fire departments in the United States, first responder units, which are typically fire engines, arrived prior to ambulances approximately 80% of the time.[53] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with multi-role firefighter/emergency medical service technicians and supplies, are more centrally located and are able to effect a quicker response and provide life-saving procedures in advance of an ambulance. This reinforces why it is in the best interest of the public good for the fire department to provide EMS transport as well as first response.

The benefit of supporting EMS transport within fire department operations is that fire departments are already geared towards rapid response and rapid intervention. Strategically located stations and personnel are positioned to deliver time critical response and effective fire suppression and are therefore equally situated to provide effective response to time critical requests for EMS service. Both fire suppression and EMS response are required by industry standards to have adequate personnel and resources operating on scene within 4 minutes. In both fire suppression and EMS incidents, time is directly related to the amount of damage, either to the structure or the patient.

When ambulance response is prolonged, a patient will be further delayed in reaching a medical facility to receive definitive care. This is especially dangerous for incidents of chest pain, stroke,

[52] The Star of Life, designated by Leo R. Schwartz, Chief of EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1997.
[53] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

and survivable cardiac arrest. Many times, patients experiencing symptoms associated with these events may not recognize the onset indicators and immediately call for assistance.[54] [55] [56] [57] Acute Coronary Syndrome (ACS), or heart attack, is the number one leading cause of death in the United States. Experts agree that an ACS event should receive definitive care from a hospital within one hour of onset of symptoms. One study found that definitive care for ACS within one hour of onset improves survivability by 50% and 23% if definitive care was given within 3 hours.[58]

Strokes, which are the number three cause of death in the U.S., as well as a leading cause of disability, also benefit from expedient treatment in definitive care. Ischemic stroke, which is a stroke caused from a blood clot, can be effectively treated if definitive care is received within 3 to 4.5 hours[59] of onset of symptoms. The sooner a patient receives definitive treatment from onset of symptoms, the less likely a patient is to suffer disability from this type of stroke. However, it is important to emphasize that before the time critical treatment can be administered to the patient in the hospital, there is a time intensive assessment that must be performed to ensure the patient is qualified to receive the treatment. The current benchmark for an ischemic stroke patient "door to needle"[60] is less than or equal to 60 minutes. However, Steps Against Recurrent Stroke (STARS) registry shows that the median door to needle time is 96 minutes or 1 hour and 36 minutes.[61]

In two-tiered EMS systems that deploy with sufficient resources, there is an increased likelihood that a patient will receive an ambulance and a first responding fire apparatus in not only a timely manner, but also frequently at the same, or close to the same time. This is extremely beneficial to the patient as most EMS responses, particularly the previously mentioned conditions, are labor intensive. Patients suffering from ACS should not perform any form of exertion as to minimize any damage that is occurring. Patients suffering from strokes are frequently unable to exert due to physical disabilities caused by the incident. An adequately sized crew is able to provide simultaneous interventions while assessment is being performed, thereby reducing the on-scene

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[54] American Heart Association, *Heart Disease and Stroke Statistics-2005 update,* Dallas, TX: AHA 2005

[55] Time from Symptom Onset to treatment and outcomes after thrombolytic therapy. Newby LK, et al. *J Am Coll Cardiol.* 1996:27:1646-1655

[56] An International Perspective on the Time to Treatment of Acute Myocardial Infarction. Dracup, K. et al. *J Nurs Scholarsh* 2003;35:317-323

[57] Prehospital and In-hospital Delays in Acute Stroke Care. Evanson, KR, et al. *Neuroepidemiology* 2001;20:65-76

[58] Association of patient delays with symptoms, cardiac enzymes, and outcomes in acute myocardial infarction. Rawles, JM. Et al. *Eur Heart J.* 1990; 11:643-648.

[59] Thrombolysis with Alteplase 3 to 4.5 Hours after Acute Ischemic Stroke. Hacke, W. et al. *N Engl J Med*. 2008;359:1317-1329

[60] "Door to Needle" is an industry specific term that refers to the time the patient entered the emergency department to the time the received the treatment. A drug named recombinant tissue plasminogen activator (rt-PA) is utilized to dissolve the thrombosis causing the stroke. Current FDA approvals limit this drug's use to 3-4.5 hours from initial symptoms and require a CT scan and labs before administration.

[61] Improving Door-to-Needle Times in Acute Ischemic Stroke: The Design and Rational for the American Heart Association/American Stroke Association's Target: Stroke Initiative. Fonarow, Gregg, et al. *Stroke* 2011;42:00-00

time. Following completion of critical tasks, the crew can then facilitate a safe removal of the patient to the ambulance and minimize the risk of injury to patient and provider.[62]

One of the most labor intensive and time critical requests for EMS response is cardiac arrest, which globally affects 20-140 out of every 100,000 people. Traditionally, the American Heart Association (AHA) taught a method of cardiac resuscitation that involved single rescuer performance of prioritized action.[63] However, there was a gap between instruction and practice which led to confusion and may have potentially reduced survival. In reality, providers respond and function in teams larger than two.

The AHA's guidelines for cardiac resuscitation focus on a team-centric approach. Evidence-based research suggested that the manner in which CPR was being performed was inherently inefficient and only provided 10-30% of the normal blood flow to the heart and 30-40% to the brain.[64] [65] This was linked to provider fatigue from administering chest compressions, and as such, these studies indicate that providers should be rotated to ensure effective depth and rhythm of chest compressions. Consensus documents from the AHA recommend that providers should rotate with every two-minute cycle of CPR. It is also recommended that requests for EMS service for cardiac arrest also have a team leader to organize priorities and direct resources as they arrive or are needed. The team leader would also be responsible for identifying symptoms of fatigue and making appropriate assignment adjustments to ensure maximally efficient CPR.

Although the AHA and other researchers have not identified what an optimally sized crew for effective team-centric CPR should be, some consensus literature from AHA has mentioned that five providers were best suited to perform resuscitation. However, providers may be required to perform multiple tasks. Industry best practices, through the guidance of medical directors, have suggested six providers would be most successful in minimizing confusion and redundancy.

An EMS crew consisting of six personnel would require four personnel arriving with the first responding fire apparatus and two with the ambulance.[66] For an all-ALS system, two of the six should be paramedics, with a minimum of one assigned to each of the responding apparatus. Some ALS systems require two paramedics on the ambulance and a minimum of one on the first responding fire apparatus. However, these deployment options are determined by state directive

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[62] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.

[63] Highlights of the 2010 American Heart Association Guidelines for CPR and ECC

[64] Determinants of Blood Flow during Cardiac Resuscitation in Dogs. Halperin, HR et al. *Circulation* 1986;73:539-550

[65] Increased Cortical Cerebral Blood Flow with LUCAS, a New Device for Mechanical Chest Compressions Compared to Standard External Compressions during Experimental Cardiopulmonary Resuscitation. Rubertson S, et al. *Resuscitation*. 2005;65:357-363

[66] NFPA 1917: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

or medical director's discretion. Regardless of the make-up of the EMS certification level of the providers on scene, an ALS integrated cardiac arrest response should provide for the following: a lead provider, an airway manager, two providers to interchangeably deliver chest compressions, a provider to establish an intravenous medication line and administer medications, and a provider to operate the monitor.

Fire Department Deployment

Before discussing the staffing and deployment analysis of MFRD resources, it is important to understand the basics of distribution and concentration. Although adequate staffing is a key element contributing to positive outcomes, fire station location and apparatus deployment are equally important.

The Importance of Adequate Resources: Distribution

Distribution involves locating geographically distributed, ideal first-due resources for all-risk initial intervention. Distribution describes first due arrival. Fire station locations are needed to assure rapid deployment for optimal response to routine emergencies within the response jurisdiction. Distribution can be evaluated by the percentage of the jurisdiction covered by the first-due units within adopted public policy service level objectives.[67] In this case, distribution is measured by the percentage of roads that are covered from each fire station within 4 minutes and 8 minutes to adhere to NFPA 1710 standards.

Distribution study requires geographical analysis of first due resources. Distribution measures may include:[68]

- Population per first due company
- Area served per first-due company (square miles)
- Number of total road miles per first-due company (miles)
- Dwelling unit square footage per first due company
- Maximum travel time in each first-due company's protection area
- Catchment areas (4-minute road response from all fire stations) to determine gap areas and overlaps of first-due resources
- Areas outside of actual performance
    1. Population not served
    2. Area not served (square miles)
    3. Roads miles not served (miles)
    4. Dwelling unit square footage not served
- First-due apparatus arrival times (Engine, Truck, ALS unit, etc.)

[67] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[68] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

A major item to be considered in the distribution of resources is travel time. It should be a matter of public policy that the distribution of fire stations in the community is based on the element of travel time and the response goal. Travel time should be periodically sampled and analyzed to determine whether or not the fire department is achieving a reasonable response performance to handle emergencies.[69]

Evaluating a small number of incidents for response time performance does not reflect the true performance of the department. Analyzing incident demand measured over a 3-5 year period will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period of time will allow for trend analysis as well.[70]

[69] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[70] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

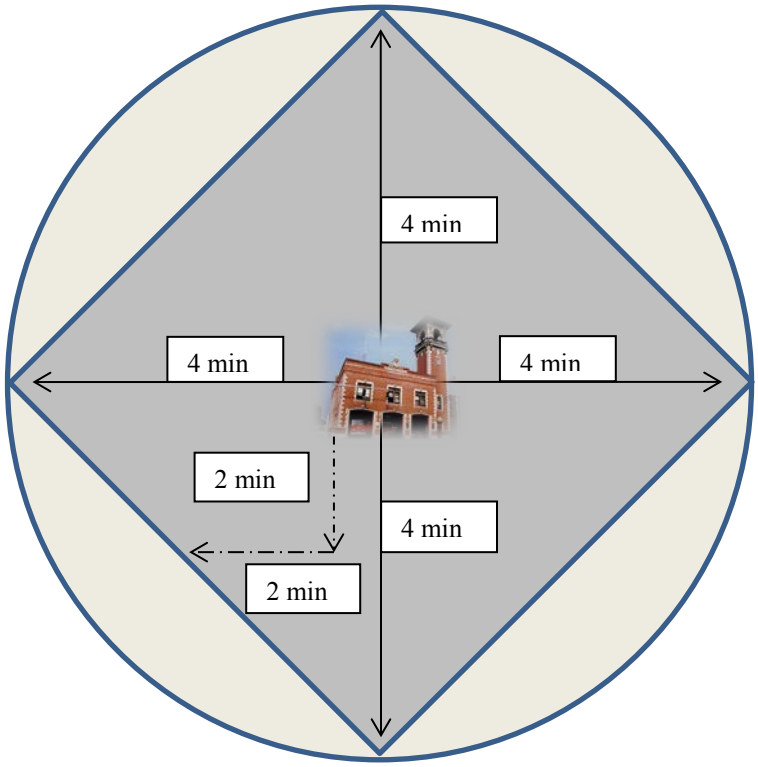


Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[71] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

Distribution strives for an equitable level of outcome. Everyone in the community is within the same distance from a fire station. Distribution is based on probabilities that all areas experience equal service demands, but not necessarily the same risk or consequences as those demands for service in other areas. For example, suburban communities in the City of Manitowoc may have the same service demand as an industrial factory area, but the level of risk is very different. This can have an impact on fire station locations as placement would probably put the fire stations near high risk areas with shorter travel times. But, would citizens in lower risk areas accept longer travel times? Additionally, EMS response times based on medical emergencies will drive equal distribution in the community and negate distribution based on risk, as the risk is equal.

First unit arrival times are the best measure of distribution. It should be noted that if an area experiences fire unit arrival times outside the adopted performance measure, in this case 4-minute travel time per NFPA 1710, it does not necessarily mean it has a distribution issue.[72] Other issues occur such as reliability, call processing times and turnout times, and traffic which can affect the overall performance of response times.

[71] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[72] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55

An effective response force for a fire department is impacted not only by the spacing of fire stations but also by the type and amount of apparatus and personnel staffing the stations. To assemble the necessary apparatus, personnel, and equipment within the prescribed timeframe, all must be close enough to travel to the incident, if available upon dispatch. The placement and spacing of specialty equipment is always challenging.[73] Specialty units tend to be trucks, rescue units, hazmat, or Battalion personnel. Most often there are less of these types of equipment and personnel compared to the first-line response of engines and medic units. Selecting where to put specialty units requires extensive examination of current and future operations within the fire department and a set goal of response time objectives for all-hazards emergencies within a jurisdiction.

Distribution vs. Concentration

Major fires have a significant impact on the resource allocation of any fire department. The dilemma for any fire department is staffing for routine emergencies and also being prepared for the fire or emergency of maximum effort. This balancing of distribution and concentration staffing needs is one that almost all fire agencies face on an ongoing basis.

The art in concentration spacing is to strike a balance with respect as to how much overlap there should be between fire station areas. Some overlap is necessary to maintain good response times and to provide back-up for distribution when the first-due unit is unavailable for service or deployed on a prior emergency.

Concentration pushes and pulls distribution. Each agency, *after risk assessment and critical task analysis,* must be able to quantify and articulate why its resource allocation methodology meets the governing body's adopted policies for initial effective intervention on both a first-due and multiple-unit basis.[74]

[73] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62
[74] Commission on Fire Accreditation International, 5th Edition. 2008. Pages 62-63

Mapping Analysis of the Manitowoc Fire Rescue Department[75]

In creating this document, it was important to ascertain where stations were located and if they were located to provide fair and equitable coverage to the citizens. In order to make this assessment, the IAFF created maps of MFRD's response area and plotted the fire stations. Computer modeling was then used to determine the distance apparatus could travel in 4 minutes and 8 minutes

Travel times were modeled using ESRI ArcGIS Pro, version 2.2.2. Fire stations were identified on GIS maps as starting points with vehicles traveling at posted road speeds.

Prior to drawing conclusions from the mapping analysis, the following issues should be taken into consideration:

- **Modeled travel speeds are based on reasonable and prudent historical traffic speeds occurring on Wednesdays at 5:00 PM.**[76] Actual response speeds may be slower, and the associated travel times greater, with any unpredictable impedances including, but not limited to:
    - Traffic Incidents: Collisions and vehicle breakdowns causing lane blockages and driver distractions.
    - Work Zones: Construction and maintenance activity that can cause added travel time in locations and times where congestion is not normally present.
    - Weather: Reduced visibility--road surface problems and uncertain waiting conditions result in extra travel time and altered trip patterns.
    - Special Events: Demand may change due to identifiable and predictable causes.
    - Traffic Control Devices: Poorly timed or inoperable traffic signals, railroad grade crossings, speed control systems, and traveler information signs contribute to irregularities in travel time.
    - Inadequate Road or Transit Capacity: The interaction of capacity problems with the aforementioned sources causes travel time to expand much faster than demand.[77]

[75] In this section the "current staffing and deployment configuration" is based on the typical daily staffing level as of August 2018. At that time the typical daily staffing was 14 firefighters. As of January 2019, the department's typical daily staffing level is now 12 firefighters.
[76] Historical traffic data contained in ESRI's StreetMap Premium, Version 17.2.
[77] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Illinois Transportation Institute, Illinois A&M University: September 2003).

- Larger emergency vehicles are generally more cumbersome and require greater skill to maneuver. Therefore, response by these vehicles may be more negatively affected by weight, size, and in some cases, inability to travel narrow surface streets.

- Computer modeling only considers travel time of apparatus. Decision makers should understand that once apparatus and personnel arrive on the incident scene there are other essential tasks that must be completed which require additional time before access, rescue, and suppression can take place. Tasks such as establishing a water supply, forcible entry (access), and deployment of an attack line are not considered in the computer modeling.

- The reliability of a community's hydrant system to supply water to fire apparatus.

- Weather conditions

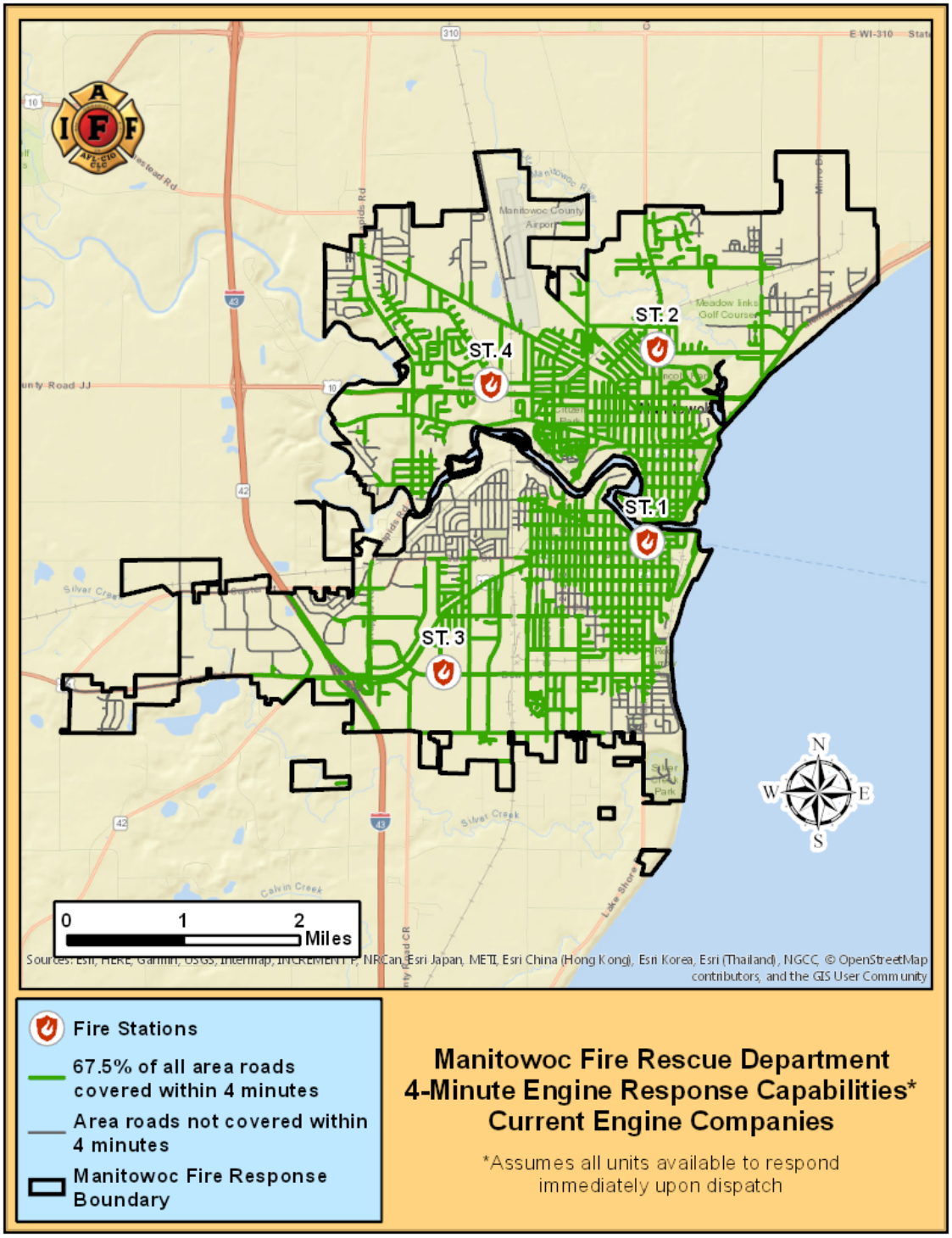
- ***Due to the unpredictable nature of responses from off-duty MRFD firefighters and volunteer departments, responses from these entities were not included in this report.***

Emergency Response Capabilities, Current Staffing and Deployment[78]

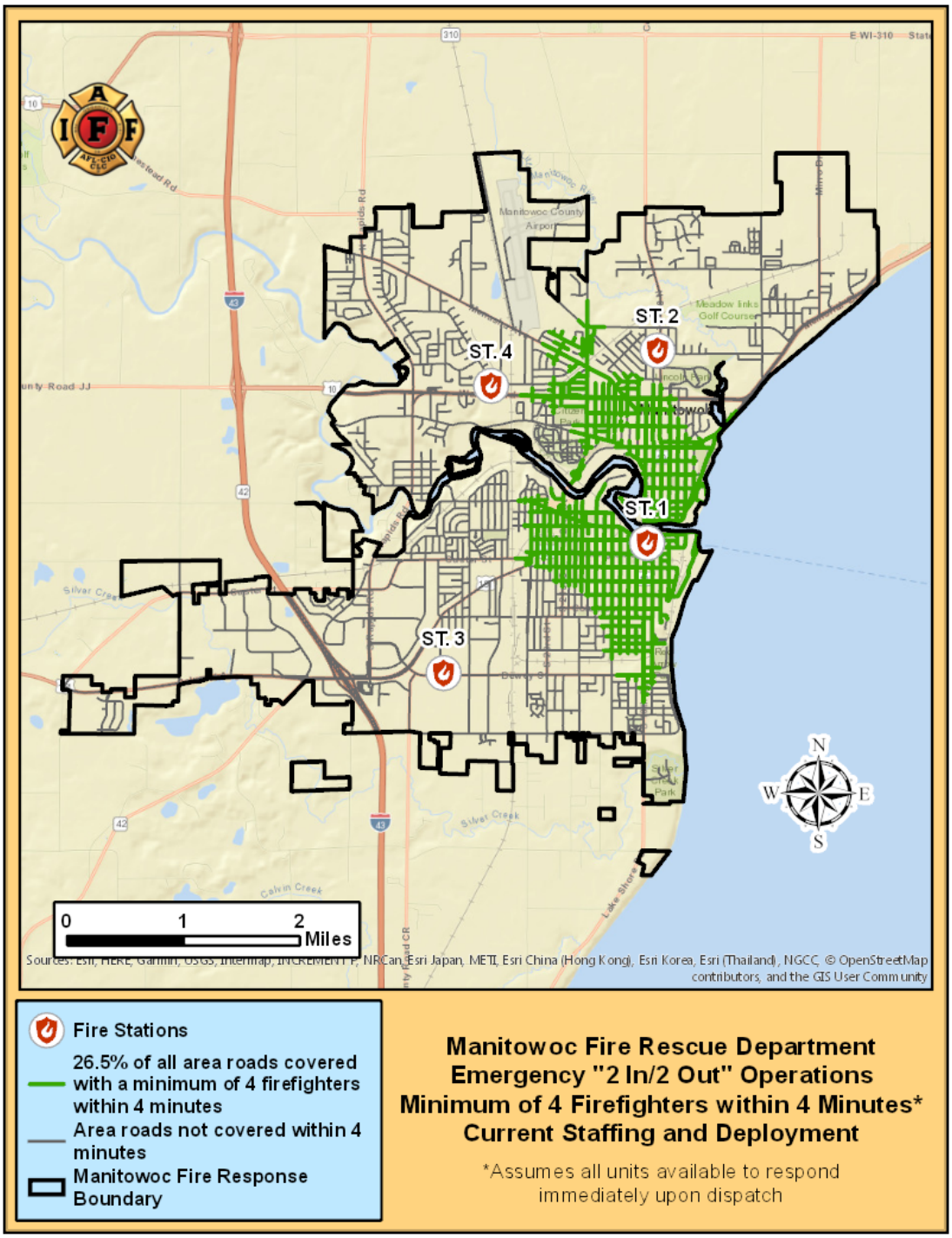
Fire Station	Address	Apparatus	Staffing
Station 1	911 Franklin Street	Engine 1 Ladder 1 Medic 1 Medic 11	3 FF Cross-Staffed 2 FF Cross-Staffed
Station 2	1410 North 8th Street	Engine 2 Medic 2	3 FF Cross-Staffed
Station 3	3820 Dewey Street	Engine 3 Medic 3	3 FF Cross-Staffed
Station 4	1125 Fleetwood Drive	Engine 4 Medic 4	3 FF Cross-Staffed

Table 6: Current Fire Station Locations and Staffing. Table 6 displays where apparatus are housed and the current staffing levels for each apparatus. If all medic units are on assignment and/or unavailable to respond to an incident, Medic 11 will be staffed with the crew from Engine 1 and placed into service resulting in both Engine 1 and Ladder 1 being placed out of service. Cross-staffing is a practice whereby firefighters staff several types of emergency response vehicles simultaneously in a work period. The type and scope of the emergency (e.g., structure fire, technical rescue, EMS call) dictates which type of emergency apparatus responds. Cross-staffing leaves frontline suppression apparatus potentially unstaffed and creates the possibility of personnel begin out of the station and unavailable when an incident occurs.

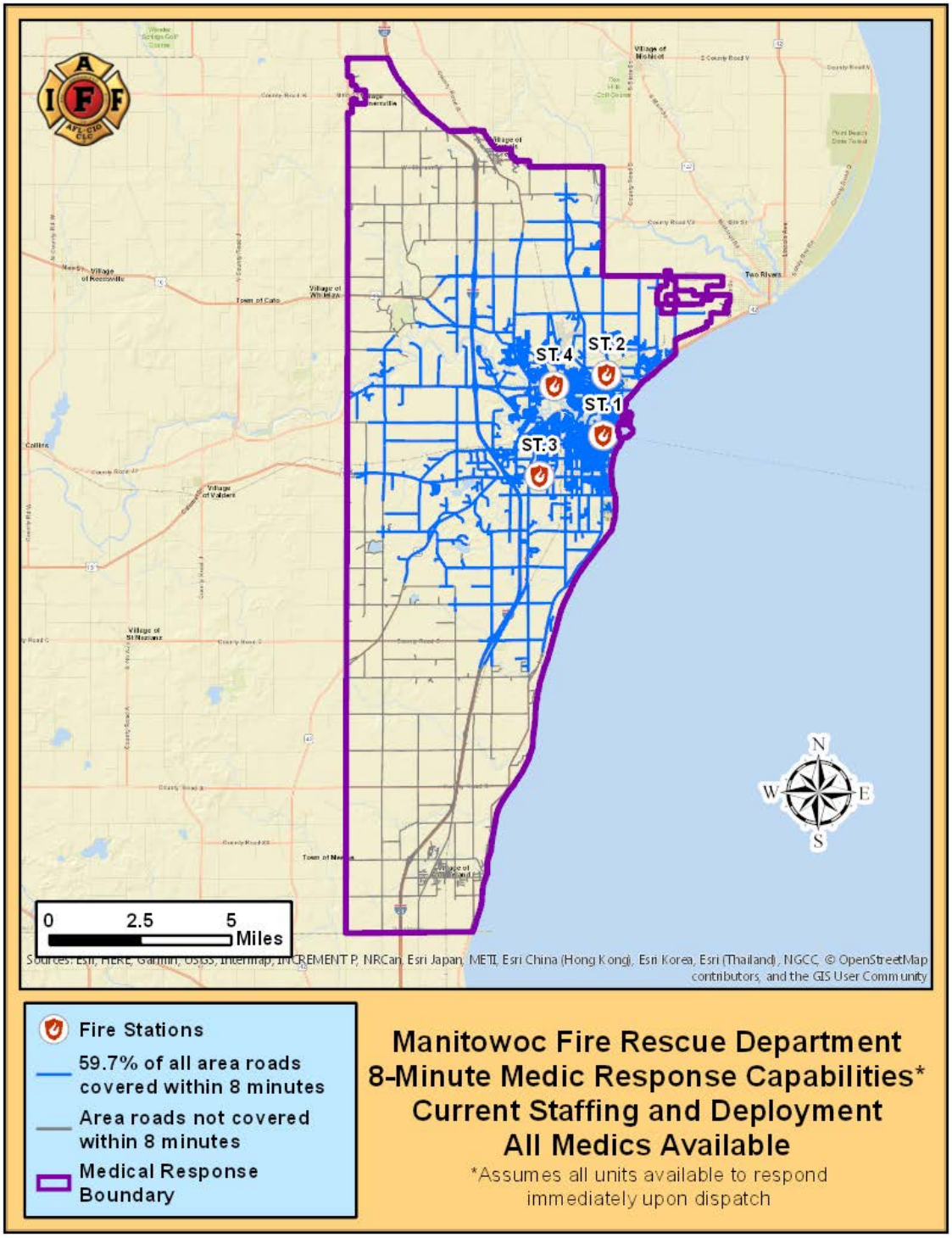
[78] Based on the current staffing and deployment configuration, MFRD cannot meet NFPA 1710 low- and medium-hazard initial alarm response. Therefore, these maps were not included.



Map 8: 4-Minute Engine Response Capabilities, Current Engine Companies. Map 8 identifies those roads where MFRD's engine companies can reach within 4 minutes of travel when all engines are staffed and available for response. Currently, the department is capable of responding on 67.5% of city roads within 4 minutes.



Map 9: Emergency "2 In/2 Out" Operations, Minimum of 4 Personnel within 4 Minutes, Current Staffing and Deployment. Map 9 identifies those roads where a minimum of four firefighters can assemble on scene within 4 minutes when all frontline apparatus are staffed. Currently, the department is able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 26.7% of city roads. Because units are not staffed with four, firefighters must rely on supplemental personnel arriving later before making entry into environments that are immediately dangerous to life and health, such as structure fires, in order to meet objectives outlined in industry standards and U.S. Occupational Safety and Health Administration rules and regulations.



Map 10: 8-Minute Medic Response Capabilities, Current Staffing and Deployment, All Medics Available. Map 10 identifies those roads where MFRD medic units, which are staffed and equipped to provide advanced life support procedures, can reach within 8 minutes of travel. NFPA 1710 states that the arrival of an ALS equipped company within a 480-second travel time to 90 percent of the incidents, provided a first responder with AED or BLS unit arrived in 240 seconds or less travel time. Currently, the department is capable of providing ALS services on 59.7% of city roads within 8 minutes when all medic units are available for immediate response.

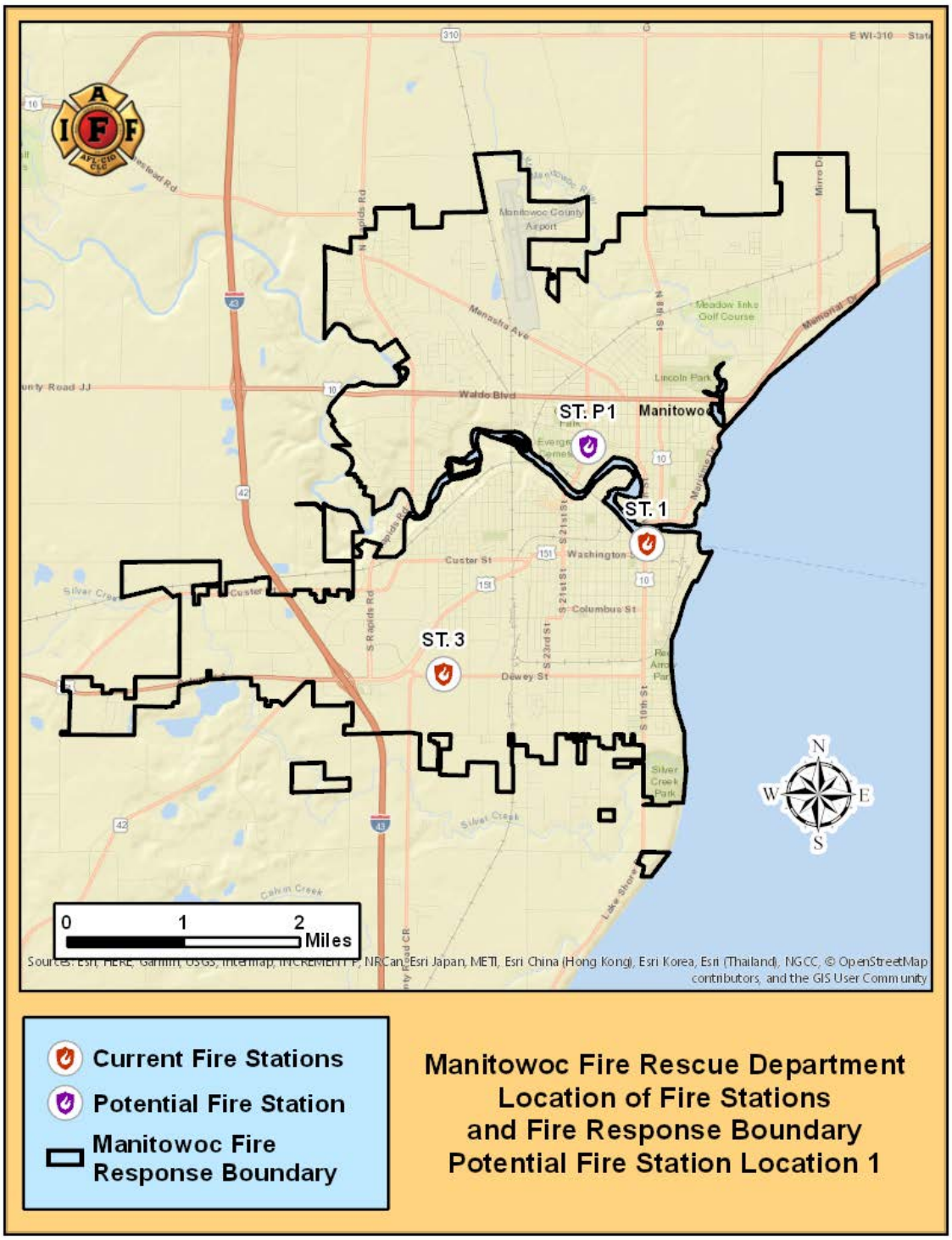
Emergency Response Capabilities, Potential Fire Station Location 1[79]

For this portion of the study, an alternate staffing and deployment scenario was examined where Fire Stations 2 and 4 would be merged together resulting in a new station being built in the 700 block of North 18th Street and Stations 2 and 4 being closed. The new fire station would be staffed with an engine company staffed with two firefighters and a medic unit staffed with two firefighters.

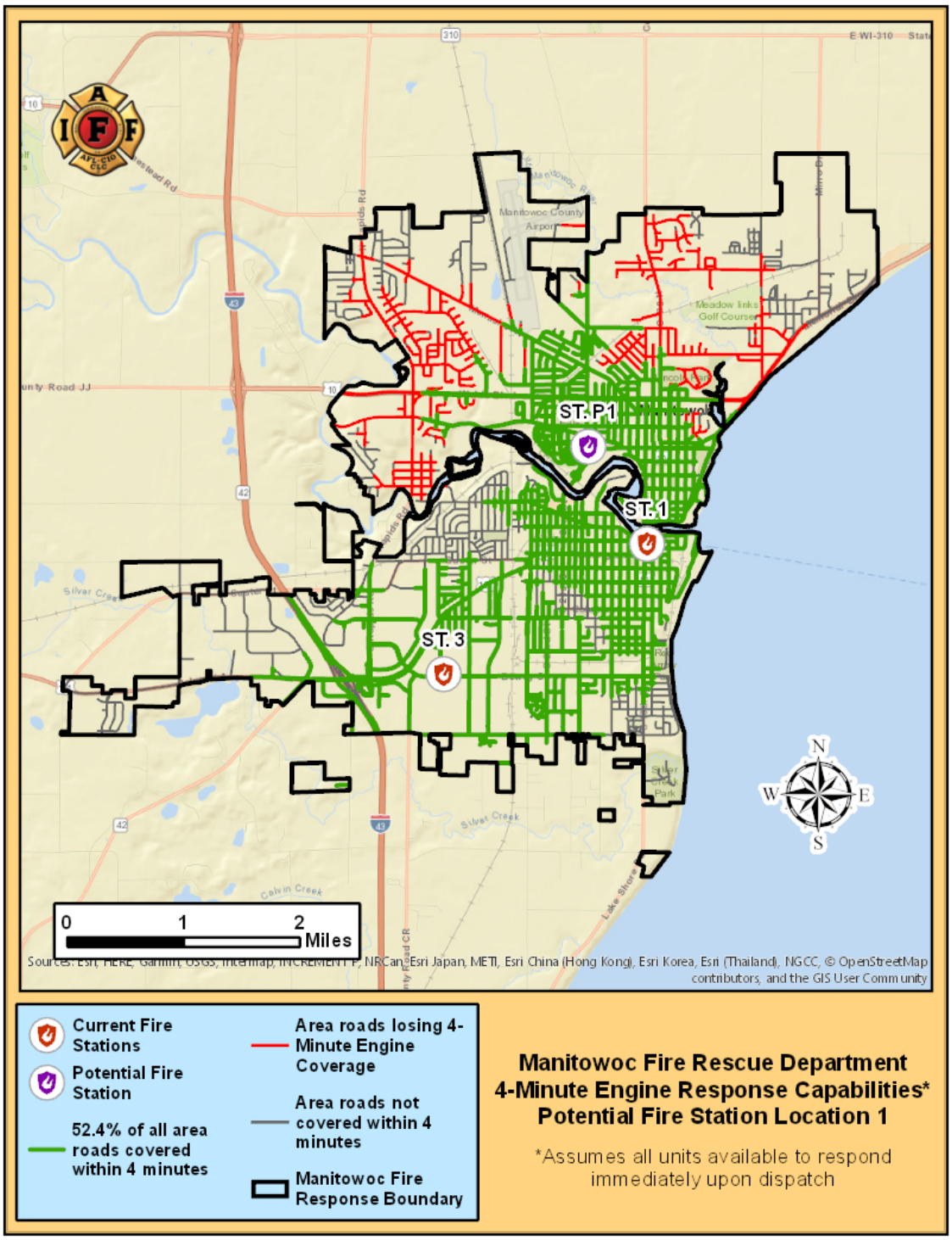
Fire Station	Address	Apparatus	Staffing
Station 1	911 Franklin Street	Engine 1 Ladder 1 Medic 1 Medic 11	3 FF Cross-Staffed 2 FF Cross-Staffed
Station 3	3820 Dewey Street	Engine 3 Medic 3	3 FF Cross-Staffed
Potential Fire Station Location 1	**700 Block of North 18th Street (44.102, -87.670)**	**Engine P1 Medic P1**	**2 FF 2 FF**

Table 7: Fire Station Locations and Staffing, Potential Fire Station Location 1. Table 7 displays where apparatus would be housed and the staffing levels for each apparatus. In this scenario, a new station replacing Stations 2 and 4 will deploy an engine company and a medic unit, both staffed with two firefighters. This would result in a typical daily staffing level of 12 firefighters. If all medic units are on assignment and/or unavailable to respond to an incident, Medic 11 will be staffed with the crew from Engine 1 and placed into service resulting in both Engine 1 and Ladder 1 being placed out of service.

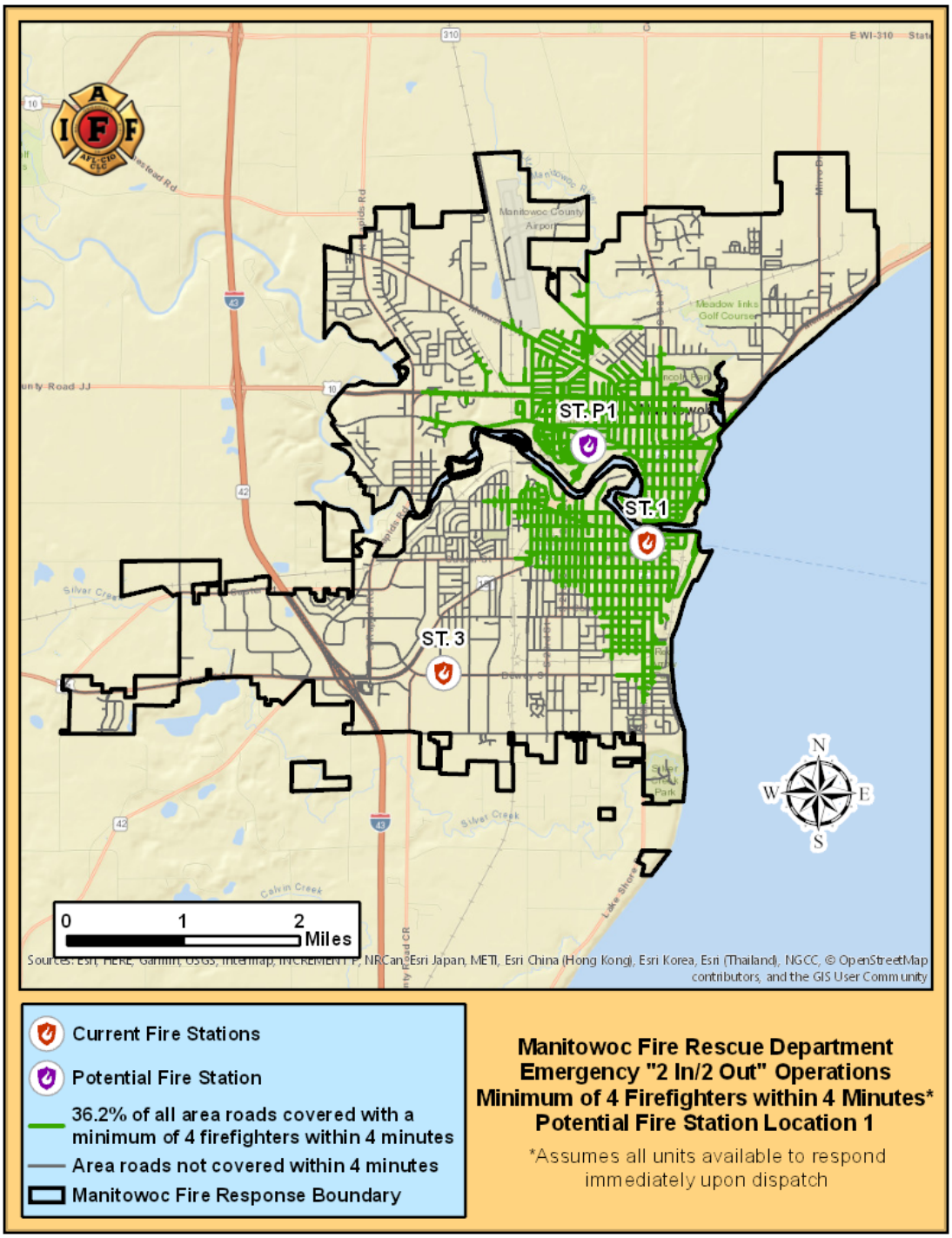
[79] Based on the potential fire station location 1 staffing and deployment configuration, MFRD cannot meet NFPA 1710 low- and medium-hazard initial alarm response. Therefore, these maps were not included.



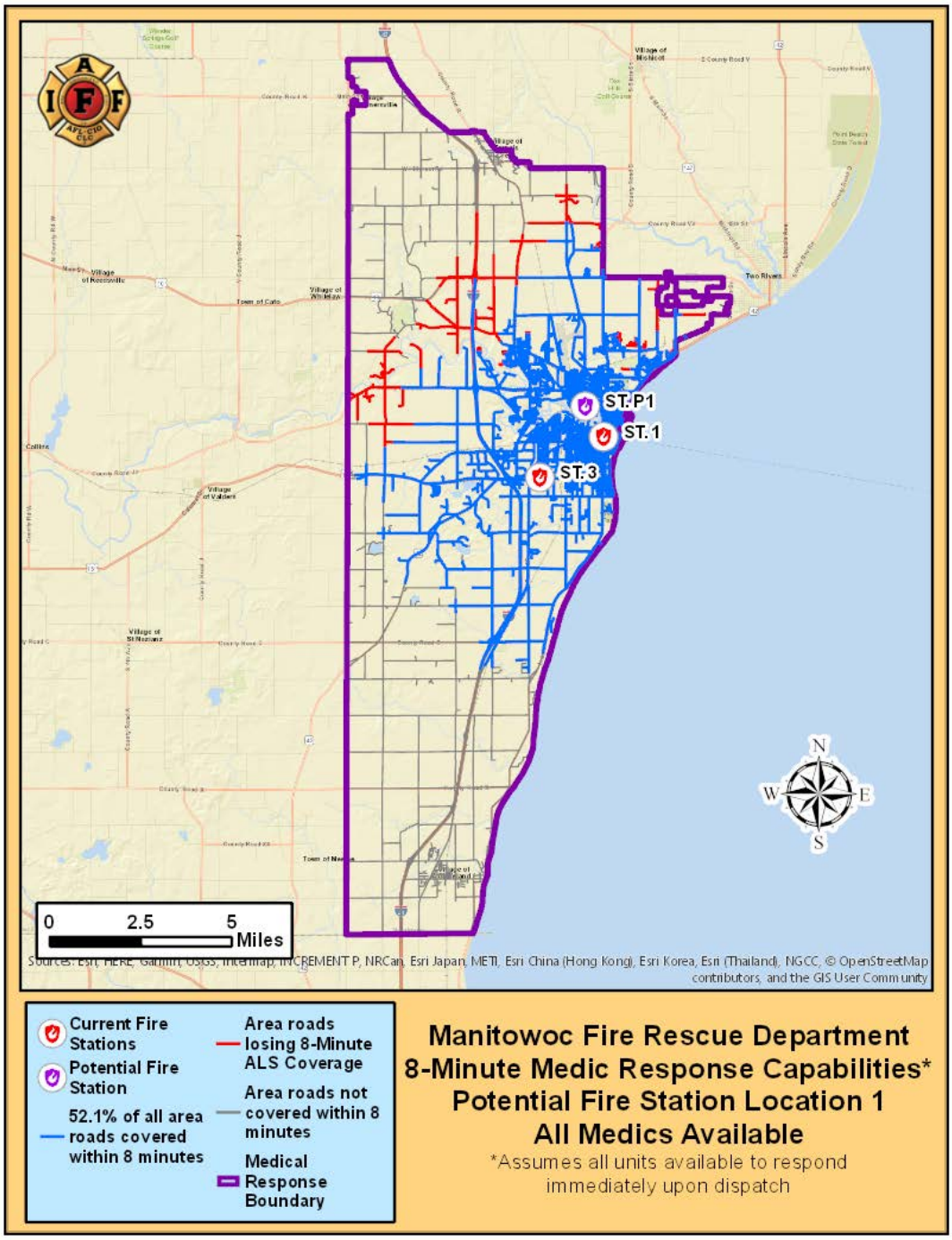
Map 11: Location of Fire Stations and Fire Response Boundary, Potential Fire Station Location 1. Map 11 depicts the location of MFRD's fire stations and the fire response boundary pursuant to Fire Stations 2 and 4 being closed and the new fire station being located in the 700 block of North 18th Street.



Map 12: 4-Minute Engine Response Capabilities, Potential Fire Station Location 1. Map 12 identifies those roads where MFRD's engine companies would likely be able to reach within 4 minutes of travel when all engines are staffed and available to respond. Based on this staffing and deployment configuration, the department would likely be capable of responding on 52.4% of city roads within 4 minutes of travel. Roads shaded in red represent roads that would no longer be responded to by an engine company within 4 minutes compared to the current staffing and deployment configuration.



Map 13: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, Potential Fire Station Location 1. Map 13 identifies those roads where a minimum of four firefighters would likely be able to assemble on scene within 4 minutes of travel when all frontline apparatus are staffed. Based on this staffing and deployment configuration, the department would likely be able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 36.2% of city roads. Because units are not staffed with four, firefighters must rely on supplemental personnel arriving later before making entry into environments that are immediately dangerous to life and health, such as structure fires, in order to meet objectives outlined in industry standards and U.S. Occupational Safety and Health Administration rules and regulations.



Map 14: 8-Minute Medic Response Capabilities, Potential Fire Station Location 1, All Medics Available. Map 14 identifies those roads where MFRD medic units, which are staffed and equipped to provide advanced life support procedures, would likely be able to reach within 8 minutes of travel. NFPA 1710 states that the arrival of an ALS equipped company within a 480-second travel time to 90 percent of the incidents, provided a first responder with AED or BLS unit arrived in 240 seconds or less travel time. Based on this staffing and deployment configuration, the department would likely be capable of providing ALS services on 52.1% of city roads within 8 minutes when all medic units are available for immediate response. Roads shaded in red represent roads that would no longer be responded to by an ALS resource within 8 minutes compared to the current staffing and deployment configuration.

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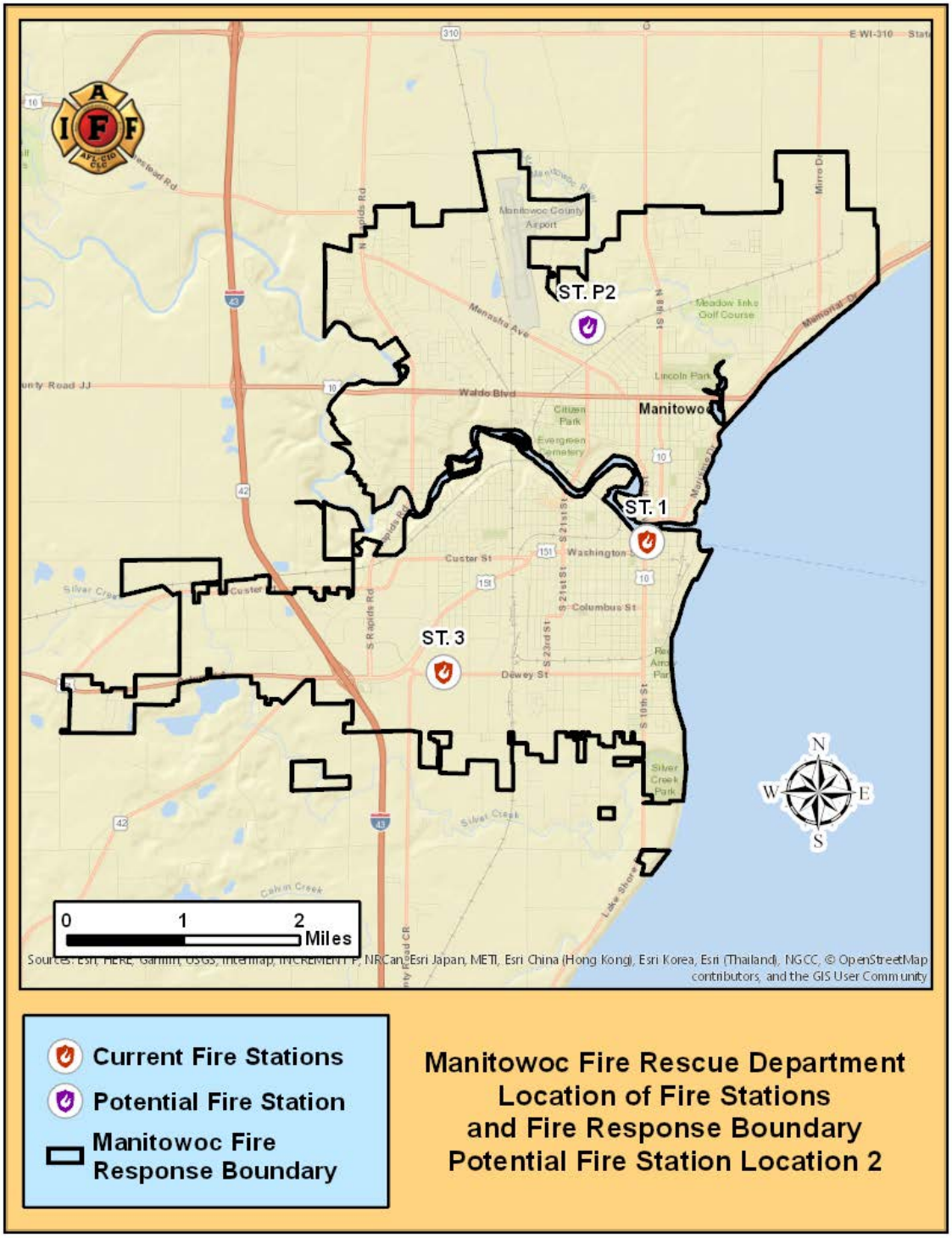
Emergency Response Capabilities, Potential Fire Station Location 2[80]

For this portion of the study, an alternate staffing and deployment scenario was examined whereby Fire Stations 2 and 4 would be merged together resulting in a new station located at the intersection of North 18th Street and Nagle Avenue and Stations 2 and 4 being closed. An engine company staffed with two firefighters and a medic unit staffed with two firefighters would be housed at the new fire station.

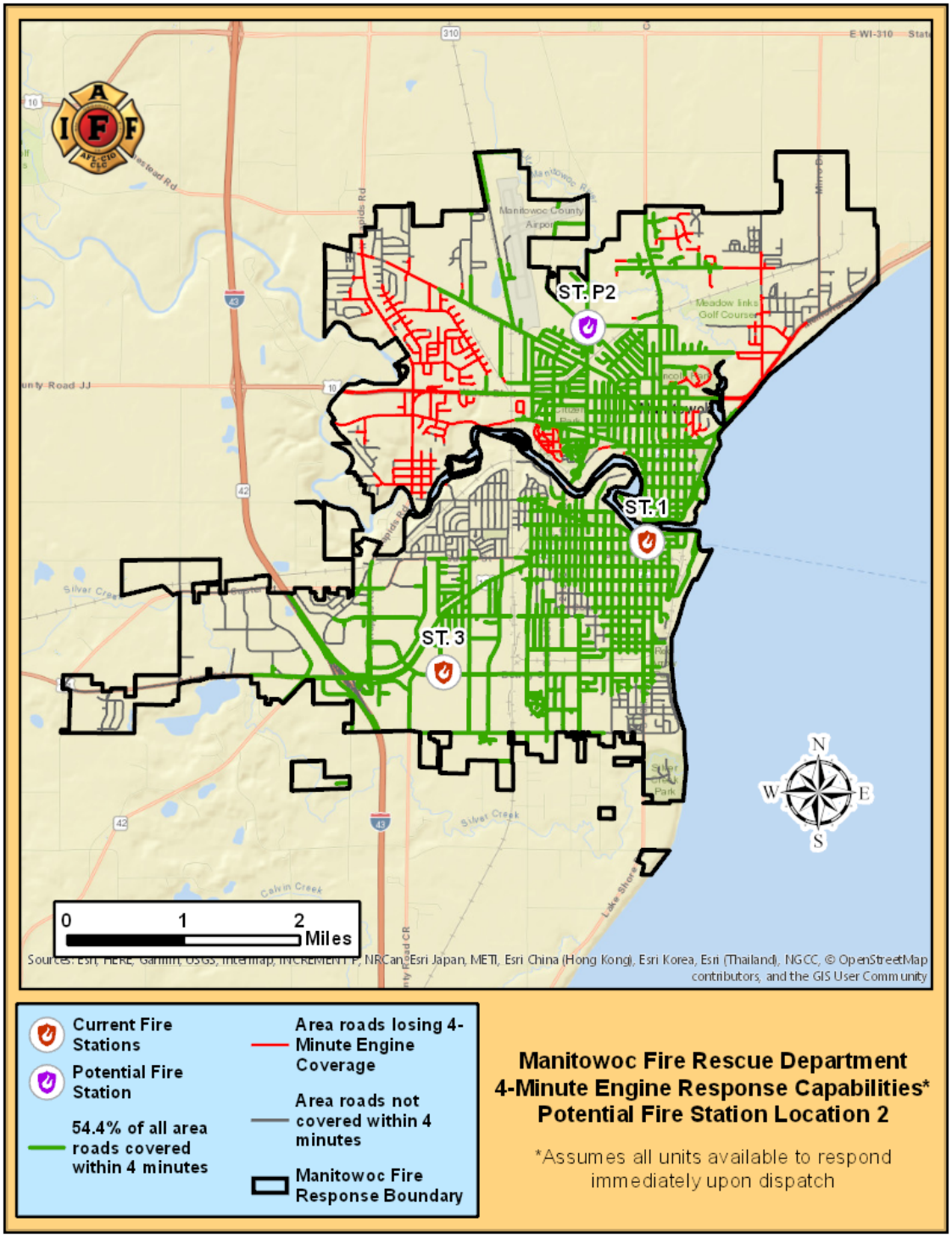
Fire Station	Address	Apparatus	Staffing
Station 1	911 Franklin Street	Engine 1 Ladder 1 Medic 1 Medic 11	3 FF Cross-Staffed 2 FF Cross-Staffed
Station 3	3820 Dewey Street	Engine 3 Medic 3	3 FF Cross-Staffed
Potential Fire Station Location 2	**Intersection of North 18th Street and Nagle Avenue (44.116, -87.671)**	**Engine P2 Medic P2**	**2 FF 2 FF**

Table 8: Fire Station Locations and Staffing, Potential Fire Station Location 2. Table 8 displays where apparatus would be housed and the staffing levels for each apparatus. In this scenario, a new station replacing Stations 2 and 4 will deploy an engine company and a medic unit, both staffed with two firefighters. This would result in a typical daily staffing level of 12 firefighters. If all medic units are on assignment and/or unavailable to respond to an incident, Medic 11 will be staffed with the crew from Engine 1 and placed into service resulting in both Engine 1 and Ladder 1 being placed out of service.

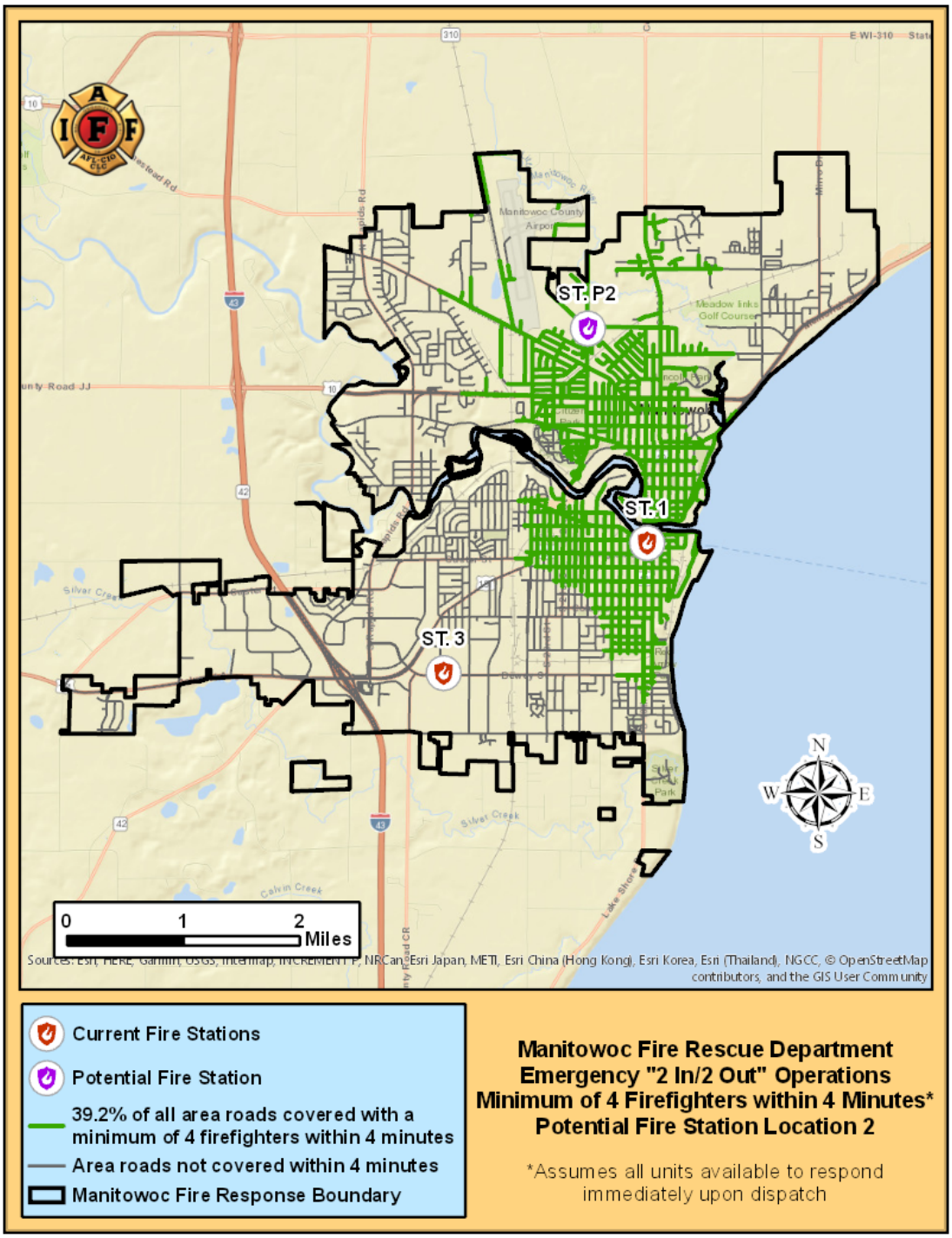
[80] Based on the potential fire station location 2 staffing and deployment configuration, MFRD cannot meet NFPA 1710 low- and medium-hazard initial alarm response. Therefore, these maps were not included.



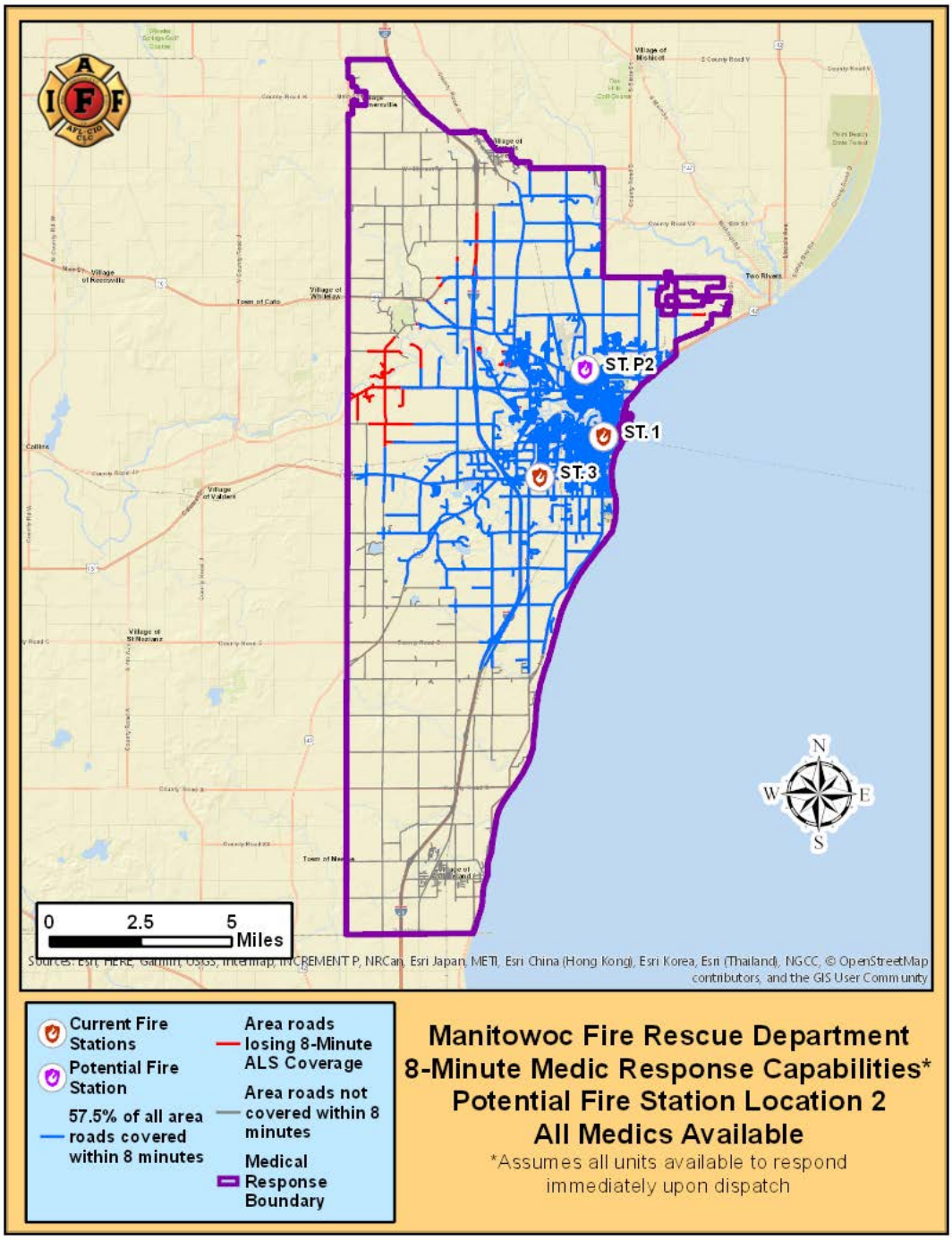
Map 15: Location of Fire Stations and Fire Response Boundary, Potential Fire Station Location 2. Map 15 depicts the location of MFRD's fire stations and the fire response boundary pursuant to Fire Stations 2 and 4 being closed and a new fire station being built at the intersection North 18th Street and Nagle Avenue.



Map 16: 4-Minute Engine Response Capabilities, Potential Fire Station Location 2. Map 16 identifies those roads where MFRD's engine companies would be able to reach within 4 minutes of travel when all engine apparatus are staffed and available for response. Based on this staffing and deployment configuration, the department would likely be capable of responding on 54.4% of city roads within 4 minutes of travel. Roads shaded in red represent roads that would no longer be responded to by an engine company within 4 minutes compared to the current staffing and deployment configuration.



Map 17: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, Potential Fire Station Location 2. Map 17 identifies those roads where a minimum of four firefighters would likely be able to assemble on scene within 4 minutes of travel when apparatus are staffed and available for response. Based on this staffing and deployment configuration, the department would likely be able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 39.2% of city roads. Because units are not staffed with four, firefighters must rely on supplemental personnel arriving later before making entry into environments that are immediately dangerous to life and health, such as structure fires, in order to meet objectives outlined in industry standards and U.S. Occupational Safety and Health Administration rules and regulations.



Map 18: 8-Minute Medic Response Capabilities, Potential Fire Station Location 2, All Medics Available. Map 18 identifies those roads where MFRD medic units, which are staffed and equipped to provide advanced life support procedures, would likely be able to reach within 8 minutes of travel. NFPA 1710 states that the arrival of an ALS equipped company within a 480-second travel time to 90 percent of the incidents, provided a first responder with AED or BLS unit arrived in 240 seconds or less travel time. Based on this staffing and deployment configuration, the department would likely be capable of providing ALS services on 57.5% of city roads within 8 minutes when all medic units are available for immediate response. Roads shaded in red represent roads that would no longer be responded to by an ALS resource within 8 minutes compared to the current staffing and deployment configuration.

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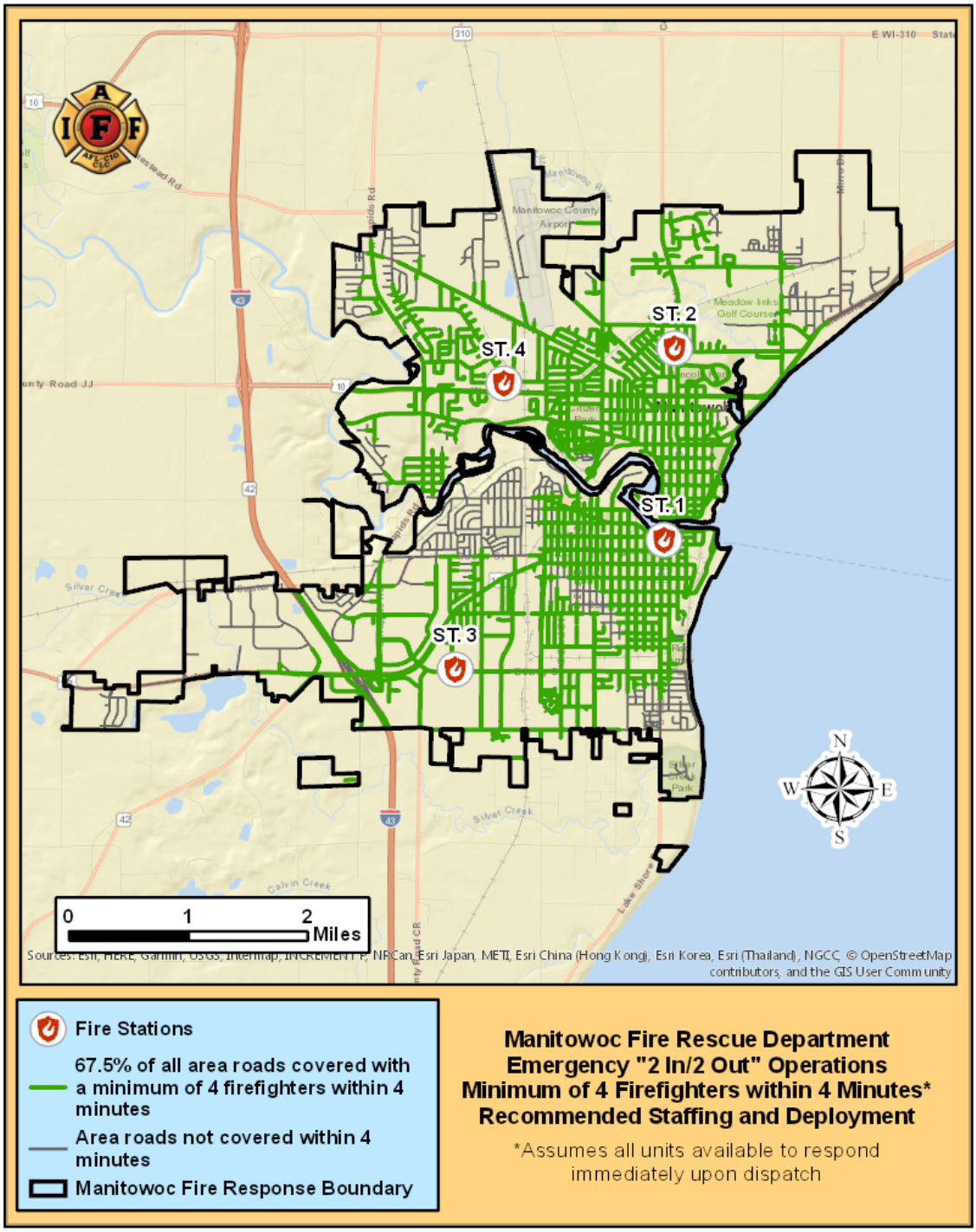
Emergency Response Capabilities, Recommended Staffing and Deployment[81]

For this portion of the study, an alternate staffing and deployment scenario was examined whereby existing stations would remain open in their current locations, all MFRD's fire suppression apparatus would be staffed in accordance with NFPA 1710 recommended minimum staffing levels, medic units and the ladder company would be staffed full-time, and cross-staffing would be eliminated. Staffing apparatus with four firefighters allows firefighters to begin an interior attack on a fire immediately rather than waiting for additional units to arrive on the scene with supplemental personnel.

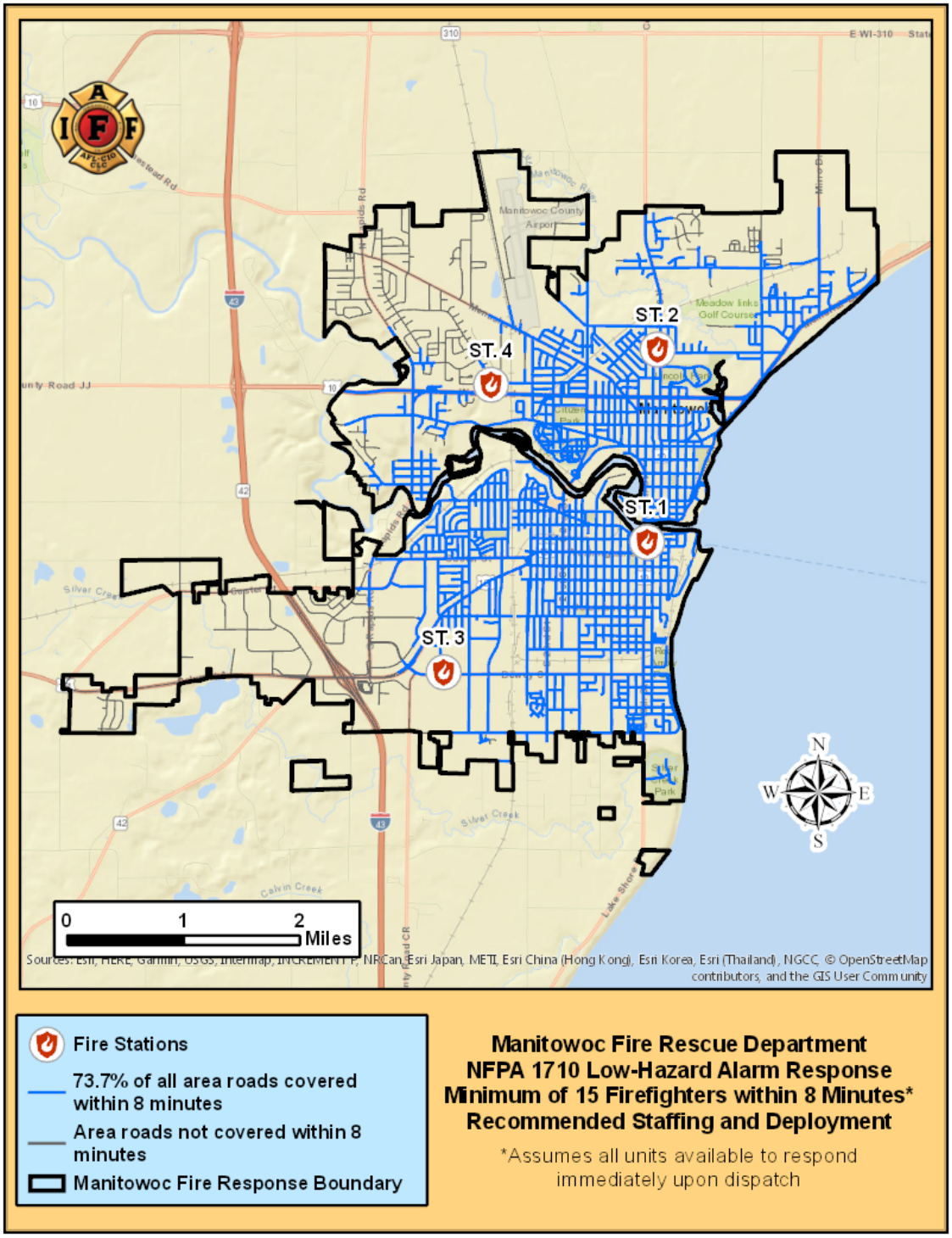
Fire Station	Address	Apparatus	Staffing
Station 1	911 Franklin Street	Engine 1 Ladder 1 Medic 1 Medic 11	**4 FF** **4 FF** 2 FF Reserved Unit
Station 2	1410 North 8th Street	Engine 2 Medic 2	**4 FF** **2 FF**
Station 3	3820 Dewey Street	Engine 3 Medic 3	**4 FF** **2 FF**
Station 4	1125 Fleetwood Drive	Engine 4 Medic 4	**4 FF** **2 FF**

Table 9: Fire Station Locations and Recommended Staffing and Deployment. Table 9 displays where apparatus would be housed and the recommended staffing levels for each apparatus.

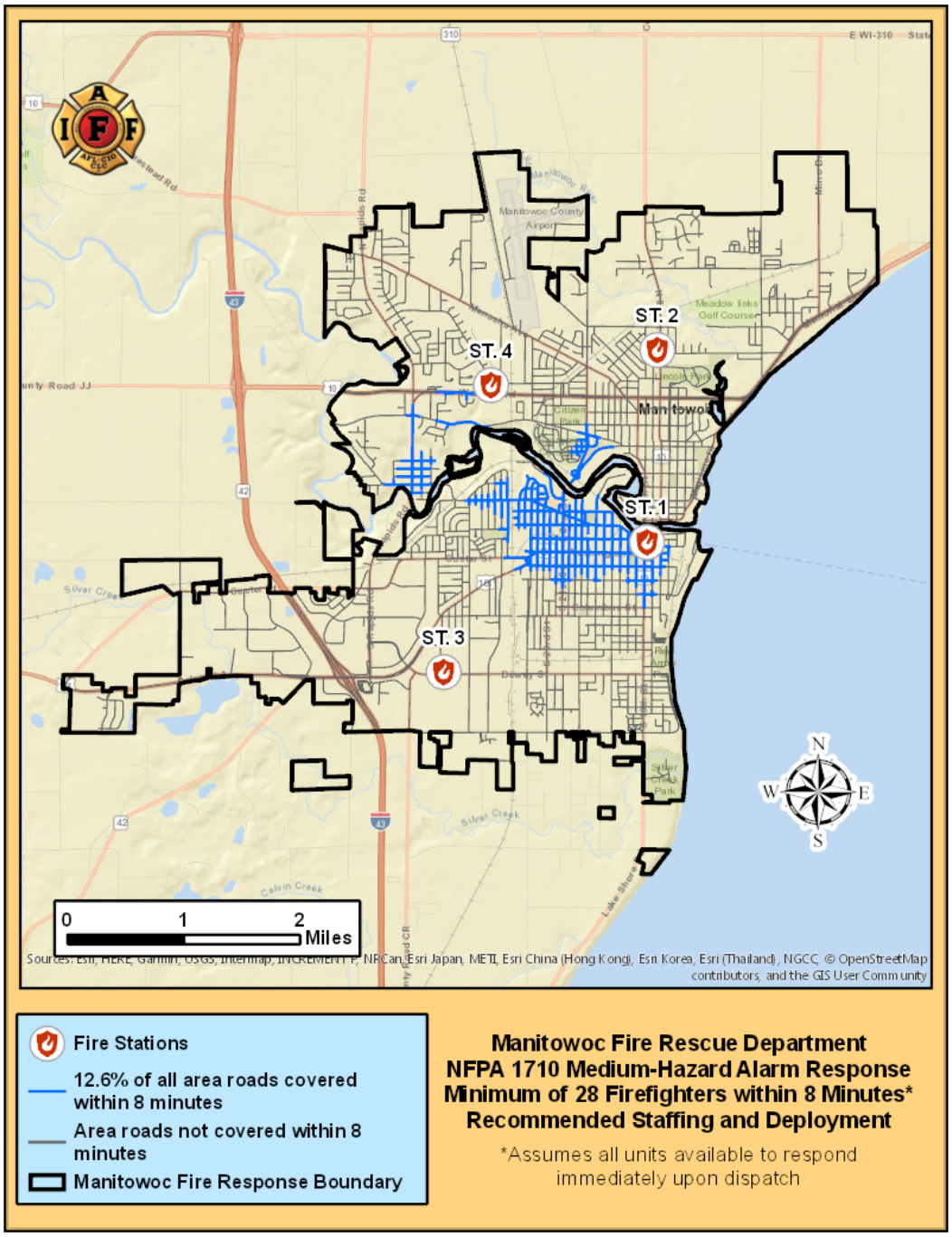
[81] The recommend staffing and deployment configuration does not alter the department's 4-minute engine response capabilities and 8-minute medic response capabilities compared to the current staffing and deployment scenario. Therefore, these maps were not included.



Map 19: Emergency "2 In/2 Out" Operations, 4-Minute Response Capabilities, Recommended Staffing and Deployment. Map 19 identifies those roads where a minimum of four firefighters will likely be able to assemble on scene within 4 minutes of travel when all apparatus are staffed and available for response. Based on this staffing and deployment configuration, the department would likely be able to assemble a minimum of four firefighters on scene within 4 minutes of travel on 67.5% of city roads. Because units are staffed with four, firefighters would be able to make entry into environments that are immediately dangerous to life and health, such as structure fires, in order to meet objectives outlined in industry standards and U.S. Occupational Safety and Health Administration rules and regulations without having to wait for additional personnel.



Map 20: NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes, Recommended Staffing and Deployment. Map 20 identifies those roads where a minimum of 15 firefighters can likely assemble within 8 minutes of travel when all apparatus are staffed pursuant to the recommended staffing and deployment plan. Based on this staffing and deployment configuration, the department would likely be capable of assembling a minimum of 15 firefighters within 8 minutes of travel on 73.7% of city roads. Under the current and the two potential staffing and deployment configurations, the department is/would be unable to meet the requirements outlined in NFPA 1710 to meet the response requirements for a low-hazard structure fire.



Map 21: NFPA 1710 Medium-Hazard Alarm Response, Minimum of 28 Firefighters within 8 Minutes, Recommended Staffing and Deployment. Map 21 identifies those roads where a minimum of 28 firefighters would likely be able to assemble within 8 minutes of travel when all apparatus are staffed and available for response. Based on this staffing and deployment configuration, the department would likely be capable of assembling a minimum of 28 firefighters within 8 minutes of travel to 12.6% of city roads. MFRD should identify where medium-hazard structures are located and add additional resources to these areas to possibly increase the department's ability to assemble a minimum of 28 firefighters within 8 minutes of travel. Under the current and the two potential staffing and deployment configurations, the department is/would be unable to meet the requirements outlined in NFPA 1710 to meet the response requirements for a medium-hazard structure fire.

Summary of Response Capabilities based on Various Staffing Scenarios

Staffing Scenario	4-Minute Engine Coverage (%)	Emergency "2 In/2 Out" Operations 4-Minute Coverage (%)	8-Minute ALS Coverage (%)	NFPA 1710 Low-Hazard Alarm Response (%)	NFPA 1710 Medium Hazard Alarm Response (%)
Current	67.5%	26.5%	59.7%	0.0%	0.0%
Potential Fire Station Location 1	52.4%	36.2%	52.1%	0.0%	0.0%
Potential Fire Station Location 2	54.4%	39.2%	57.5%	0.0%	0.0%
Recommended Staffing and Deployment	67.5%	67.5%	59.7%	73.7%	12.6%

Table 10: Response Capabilities and Percent Change based on Various Staffing and Deployment Scenarios. Table 10 displays the percentage of city roads that would likely be covered for four response capabilities' benchmarks under four separate deployment scenarios. The four deployment scenarios compare the department's current capabilities, when Fire Stations 2 and 4 are closed and a new fire station is built, and under a recommended staffing and deployment plan.

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Manitowoc Fire Rescue Department Workload Analysis

Analysis of the department's response capabilities is based on the assumption that all units are available to respond immediately upon dispatch, which allows for a general evaluation of the department's response capabilities. However, instances when all units are available for dispatch at the same time rarely happens. In order to more accurately evaluate the department's workload, incident data must be examined on a smaller scale.

The Manitowoc Fire Rescue Department provided historical CAD data for all emergency responses from January 1, 2015 to December 31, 2017. The CAD data include, but are not limited to, details such as incident identifier number, type of incident, responding apparatus, time the call was received, dispatch time, en route time, arrival time, the time when apparatus and personnel have cleared the incident, and the total on-assignment time. CAD data have the necessary information needed in order to: determine the total number of incidents and apparatus responses, determine when the highest volume of incidents and apparatus responses occur throughout the day, determine the number of hours apparatus were on assignment, determine the number of hours multiple apparatus were on assignment at the same time, and calculate the average and 90^{th} percentile travel times for the first arriving apparatus. Also, an examination of the department's interfacility transfers was performed to determine the number of responses and the number of hours spent performing interfacility transfers.

Using these findings, the department will be able to understand how workload, increased call volume, and the lack of resources affects MFRD's response capabilities. It will provide decision makers with the necessary information to better allocate resources to ensure MFRD provides effective and efficient emergency response at all times.

Key Definitions

As stated above, an examination of the department's historical call volume data (January 1, 2015 to December 31, 2017) was completed to evaluate the department's response capabilities and performance. The following definitions were created to identify terminology used in the department's CAD reporting system and specific characteristics used to evaluate the department's performance.

Fire Crew: is the full-time personnel assigned to each station that cross-staffs multiple apparatus.

Incident: refers to an emergency to which fire department mobile and personnel resources are dispatched to intervene and mitigate. An incident may require a single or multiple apparatus to respond.

Response: refers to an individual unit, or units, being dispatched and traveling to the scene of an incident.

Hour: refers to the 60-minute period between whole numbers on a clock, for example, 1:00 to 2:00 or 15:00 to 16:00, unless otherwise stated.

Call Time: refers to the time when the alarm (request for emergency) is answered by the dispatch center.

Dispatch Time: refers to the time when units and personnel are assigned to an incident.

En route Time: refers to the time when units and personnel are beginning their travel to the emergency.

Arrival Time: refers to the time when the assigned units and personnel arrive at the incident location.

Clear Time: refers to the time when apparatus and personnel have cleared the scene and are available for service.

Travel Time: refers to the time interval that begins when a unit is en route to the emergency scene and ends when the unit arrives at the scene.[82]

On-Assignment Time: refers to the total time spent on an incident from dispatch time until the assigned units (apparatus and personnel) complete all tasks and become available for service.

[82] NFPA 1710 §3.3.53.7 (2016)

Data Parameters

CAD data provided by MFRD list all incidents responded to by the department's personnel and resources from January 1, 2015 to December 31, 2017. Parameters were created to accurately examine the department's workload and past performance. Below are the parameters used when analyzing the data:

- Only engine, ladder, and medic companies were considered when evaluating the travel times of the first arriving apparatus. Travel time analysis did not include reserve and specialty units.

- Records with errors in reporting en route time, arrival time, and/or incidents that were cancelled before the first apparatus arrived on scene were excluded from the travel time analysis.[83]

- Records with errors in reporting dispatch time and/or clear time were excluded when calculating the number of hours apparatus were engaged on assignment and the number of hours multiple apparatus were on assignment at the same time.[84]

[83] 13.0% of incidents were excluded due to errors in reporting en route time, arrival time, or were cancelled before arriving on scene.
[84] 2.4% of responses were excluded due to errors in reporting dispatch or clear time.

Call Volume Analysis

An important parameter to consider is the number of incidents compared to the number of apparatus responses. Incidents may, and frequently do, require responses from multiple apparatus. Responses to all incident types can be labor intensive and frequently require personnel from multiple units to complete critical tasks simultaneously. It is important to understand at what times during the day most incidents and apparatus responses take place. Also, examining the number of responses performed by each MFRD apparatus and knowing that number of hours each apparatus were on assignment will assist in assessing the workload of each apparatus.

From January 1, 2015 and December 31, 2017, MFRD apparatus responded to 17,077 incidents and performed 18,639 responses. The highest volume of incidents and apparatus responses took place between the hours of 7:00 a.m. and 9:00 p.m. The department experienced its lowest call volume between 1:00 a.m. and 6:00 a.m. While call volume may be lower during the overnight hours, the risk for civilian fire fatalities peaks during these hours. According to a 2017 study performed by the U.S. Fire Administration (USFA), 51% of civilian fire fatalities in residential buildings occurred between the hours of 11:00 p.m. and 7:00 a.m.[85] Even though MFRD experienced a lower call volume during the overnight hours, the department must be equipped appropriately in order to have the necessary resources and personnel available to respond to all types of incidents and hazards at all times.

During this time period (January 1, 2015-December 31, 2017), medic units performed approximately 80% of the department's total responses. Due to the department's practice of cross-staffing apparatus, anytime Medics 2, 3, 4, or 11 (as well as the reserve medic units) respond to an incident, Engines 1, 2, 3, 4, or Ladder 1 will be placed out of service (depending on which medic unit responds to the incident). Frontline medic units experienced a 13.5% **increase** in total responses in 2017 compared to total responses in 2015. Because the department cross-staffs multiple apparatus, it is important to also examine the number of responses executed by each fire crew. For the purposes of this report, "fire crew" is defined as the full-time personnel assigned to each station that cross-staffs multiple apparatus. Between January 1, 2015 and December 31, 2017, the fire crew assigned to Fire Station 3 (Engine 3, Medic 3, and Medic 33) saw a 19.5% **increase** in responses in 2017 compared to responses in 2015. As responses increase, MFRD must evaluate the need for additional resources to provide efficient and effective emergency response.

[85] https://www.usfa.fema.gov/downloads/pdf/statistics/v18i4.pdf

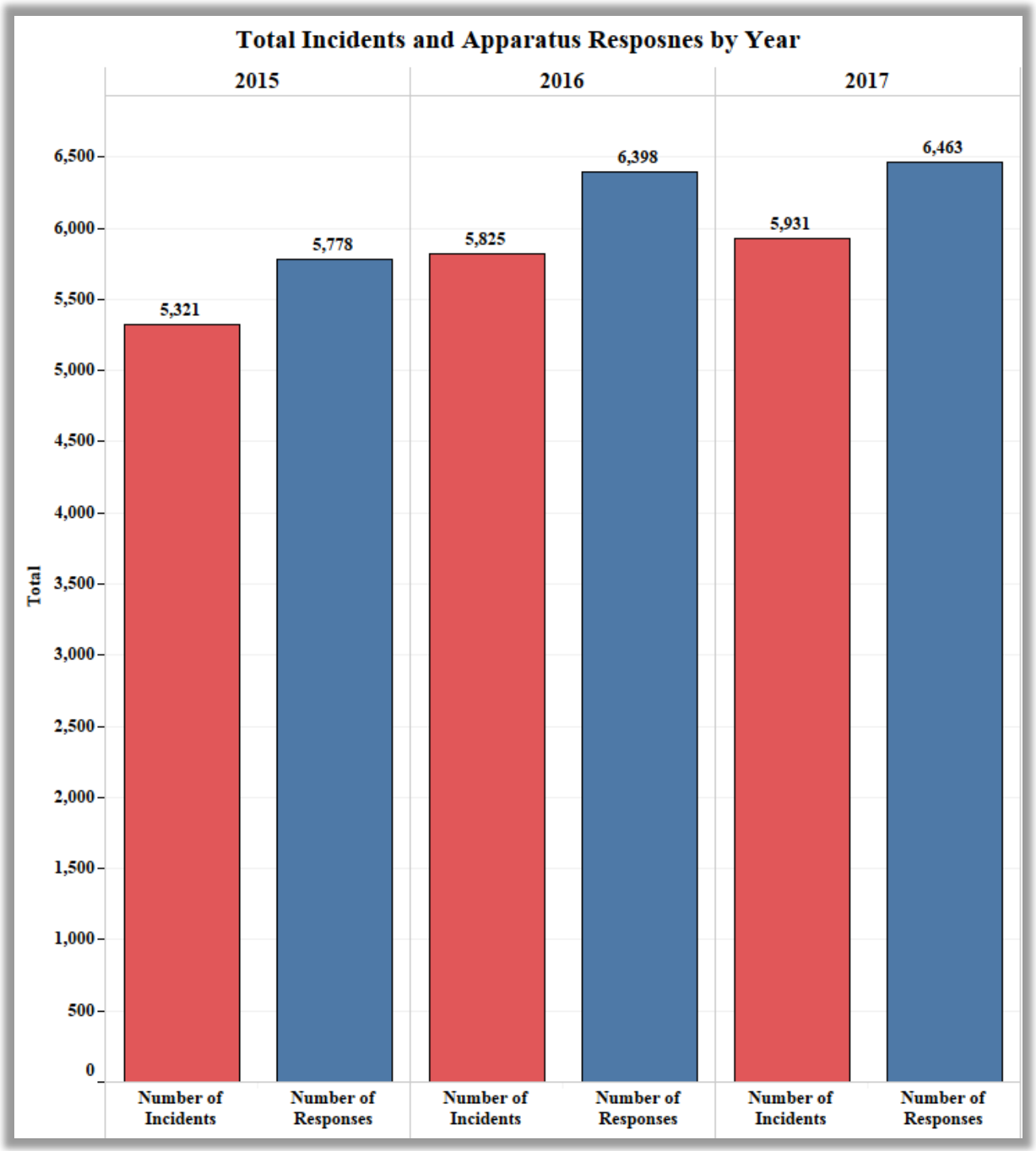


Chart 5: Total Incidents and Apparatus Responses by Year. Chart 5 depicts the total number of incidents and apparatus responses executed by MFRD from January 1, 2015 to December 31, 2017. Incidents may, and frequently do, require responses from multiple apparatus. Responses to all incident types can be labor intensive and frequently require personnel from multiple units to complete critical tasks simultaneously. The department experienced an 11.5% **increase** in incidents and 11.8% **increase** in apparatus responses in 2017 compared to the total incidents and apparatus responses in 2015.

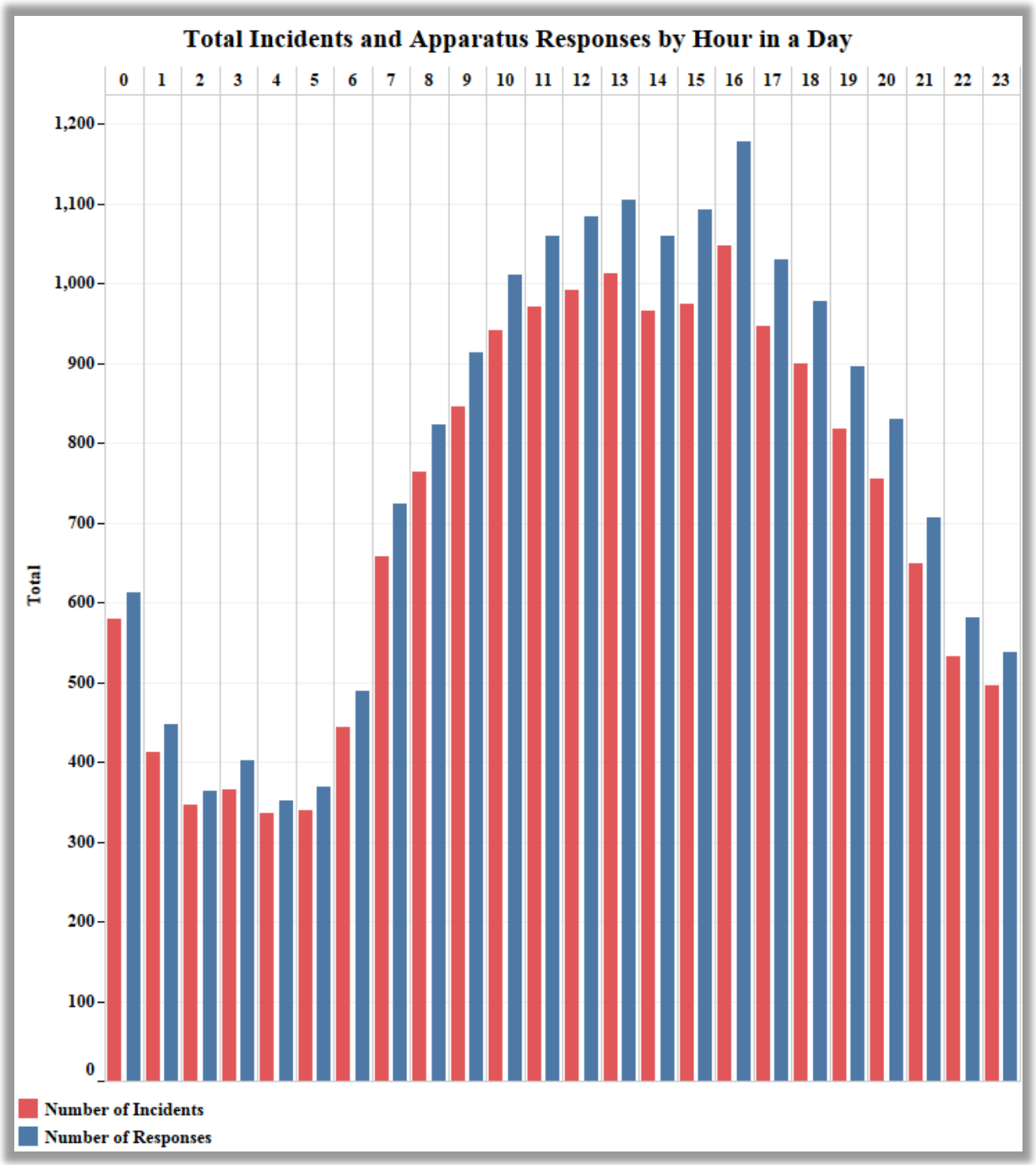


Chart 6: Total Incidents and Apparatus Responses by Hour in a Day. Chart 6 depicts the total number of incidents (red bars) and apparatus responses (blue bars) executed by MFRD for each hour in the day (the 0-23 horizontal axis at the top). From January 1, 2015 to December 31, 2017, the highest volume of incidents and apparatus responses took place between 7:00 a.m. and 9:00 p.m.

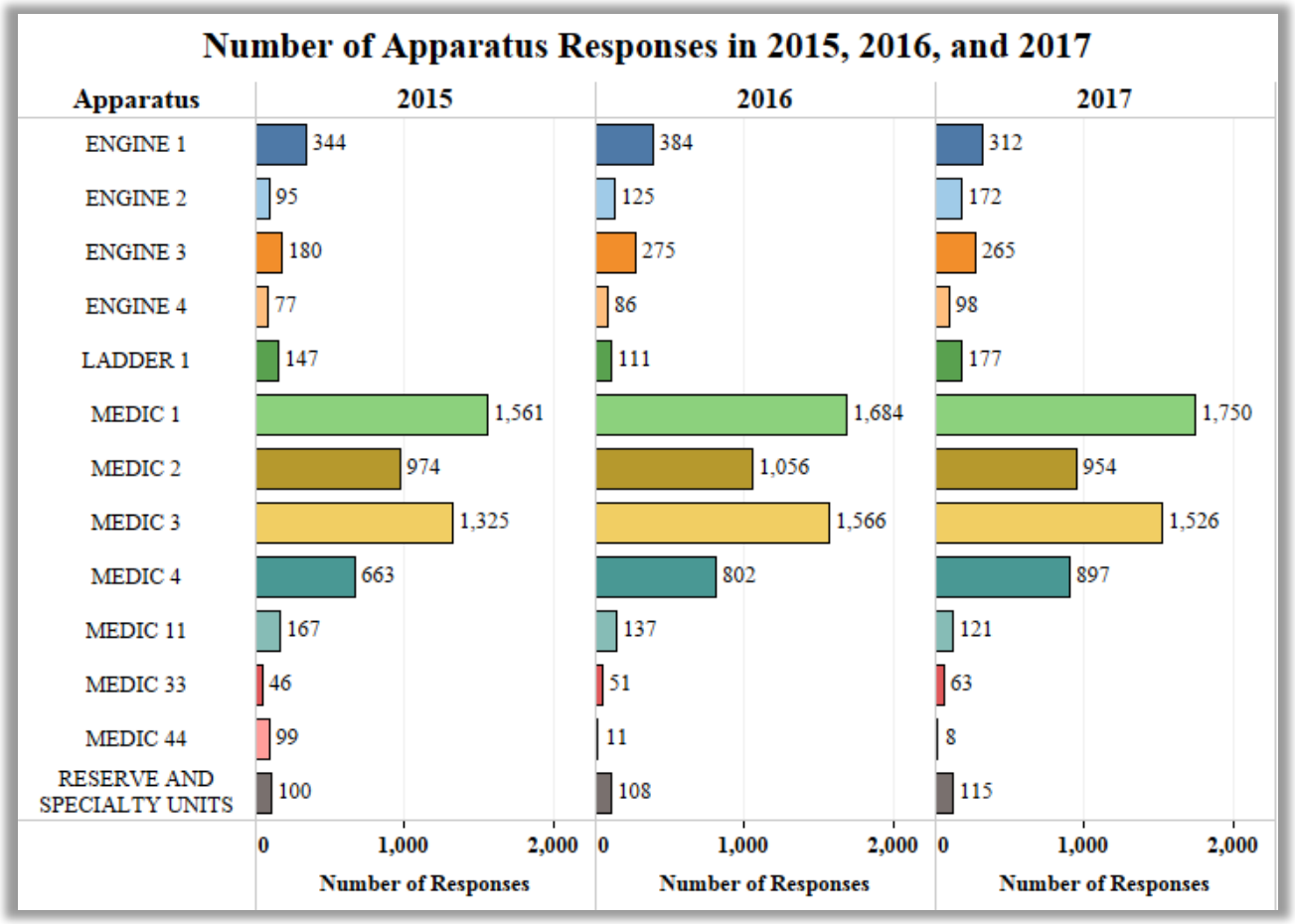


Chart 7: Number of Apparatus Responses in 2015, 2016, and 2017. Chart 7 depicts the total number of responses performed by MFRD's apparatus in 2015, 2016, and 2017. Medics 11, 33, and 44 are only deployed during times of high call volume or if frontline medic units are out of service due to maintenance or repairs. During this time period, medic units performed approximately 80% of the department's total responses. Due to the department's practice of cross-staffing apparatus, anytime Medics 2, 3, 4, or 11 respond to incidents Engines 1, 2, 3, 4, or Ladder 1, will be placed out of service depending on which medic unit responds. Frontline medic units experienced a 13.5% **increase** in total responses in 2017 compared to total responses in 2015. As responses increase, MFRD must add additional resources to ensure sure the city receives efficient and effective coverage.

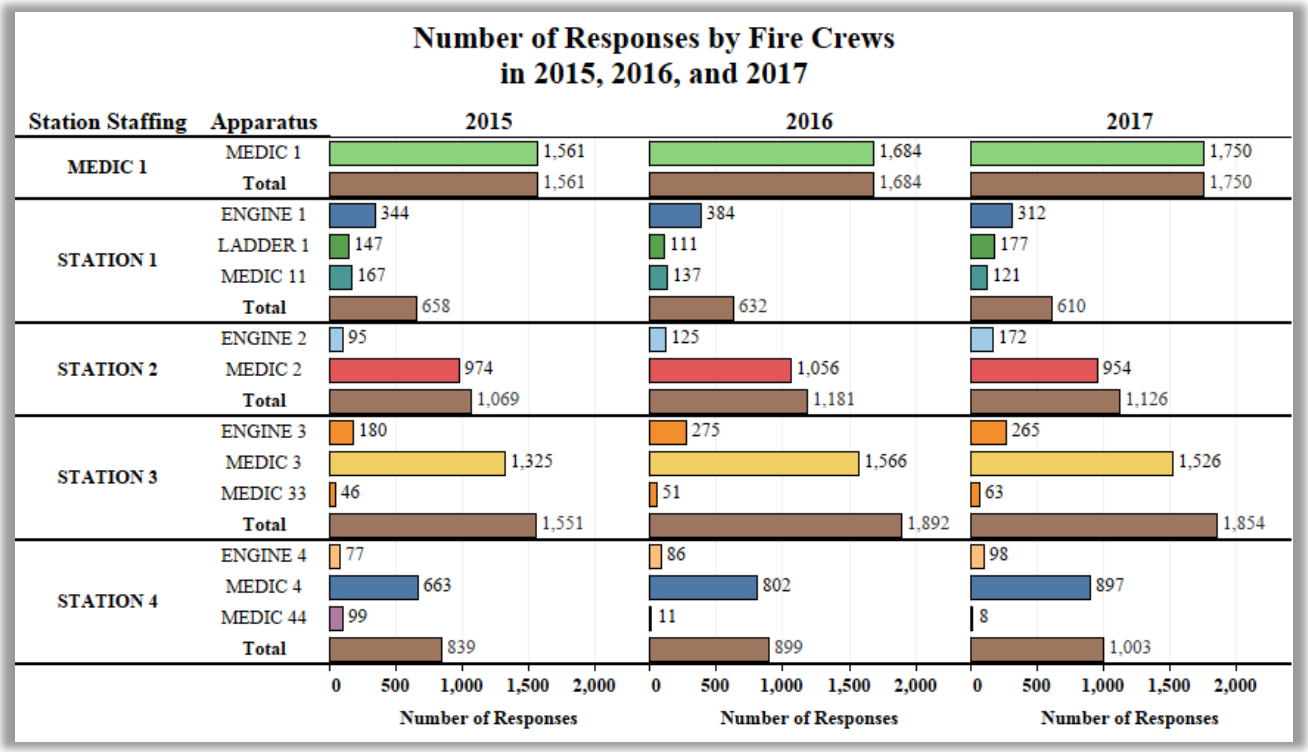


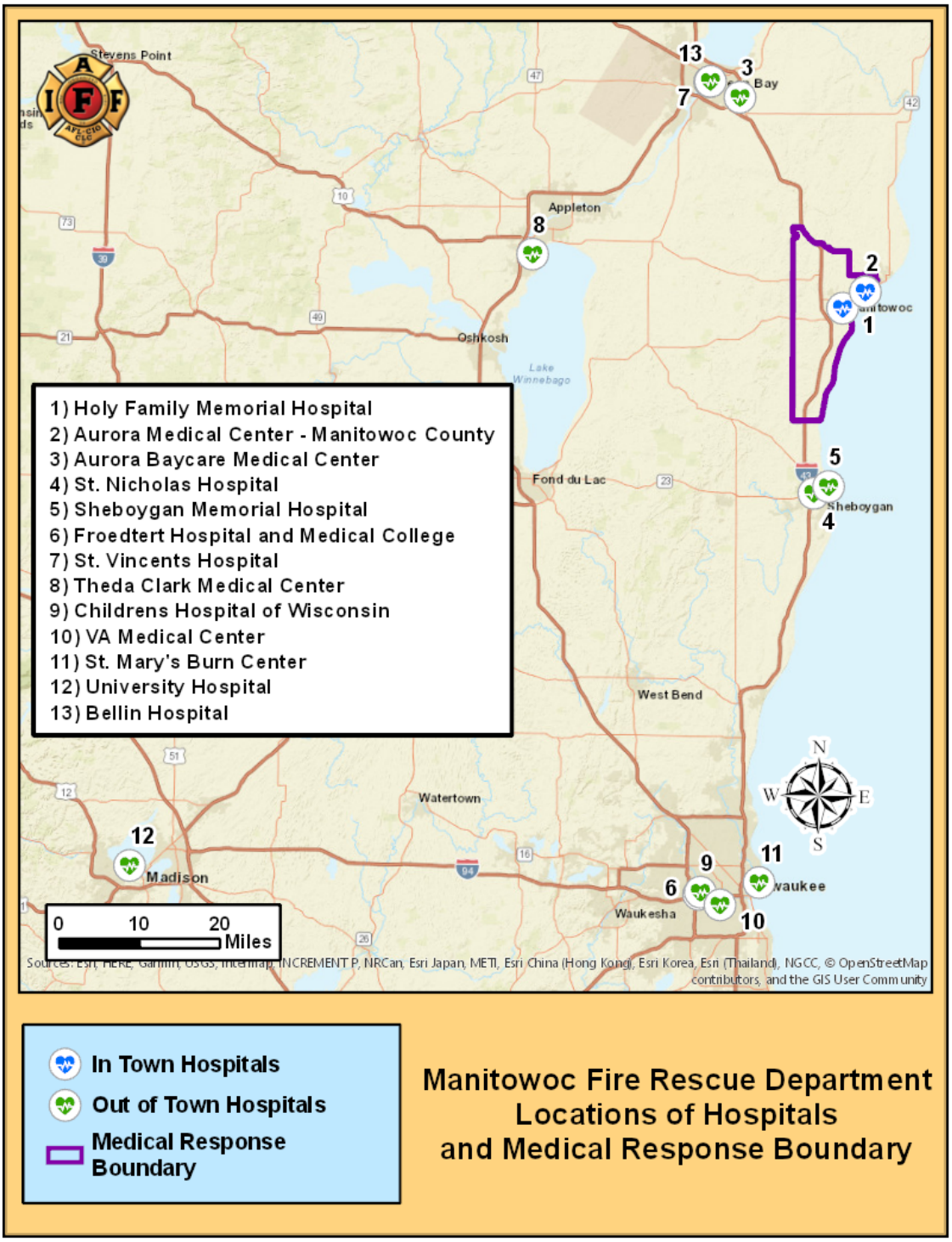
Chart 8: Number of Responses by Fire Crews in 2015, 2016, and 2017. Chart 8 depicts the total number of responses performed by MFRD's fire crews in 2015, 2016, and 2017. Because MFRD cross-staffs apparatus, the crews assigned to each fire station will respond on the apparatus appropriate for the type of call received. Medic 1 is the only full-time crew that doesn't typically cross-staff another apparatus so it has been grouped separately. Medic 1 experienced a 12.1% **increase** in responses in 2017 compared to responses in 2015. The fire company positioned at Fire Station 3 (Engine 3, Medic 3, and Medic 33) saw a 19.5% **increase** in responses in 2017 compared to responses in 2015.

Interfacility Transfers Analysis

MFRD provides emergency and non-emergency medical services for the City of Manitowoc and the contracted municipalities. MFRD's EMS response boundary covers approximately 142 square miles (third of Manitowoc County). MFRD performs interfacility transfers primarily from two hospitals located within city boundaries (Holy Family Memorial Hospital and Aurora Medical Center – Manitowoc County) to eleven hospitals located outside of the city. Medic 1 executes the majority of interfacility transfers placing this unit unavailable to respond to other incidents, on average, for more than two hours.

Analysis was performed to calculate the estimated number of miles and time it takes to complete a roundtrip interfacility transfer starting at each hospital within the city to the eleven hospitals located outside of the city. These results will give fire administrators and decision makers an estimate of how long an apparatus is on assignment when performing interfacility transfers. On average, roundtrip interfacility transfers from Holy Family Memorial Hospital to the eleven hospitals outside of the city takes two hours and fifteen minutes and totals 122 miles. On average, roundtrip interfacility transfers from Aurora Medical Center – Manitowoc County to the eleven hospitals outside of the city takes two hours and eighteen minutes and totals 126 miles. These results only considered the total drive time and does not include the time it takes for personnel to receive patient information, transfer and secure patient in ambulance, fill out patient care report, and clean and resupply the apparatus to a ready state to respond to calls. When Medic 1 performs an interfacility transfer, the department no longer has a dedicated staffed medic unit available to respond to incidents in Station 1's fire-due district. This results in medic units positioned outside of its Station 1'sfirst-due district having to respond to a medical call occurring in Station1's first-due district. In this scenario response times will be longer due to medic units having to respond from further away.

Analysis examined the number of interfacility transfers performed by each apparatus and the total number of hours those apparatus were on assignment. MFRD performed a total of 738 interfacility transfers in 2017, which equates to a 13.4% **increase** in interfacility transfers compared to 2015. Medics 1, 2, and 3 all performed more interfacility transfers in 2017 than in 2016. MFRD was on assignment to interfacility transfers for 1,403 hours in 2017, which equates to a 23.0% **increase** in total hours on assignment for interfacility transfers compared to 2015. As responses and total time on assignment increases, the department's likelihood all frontline apparatus are staffed and ready to immediately respond to an emergency decreases.



Map 22: Locations of Hospitals and Medical Response Boundary. Map 22 identifies the hospitals between which MFRD provides interfacility transfers as well as the department's medical response boundary. The majority of interfacility transfers involve transporting patients from either Holy Family Memorial Hospital or Aurora Medical Center – Manitowoc County to one of the eleven hospitals located outside of the City of Manitowoc.

Hospital/Medical Center	Trip to Hospital (Miles)	Trip to Hospital (Minutes)	Return from Hospital to Response Boundary (Miles)	Return from Hospital to Response Boundary (Minutes)	Total Miles	Total Time (Minutes)
Aurora Baycare Medical Center	35	39	36	36	71	75
St. Nicholas Hospital	28	32	24	25	52	57
Sheboygan Memorial Hospital	27	35	23	28	50	63
Froedtert Hospital and Medical College	86	94	82	88	168	182
St. Vincents Hospital	38	44	39	42	77	86
Theda Clark Medical Center	46	61	46	58	92	119
Childrens Hospital of Wisconsin	87	95	84	89	171	184
VA Medical Center	84	88	80	82	164	170
St. Mary's Burn Center	80	86	77	80	157	166
University Hospital	133	151	129	142	262	293
Bellin Hospital	38	44	39	41	77	85
Average	***62***	***70***	***60***	***65***	***122***	***135***

Table 11: Total Time (Minutes) and Miles for MFRD Interfacility Transfers from Holy Family Memorial Center. Table 11 displays the total time (minutes) and miles it takes for MFRD to travel from Holy Family Memorial Center to the eleven hospitals to which MFRD provides interfacility transfers. On average, it takes 2 hours and 15 minutes and 122 miles for MFRD to perform round trip interfacility transfers from Holy Family Memorial Center to the eleven out-of-town hospitals. These results only considered the total drive time and does not include the time it takes for personnel to receive patient information, transfer and secure patient in ambulance, fill out patient care report, and clean and resupply the apparatus to a ready state to respond to calls.

Hospital/Medical Center	Trip to Hospital (Miles)	Trip to Hospital (Minutes)	Return from Hospital to Response Boundary (Miles)	Return to from Hospital Response Boundary (Minutes)	Round Trip Total Miles	Round Trip Total Time (Minutes)
Aurora Baycare Medical Center	35	38	36	36	71	74
St. Nicholas Hospital	33	37	24	25	57	62
Sheboygan Memorial Hospital	32	41	23	28	55	69
Froedtert Hospital and Medical College	92	99	82	88	174	187
St. Vincents Hospital	39	44	39	42	78	86
Theda Clark Medical Center	48	62	46	58	94	120
Childrens Hospital of Wisconsin	93	100	84	89	177	189
VA Medical Center	89	93	80	82	169	175
St. Mary's Burn Center	86	92	77	80	163	172
University Hospital	137	155	129	142	266	297
Bellin Hospital	39	43	39	41	78	84
Average	***66***	***73***	***60***	***65***	***126***	***138***

Table 12: Total Time (Minutes) and Miles for MFRD Interfacility Transfers from Aurora Medical Center – Manitowoc County. Table 12 displays the total time (minutes) and miles it takes for MFRD to travel from Aurora Medical Center – Manitowoc County to the eleven hospitals to which MFRD provides interfacility transfers. On average, it takes 2 hours and 18 minutes and 126 miles for MFRD to perform round trip interfacility transfers from Aurora Medical Center – Manitowoc County to the eleven out-of-town hospitals. These results only considered the total drive time and does not include the time it takes for personnel to receive patient information, transfer and secure patient in ambulance, fill out patient care report, and clean and resupply the apparatus to a ready state to respond to calls.

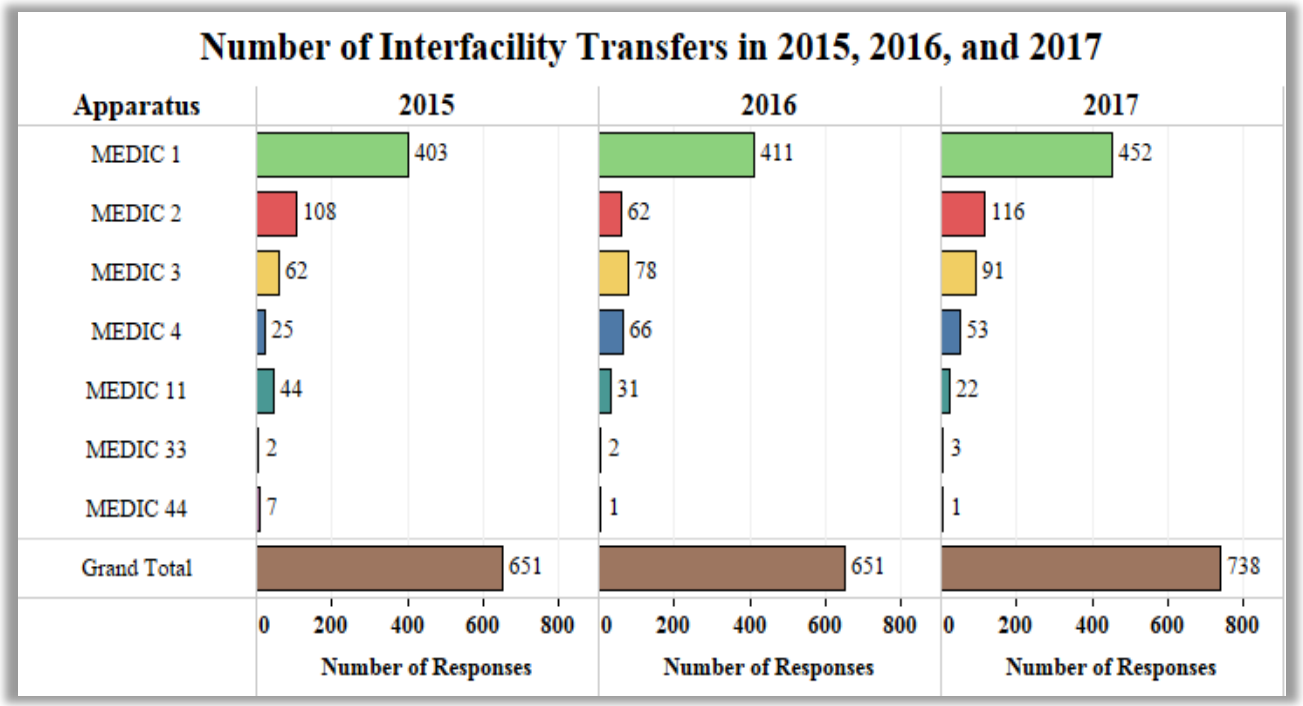


Chart 9: Number of Interfacility Transfers in 2015, 2016, and 2017. Chart 9 depicts the total number of interfacility transfers performed by MFRD's apparatus in 2015, 2016, and 2017. MFRD performed a total of 738 interfacility transfers in 2017, which equates to a 13.4% **increase** in interfacility transfers compared to 2015. Medics 1, 2, and 3 all performed more interfacility transfers in 2017 than in 2016. In 2017, 61.2% of total responses to interfacility transfers were performed by Medic 1. When Medic 1 is performing an interfacility transfer, the department is forced to place a suppression apparatus out of service in order to dispatch a medic unit. Placing suppression apparatus out of service significantly limits the department's ability to respond to emergencies such as a structure fire or motor vehicle accident.

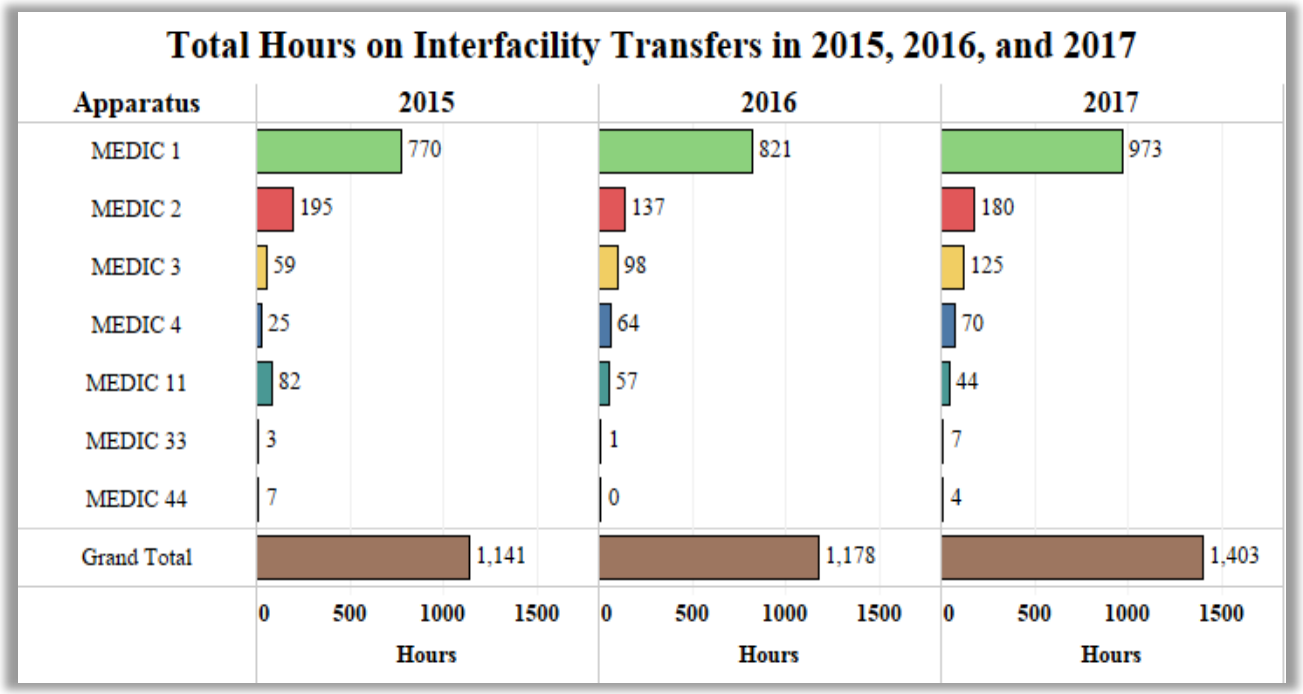


Chart 10: Total Hours on Interfacility Transfers performed by MFRD's Apparatus in 2015, 2016, and 2017. Chart 10 depicts the total hours on interfacility transfers performed by MFRD's apparatus in 2015, 2016, and 2017. MFRD was on assignment performing interfacility transfers for 1,403 hours in 2017, which equates to a 23.0% **increase** in total hours on assignment for interfacility transfers compared to 2015. In 2017, 69.4% of the total hours the department was on assignment performing interfacility transfers were allocated to Medic 1. When Medic 1 is performing an interfacility transfer, the department is forced to place a suppression apparatus out of service in order to dispatch a medic unit. Placing suppression apparatus out of service significantly limits the department's ability to respond to emergencies such as a structure fire or motor vehicle accident.

On-Assignment Time Analysis

Examining the total number of responses performed by each apparatus and the fire companies is one way of examining the department's workload. Another useful method is to calculate the total number of hours each apparatus and fire company were on assignment. Using the CAD provided by MFRD, the total time each apparatus and fire company were on assignment was calculated by determining the total time interval between the time when a unit was dispatch to an incident and the time when the unit (apparatus and personnel) completed all tasks and became available for service.

In 2017, department resources were on assignment for a total of 5,196 hours, which equates to an 18.1% **increase** in total on-assignment time compared to total on-assignment time in 2015. The four primary medic units all saw an increase in total on-assignment time in 2017 compared to 2015. Due to three of the four medic units being cross-staffed, the amount of time the cross-staffed engine companies were out of service also increased, resulting in vital fire suppression resources being unavailable to immediately respond to an emergency and longer response times.

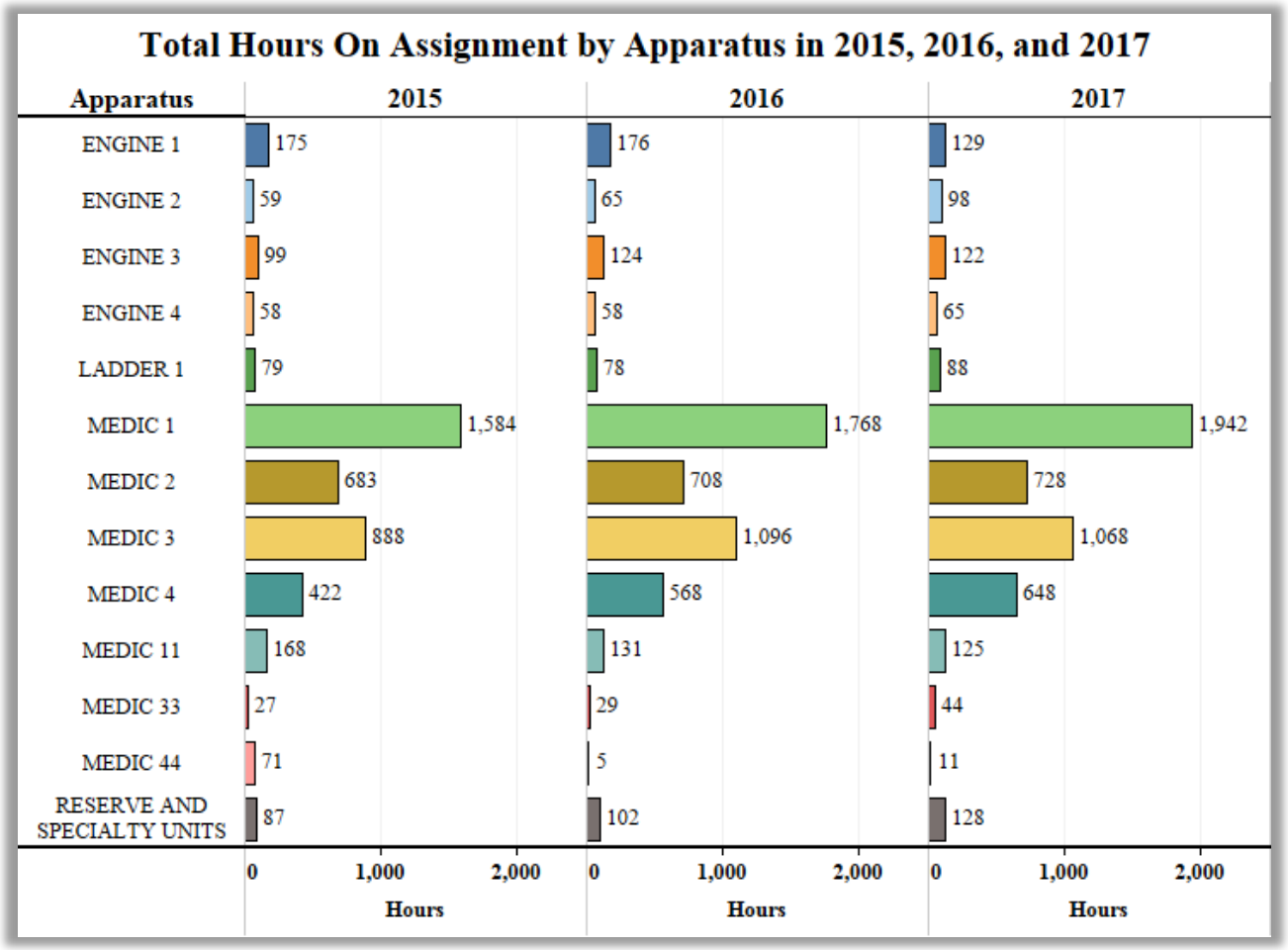


Chart 11: Total Hours on Assignment by Apparatus in 2015, 2016, 2017. Chart 11 depicts the total number of hours each apparatus was on assignment in 2015, 2016, and 2017. Medic 1, the primary apparatus that performs interfacility transports, was on assignment for the most hours compared to the other apparatus. However, all medic units each experienced an increase in the total hours on assignment in 2017 compared to total hours on assignment in 2015. As the total hours on-assignment time increases, the likelihood the department will have the necessary resources to respond to multiple incidents at the same time, or provide the resources necessary for a structure fire, will decrease.

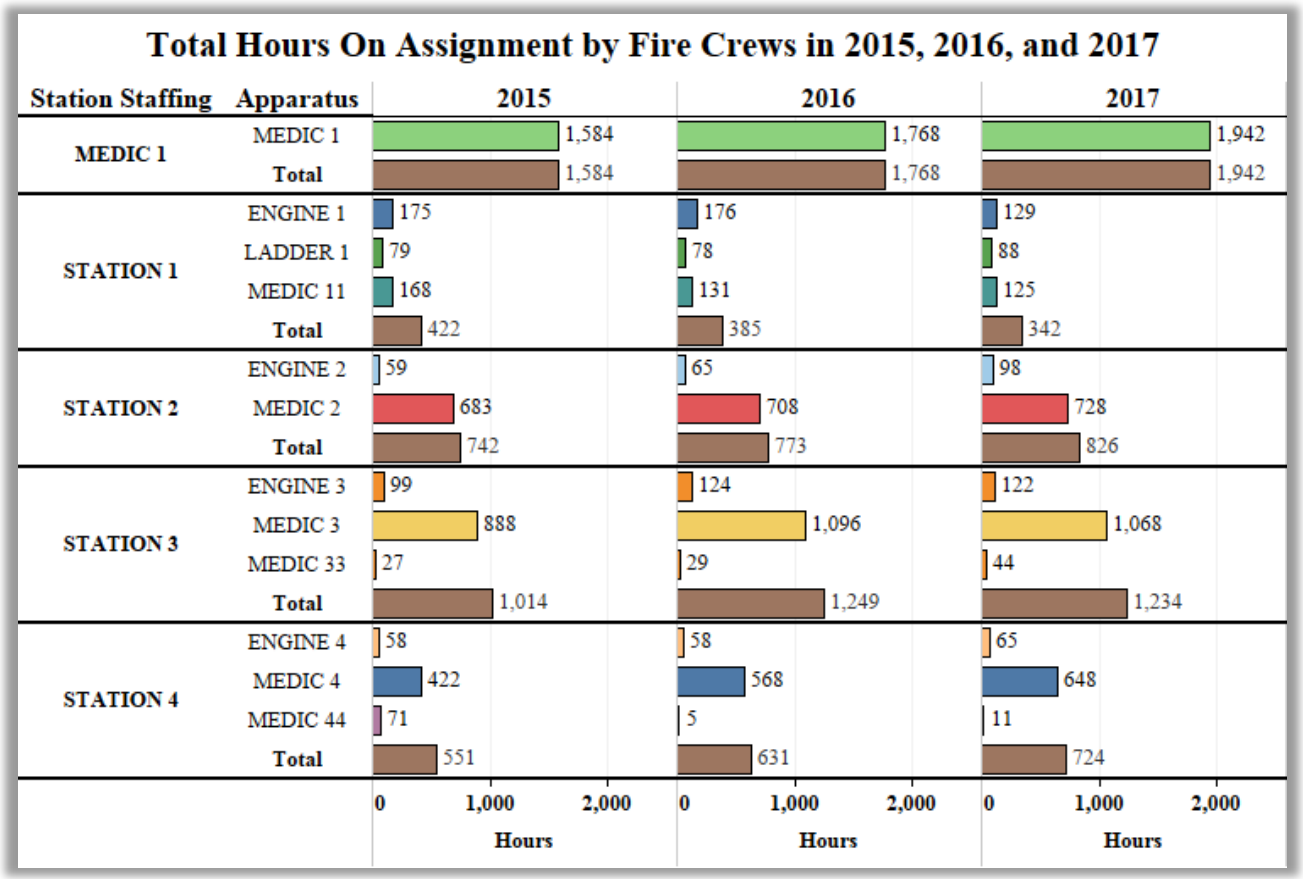


Chart 12: Total Hours on Assignment by MFRD's Fire Crews in 2015, 2016, and 2017. Chart 12 depicts the total hours MFRD's fire crews were on assignment in 2015, 2016, and 2017. Because MFRD cross-staffs apparatus, the crew assigned to each fire station will respond on the apparatus appropriate for the type of call received. Medic 1 is the only full-time crew that doesn't typically cross-staff another apparatus so it has been grouped separately. Medic 1 experienced a 22.6% **increase** in total on-assignment time in 2017 compared to on-assignment time in 2015. The fire company assigned to Fire Station 4 saw the largest increase in on-assignment time in 2017 with an **increase** of 31.4% compared to on-assignment time in 2015.

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Apparatus Engaged at the Same Time

Another indicator of demand placed on a department is the percentage of hours in a year that multiple units are engaged at the same time, either responding to the same incident or to different incidents. Currently, the department staffs five apparatus with 14 on-duty personnel. Besides Medic 1, all apparatus are staffed with three firefighters. Due to MFRD staffing fire suppression apparatus with only three firefighters, the department must send a minimum of two units to all non-EMS calls. As the number of apparatus engaged on assignment at the same time increases, the department is not capable of providing effective and efficient response to incoming emergencies and must rely on off duty and/or volunteer personnel.

The department currently responds to a structure fire with two engine companies, the ladder company, and a medic unit. If the incident is a confirmed structure fire, an additional engine company will be dispatched resulting in all staffed frontline apparatus being sent. If at least one apparatus is on assignment at the time a confirmed structure fire is reported, the department would not have the necessary resources to respond based on the department's own response protocols. In 2017, for 51.2% of the total annual hours, one or more apparatus were on assignment at the same time. Based on this finding, over 50% of the time MFRD did not have the available resources to appropriately respond to a confirmed structure fire and would have to rely on calling in off-duty MFRD firefighters and/or volunteer departments. In 2017, the department experienced a 38.1% **increase** in the number of hours one or more apparatus were on assignment at the same time compared to 2015.

Based on information provided by Local 368, when three or more apparatus are engaged on assignment at the same time, the department will be subjected to calling in off-duty MFRD firefighters and/or resources from volunteer departments to respond to an incident or cover MFRD's fire stations. In 2017, for 7.5% of the annual hours, more than three apparatus were on assignment at the same time. In 2017, the department experienced a 150% **increase** in the number of hours three or more apparatus were on assignment at the same time compared to 2015. This indicates the department must add additional staffed apparatus to ensure it has the necessary resources to respond to all types of emergencies without relying on the unpredictable responses from off-duty and volunteer firefighters.

Apparatus Engaged at the Same Time	Zero Apparatus	One of More Apparatus	Two or More Apparatus	Three of More Apparatus	Four or More Apparatus	Five or More Apparatus
2015	62.9%	37.1%	10.5%	3.0%	1.1%	0.4%
2016	60.1%	39.9%	12.2%	3.7%	1.4%	0.6%
2017	48.8%	51.2%	19.6%	7.5%	2.7%	1.0%

Table 13: Percentage of Hours in a Year when Apparatus are on Assignment at the Same Time. Table 13 displays the percentage of hours in a year apparatus were engaged on assignment at the same time. In 2017, for 51.2% of the total annual hours, one or more apparatus were on assignment at the same time, which equates to a 38.1% **increase** compared to 2015. Based on information provided by Local 368, when three or more apparatus are engaged on assignment at the same time, the department will be subjected to calling in off-duty MFRD firefighters and/or resources from volunteer departments to respond to an incident or cover MFRD's fire stations. In 2017, for 7.5% of the total annual hours, more than three apparatus were on assignment at the same time, which equates to a 150.0% **increase** compared to 2015.

Travel Time Analysis

Travel times for the first arriving apparatus were calculated using the respond time and arrival on scene times included in the CAD. NFPA 1710 states that the first arriving apparatus should be on scene within 4 minutes (240 seconds) or less of travel to 90% of incidents. Travel times that are consistently higher than this benchmark suggest that the department may need additional resources. This analysis excluded CAD entries where the respond and/or arrival on scene times were missing or inaccurately reported.

Analysis examined the department's overall average and 90th percentile travel times for the first arriving unit.

- From January 1, 2015 to December 31, 2015, the average travel time of the first arriving apparatus was 4 minutes and 10 seconds and the 90th percentile travel time was 7 minutes.

- From January 1, 2016 to December 31, 2016, the average travel time of the first arriving apparatus was 4 minutes and 42 seconds and the 90th percentile travel time was 7 minutes and 18 seconds.

- From January 1, 2017 to December 31, 2017, the average travel time of the first arriving apparatus was 4 minutes and 33 seconds and the 90th percentile travel time was 8 minutes.
- From January 1, 2015 to December 31, 2017, the average travel time of the first arriving apparatus was 4 minutes and 29 seconds and the 90th percentile travel time was 7 minutes and 14 seconds.

Based on these results, MFRD did not meet NFPA 1710 travel time objectives for incidents occurring from January 1, 2015 to December 31, 2017. There was a 9.2% **increase** (23 seconds longer) in the average and a 14.3% **increase** (1 minute longer) in the 90th percentile travel times in 2017 compared to travel times in 2015.

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Conclusion

In conclusion, MFRD's fire suppression apparatus are staffed with less than four firefighters. Apparatus not staffed with a minimum of four firefighters do not meet the minimum staffing objectives outlined in NFPA 1500 and NFPA 1710. MFRD's fire suppression resources are not deployed adequately for the arrival of the first arriving apparatus within 4 minutes to 90% of incidents. MFRD's response capabilities do not meet travel time objectives included in the industry standard NFPA 1710, which directs the assembly of 15 firefighters to a low-hazard structure fire and 28 firefighters to a medium-hazard structure fire within 8 minutes to 90% of incidents.

Implementing a potential plan to close Fire Stations 2 and 4 and relocate apparatus to a new fire station would result in a reduction in the department's response capabilities. The plan may lead to the typical daily staffing being lowered from fourteen to twelve firefighters. The department already frequently relies on calling in off-duty MFRD and volunteer firefighters to provide the appropriate resources needed to respond to emergencies or to cover stations as resources are depleted.

The analysis shows that low staffing levels and a lack of resources result in the department's emergency response capabilities being significantly limited.

Specifically, this analysis found that:

- MFRD's fire suppression apparatus are staffed with less than four personnel. Apparatus not staffed with a minimum of four firefighters do not meet the company staffing objectives outlined in NFPA 1500 and NFPA 1710.

- The current daily staffing level of fourteen firefighters restricts MFRD's ability to respond appropriately to low-hazard structure fires to meet NFPA 1710 requirements.

- Based on GIS computer modeling, MFRD cannot meet NFPA 1710 performance objectives requiring the first arriving apparatus to be on scene within a 4-minute travel time to 90% of incidents. MFRD also cannot meet NFPA 1710 response criteria for low- or medium-hazard structure fires.

- From January 1, 2015 and December 31, 2017, MFRD frontline apparatus responded to 17,077 incidents and performed 18,639 responses. The department experienced an 11.5% **increase** in incidents and 11.8% **increase** in responses in 2017 compared to 2015. As call

volume increases, the department must assess the need for additional resources to meet demand.

- In 2017, for 51.2% of the total annual hours, one or more apparatus were on assignment at the same time. Based on this finding, over 50% of the total annual hours MFRD did not have the available resources to appropriately respond to a confirmed structure fire and would have had to rely on calling in off-duty MFRD and/or volunteer firefighters to provide the necessary resources and personnel to mitigate the incident. In 2017, the department experienced a 38.1% **increase** in the number of hours one or more apparatus were on assignment at the same time compared to 2015.

- In 2017, for 7.5% of the total annual hours, more than three apparatus were on assignment at the same time. When three or more apparatus are engaged on assignment at the same time, the department will be subjected to calling in off-duty MFRD firefighters and/or resources from volunteer departments to respond to an incident or cover MFRD's fire stations. In 2017, the department experienced a 150.0% **increase** in the number of hours three or more apparatus were on assignment at the same time compared to 2015.

- MFRD does not meet the NFPA 1710 travel time objective that states the first arriving apparatus should be on scene within 4 minutes or less of travel to 90% of incidents. From January 1, 2015 to December 31, 2017, the average travel time of the first arriving apparatus was 4 minutes and 29 seconds and the 90th percentile travel time was 7 minutes and 14 seconds.

Deficiencies in staffing and apparatus utilization contribute to delays in fire suppression, rescue, and response. Delays are more likely as staffing decreases and apparatus are unable to respond due to the lack of on-duty personnel. The city and department should remedy current deficiencies, not add to them. It is essential that departmental resources are able to meet demand. The department's current insufficiencies indicate the need for additional resources. As resources become scarce as demand increases, performance will worsen. This increases the risk of death or injury due to fire for both citizens and firefighters of Manitowoc. It also increases the risk of considerable property loss for housing units and businesses in many areas of the city.

While it is impossible to predict where most of a jurisdiction's fire and medical emergencies will occur, MFRD should examine where emergencies have typically occurred in the past and make efforts to ensure these areas continue to enjoy the same level of coverage, while adjusting resources and deployment as needed in an effort to achieve complete compliance with industry standards. Areas with accelerated development and population growth will require additional coverage in the future. Any projected increase in emergency response demands should also be

considered before changes are implemented, focusing on associated hazard types and planned response assignments.

As explained by the Commission on Fire Accreditation International, Inc. in its Creating and Evaluating Standards of Response Coverage for Fire Departments manual, "If resources arrive too late or are understaffed, the emergency will continue to escalate. What fire companies must do, if they are to save lives and limit property damage, is arrive within a short period of time with adequate resources to do the job. To control the fire before it reaches its maximum intensity requires geographic dispersion (distribution) of technical expertise and cost-effective clustering (concentration) of apparatus for maximum effectiveness against the greatest number and types of risks." Optimally, there needs to be a balance between both elements.

The ramifications of low staffing levels, as they pertain to the loss of life and property within a community, are essential when considering a fire department's deployment configuration. A fire department should be designed to adequately respond to a number of emergencies occurring simultaneously in a manner that aims to minimize the loss of life and the loss of property that the fire department is charged to protect. Any proposed changes in staffing, deployment, and station location should be made only after considering the historical location of calls, response times to specific target hazards, compliance with departmental Standard Operating Procedures, existing industry standards, including NFPA 1500 and NFPA Standard 1710, and the citizens' expectation of receiving an adequate number of qualified personnel on appropriate apparatus within acceptable time frames to make a difference in their emergency.

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Appendix: Performance Standards

The National Fire Protection Association (NFPA) produced NFPA 1710 *Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.[86]

Key Sections included in the 1710 Standard that are applicable to this assessment are:

- 4.3.2
  - The fire department organizational statement shall ensure that the fire department's emergency medical response capability includes personnel, equipment, and resources to deploy at the first responder level with AED or higher treatment level.
- 5.2.3
  - **Operating Units**. Fire company staffing requirements shall be based on minimum levels necessary for safe, effective, and efficient emergency operations.
- 5.2.3.1 & 5.2.3.1.1
  - Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with a minimum of four on-duty members.
- 5.2.3.2 & 5.2.3.2.1
  - Fire companies whose primary functions are to perform the variety of services associated with truck work, such as forcible entry, ventilation, search and rescue, aerial operations for water delivery and rescue, utility control, illumination, overhaul and salvage work… shall be staffed with a minimum of four on-duty members.
- 5.2.3.1.2 & 5.2.3.2.2
  - In jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other factors as identified by the AHJ[87], these companies shall be staffed with a minimum of five or six on-duty members.

[86] NFPA 1710, 2016
[87] AHJ- Authority Having Jurisdiction

- 5.2.4.1.1
    - The fire department's fire suppression resources shall be deployed to provide for the arrival of an engine company within a 240-second travel time to 90 percent of the incidents.

- 5.2.4.2.1
    - The fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90 percent of the incidents.

- 5.2.4.1.1
    - The initial full alarm assignment to a structure fire in a typical 2,000 ft^2 two-story single-family dwelling without a basement and with no exposures shall provide for the following

Assignment	***Minimum Required Personnel***
Incident Command	1 Officer
Uninterrupted Water Supply	1 Pump Operator
Water Flow from Two Handlines	4 Firefighters (2 for each line)
Support for Handlines	2 Firefighters (1 for each line)
Victim Search and Rescue Team	2 Firefighters
Ventilation Team	2 Firefighters
Aerial Operator	1 Firefighter
Initial Rapid Intervention Crew (IRIC)	2 Firefighters
Required Minimum Personnel for Full Alarm	**14 Firefighters & 1 Scene Commander**

- 5.2.4.2.1
  - The initial full alarm assignment to a structure fire in a typical open-air strip shopping center ranging from 13,000 ft^2 to 196,000 ft^2 (1203 m^2 to 18,209 m^2) in size
- 5.2.4.3.1
  - The initial full alarm assignment to a structure fire in a typical 1,200 ft^2 (111 m^2) apartment within a three-story, garden-style apartment building shall provide for the following:

Assignment	***Minimum Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply (2)	2 Firefighters
Water Flow from Three Handlines	6 Firefighters (2 for each line)
Support for Handlines	3 Firefighters (1 for each line)
Victim Search and Rescue Teams	4 Firefighters (2 per team)
Ladder/Ventilation Teams	4 Firefighters (2 per team
Aerial Operator	1 Firefighter
Rapid Intervention Crew (RIC)	4 Firefighters
EMS Transport Unit[88]	2 Firefighters
Required Minimum Personnel for Full Alarm	**27 Firefighters** **1 Incident Commander**

[88] The Standard further states, "Where this level of emergency care is provided by outside agencies or organizations, these agencies and organizations shall be included in the department plan and meet these requirements."

- 5.2.4.4.1
    - Initial full alarm assignment to a fire in a building with the highest floor 75 ft. (23 m) above the lowest level of fire department vehicle access shall provide for the following:

Assignment	***Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters (1 for each line)
Rapid Intervention Crew (RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Team	4 Firefighters (2 per team)
Point of Entry/Oversight Fire Floor	1 Officer 1 Officer's Aide
Point of Entry/Oversight Floor Above	1 Officer 1 Officer's Aide
Evacuation Management Teams	4 Firefighters (2 per team)
Elevator Management	1 Firefighter
Lobby Operations Officer	1 Officer
Trained Incident Safety Officer	1 Officer
Staging Officer Two Floors Below Involved Floor	1 Officer
Equipment Transport to a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

- 5.3.3.2.2
    - EMS staffing requirements shall be based on the minimum levels needed to provide patient care and member safety.

- 5.3.3.2.2.2 & 5.3.3.2.2.3
    - Units that provide BLS (ALS re: 5.3.3.2.2.3) transport shall be staffed and trained at the level prescribed by the state or provincial agency responsible for providing EMS licensing.

- 5.3.3.3.3
    - When provided, the fire department's EMS for providing ALS shall be deployed to provide for the arrival of an ALS company within a 480-second travel time to 90 percent of the incidents, provided a first responder with AED or BLS unit arrived in 240 seconds or less travel time as established in Chapter 4.

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