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# USING TECHNOLOGY TO REDUCE BARRIERS IN COMMUNITY HEALTH: AN INTERSECTION BETWEEN BROADBAND ACCESS, EHR & TELEHEALTH ADOPTION IN FEDERALLY QUALIFIED HEALTH CENTERS

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AN INTERSECTION BETWEEN BROADBAND ACCESS, EHR & TELEHEALTH  
ADOPTION IN FEDERALLY QUALIFIED HEALTH CENTERS

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2020

## DEDICATION

to

my father, John C. Madu, M.Sc., Ed. D.

my mother, Stella I. Madu, M.Sc., MPAS, PA-C.

and my siblings Jacqueline, Fitzgerald and Kennedy

USING TECHNOLOGY TO REDUCE BARRIERS IN COMMUNITY HEALTH:  
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ADOPTION IN FEDERALLY QUALIFIED HEALTH CENTERS

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Presented to the Faculty of The University of Texas

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in Partial Fulfillment

of the Requirements

for the Degree of

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THE UNIVERSITY OF TEXAS  
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## PREFACE

Working as a family medicine physician assistant (PA) for a community health center in Houston that treats people who were, underserved, uninsured or had little money to pay for health care led to my interest and involvement with CHI Baylor St. Luke's Project ECHO Program. The purpose of Project ECHO is to bring specialized care to underserved areas by empowering providers and giving us the knowledge and the confidence to serve our patients through telehealth.

Being a part of Project ECHO changed my thinking on so many levels about access to health care, education, being part of a team, my own strengths and capabilities—and about what I wanted to do with my life. I love being a PA and I love teaching but through Project ECHO, I also discovered that I am passionate about public health.

Thinking globally, after all, Project ECHO is now in more than 20 countries. I still have family who live in a small village in Nigeria where the only decent health care is hours away. People there die from common diseases, which could easily be managed remotely by trained health care professionals.

## ACKNOWLEDGEMENTS

I am sincerely appreciative and grateful to my advisor and committee chair, Dr. Gretchen Gemeinhardt, for the support, and guidance she showed me throughout my PhD tenure and dissertation writing. She consistently conveyed a spirit of positivity, enthusiasm and hope in this adventure of research and scholarship. I am certain it would not have been possible without her encouragement and comprehensive advice and it was a great honor to work under her supervision.

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I would like to express my gratitude to my UT SPH PhD cohort: my colleagues, my classmates, ultimately becoming my friends, who continued to support and motivate me through their positivity and guidance. They boosted me morally and provided me with valuable practical and professional resources that will last forever.

I am indebted to my family and would like to express my deepest thanks and sincere appreciation. They continued to directly motivate and support me throughout this life changing experience and always served as my truest champions. There was never a time where they doubted my abilities and encouraged me whenever possible.

And above all, I am thankful to the Almighty God, Whom without His Grace and Mercy, none of this would have been possible.

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ADOPTION IN FEDERALLY QUALIFIED HEALTH CENTERS

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School of Public Health, 2020

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While Federally Qualified Health Centers (FQHCs) provide affordable, high quality, accessible and cost-effective primary health care to all individuals regardless of their inability to pay, patients continue to have difficulty accessing affordable primary care as well as broader specialty services that other patients may receive living near larger health systems and hospitals. Health information technology (HIT) serves as a cost-effective means to overcome barriers related to accessing care, particularly for individuals living in rural and remote areas. We examined if the key influencers of an FQHC's structure, broadband access and/ or state and federal policies impacted the utilization of telehealth and electronic health records (EHRs).

**Methods:** In this retrospective, observational study, 2018 UDS data and 2018 FCC data were used to examine key influencers on health information technology (HIT) adoption among FQHCs (n=1,356) by analyzing the extent of technology utilization by providers and patients at the census block code level using SPSS. ArcGIS and GeoDa was used to descriptively map adoption of HIT and broadband



availability and to examine spatial clustering and correlation of EHR and Telehealth adoption with patient volume

**Results:** While several characteristics, such as CMS grant incentives and meaningful use, were identified as significant factors influencing full utilization of health technology within health centers, only the variable related to patient volume, our indicator of clinic size, was found to impact both EHR and telehealth adoption by providers as well as patients within 2018 FQHCs using bivariate regression analysis. Spatially, there were no obvious associations with adoption of HIT with broadband characteristics of speed and provider density. There was significant clustering noted between patient volume and HIT adoption based on spatial analysis.

**Conclusion:** The purpose of this research was not to evaluate the overall health of FQHC patients, but to instead evaluate the technological tools that have the potential to improve the health of this specific population of patients. This study addressed access to care in a period where an expanded population needs healthcare resources. FQHCs provide healthcare access to the underserved, and with more health information technology, these safety net clinics could better serve this population.

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## **BACKGROUND**

The passage of the Affordable Care Act (ACA) and the mandate to expand access to health care to millions of Americans has increased the strain on an already overburdened and extremely costly healthcare delivery system. At present, the current healthcare system is struggling to provide access to medical services, particularly in remote areas, to those uninsured and under-represented.

Federally Qualified Health Centers (FQHCs) provide affordable, quality, accessible and cost-effective primary health care to all, regardless of their inability to pay. These centers provide an integrated, patient-centered model of care that coordinates medical, dental, mental health, substance abuse, and patient support services <sup>1</sup>. According to the Bureau of Primary Health Care (BPHC), and data from the 2018 Uniform Data System (UDS), more than 28 million individuals in 2018, depended on a Health Resources & Services Administration (HRSA) funded health centers for affordable, accessible primary care <sup>1</sup>. There has been a 9% increase in the health center patient population from 25.9 million to 28.4 million patients from 2016 to 2018 <sup>1</sup>. Patients are seen at 12,000 service delivery sites operated by almost 1,400 FQHCs located in every state, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and the Pacific Basin <sup>1</sup>.

Health centers have shown the potential to improve health outcomes as important safety-net providers. A 2011 study demonstrated improved health outcomes and found that Medicaid patients, whose usual source of care was a community health center or FQHC, were almost one-third less likely to have emergency department visits, inpatient hospitalizations, or preventable hospital admissions compared to patients who primarily frequented private, fee-for-service providers <sup>3</sup>. Regarding potential ability to reduce costs

through services provided, Nocon et al. (2016) found that health center patients had 24% lower spending as compared to non-health center patients across all services including specialty care, inpatient admissions and inpatient care <sup>2</sup>. Even with the unique benefits offered by FQHCs, patients continue to have difficulty accessing affordable primary care as well as broader specialty services that other patients may receive living near larger health systems and hospitals <sup>6, 15, 66</sup>.

Health information technology (HIT) may aid in bridging that access gap and serving as a cost-effective means to overcome barriers related to accessing care, particularly for communities located in rural and remote areas <sup>4-8</sup>. The Department of Health and Human Services simply defines HIT as the “exchange of health information in an electronic environment” <sup>67</sup>. The Robert Wood Johnson Foundation uses a broader definition that was utilized to guide this research where HIT is “a variety of electronic methods used to manage information about people’s health and healthcare, on both the individual and group level” <sup>16</sup>. Enacted in 2009, the Health Information Technology for Economic and Clinical Health (HITECH) Act and the American Recovery and Reinvestment ACT (ARRA), promoted the adoption of health information technology by healthcare delivery organizations with the purpose of facilitating patient-centeredness and improving health care delivery, quality and cost <sup>7-8</sup>. A 2013 study found a positive association between greater HIT capacity and quality of care within FQHCs <sup>8</sup>, while Lin et al, noted that HIT utilization among health centers, specifically telehealth, could reduce the resource gaps between urban and rural areas <sup>6</sup>.

The Bureau of Primary Health Care, which funds FQHCs, requires grant recipients and look-alike clinics to report program data annually for key measures that

evaluate access, quality, outcomes and financial cost and viability through HRSA's Uniform Data System in order to monitor the program's performance and identify areas for quality improvement <sup>86</sup>. This data is reported annually to Congress and is evaluated against state and national benchmarks from programs and initiatives such as Healthy People 2020, Centers for Disease Control and Prevention, and the National Quality Forum <sup>87</sup>.

In 2018, the Uniform Data System identified 1,362 FQHC parent organizations in 51 states and 7 U.S. territories as well as an additional 56 look-alike centers <sup>1</sup>. These clinics are often situated in areas of high need and low accessibility to primary care. This means that clinics are often located in isolated or rural areas. The only way to achieve the goal of improved access is with HIT, specifically electronic health records and telehealth. Both technologies have been demonstrated as effective means to overcome access barriers <sup>4-10</sup>.

While these technologies can improve access, their adoption in FQHCs has not been commonly evaluated outside of research done by HRSA's Office of Quality Improvement <sup>6</sup>. In 2017, over 96% of grantees reported having an EHR installed compared to only 43% reporting telehealth utilization. There is sparse evidence identifying the barriers to uptake of adoption among FQHCs, the level of utilization by patients and providers as well as the demographic distribution of adoption of HIT and the potential for spatial clustering among Federally Qualified Health Centers (FQHCs) across the U.S. Barriers such as rurality <sup>15</sup>, provider and patient volume size <sup>6, 15</sup>, HIT costs and grant funding <sup>27, 73</sup>, and broadband density and speed <sup>15</sup> have individually begun to take shape as significant obstacles among private practice adoption across



the nation. This paper will explore whether these most noted issues similarly impact an FQHCs' adoption of health information technology.

### *Specific Aims*

Overall, studies examining the impacts of HIT on patient outcomes within FQHCs found that though evidence supports the potential to improve the health of underserved populations and reduce health disparities; yet, the use of HIT remains relatively low in FQHC's compared to private clinics and larger hospital systems<sup>5-6,8</sup>. Therefore, this study sought to:

*AIM 1)* Identify how key structural influencers at FQHCs (patient volume, urban and rural status, implementation of a meaningful use program, telehealth modality), broadband access (provider network density and upload/download speed), state level policies (grant incentive payments and Medicaid expansion) and the process of adopting EHR (1a) impact providers (clinical decision-making support and clinical information exchange) and patients (e-prescribing, patient portals and after-visit summaries) and the process of adopting telehealth (1b) impact providers (communication with specialist outside the FQHC) and patients (communication with patients at remote locations outside the FQHC) at the census block level.

*AIM 2)* Utilize ArcGIS to descriptively map adoption of HIT and broadband availability at the zip code level (2a) and then utilize GeoDa to examine

spatial clustering of adoption of EHRs and telehealth with patient volume variables to provide a correlation analysis comparing FQHC organizations and locations' adoption of HIT (2b) and this clinic characteristic.

## *Literature Review*

### *Health Information Technology*

Due to factors such as healthcare provider shortages, increases in chronic diseases and the geriatric population, advancements in technology are necessary to improve healthcare delivery <sup>32</sup>. Health Information Technology, which is the electronic exchange of health information, has played an important role in improving outcomes and increasing access to providers while achieving population health <sup>32</sup>. HIT encompasses several processes including the patient, provider and payer utilization of electronic health records; health information exchanges across systems, industries and geography; the detection of population and public health trends as well as remote monitoring, education/training and patient consultation <sup>8, 32</sup>.

The 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act and the American Recovery and Reinvestment Act of 2009 (Recovery Act-ARRA) were signed into law primarily to increase rate of EHR adoption among eligible professionals and hospitals defined by the Centers for Medicare and Medicaid Services (CMS). Eligible professionals (EP) were defined as physicians, practitioners and therapists who are paid under or based on Medicare Physician Fee Schedules (MPFS) and utilize certified information technology throughout their practice <sup>88</sup>. Through the authorization of Medicare and Medicaid incentive payments, EPs were expected to not

only adopt electronic health records but also demonstrate meaningful use in regards to quality of care and cost efficiency <sup>26, 31</sup>. Meaningful use objectives set forth by the HITECH Act include the use of certified EHR to meet core and menu requirements such as e-prescribing, computerized order entry for medication orders, clinical decisions, medication reconciliation, and providing patients with electronic access to their health information <sup>89</sup>. The HITECH Act also provided capital contributions towards EHR systems for health centers as well as funding the Regional Extension Center Program, which provided small practices or those serving disadvantaged populations with assistance in adoption, implementation and meeting meaningful use requirements <sup>26, 53</sup>. A year later, the Affordable Care Act of 2010, emphasized the importance of health information technology through the promotion of health IT related goals tied to health care quality and efficiency <sup>7</sup>.

Research has varied as to whether these policies have had weak <sup>31</sup> or strong <sup>7, 23, 26</sup> impacts on motivating healthcare providers to adopt health information technology. Vest and Gamm (2010) found that though policies such as HITECH and grant funding may have helped with the initial adoption of HIT, the benefits of adoption and implementation primarily carries over to patients and their communities and less to providers <sup>69</sup>. These researchers believed that current policies related to HIT excluded providers in certain professional areas, restricted exchanges to specific subpopulations due to the competitive nature of health care entities and limited availability of data elements <sup>69</sup>. Gold et. al. (2012), noted that the HITECH act addressed provider concerns regarding costs, efficiency and operational feasibility indirectly, therefore, buy-in depended on initiatives such as Beacon and SHARP grants as well as Meaningful Use

Incentive Payments that coordinate national and state policies that will ultimately influence provider perceptions and attitudes <sup>26</sup>. Mennemeyer et al. (2015) showed that HITECH subsidies may have only contributed to “inevitable adoptions” by physicians and practices influenced by mimetic and institutional forces <sup>31</sup>.

Burt and Sisk (2005) found relationships between HIT, physicians and practice characteristics <sup>73</sup>. While exploring practice size as measured by the number of physicians instead of number of patients or encounters, they found that “larger practices” were more likely to implement HIT than smaller practices due to their ability to spread the investment over more providers and services <sup>73</sup>. While the authors in the study were not able to obtain the number of patients seen in the individual practices by using National Ambulatory Medical Care Survey (NAMCS) data <sup>73</sup>, the UDS allows for the capturing of such numbers.

Most of the literature has focused on the effects of these policies on large health systems, and specialty practices <sup>5, 8-10, 15, 31</sup>. It has shown that there is limited evidence concerning the adoption, implementation and utilization of HIT such as EHRs and Telehealth in FQHCs and impact on provider and patient <sup>8</sup>.

### *Review of Electronic Health Records (EHRs)*

Technology has been shown to promote better patient care and quality among the populations seeking care at FQHCs<sup>8</sup>, though much of the research has focused on the impact of EHRs <sup>22, 27</sup>. Frimpong et al (2013), found that an increased adoption and utilization of HIT increased the patient’s perception of improved quality of care <sup>8</sup>. In their study, FQHCs were classified as either low, medium or high HIT capacity and survey variables supporting HIT capacity were defined by EHR-specific functionalities

corresponding to the HITECH meaningful use objectives<sup>8</sup>. HIT capacity was considered high when clinics utilized functionalities such as decision-support, patient reminders, timely appointments made for specialist care and discharge summaries <sup>8</sup>.

Similar studies have also found that HIT demonstrated quality benefits using e-prescriptions, reminders and messaging functions <sup>21</sup>. The overall utilization of EHRs also demonstrated benefits associated with quality and efficiency by improving the organization of data, availability of progress notes and legibility of clinician notes. Increased use of EHRs also provided financial benefits and quality improvements when EHR documentation and care management was analyzed <sup>27</sup>. Miller and Sim also noted that clinics utilizing basic electronic messaging improved the “availability, timeliness and accuracy of messages reducing dropped balls and safety problems” <sup>27</sup>. Advanced messaging has improved the coordination of care with outside providers increasing interoperability, and with patients in order to improve compliance and promote better self-care <sup>24, 25, 27</sup>. Studies have also identified a correlation between HIT use service delivery and quality of care <sup>8, 20, 27</sup>. Utilization of HIT has also resulted in improved process measures <sup>8</sup>. Health Information Systems such as EHRs have been shown to improve clinical processes, and workflows, therefore reducing medication errors and resulting in quality improvement <sup>22</sup>. Implementation of HIT resulted in more advanced decision support through the electronic transmission of prescriptions and lab tests <sup>27</sup>.

Though over 98% of FQHC reported having EHRs in place in a 2017 UDS study <sup>6</sup>, not all utilize them for patient services. UDS recommends the use of EHRs to ease data generation for reporting, but research has shown that some centers may experience challenges to reporting through these systems and many experience more

challenges related to interfacing between the UDS-Electronic Handbook (EHB) System and the individual clinic EHR <sup>85</sup>. This study addressed this the gap by looking at utilization of HIT that impact both patients and providers directly.

### *Review of Telehealth*

Among research related to telehealth utilization, studies found that both patients and clinics benefitted from the increased use of telehealth <sup>6, 32</sup>. The American Telemedicine Association (ATA) defines “telehealth” as a broad encompassing term related to the remote provision of healthcare that includes patient care, education and monitoring <sup>48, 49</sup>. Telemedicine is the use of electronic communications to exchange health information from one site to another to improve patient health <sup>48</sup>. Health Resources Services Administration (HRSA) defines telehealth similarly as the “the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health and health administration” <sup>109</sup>. Researchers have used the terms interchangeably, however while telehealth characteristically refers to the comprehensive range of electronic health related services including “remote non-clinical services such as provider training, administrative meetings and continuing medication education, in addition to clinical services” <sup>90</sup>, telemedicine specifically refers to remote clinical services <sup>48</sup>. Telemedicine services utilize current staff and have been shown to serve as a potential solution to alleviate shortages of health care providers through remote consultations by providers and nurses in other states and countries <sup>32</sup>. Telehealth raises the responsibility level of patients by empowering them to be more involved in their health and by allowing them the

convenience of easier access to their primary care providers and specialists <sup>6, 32</sup>. The electronic sharing of images and consultations by video, also allows for a quicker turnaround in response to rarer health conditions with experts outside of the provider practice. This benefit allows public health providers and governments to make faster and better decisions regarding population potentially at risk <sup>32</sup>.

For the purposes of this study, HRSA has specifically defined and differentiated telehealth from telemedicine due to its broader scope <sup>109</sup>. The Uniform Data System defines these utilizations of technology as “Telehealth” and captures this information in order to acknowledge the comprehensive nature of health centers and the methods used to expand services and improve their delivery of health care <sup>90</sup>. Similar to the use of this definition, Lin et al (2018) specifically analyzed key adoption factors, barriers and opportunities of telehealth in health centers. Our research went further by exploring organizational factors, including FQHC structure, state and federal policies as well as broadband in determining potential barriers to adoption as well as exploring provider and patient impact, variables not available in the previous 2017 iteration of the UDS <sup>6</sup>.

### *Barriers to HIT*

There are barriers to adoption of HIT observed in the literature such as disparities in income of health care patients in addition to disparities in region and health center size <sup>9, 53</sup>. Shields et al. found that patient mix characteristics were one of the most important factors in understanding HIT adoption rates <sup>5</sup>. They found that FQHCs providing care to the highest proportion of poor and uninsured patients were significantly less likely to utilize HIT including EHRs <sup>5</sup>.

Literature supports the assertions that the lack of capital, dependence on public financing and lack of infrastructure contribute to a lower adoption rate of these telehealth services <sup>5, 53</sup>. Samuel found lower EHR adoption in counties with greater minority populations and slower adoption rates in underserved areas <sup>53</sup>. Samuel also noted the uptake is influenced by “tight operating budgets, staff shortages, and limited capacity for integrating EHR training into the clinical workflow” <sup>53</sup>. Fiscella and Geiger asserted “in the absence of federal leadership and investment, adoption of HIT will be slow, haphazard, duplicative and wasteful” <sup>10</sup>.

Since the implementation of the HITECH and ARRA, and the emphasis on meaningful use and expanding access and quality, health care providers in primarily small practices frequently cited financial reasons as barriers to adoption of EHR <sup>53, 118</sup>. Studies indicate barriers such as “high start-up costs, lack of capital, concern that a system would soon become obsolete and a lack of adequate and reliable information about return on investment” <sup>118</sup>. Providers in practices that primarily serve underserved and underrepresented populations, also cited clinical productivity and the uncertainty of the diverse costs associated with implementation as well <sup>118</sup>. Fleming et al (2011) examined the financial and non-financial costs of implementing EHRs in primary care practices and noted that “costs” included purchasing of the hardware and software licenses, maintenance costs associated with licenses and hosting as well as costs associated with technical support <sup>118</sup>. Impactful non-financial costs were related to the pre-implementation efforts and time needed to train install and bring the system online and into use <sup>118</sup>.

The Office of the National Coordinator for Health Information Technology (ONC) established Regional Extension Centers (REC) to support smaller providers. The REC



supports individual and smaller practice provider practices, critical access hospitals, community health centers and clinics that primarily served patients who lack adequate medical coverage. The RECs' primary purposes of providing direct funds and technical assistance allowing for the optimization of health IT for this specific population of healthcare settings and providers. These roles include:

- EHR implementation and project management
- Health IT education and training
- Vendor selection and financial consultation
- Practice/workflow redesign
- Privacy and Security
- Partnering with state and national health information exchange
- Ongoing technical assistance <sup>121</sup>

Due to the resources provided by RECs, research has shown a positive impact on enrolled providers in assisting in the implementation and achievement of meaningful use status <sup>120-122</sup>.

Though federal funding for RECs must be regularly renewed, their impacts have allowed costs related to EHR implementation to be less of a barrier for these populations of health centers, but the data does not include the funding needed to support the implementation and adoption of Telehealth. The Department of Health and Human Services has therefore provided incentives and increased funding through the Federal Office of Rural Health Policy and HRSA-funded Regional Telehealth Resource Centers to provide technical assistance supporting telehealth program development in critical areas that lack access to health care services, including specialty care. This

funding has led to supporting HRSA grantees in the implementation of “internet technical assistance, provider-to-provider (patient-to-provider) videoconferencing, store-and-forward diagnostic imaging as well as streaming media and closed-circuit communications through regional and national telehealth hubs” <sup>123</sup>.

But even with federal incentive programs supporting and funding adoption of HIT, 2018 research examining factors associated with telehealth within federally qualified health centers using 2016 UDS data found cost and technical issues as major barriers to adopting Telehealth, along with rurality, reimbursement policies and operational factors <sup>6</sup>. UDS data showed that costs related area related to HIT/EHR system development and analysis, supplies and equipment but is not publicly available, listing this section of the Reporting Handbook as proprietary <sup>79,106</sup>. In 2017, only 117 out of a total of 1,373 FQHCs reported costs associated with HIT/EHR implementation <sup>79,106</sup>. Therefore, due to the limited data reported and publicly available, actual cost in relation to technology adoption as a barrier to implementation is considered outside of what this study can address.

### *Broadband and HIT*

For FQHCs to adopt EHRs and telehealth, there must be enough internet bandwidth for their systems to optimally function, but there is no research that specifies what speeds must be used within these centers. Broadband has been linked to clinic size based on the number of providers utilizing the technology <sup>65</sup>. While the terms “bandwidth” and “speed” may be used interchangeably, bandwidth, measured in megabits per second (mbps) refers to the “maximum amount of data that can be transmitted over an internet

connection” while speed (mbps) refers to the “rate at which data can be downloaded/uploaded to a given device using internet connectivity” <sup>125</sup>. Broadband consists of the technology used (such as cable, fiber, fixed wireless) as well as the speed or bandwidth <sup>130</sup>. The Federal Communication Commission officially defines adequate broadband as a minimum of 25 mbps download and 3 mbps upload. This definition was recently updated from a 2010 standard of 4 mbps download and 1 mbps upload due to the advancements in technology and increased consumer demands <sup>84</sup>. A few of the FCC’s many roles include maintaining a publicly available comprehensive database documenting broadband provision across the United States <sup>81</sup> and ensuring the adoption and utilization of technology by maximizing the availability of broadband across all “demographic groups, geographic locations, and sectors of the economy” <sup>43</sup>. Multiple studies have demonstrated that there is unequal broadband availability in areas with a higher concentration of minorities, populations living below the federal poverty level and rural households <sup>6, 15, 29,40,44,53, 65, 70, 71, 84</sup>.

Access to telecommunication services in the US has demonstrated early disparities and gaps <sup>64</sup>. Smaller and more rural areas experienced higher premiums and long-distance charges for accessing Internet services due to the lack of adequate network presences <sup>64</sup>. And even as the newer generation of broadband developed in the late 1990s, the debate between access, and equity of services continued to emerge <sup>64</sup>. Rural and remote areas received access to these newer technologies at slower rates compared to more urban counterparts due to the lack of market competition between broadband providers, and the significant amount of capital needed to upgrade the network infrastructure <sup>64</sup>. Tedesco et al. (2011), noted that broadband can be accessed through

either wired or wireless services <sup>72</sup>. While wired or fixed broadband services tend to be faster than their wireless counterparts, these technologies are often not accessible in geographically remote regions <sup>72, 84</sup>. Grubestic (2006), attempted to describe the spatial dynamics of broadband availability between remote, rural and more suburban communities and the extent to which socioeconomic and demographic characteristics influenced access <sup>64</sup>. The author found that larger urban areas benefitted from vigorous levels of broadband competition while “islands of inequity” were noted in areas with unfavorable demand conditions such as “older population, low incomes, geographical remoteness and monopoly control of providers” <sup>64</sup>. Market competition in mostly urban and suburban regions has led to better access by promoting better pricing, quality of service and more continuous network upgrades <sup>64</sup>.

Broadband providers tend to be influenced geographically and socially, infiltrating areas with more profitable markets that exhibited higher returns on investment <sup>64</sup>. Interestingly to this point, the American Medical Informatics Association (AMIA) has acknowledged ‘broadband internet service’ as a social determinant of health arguing that the FCC should consider the “specific challenges related to inadequate access to affordable and consistent high-speed internet faced by vulnerable and underserved group attempting to access digital communications for health-related purposes” <sup>129</sup>. CMS also updated healthcare providers participating in the Medicare and Medicaid EHR Incentive Programs with the national broadband map tool provided by the FCC, allowing these practices to determine broadband speeds in their neighborhoods or at their particular location. This data ultimately qualifies their practice facility for an exclusion under the EHR Incentive Program<sup>126</sup>. Eligible hospitals and critical access hospitals (CAH), experiencing

inadequate internet speeds and broadband service, qualify for hardship exemption from the Medicare downward payment adjustment if evidence can be shown that “compliance with the requirement for being a meaningful EHR user would result in a significant hardship” <sup>128</sup>.

There is little to no research specifically delineating what specific broadband speeds FQHCs need to access and optimally utilize EHR, Telehealth system or both <sup>65</sup>. The National Broadband Plan (BDP) analyzed connectivity for three types of providers: small practices, large practices and federally funded providers (although the federally funded provider category may overlap with the other two categories). Regarding federally funded providers such as FQHCs, the need to understand connectivity is important since accessibility for vulnerable populations are directly related to government funding and costs. <sup>65</sup>. Based on a BDP analysis, even though the FCC recommends broadband speeds of 25/3 mbps <sup>84</sup>, a rural health clinic with at least 5 practitioners would require an average bandwidth of at least 10 mbps in order to utilize EHR and general web-based activities such as billing, scheduling and web browsing and allow for video consultations, remote monitoring and non-real-time image downloads for 3 of the 5 providers <sup>65</sup>. Bauer et al., noted that broadband speed is also considered a metric in characterizing quality and can be directly related to capacity and ultimate performance <sup>63</sup>. High-speed internet connectivity is essential for applications requiring the transmittal of signals carrying health information, video and images between providers that are potentially separated by large distances <sup>65</sup>. When considering that most federally funded clinics communicate and may consult with larger hospitals and academic medical centers, it is important to consider that these larger systems may require between 100 mbps to greater than 1 gbps to

maintain the same types of services <sup>65</sup>. While researching most EHR system requirements, consensus has shown that “business-grade internet connectivity” is required <sup>127</sup>. *Eyefinity EHR* © provided the most extensive definition for minimum and recommended bandwidth speeds that can be used generally as a definition for multi-provider and practices, while considering that the number of practice users\* includes ***clinicians, staff and patients***, simultaneously using the system at a single practice location: <sup>127</sup>

NUMBER OF PRACTICE USERS*	MINIMUM BANDWIDTH SPEED	RECOMMENDED BANDWIDTH SPEED
1-5	5 mbps download 3.5 mbps upload	10 mbps download 5 mbps upload
6-10	10 mbps download 5 mbps upload	20 mbps download 10 mbps upload
11-15	20 mbps download 10 mbps upload	30 mbps download 15 mbps upload
16-20	30 mbps download 15 mbps upload	50 mbps download 20 mbps upload
21+	50 mbps download 20 mbps upload	100 mbps download 25 mbps upload

**Table 1:** Recommended EHR Implementation Speeds

Current research has evaluated and identified estimated broadband speeds required for adoption of EHR either by number of providers utilizing the technology within the clinical setting, or specific within critical access hospitals which serve underserved rural patient populations as well <sup>65, 115</sup> but information regarding telehealth has not been found. An article evaluating factors influencing the adoption of EMR since the implementation of government incentives, found that the “amount of bandwidth needed is a function of how many users a clinic anticipates needing access simultaneously as well as the installed applications that the different HIT technologies may include” <sup>117</sup>.

The UDS, does not require that the number of FTEs within FQHC entities be reported annually and views this data as proprietary information, allowing clinics to not

report it at their discretion <sup>90, 106</sup>. Though publicly available at the state level, this limitation of the dataset prevents adequate comparisons to other studies that determine average speeds for adoption, based on FTEs <sup>15, 65, 115</sup>. Whitacre and Williams (2014) used state level data to assess average upload/download speeds impact on adoption of EHR among FQHCs in rural vs urban areas of Oklahoma <sup>15</sup>. These researchers showed that speed data, broken into 10 categories, ranged from 200-500 kilobytes (kbps) to greater than 1 gigabyte per second (gbps) varied across states <sup>15,116</sup>. And even with access to FTE numbers for private practices in rural and urban areas, their research to summarized average broadband speeds associated with EHR adoption based on rurality <sup>15</sup>.

### *Geographical Information Systems (GIS) and HIT*

Research findings vary as to primary barriers to adoption of HIT within FQHCs , and the effect location has played on implementation <sup>6, 44</sup>. Several factors such as cost, reimbursement and technical issues were commonly described as potential barriers to adoption of EHR and Telehealth <sup>6, 22</sup>. Technical issues such as inadequate broadband infrastructure has specifically been cited by FQHCs in rural and urban areas as a reason for not adopting technology <sup>6, 22, 48</sup>. Lin et al found evidence that the lack of broadband, or insufficient bandwidth, was not a commonly reported barrier to adoption due to the availability of broadband funding awareness of the Federal Communication's Rural Health Care Program. This program has the potential to decrease the numbers of FQHCs without internet service <sup>6</sup>. But other studies have found that though physicians' practices are in areas with documented broadband activity <sup>6</sup>, they lacked adequate bandwidth required for EHR interoperability <sup>44</sup>. With the growing demand and complexity of HIT such as

telehealth, more broadband speed will be necessary. Modalities such as real-time videoconferencing and store-and-forward, for example, use higher bandwidth <sup>6</sup>. The increased utilization of mobile devices and mHealth, which allows patients to have access to their providers from home, also requires adequate broadband speeds in communities where patients live. <sup>6</sup>.

Geographical Information Systems (GIS) is used to map spatial variations in healthcare services and has assisted in identifying gaps in health care services <sup>38-40, 46</sup>. Studies have shown the disparities in health outcomes across populations and how geographical disparities in access to technology has led to worsening outcomes <sup>41, 42</sup>. Luther et, a <sup>41</sup>. used GIS zip code mapping of communities with high and low primary care access. They found that areas with more minority populations had a higher prevalence of mortality related to cancer, health disease and stroke <sup>41</sup>. Interestingly, they also found that minorities in high primary care access area had lower rates of these conditions compared to those in low primary care access areas <sup>41</sup>. Parker and Campbell (1998) also noted that both socioeconomic and geographical aspects of accessibility affected health care outcomes <sup>46</sup>. These researchers used geocoded postcode data was geocoded using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) software and showed that the utilization of health services decreased as the patients' distance from services increased <sup>46</sup>. Dulin et al geocoded census-based geographic data using ArcGIS to create data points and maps examining attributes of populations and their primary care needs to identify areas that would benefit from increased access to community health organizations <sup>39</sup>. Research by Soares, Dewalle and Marsh applied patient-level GIS data to prospectively model optimal telemedicine locations for pediatric



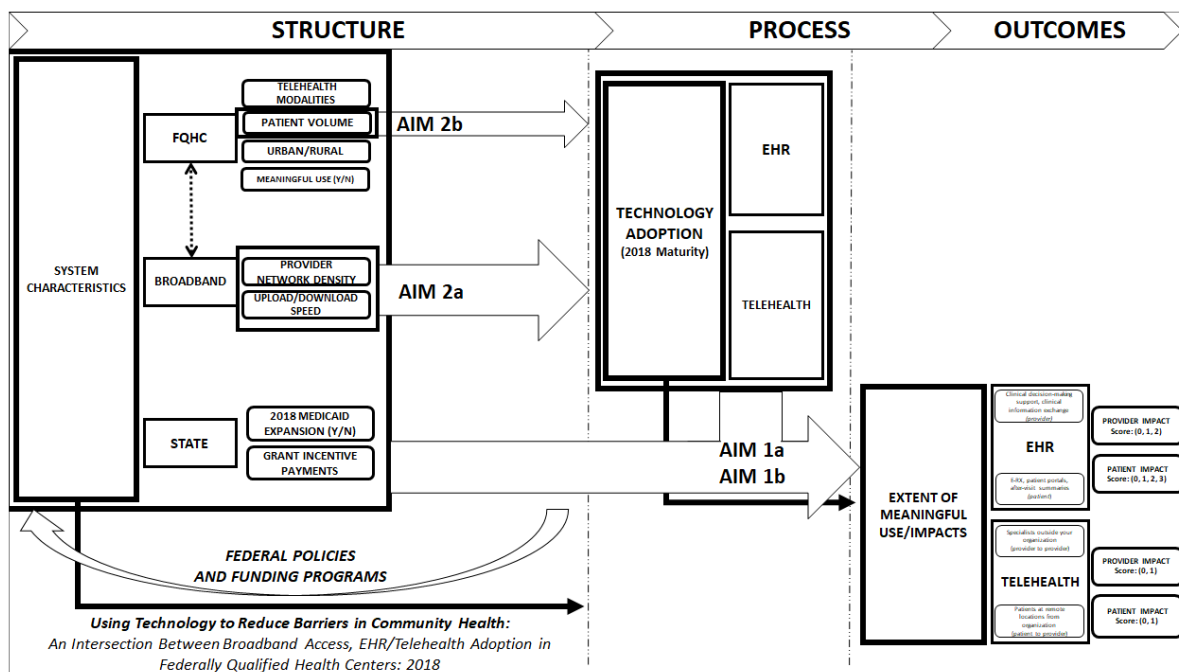
specialty services in a rural area using EHR data <sup>48</sup>. The Connect2Health<sup>FCC</sup> Task Force uses GIS enabled tools to explore the intersection between broadband access, health information technology and health through their project *Mapping Broadband Health in America* by allowing users to geographically overlay and analyze broadband and health data at the national, state and county level <sup>35</sup>. This mapping tool has been used to link broadband access, telehealth and disease prevalence such as diabetes <sup>12</sup>.

The effectiveness of FQHCs and their adoption of HIT, therefore, relies on accurate measures of access and speed of broadband networks so that resources can be allocated appropriately <sup>45</sup>. Further, studies need to focus on how geographic variability of broadband speeds and internet providers has impacted the adoption of telehealth and EHR.

### *Conceptual Model*

Several models for telehealth implementation and evaluation exist in literature. The Institute of Medicine and Donabedian frameworks have served as “gold standards” for the development of evaluation and implementation HIT models <sup>60,61</sup>. These frameworks have specifically guided research concerning issues of quality, accessibility, cost and acceptability of clinical telehealth <sup>61</sup>.

The Donabedian Framework conceptualizes any health service as having three components, structure, (inputs), process (outputs) and outcomes <sup>63</sup>. Herbert et al. proposed a telehealth framework that expanded upon Donabedian <sup>60</sup>. The purpose of this modified framework was to “begin development of a body of knowledge around telehealth and to identify influential relationships among the success variables defined for telehealth” <sup>60</sup>. DeLone and McLean developed a Donabedian-influenced framework that considered structure measures with accessibility, availability, and quality of resources, process measures with delivery of health care services by clinicians and providers through system



**Figure 1:** Adapted Donabedian Framework

use and user satisfaction, and outcome measures with individual and organization impact <sup>59</sup>.

Upon review, researchers have demonstrated the application of the Donabedian Framework in health information technology through its application to other existing models <sup>57</sup>. Chang proposed a comprehensive evaluation framework utilizing a Logical Framework approach due to the very complex nature of health information services <sup>57</sup>.

The general logic framework consists of inputs (IT infrastructure, manpower, skills and knowledge and funding); activities (telemedicine system development, training and education); output (just-in-time care, better professional communication, enlarged catchment area, and improved accessibility), outcomes (improved quality of care, enhanced efficiency, patient satisfaction, provider satisfaction and reduced costs), and impact (improved health status of target population, improved health related quality of life)<sup>57</sup>. In this study, the Donabedian model will be adapted to develop a conceptual model (Figure 1) to analyze barriers of EHR and Telehealth adoption and resulting physician and patient impacts based on adoption of these technologies. Independent variables were included based on a review of existing literature as well as original contributions based on variables not previously examined.

### *Public Health Significance*

This research addresses access to care in a period where an expanded population needs healthcare resources. FQHCs provide healthcare access to the underserved, and with more health information technology, these safety net clinics could better serve this population. Specifically, health centers have shown the potential to improve health outcomes as important safety-net providers<sup>3</sup> as well as lower overall spending when compared to non-health center patients<sup>2</sup>. Technology has been shown to promote better patient care and quality among patients using FQHC services<sup>8, 22, 27</sup> while also raising the accountability and patient involvement by empowering them to be more involved in their own health care<sup>6, 32</sup>.

This research informs policy and promotes the meaningful use and utilization of

health technologies to improve access and quality of care, an understanding of the distribution of broadband speeds and providers impact on FQHCs' adoption of telehealth and EHR. Findings can help direct federal and state funds towards improving the technical and structural infrastructure in low adopting areas through spatial analysis of adoption. This work will potentially influence FCC policies on broadband fund allocations to ensure enough speed is available where needed as well show characteristics of FQHCs, which will more readily adoption technology and for what primary uses.

Key factors such as the patient volume, rural/urban designation and broadband availability may impact and inform adoption of HIT among health centers, therefore inciting changes in policy that emphasize structural and community factors rather than dollars to affect change that can benefit underserved populations.

## **METHODS**

### *Study Design*

This was a retrospective, observational study integrating 2018 Health Resources and Services Administration (HRSA) UDS data with 2018 FCC broadband data. First, we identified how key structural influencers at FQHCs (patient volume, urban and rural status, implementation of a meaningful use program, telehealth modality), broadband access (provider network density and upload/download speed), state level policies (grant incentive payments and Medicaid expansion) and the process of adopting EHR (1a) impacted providers (clinical decision-making support and clinical information exchange) and patients (e-prescribing, patient portals and after-visit summaries) and the process of

adopting telehealth (1b) impacted providers (communication with specialist outside the FQHC) and patients (communication with patients at remote locations outside the FQHC). We then used ArcGIS to descriptively map broadband characteristics and adoption of HIT as well as utilized GeoDa to examine the potential for spatial clustering of adoption of EHRs and telehealth with patient volume variables to provide a correlation analysis comparing FQHC organizations and locations with adoption of HIT.

### *Study Setting*

The 2018 Uniform Data System provided by HRSA consisted of demographics, services and utilization data for approximately 1,362 parent FQHC organizations across 51 states and 7 territories serving over 28 million total patients. Due to a limitation of a restricted 2018 U.S Census Bureau shapefile needed for a spatial association (Aim 2), we only analyzed 4 of the 7 territories that also have FQHCs and associated parent organization data for a total of 51 total states and 4 territories. This was linked to 2018 FCC broadband data that also covered the same states and territories. Based on this adjustment of clinic locations, the total parent organizations studied were also adjusted to 1,356.

### *Data Sources*

**UDS Data:** We used organizational data from the Health Resources and Services Administration's (HRSA) calendar year (CY) 2018 Uniform Data System (UDS) reported by grant recipients. For this study we included data for patients served through the Health Center Program. The program began receiving federal support in 1965 and was

authorized in 1975 under Section 330 of the Public Health Service Act <sup>101</sup>. There are separate legislative authorities under this act that include the Community Health Center Program (330e), Migrant Health Center Program (330g), Health Care for the Homeless Program (330h) and Public Housing Primary Care Program (330i). The HRSA Health Center Program provides information regarding two aspects of the program, which divide FQHCs into locations that have been designated as a Health Center Program Awardees and Health Center Program Look-Alike Clinics <sup>107</sup>. Both types of clinics operate and provide services that ensure access to health care for the underserved populations regardless of the inability to pay.

While Health Center Program Awardees receive full federal funding to assist in providing health care, Health Center Look-Alike clinics do not receive Health Center federal program funding but are eligible to apply to CMS for reimbursement under FQHC Medicare and Medicaid payment methodologies <sup>107</sup>. These clinics are also eligible to receive discounted drugs through the 340b federal Drug Pricing Program, Health Professional Shortage Area (HPSA) Designation and may access National Health Service Corp (NHSC) Providers <sup>107</sup>.

Each FQHC parent organization reported UDS data including, state, patient and provider volume size, region, location, racial and ethnic groups served, as well as financial and revenue sources for health center patients. Health center grantee organizations report UDS data annually in response to questions on health center operations, patients' demographic characteristics, and location. Yearly reporting is required under section 330 of the Public Health Service Act <sup>101</sup>. Multiple steps were

taken by HRSA and the Office of Quality Improvement to help ensure accuracy and validity of the reported data.

Information regarding FQHCs' EHR adoption has been collected by UDS since 2010 and Telehealth adoption and the extent of Telehealth use has been collected since 2016. In 2018, UDS updated Appendix E: Other Data Elements, to capture the changing landscape of FQHCs and their expanded services and delivery systems. Additional questions regarding telehealth in the 2018 UDS Report identified specific modalities/technologies utilized and potential barriers to implementation optimization.

The Freedom of Information Act (FOIA) allows UDS data to be made available to the public in an electronic format. Multiple steps were taken by HRSA and the Office of Quality Improvement to help ensure accuracy and validity of the reported data. Importantly, FQHCs self-report their data and it does “not represent scientific research conducted by the federal government” <sup>79</sup>. Under Exemption 4 of the FOIA, data in Tables 5, 8A, and 9D were withheld from public release at the discretion of individual FQHCs to protect against the release of proprietary business information that may provide an unfair advantage to competitors for future grants <sup>79</sup>. Data pertaining to staffing and utilization, financial costs and other revenues were not available at the parent organization level. FOIA protects the interest of agencies and allows for the withholding of information when it is determined that the disclosure falls under at least one of nine exemptions that include information related to “internal personnel rules of an organization”, financial information that is otherwise considered “confidential or privileged” <sup>80</sup>. HRSA and the Office of Quality Improvement collects and uses this data for auditing purposes internally. Individual

organizations must consent to have this data from the associated Tables 5, 8A and 9D available for public release under the Freedom of Information Act.

***FCC Data:*** This study used 2018 FCC nationwide broadband datasets as of June 30, 2018, which was the most recent data available for this study. June 2018 FCC data was released on September 10, 2019 by the Office of Economics and Analytics (OEA), in association with the Wireline Competition Bureau (WCB) and the Wireless Telecommunications Bureau (WTB) and included revisions made by reporters through October 2019. Available since 2010, The National Broadband Plan provides a detailed listing of broadband availability and capability across the United States by census block. Providers of broadband services report Form 477 data annually in June and December. Any facilities-based firm with greater than or equal to 250 terrestrial broadband lines or wireless broadband channels is required to report information about basic services and customer base on the FCC Form 477 questionnaire <sup>65</sup>. The National Telecommunications and Information Administration and the FCC collects this data and the FCC masks data for zip codes with less than 4 providers <sup>65</sup>. It includes information on the number of broadband providers and the average upload/download speeds, aggregated to the block code level. Because FCC data is reported at the census block level, it is important to note that “individual internet providers may not offer service to every home or business in every block in which they report service even though the calculations used to create broadband maps and graphs treat every location as having service” <sup>124,130</sup>. This application of the data may lead to an overestimation of broadband coverage, especially in areas with large census blocks <sup>130</sup>.



Data provided by Internet Service Providers (ISP) are extensively audited during the “collection, pre-collection data analysis and processing” portions of the data integrity check <sup>78</sup>. This is because some research has noted that data reported may not include all broadband carriers or accurately report geographic coverage areas <sup>65,81,82,91</sup>. Lennett and Meinrath (2011) noted that ISP may overestimate broadband availability and provider choice for covered regions <sup>92</sup>. To address these limitations, studies have analyzed and spatially created maps using network distances instead of Euclidean distance to estimate coverage and service to an area, which allows for the service zones to be clipped <sup>81,82,91</sup>. Previous studies have also used block level aggregates that include information at the block group level and higher to allow for a more robust analysis in comparing blocks and associated demographic and socioeconomic data <sup>82,91</sup>. The Census Bureau created block group levels as clusters of census blocks that serve as a geographically level between census blocks and census tracts and are known to not cross state and county boundary lines <sup>102</sup>. Block groups are the smallest geographical unit of analysis published by the Census Bureau and generally contains between 600 and 3,000 people <sup>102</sup>.

***Census Bureau TIGER/Line Shapefiles Data:*** The base map of the United States and its associated territories was available from the United States Census Bureau TIGER/Line Shapefiles <sup>108</sup>. The 2018 shapefile provided did not include associated US territories Marshall Islands, Palau and Federated States of Micronesia were the territories excluded from the final analysis in order to match UDS data totaling 51 total states and 4 territories. The exclusion of these territories was further confirmed and verified once

FQHC zip codes were matched to ZCTA codes. It was noted that these specific areas also lacked corresponding ZCTA codes developed by the U.S. Postal Service.

### *Measures*

Structure in our model represented the resources used to deliver care as well as the system influences through which HIT is either delivered or financed. It is divided into three levels of system characteristics 1) FQHC, 2) Broadband, and 3) State.

### FQHC:

Variables associated with patient volume, rural or urban identification as well meaningful use program implementation, were available at both the state and individual health center parent organization level. For the purpose of this study, these variables were analyzed at the organizational (clinic) level.

**Telehealth modalities:** The study used self-reported UDS data regarding the actual uses of Telehealth within a parent FQHC organization. Telehealth is a broader more encompassing term incorporating remote and non-remote clinical services. Telehealth technologies vary in their modality and scope of practice in providing benefits to both the patient as well as a physician. According to the Center for Connected Health Policy, the 4 different telehealth modalities include:

Real-time communication (synchronous): allows for a real-time two-way connection between a patient, caregiver or provider, and a provider and can serve as a substitute for a face-to-face encounter. This modality has been used for consultations, diagnosis and treatments <sup>110-111</sup>.

Store-and-forward (asynchronous): allows for the electronic transmission of medical information such as images, documents or pre-recorded videos of patient examinations through a secure email channel <sup>110-111</sup>.

Remote Patient Monitoring (RPM): use technology to collect and record health data from a patient in one location and electronically transmit through secure channels to health care providers. This modality allows for tracking and monitoring of patients <sup>110-111</sup>.

mHealth (mobile health): allows for the use of mobile apps and online services to allow patients and providers to track health and wellness <sup>110-111</sup>

The executive director of the Institute for e-Health Policy, and the president of Health Tech Strategies, Neal Neuberger, stated after participating in a panel at the American Telemedicine Association, “there is no real inclusion for telemedicine and telehealth as a direct component of the three stages of meaningful use” <sup>113</sup>. Though researchers such as Vo et al. (2015) have proposed integrated telemedicine models that attempt to parallel current meaningful use staging in a three tiered approach <sup>114</sup>, policies such as ARRA and the HITECH Act have failed to align mandates of the ACA with telehealth initiatives. These initiatives and policies will allow for monetary incentives towards adoption and meaningful utilization as well as serve to influence the Office of the National Coordinator for

Health Information Technology (ONC) to support policies creating “mandatory objectives for telehealth in Stages 2 and 3 of meaningful use ... that will give vendors the impetus to build models for telehealth into EMR and health information exchange (HIE) technologies” <sup>113</sup>. This variable was derived by quantifying the total telehealth technology responses to Appendix E question 2a2 to create a Telehealth Modality variable that ranged from 0 to 6, depending on the type of technology as well as the number of technologies per FQHC location.

**patient volume (size):** In this study, patient volume was determined based on the unduplicated numbers of individuals encountered by each parent organization for the 2018 reporting year, an approach used as a common size metric in studies involving patient level analysis and HIT <sup>94-99</sup>. Previous studies have not evaluated patient volume as an independent variable related to FQHCs and adoption of Technology. Currently FQHCs report patient counts by gender and age, so total patient volume variable was derived by totaling male patients and total female patients per FQHC parent organizations <sup>90, 106</sup>.

**rural/urban:** A rural/urban location indicator was used as a variable and determined by the Federal Office of Rural Health Policy (FORHP) based on 2010 Census data that was used to assign a code to each Census Tract <sup>75</sup>. Several studies used similar definitions of rurality to classify study areas and practices <sup>6, 71</sup>. Based on FORHP guidelines, health centers self-reported this status for the parent organization sites<sup>75</sup>.

**Implementation of meaningful use incentive program:** The study determined the impact of the meaningful use criteria and HIT adoption in the clinics by examining the UDS survey question: “Are your eligible providers participating in the Centers for Medicare and Medicaid Services (CMS) EHR incentive program, commonly known as Meaningful Use?” This study determined the impact of meaningful use criteria and adoption and uptake of HIT in clinics <sup>31</sup>.

#### Broadband:

The purpose of this study was to examine the association of broadband provider density and average speed spatially using GIS technologies and assess if broadband serves as an influencer of HIT adoption.

Limitations noted by the FCC acknowledges that “A provider that reports deployment of a particular technology and bandwidth in a particular census block may not necessarily offer that particular service everywhere in the census block. Accordingly, a list of providers deployed in a census block does not necessarily reflect the number of choices available to any particular household or business location in that block, and the number of such providers in the census block does not purport to measure competition” <sup>124</sup>.

#### **provider density**

Research by Grubestic (2006), found that larger urban areas benefitted from vigorous levels of broadband competition while areas with unfavorable demand conditions lacked an adequate supply and competition of broadband providers <sup>64</sup>.

Broadband providers tended to be influenced geographically and socially, infiltrating areas with more profitable markets that exhibited higher returns on investment <sup>64</sup>.

### **upload/download speeds**

Whitacre and Williams (2014) examined the link between broadband availability in relation to speed and density and EMR adoption in the state of Oklahoma. They found that adoption rates differed between rural and urban private practices, and generally, while adoption of EMR increased with the number of broadband providers available, higher adoption was correlated with slower upload/download speeds <sup>15</sup>. Using this 2014 study as a reference, similar average upload/download speeds were used to categorize available and reported speeds associated with FQHC clinics <sup>15</sup>.

### **State:**

State policy could influence and drive adoption of technology and therefore the variables that were studied include:

### **Medicaid Expansion**

In this study, Medicaid expansion determined by research and data from the Henry J. Kaiser Family Foundation as well as Medicaid.gov (concerning differences in Medicaid programs and eligibility within territories) <sup>131-135</sup>, was specifically used to determine association between both EHR and telehealth adoption. Research by

Lin et al (2018) analyzed whether state-level Medicaid policy characteristics potentially impacted a health centers investment and utilization in telehealth <sup>6</sup>. Patients' insurance status (Medicaid, Medicare, uninsured) was also included as a variable in the study analyzing telehealth adoption among FQHCs due to HRSA's observation of its influence on an entity's adoption of telehealth <sup>6</sup>.

### **grant financing**

We examined the association between adoption of HIT and the FQHCs reported grant financing. Research has noted that larger private institutions have more organizational and financial resources to implement HIT and hire appropriate staff <sup>27</sup>. Grant sources related to HIT vary among FQHCs but can determine the likelihood of a clinic adopting advanced technologies as well as indicate the role that supplemental funding has on adoption of technology within health centers. Gold et. al (2012), noted that grant funding has not been found to be a viable alternative to revenue streams involving the utilization of HIT due to the costly nature of its ongoing management <sup>26</sup>.

*Process* had two subdomains,

### **adoption of EHR**

We used: "Does your center currently have an Electronic Health Record (HER) system installed and in use? (2018 UDS Manual: Appendix D:1) <sup>73, 90</sup> to measure adoption of EHR. In a 2005 study, the authors used similar study questions from

the NAMCS survey to evaluate adoption and utilization of EHR in the private clinic setting.

### **adoption of Telehealth**

“Did your organization use telehealth in order to provide remote clinical care services?”<sup>90</sup> (UDS 2018 Manual: Appendix E:2) will be examined. Lin et al. (2018) also utilized a similar close-ended question extracted from the then 2016 UDS survey to evaluate telehealth adoption

### *Outcomes:*

#### **EHR: Provider Impact**

We evaluated how providers were using EHR to facilitate care. Specifically, we looked at responses to: Clinical decision-making support by examining the UDS question, “Does your center use computerized, clinical decision support, such as alerts for drug allergies, checks for drug-drug interactions, reminders for preventive screening tests, or other similar functions?” (2018 UDS Manual: Appendix D)<sup>90</sup> and the variable electronic clinical information exchange by evaluating the question “Does your center exchange clinical information electronically with other key providers/health care settings, such as hospitals, emergency rooms, or subspecialty clinicians?” (2018 UDS Manual: Appendix D)<sup>90</sup>. This variable was derived by quantifying the total “yes” responses to Appendix D questions 3 and 4 pertaining to EHR Provider Impact to create an Impact Score between 0-2.



### **EHR: Patient Impact**

To examine the impact on patients of EHR adoption, we looked at variables related to e-prescribing, patient portal use and after-visit summaries. Use of electronic prescriptions were evaluated by examining the question “Does your center send Rx to the pharmacy electronically? (Do not include faxing)” (*2018 UDS Manual: Appendix D*)<sup>90</sup>, patient portals using “Does your center engage patients through health IT, such as patient portals, kiosks, or secure messaging (i.e., secure email) either through the EHR or through other technologies?” (*2018 UDS Manual: Appendix D*)<sup>90</sup> and after-visit summaries “Does your center use the EHR or other health IT system to provide patients with electronic summaries of office visits or other clinical information when requested?” (*2018 UDS Manual: Appendix D*)<sup>90</sup>. This variable was derived by quantifying the total “yes” responses to Appendix D questions 2, 5 and 6 pertaining to EHR Patient Impact to create an Impact Score between 0-3.

### **Telehealth: Provider Impact**

Provider to Provider telehealth impact was evaluated by the UDS question “If YES.... Who did you use telehealth to communicate with: Specialists outside your organization? (e.g. specialists at referral centers)” (*2018 UDS Manual: Appendix E*)<sup>90</sup>. This variable was derived by quantifying the total “yes” responses to Appendix E question 2a pertaining to Telehealth Provider Impact to create an Impact Score between 0-1.

### **Telehealth: Patient Impact**

Provider to Patient telehealth impact was then evaluated by the UDS question “If YES.... Who did you use telehealth to communicate with: Patients at remote locations from your organization? (e.g., home telehealth, satellite locations) (2018 *UDS Manual: Appendix E*)<sup>90</sup>. This variable was derived by quantifying the total “yes” responses to Appendix E question 2b pertaining to Telehealth Patient Impact to create an Impact Score between 0-1.

Ideally, FQHCs who were not already located in a ZCTA with sufficient broadband to support EHR or Telehealth would be excluded from the sample, but due to the limitations of the UDS data set and inadequate FTE numbers per FQHC parent organization reported, there cannot be a determination of average speed or adequate speed based on the number of clinicians utilizing the technology<sup>65</sup>. Therefore, this research identified average speeds associated with FQHC adoption of EHR as well as telehealth, information not found in prior research studies.

The outcome variables considered the extent to which EHR and telehealth was used by providers and patients. Frimpong et al. (2013) classified FQHCs as either low, medium, or high HIT capacity based on specific EHR functionalities, defining high HIT capacity as clinics utilizing decision support, patient reminders and discharge summaries<sup>8</sup>. Perzynski et al (2017) found a digital divide in patient portal use and that this function was less likely used in areas that lack broadband access and areas with more minorities and patient with lower socioeconomic status<sup>74</sup>. What was interesting was that in the private practices the utilization of patient portals was less likely used in urban areas<sup>74</sup>.

This study examined whether similar results were found in FQHC settings. Research in the private practice setting, found that implementation of HIT resulted in more advanced decision support through the electronic transmission of prescription and lab tests <sup>27</sup>. An analysis of this variable has not specifically been done in the FQHC population; therefore, this study examined if similar results were found in this population of healthcare clinics primarily serving underserved populations.

## Measurement Matrix

**Table 2:** Primary Study Measures (AIM 1)

MEASURED VARIABLE	DATA SOURCE	DEFINITION	Variable Type	
AIMs 1a and 1b				
STRUCTURE				
Independent Variable: FQHC characteristics			Descriptive Analysis	Regression Analysis
Patient volume	UDS 2018	<p>A patient is an individual who has at least one visit during the reporting year. Within each category, an individual can only be counted once as a patient. A person who receives multiple types of services should be counted once (and only once) for each service. An individual patient may be counted once (and only once) in each of the following categories:</p> <p>Variable will be derived by adding rows: Total Patients - Male Patients (T3a_L39_Ca) and Total Patients - Female Patients (T3a_L39_Cb I) to construct the variable of total patients per clinic site seen in 2018</p> <p>(Table 3A)</p>	Derived Continuous variable	
Rural	UDS 2018	Self-Reported variable by parent organization	Categorical variable Rural/Urban Where Rural = 1 and Urban = 0	
Meaningful use	UDS 2018	Are your eligible providers participating in the Centers for Medicare and Medicaid Services (CMS) EHR incentive program, commonly known as Meaningful Use? (Appendix D: 8)	Derived Categorical Variable <b>Yes = 2</b> <i>Yes, all eligible providers at all sites participate</i> <i>Yes, some eligible providers at some sites participate</i>  <b>NO=1</b>	<b>Collapsed</b> Derived Categorical <b>Yes= 1</b>  <b>No/Not Sure= 0</b>

			<i>No, our eligible providers are not participating</i> <i>No, because our providers are not eligible</i>  <b>0= Not sure</b>	
Telehealth Modalities	UDS 2018	<p>What telehealth technologies did you use? (Select all that apply) (Appendix E: 2a2)</p> <p>This variable will be derived by quantifying the total telehealth technology responses to Appendix E question 2a2 to create a Telehealth Modality variable that will range between a variable of 0 to 6.</p> <ul style="list-style-type: none"> <li>- Real-time telehealth (e.g., video conference)</li> <li>- Store-and-forward telehealth (e.g., secure email with photos or videos of patient examinations)</li> <li>- Remote patient monitoring</li> <li>- Mobile Health (mHealth)</li> </ul>	<p>Derived Categorical Variable</p> <p><b>6</b> = Real Time  <b>5</b> = Store and forward  <b>4</b> = RPM  <b>3</b> = mHealth  <b>2</b> = 2 Modalities  <b>1</b> = 3 Modalities  <b>0</b> = 4 Modalities</p>	<p><b>Collapsed</b> Derived Categorical</p> <p><b>0</b> = Real Time  <b>1</b> = Store and forward  <b>2</b>= RPM  <b>3</b>= mHealth  <b>4</b>= 1 + Modalities</p>
<b>Independent Variable:</b>				
Broadband				
Provider/Network Density	FCC 2018	<p>Broadband Provider Density</p> <p>Derived variable based on the number of provider IDs identified per block area and a list of providers deployed in the census block.</p> <p>Limitation per FCC: “A provider that reports deployment of a particular technology and bandwidth in a particular census block may not necessarily offer that particular service everywhere in the census block. Accordingly, a list of providers deployed in a census block does not necessarily reflect the number of choices available to any particular household or business location in that block, and the number of such</p>	<p>Derived Categorical</p> <p><b>0</b>= 0/None Reported  <b>1</b>= 1-2  <b>2</b>= 3-4  <b>3</b>= 5-6  <b>4</b>= 7-8  <b>5</b>= 9-10  <b>6</b>= 11+</p>	<p><b>Collapsed</b> Derived Categorical</p> <p><b>0</b>= 0-4  <b>1</b>= 5-8  <b>2</b>= 9+</p>

		providers in the census block does not purport to measure competition.” <a href="https://www.fcc.gov/general/explanation-broadband-deployment-data">https://www.fcc.gov/general/explanation-broadband-deployment-data</a>		
Download/Upload Speed	FCC 2018	<p>Avg Max. Download/Upload Speed</p> <p><b>MaxAdDown:</b> Maximum advertised downstream speed/bandwidth offered by the provider in the block for Consumer service</p> <p><b>MaxAdUp:</b> Maximum advertised upstream speed/bandwidth offered by the provider in the block for Consumer service <a href="https://www.fcc.gov/general/explanation-broadband-deployment-data">https://www.fcc.gov/general/explanation-broadband-deployment-data</a> <sup>124</sup></p>	<p>Derived Categorical</p> <p><b>0</b>= 0.2/0.2 - 4/1 mbps  <b>1</b>= 10/1 - 10/3mbps  <b>2</b>= 10/10 - 25/1 mbps  <b>3</b>= 25/3 - 25/10 mbps  <b>4</b>= 25/25 - 100/1 mbps  <b>5</b>= 100/3 - 100/10 mbps  <b>6</b>= 100/25 - 100/100 mbps  <b>7</b>= 250/3 - 250/10 mbps  <b>8</b>= 250/25 - 250/100 mbps  <b>9</b>= &gt;250/100 - 1000/25 mbps  <b>10</b>= 1000/100 - &gt;1000/100 mbps</p>	<p><b>Collapsed</b> Derived Categorical</p> <p><b>0</b>= average speeds less than 25/1 mbps  <b>1</b>= average speeds between 25/3 mbps - 100/100 mbps  <b>2</b>= average speeds greater than 250/3 - mbps</p>
<b>Independent Variable:</b>				
State Characteristics				
Medicaid Expansion	<a href="http://www.kff.org">www.kff.org</a> Medicaid.gov	<p>Expansion of Medicaid to low-income adults <sup>131-135</sup>            (Date of Data extraction: 12/23/2019)            (Timeframe as of: 11/15/2019)  <a href="https://www.kff.org/health-reform/state-indicator/state-activity-around-expanding-medicaid-under-the-affordable-care-act/?activeTab=map&amp;currentTimeframe=0&amp;selectedDistributions=status-of-medicaid-expansion-decision&amp;sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D">https://www.kff.org/health-reform/state-indicator/state-activity-around-expanding-medicaid-under-the-affordable-care-act/?activeTab=map&amp;currentTimeframe=0&amp;selectedDistributions=status-of-medicaid-expansion-decision&amp;sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D</a></p>	<p>Categorical Variable</p> <p>Yes/No            Where Yes = 1 and No = 0</p>	

HITECH Administrative Funding Grant \$\$	UDS 2018	Use of administrative funds to support health information exchange as part of the Medicaid EHR Incentive Program	Continuous Variable Adjusted for inflation	
PROCESS				
Independent Variable: 2a: Adoption of EHR 2b: Adoption of Telehealth	UDS 2018	Does your center currently have and <b>EHR</b> system installed and in use (Appendix: D: 1) <i>Any yes responses to Appendix D 1a or 1b noted installed EHRs at all sites or some sites will be considered a yes response for this variable</i>  Did your organization use <b>telehealth</b> in order to provide remote clinical care services (Appendix: E: 2)	Categorical Yes/No Where Yes = 1 and No = 0  Derived EHR Categorical Variable where Yes responses will equal to 1	
OUTCOME				
Dependent Variable: EHR Impacts				
EHR Provider Impact Score (Appendix D 3:4)  <				

E-Prescribing (Question # 2)	Question # 2 Does your center send Rx to the pharmacy electronically? (Do not include faxing) Yes/No/Not Sure Where Yes = 2, No = 1 and Not Sure = 0 *derived categorical variables in this column will be used for descriptive analysis of EHR communication only		Derived Categorical Impact Score Variable based on “YES” responses (0, 1, 2, 3)	Collapsed Derived Categorical 1 = 3 impacts 0 = less than 3 impacts
Patient Portal (Question # 5)	Question # 5 Does your center engage patients through health IT, such as patient portals, kiosks, or secure messaging (i.e., secure email) either through the EHR or through other technologies?  Yes/No/Not Sure Where Yes = 2, No = 1 and Not Sure = 0 *derived categorical variables in this column will be used for descriptive analysis of EHR communication only			
Visit Summaries (Question # 6)	Question # 6 Does your center use the EHR or other health IT system to provide patients with electronic summaries of office visits or other clinical information when requested?  Yes/No/Not Sure Where Yes = 2, No = 1 and Not Sure = 0 *derived categorical variables in this column will be used for descriptive analysis of EHR communication only			
Dependent Variable: Telehealth Impacts	UDS 2018	If YES.... Who did you use telehealth to communicate with? . . . (Appendix E: 2)		
Telehealth Provider Impact Score Appendix E: 2a1	Question # a Specialists outside your organization (e.g. specialists at referral centers) [provider to provider]  This variable will be derived by quantifying the total “yes” responses to Appendix E question 2a pertaining to Telehealth Provider Impact to create an Impact Score that will potentially range between 0-1.	Derived Categorical Variable  2 = Both Patients and Specialists 1 = Patient Only 0= Specialist Only  *derived categorical variables in this column will be used for descriptive analysis of telehealth communication and spatial analysis only	Derived Categorical Impact Score Variable based on “YES” responses (0, 1)	
Telehealth Patient Impact Score Appendix E: 2a1	Question # b Patients at remote locations from your organization (e.g., home telehealth, satellite locations) [patient to provider]  This variable will be derived by quantifying the total “yes” responses to Appendix E question 2b pertaining to		Derived Categorical Impact Score Variable based on “YES” responses (0, 1)	



	Telehealth Patient Impact to create an Impact Score that will potentially range between 0-1.		
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**Table 3:** Primary Study Measures (AIM 2)

MEASURED VARIABLE	DATA SOURCE	DEFINITION	CATEGORY	
<b>AIMs 2a and 2b</b>				
<b>Dependent Variable:</b> 1a: Adoption of EHR 1b: Adoption of Telehealth	UDS 2018	Does your center currently have an <b>EHR</b> system installed and in use (Appendix: D:1)? <i>Any yes responses to Appendix D 1a or 1b noted installed EHRs at all sites or some sites will be considered a yes response for this variable</i>	Derived Categorical <b>0</b> = Neither <b>1</b> = EHR Only Adopted <b>2</b> = Telehealth Only Adopted <b>3</b> = Both	
		Did your organization use <b>telehealth</b> in order to provide remote clinical care services (Appendix: E: 2)?		
<b>Independent Variable:</b> Broadband			<b>Descriptive Analysis</b>	<b>GIS Spatial Analysis</b>
Provider/Network Density	FCC 2018	Broadband Provider Density Derived variable based on the number of provider IDs identified per block area and a list of providers deployed in the census block.  Limitation per FCC: “A provider that reports deployment of a particular technology and bandwidth in a particular census block may not necessarily offer that particular service everywhere in the census block. Accordingly, a list of providers deployed in a census block does not necessarily reflect the number of choices available to any particular household or business location in that block, and the	Derived Categorical <b>0</b> = 0/None Reported <b>1</b> = 1-2 <b>2</b> = 3-4 <b>3</b> = 5-6 <b>4</b> = 7-8 <b>5</b> = 9-10 <b>6</b> = 11+	<b>Collapsed</b> Derived Categorical <b>0</b> = 0-4 <b>1</b> = 5-8 <b>2</b> = 9+

		number of such providers in the census block does not purport to measure competition.” <a href="https://www.fcc.gov/general/explanation-broadband-deployment-data">https://www.fcc.gov/general/explanation-broadband-deployment-data</a> <sup>124</sup>		
Download/Upload Speed	FCC 2018	<p>Avg. Max. Download/Upload Speed</p> <p><b>MaxAdDown:</b> Maximum advertised downstream speed/bandwidth offered by the provider in the block for Consumer service</p> <p><b>MaxAdUp:</b> Maximum advertised upstream speed/bandwidth offered by the provider in the block for Consumer service</p> <p><a href="https://www.fcc.gov/general/explanation-broadband-deployment-data">https://www.fcc.gov/general/explanation-broadband-deployment-data</a><sup>124</sup></p>	<p>Derived Categorical</p> <p><b>0</b>= 0.2/0.2 - 4/1 mbps  <b>1</b>= 10/1 - 10/3mbps  <b>2</b>= 10/10 - 25/1 mbps  <b>3</b>= 25/3 - 25/10 mbps  <b>4</b>= 25/25 - 100/1 mbps  <b>5</b>= 100/3 - 100/10 mbps  <b>6</b>= 100/25 - 100/100 mbps  <b>7</b>= 250/3 - 250/10 mbps  <b>8</b>= 250/25 - 250/100 mbps  <b>9</b>= &gt;250/100 - 1000/25 mbps  <b>10</b>= 1000/100 - &gt;1000/100 mbps</p>	<p><b>Collapsed</b></p> <p>Derived Categorical</p> <p><b>0</b>= average speeds less than 25/1 mbps  <b>1</b>= average speeds between 25/3 mbps - 100/100 mbps  <b>2</b>= average speeds greater than 250/3 - mbps</p>

### *Data Collection*

In order to analyze the data provided by UDS and FCC, the data sets were downloaded from their respective websites. UDS 2018 data was downloaded upon FOIA request from HRSA Electronic Reading Room <sup>106</sup>. FCC 2018 data was accessed from the FCC Form 477 using data, which included only *wired* versions of broadband, excluding wireless or cellular. The variables were then extracted, and questions not required for our research removed. Once the data was downloaded on day 1 of analysis, we ensured that the most recent and up to date data was used by checking the data sources monthly for any updates.

### *Human Subjects or Safety Considerations*

Though the data for this research was publicly available and contained no personal identifiers, and the analysis was at the parent organizational level, IRB approval was obtained from the UTHealth Committee for the Protection of Human Subjects (CPHS) to ensure that study design and data management was adequate.

### *Sample Size Calculation and/or Study Power*

In 2018, there were 1,362 total reporting program awardees across 51 states and 7 territories. For the purpose of this study 1,356 parent organizations were analyzed. Due to the large sample size, we expected to have enough statistical power reasonable for the purpose of this study. To confirm that assumption, statistical power was calculated using standard methodology by applying the below conventional formula

<sup>77,112</sup>. An adequate power will assist in determining the minimum sample size needed to detect an effect at a desired significant level if an effect exists.

$$\text{Power} = \text{effect size} * \alpha * \sqrt{n}/\sigma$$

$$\text{Expected Power} = (1 - \beta)$$

$\alpha$  = alpha

n = sample size

$\sigma$  = standard error

Although there were no previous studies calculating statistical power while analyzing the adoption of HIT between the structural variables discussed in our Donabedian framework, specific statistical power and effect size analysis was most commonly calculated in general HIT adoption studies using standard guidelines cited from Cohen (1988) where a significance level of 0.5, power (1-beta) of 0.80 and conservative effect size of ( $r=0.10 - 0.30$ ) was used to calculate an adequate sample size <sup>103-105</sup> .

### *Data Analysis*

The two datasets were downloaded and edited as discussed above and protected on a password accessible computer as well as an encrypted jump-drive. Original versions of the datasets were saved and used in case of rebuilding. Missing variables due to the

parent organizations right to withhold and suppress data deemed proprietary were recoded with the numerical value -999.

Analysis:

At this point of the analysis, we identified three different levels considered for the initial regression model where, level 1: FQHC entity level (x, y); level 2: census block code level, and level 3: state level.

**FQHC Clinic Point File – U.S. Census Bureau Dataset Join:** In order to preserve adequate power, especially with the expected adjustment and decrease in total FQHC parent organizations analyzed secondary to a limited U.S. Census Bureau data set due to some territories without a ZCTA code associated by the U.S. Postal Service; we attributed the parent FQHCs with their corresponding ZCTAs and then relate those ZCTAs to census block codes that they are located within. We accomplished this task by 1) using HRSA's Zip Code to ZCTA cross walk, 2) accessing ArcGIS Pro to geocode clinic addresses and 3) utilizing ArcGIS/ArcMap to do a spatial join between ZCTA and GEOID/Block Codes provided by the U.S. Census Bureau to create a UDS Clinic geocoded geodatabase with ZCTA associated block codes named *Census\_Clinic\_Join\_Output*. We assumed that since a FQHC was in a specific block code, then that provider density or upload/download speed found in the census block code was also associated with the FQHC organization. We viewed it as a valid assumption that also served as a limitation of the UDS data set since individual sites were not included. UDS data reported at the parent organization level means that FQHCs with multiple satellite sites may be in another ZCTA or block

code and therefore may not serve as a realistic representation of broadband availability for all FQHCs.

**2018 FCC File Data Edit:** The 2018 FCC data was only reported at the census block code level and therefore the next step was to join this data with the *Census\_Clinic\_Join\_Output* file which now contained a GEOID block code “BlockID” attribute field after the previous spatial join with the US Census Bureau Block Code Geodatabase. The FCC “Block Code” field was in a “text” format while the US Clinic GEOID block code field was in a “double” format. While the solution could have simply been to change the format of the GEOID field in the smaller US Clinic file, there were other deterrents noted while attempting to merge datasets.

Since the FCC block code field was “text” form, the data was therefore in exponential form with differing decimal points between rows while the US Clinic block code field had the block code value in its full 15-digit block code form. Therefore, we decided to instead reformat the field in the larger FCC dataset. The 2018 FCC data file is over 10 gigabytes and consisted of over 69 million rows (69,548,702) and 17 columns. Due to the size of the database, there were difficulties downloading, adding fields and sorting the file in ArcGIS. Upon further research, we downloaded a free program called Delimit (<http://delimitware.com/>), which was developed to handle large CSV and TAB delimited files allowing for editing and joining. This program allows for the editing of files that are up to 2 billion rows and 2 million columns, while Excel has a limit of up to ~ 1 million rows. For the purpose of this study, we needed to condense the number of columns. After manipulating the data and removing columns and variables not needed

for the scope of this study, the file sized decreased to ~4gigabytes. This smaller FCC data file was then uploaded to ArcGIS, and fields were reformatted. This file was saved and named *FCC\_Main*.

**Census\_Clinic\_Join\_Output File – 2018 FCC\_Main File Join:** Using the Delimit software, it was noted that out of the 69+ million rows of data, there were 58,383,286 duplicates. These duplicates represented multiple broadband providers offering services to the different block codes. Since broadband provider density was required for our analysis, we needed to account for the specific number of providers available to provide broadband technology to the FQHCs in their particular block codes. Therefore, the next step was to pull out the duplicated FCC data rows with block codes matching the specific block codes related to the 1,356 U.S. Clinic geocoded points. First, we created two new double integer formatted fields in the *Census\_Clinic* point file; X-Coord, and then Y-Coord. For the X-Coord field we calculated geometry > property: x coordinate of point and using the coordinate system of the data source. For the Y-Coord field we also calculated geometry > property: y coordinate of point and using the coordinate system of the data source. We then performed a spatial join from the 2018 *FCC\_Main* file “Block Code” field to the *Census\_Clinic\_Join\_Output* file “BlockID” fields, keeping only matching records. As a result of this join, we were able to condense our dataset to 11,918 rows representing duplicates linked to our specific clinic points. The duplicated rows represented the individual broadband providers that serving the specific block codes where FQHCs were located. We exported this new file to a new geodatabase and named it *FCC\_Clinic\_SelectXY*. Next, we exported this new file by selecting “display XY data”

based on the X and Y coordinate fields. This created a new file called *FCC\_Clinic\_SelectXYEvents* that allowed us to note each clinic point file and the duplicated broadband providers serving that site. Unfortunately, due to the General Counsel's Office prohibition by statute regarding the FCC capturing which consumers subscribe to which services, it was not feasible to select specific down and upload speeds among the multiple providers to determine which broadband speeds were actually chosen and being used in 2018 per FQHC for our analysis.

**Broadband Speed Range Categorical Variable:** Using the *FCC\_Clinic\_SelectXYEvents* geodatabase, we exported the file into a single geodatabase using ArcCatalog and simplified the many columns to create a more user friendly and condensed dataset for ArcGIS. We deleted rows not needed for the analysis and saved the file as a new layer titled *FCC\_Clinic\_SelectXYSimplified*. We then applied a Geoprocessing tool and applied the dissolve feature in order to calculate statistics sorted by the "user\_field" ID attribute. We developed a new output folder titled *FCC\_Clinic\_SelectXYDissolveMaxAdv*. Within the dissolve feature, we referenced a study by Whitacre and Williams (2014) and used a similar statistic to consolidate and determine derived categorical speed variables across different providers servicing a particular census block by adding mean (average) statistics for the fields: "MaxAdUp" and "MaxAdDown" <sup>15</sup>. Once applied the function decreased the # of rows from 11,918 to 1,353 based on the specific clinic points associated with the census blocks.

Three clinic points (clinic ID # 500, 502 and 1036) failed to merge into the dissolve data set which should have resulted in 1,356 clinic points instead of the 1,353 noted in the dissolved data. Once the missing data points were identified and examined in ArcGIS



Pro, it was noted that the points, depending on their block codes, shared the same address as another point in the block and were on top of one another and therefore once the points were dissolved and merged, the touching points merged into one row. Though the addresses were the same for some of the clinic sites as reported by HRSA UDS 2018, the clinics were individually classified as separated parent organizations and entities. Due to these similarities, the dissolved function transformed the data from single point data, to multipoint data. Since the data was determined to be a multipoint feature, we decided to edit the dissolved data set and manually add the missing data points for the three clinic sites. We used the Delimit software to extract the specific FCC- Clinic rows from the *FCC\_Clinic\_SelectXYSimplified* data file and documented the speeds for each missing point and their corresponding points in their particular block codes and calculated the average (mean) using Excel while then determining the speed variables using the process previously mentioned. We used the Edit-Sketch-Properties tool to edit *FCC\_Clinic\_SelectXYDissolveMaxAdv* data in ArcGIS. This was done by starting an editing session in editor, selecting the editing window option and then selecting the sketch properties option. We added a new point to our map, which resulted in a new editable row in our *FCC\_Clinic\_SelectXYDissolveMaxAdv* data set. We then documented the data missing and needed, saved edits and then stopped edits.

Upon opening the attribute table for the new file, two new fields were created: a text field titled "Download Speed" and another titled "Upload Speed". We then arranged the "Mean\_MaxAdDown" field in ascending order and referenced past FCC broadband map legends to determine download speeds values commonly used to create definitions in the corresponding "Download Speed" text field using the field calculator feature. A

similar process was also applied to the “Mean\_MaxAdUp” field and corresponding “Upload Speed” text field. Next, a new double formatted field was created titled “DownUpSpeed” and a field calculator was applied where the highest speed value in the associated upload and then download text range row was used to determine the values for the “DownUpSpeed”; resulting in 21 different speed values. A new double field was then created titled “DownUpRange” and the previously determined speed values were combined into ranges further condensing the 21 different speeds to 10 range values. A short integer field was created titled “DownUpRangeSPSS” where each range was assorted in ascending order and assigned a variable between 0 -10.

**Broadband Provider Duplicate Count Variable:** We also used ArcGIS to determine the broadband provider variable. We first created a new short integer formatted field in the *FCC\_Clinic\_SelectXYEvents* attribute table and named it “number\_prov”. Field calculation was then performed for that field and was equaled to “1”. We then did a spatial join from the *Census\_Clinic\_Join\_Output* and joined data from “another layer based on spatial location” to the *FCC\_Clinic\_SelectXYEvents* file. We summarized the attributes by calculating the sum and saved the layer naming the new file *Join\_Number*. We copied the sum field only and saved it in a separate Excel cumulative dissertation variables dataset.

We will analyze UDS and FCC data with SPSS, version 25 (IBM SPSS Statistics Armonk, NY). We performed descriptive analyses for the independent and dependent variables representing the various structural influences potentially affecting HIT adoption across the United States as well as variables related to capacity of HIT functionalities impacting the patient and provider. Statistical analysis was at the parent organizational

level and therefore the means, medians, quartiles, and standard deviations calculated were based on this level of data reported. Frequencies and weighted percentages were generated for the distribution of characteristics of FQHCs as well. Regarding broadband providers and speeds, descriptive statistics were also provided including general distribution and number of providers per Census Block as well as average speed.

Once descriptive statistics were completed on each of the eight core structural variables and seven dependent (impact and outcome) variables, we determined if any of the variables would either need collapsing or if a log transformation was ultimately required in order to “normalize” the data due to the potential of skewness that may alter the analysis. Once the variables were cleaned, we began to build our model by running a bivariate regression.

In order to preserve an adequate power, especially with the expected adjustment and decrease in total FQHC parent organizations analyzed due to a limited U.S. Census Bureau data set, we attributed the parent FQHCs with census block codes that they were located, to put them all at the same level for our regression analysis. We assumed that since a FQHC was in a specific census block code, then that provider density or upload/download speed found in the block code was also associated with the FQHC organization. We see it as a valid assumption but also serves as a limitation of the UDS data set since individual sites are not included in the current iteration. The UDS data is currently based at the parent organization level, therefore multiple satellite sites associated with the parent location may be in another block code and therefore may not serve as a realistic representation of broadband availability for all FQHCs.

Variables related to capacity of HIT functionalities were divided into 1) whether the function was related to the adoption of EHR or the adoption of telehealth and 2) whether the impacts were related to the Patient or the Provider. There were three separate categories measuring utilization within the patient category and two categories related to the provider impact regarding the adoption of EHR. For the adoption of telehealth, there were two measures across both patient and provider categories. Due to the variation of FQHC responses for the 7 survey items, the responses in each category were collapsed and re-classified as ordinal variables that would serve as 4 derived variables that ultimately scored clinics based on the number of “yes” answers reported for each impactful utilization of the technologies. Descriptive analysis was performed on a clinic’s utilization scores as well.

Provider Impact of EHR: scores ranged from (0,1,2)

Patient Impact of EHR: scores ranged from (0,1,2,3)

Provider Impact of Telehealth: scores range from (0,1)

Patient Impact of Telehealth: scores range from (0,1)

Based on the characteristics and the aims of this research, a logistic regression was performed to determine how the independent variables related to system structural and process characteristics impacted the outcomes of full potential adoption and utilization of EHR and Telehealth functionality by either a clinics’ provider or patient. Though the dependent variables (EHR patient score, EHR provider score, Telehealth patient score, Telehealth provider score) were derived ordinal variables based on perceived impact/ utilization of EHR and telehealth, the ordinal variables were collapsed

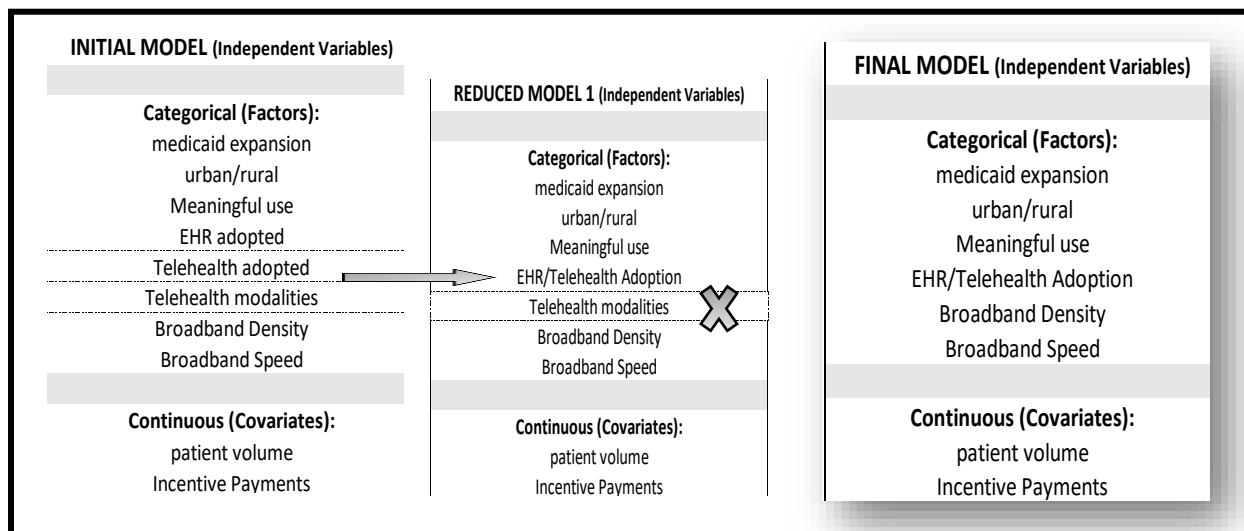
into dichotomous variables demonstrating either a high impact score (event of interest) or a low impact score due to low cell counts and errors noted during the initial model analysis. Our study's general linear model, binary logistic regression, was used to examine interaction between the independent variables to predict the 4 dependents. Using a bivariate regression, the association between the dependent variables (EHR Provider Impact Score, EHR Patient Impact Score, Telehealth Provider Impact Score and Telehealth Patient Impact Score) and characteristics representing independent variables representing the FQHCs, Broadband structure and State policies as well as overall adoption of these technologies, assisted in determining which characteristics were significantly influential for HIT adoption.

For the purpose of the model, independent variables were also collapsed based on supporting evidence from the literature and cross-tabulation analysis in SPSS noting small cell counts amongst various variables. Considering the recommended broadband speed of 25/3 mbps by the FCC <sup>84</sup> and examples of recommended bandwidth download/upload speeds for optimal EHR based on the number of practice users <sup>127</sup>, the derived categorical variables for "average broadband speed" were further collapsed from 11 variables to 3 variables where 0 = average speeds less than 25/1 mbps, 1 = average speeds between 25/3 mbps -100/100 mbps, 2 = average speeds greater than 250/3 mbps. Similarly, we replicated the methods from a similar research study by Whitacre and Williams (2014), where variables representing the number of broadband providers serving Oklahoma private practice physicians and specialty offices, were collapsed into smaller range groups. Therefore, the derived categories for the variable "broadband provider density" were reduced from 7 ranges to three categorical values where 0= 0-4, 1= 5-8,

and 2= 9+ broadband providers servicing each FQHC associated census block. Based on descriptive analysis of telehealth modalities, categories were also condensed from 7 measures into 5 categories, taking into account the individual modalities, and a clinics propensity to use more than one technology within a practice setting (0= real time, 1= store and forward, 2= RPM, 3= mHealth, 4= 1+ modalities). The variable related to Meaningful Use, was collapsed from 3 categories (Yes, No and Not sure) to 2 categories (Yes and No/Not Sure). This was done because of the results of the descriptive analysis which noted that out of 1,356 FQHCs, 1,052 answered yes, 266 reported no, and 38 respondents were not sure if their clinics participated in the meaningful use incentive program. The dependent variables for EHR Impact scores were also condensed to dichotomous ordinal values. The EHR Provider Impact Score was updated from 3 levels of 0, 1, 2; to two levels where the variable 1 = 2 impacts related to EHR Provider utilization, and 0 = less than 2 impacts. Regarding the Patient Impact score where there were originally four levels of 0,1,2,3; the values were collapsed where 1= 3 impacts related to EHR Patient utilization, and 0 =less than 2 impacts.

Model building was then done to create the best model for the included proposed data identified by the research. Based on this step, certain variables were ultimately eliminated because they did not actually influence the outcome and instead were more explanatory variables created from the combination of other primary factor variables. The original analysis on the model that included all ten variables noted from the modified Donabedian framework demonstrated multicollinearity because certain variables contained values from other variables in our models that would ultimately cause problems with estimation. Therefore, we removed variables in the original model that were

functions of variables already included in the model or we created new variables by combining different variables. Most of these variables served as a function of the EHR and telehealth adoption variables and if include could potentially dilute the effect of all associated variables or unnecessarily explain the same variations. We also noted initial “quasi-likelihood” errors” due to the potential of overstretching the data due to the inclusion of too many variables with insufficient data. We also combined the separate EHR and telehealth adoption variables and combined them into one single variable indicating the adoption of EHR, telehealth, both and neither as a missing variable. This was done to prevent accidentally excluding clinics from the analysis entirely because missing data that meant not applicable. The removed variables were still analyzed descriptively using SPSS.



**Figure 2:** Final Model (Independent Variables)

$$Y_{1a} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_k X_k$$

$$Y_{1b} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_k X_k$$

Where:

$Y_{1a}$  = EHR Provider Impact Score

$Y_{1b}$  = EHR Patient Impact Score

$Y_{1c}$  = Telehealth Provider Impact Score

$Y_{1d}$  = Telehealth Patient Impact Score

$\beta_1 X_1$  = patient volume

$\beta_2 X_2$  = rural/urban

$\beta_3 X_3$  = meaningful use (Y/N)

$\beta_4 X_4$  = adoption (EHR, Telehealth, Both, Neither)

$\beta_5 X_5$  = broadband provider density

$\beta_6 X_6$  = upload/download speed

$\beta_7 X_7$  = Medicaid expansion (Y/N)

$\beta_8 X_8$  = grant \$\$\$\$

Due to the high number of variables being used to analyze our final model, a Bonferroni multiple comparison adjustment test was performed to adjust the significant p-value of 0.05 appropriately for the 11 statistical tests in order to avoid the possibility of false positives.

Using Excel, UDS FQHC clinics no longer being evaluated due to a limited U.S. Census Bureau Tiger file, were extracted. UDS data tables and columns (Table 3A, HIT Information and Other Data Elements) needed for analysis were also extracted and merged into one file. ArcGIS was used to associate and join matching Clinical related variables associated with HIT adoption and patient volume to broadband provider and speed variables. Tabular data provided by the FCC (2018)



(<https://opendata.fcc.gov/Wireline/Fixed-Broadband-Deployment-Data-Jun-2018-Status-V1/ehbi-rr4z>) was pre-processed using Delimit Software and ArcGIS to standardize the format for input into Arc Map and spatially joined with FQHC point files that were already geocoded and joined with the 2018 US Census Bureau TIGER/Line Geodatabase: Census Blocks National Geodatabase (<https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-geodatabase-file.2018.html>) in order to create a shapefile. Maps will be created with this information demonstrating 1) upload/download speeds defined as the maximum advertised speed/bandwidth offered by the provider in the block, 2) provider/network density map defined as “Number of Wired Providers”, 3) Patient Volume by FQHC Location and 4) National FQHC Point Location Map

Through ArcGIS, a spatial layer of FQHCs and geocode clinic addresses was created. Broadband addresses were geocoded to census blocks provided by the U.S. Census Bureau TIGER/Line files. This data was then uploaded into ArcGIS and once the layer was created, sites were categorized into three adoption level groups 1) adopted EHR 2) adopted Telehealth 3) adopted both technologies. This information was used to plot points of locations meeting those specific characteristics on different national maps.

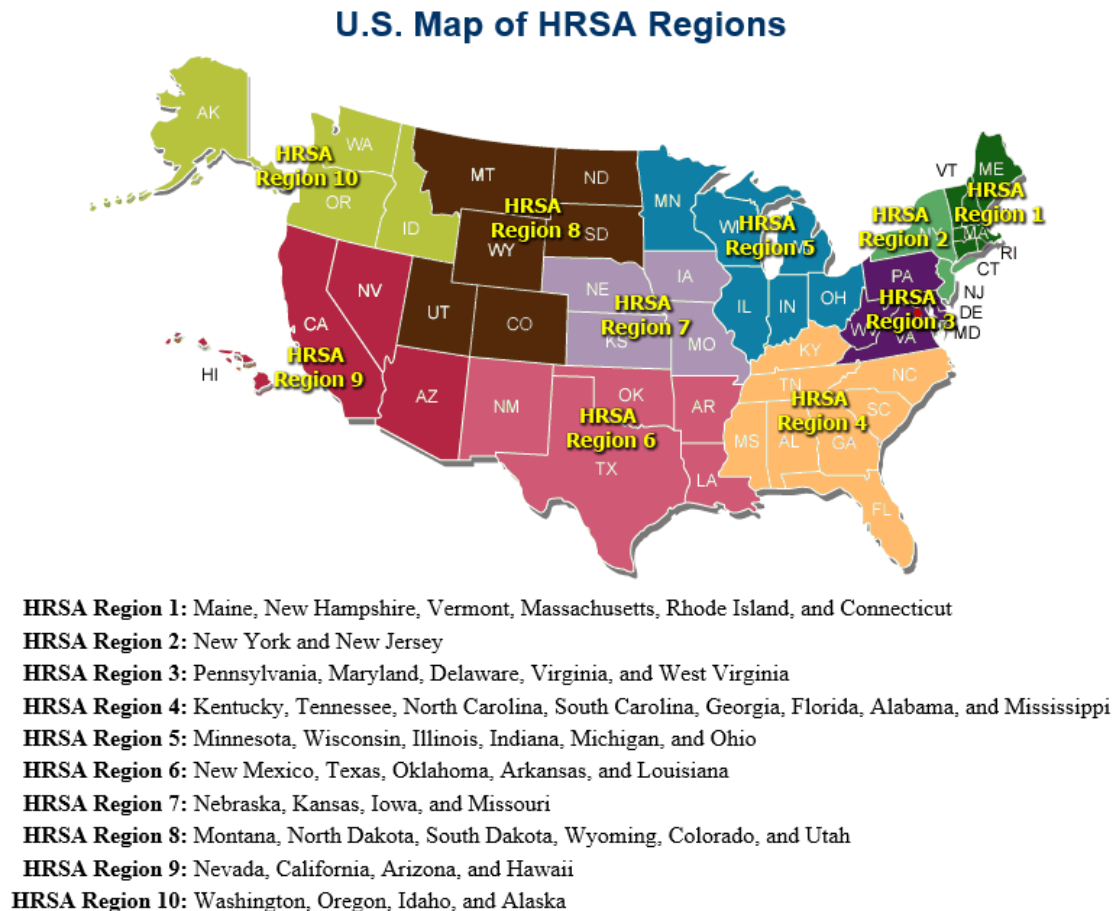
The FCC does not report broadband data at the zip code level, and instead uses census block codes related to zip code tabulation areas (ZCTAs) to approximate zip codes. Though Perzynski et al (2017) and Grubestic (2008) note limitations to using ZCTAs for spatial analysis <sup>74, 76</sup>, it has been found to be appropriate because broadband providers routinely use zip code-level data when making infrastructure decisions and evaluating research on broadband availability <sup>65, 74, 76</sup>.

To create a final spatial layer of parent organization level data on FQHCs, the updated FQHC Census Block Code file was then joined with the 2018 FCC file. In ArcGIS, these files were joined based on the GEOID and Block Code fields and once joined, the layer was exported and saved as a shapefile layer. Once block code level variables were created and extracted needed specifically to generate the maps, which is the granular level in which the FCC is reported and represented in Form 477, it was determined that representing the data on a national map was not viewable due to the very small and at times completely indistinguishable block sizes. Importantly, the FCC Broadband map, is published at the county level for this same reason. Therefore, it was decided to represent the adoption of telehealth and EHR in relationship to broadband provider density and speeds at the zip code/ZCTA level.

The first assumption and therefore limitation considered was that one zip code can contain several census block codes, therefore we needed to account for the duplicated values using Excel. We created a new excel document with all corresponding clinic codes and then created a field called “clinics” where were applied the “=count if (range, criteria)” function to count cells that meet a certain range and criteria. We saved this file as *Zip Code Data Table* and performed an “excel to table” export using ArcCatalog /ArcGIS. We then joined this file based on attributes from a table from a 2018 U.S. Zip Code file previously saved as geodatabase; keeping all matching records.

While data used for SPSS statistical analysis remained at the census block level between the FQHC and FCC datasets, zip code level data was used to spatially map in ArcGIS. Mapping at the zip code level presented a better option to spatially represent

the data, but due to the still small nature of the zip code areas associated with the multiple clinic points, it was ultimately decided to create multiple maps dividing the data maps based on the 10 designated HRSA regions <sup>136</sup>.



Source: The Data Resource Center for Child and Adolescent Health

**Figure 3:** U.S. Map of HRSA Regions

Using this combined data, maps were then generated comparing adoption of EHR and adoption of Telehealth with broadband characteristics (speed and provider density).

- 1) HRSA Regions (Speed) 1-10: base layer of broadband speed ranges and 2) second layer of geocoded clinic points differentiated by whether the clinic adopted only EHR, only Telehealth or both technologies.

2) HRSA Regions (Provider Density) 1-10: base layer of broadband service provider ranges and 2) second layer of geocoded clinic points differentiated by whether the clinic adopted only EHR, only Telehealth or both technologies.

Once we have developed our maps and have determined our best fit model based on the most significant variables from the SPSS analysis, the most significant variable chosen from the final models was used to evaluate for spatial autocorrelations using Global Moran's I. In GeoDa, a bivariate local Moran's I and bivariate global Moran's I of the two variables with x=adoption of only EHR, adoption of only Telehealth, adoption of Both, and y= FQHC patient volume. The data was weighted based on the numerical Field ID assigned to each FQHC in the data set. A soft sensitivity analysis to determine an appropriate k-nn value was also performed based on literature reviews on studies that performed Moran's I on state level U.S. national data. It was noted that most studies used only the 48 contiguous states and a k-nn between 4-8, We chose a conservative midpoint value commonly used in research, k-nn=6. A higher value than 4 was also used because several major island territories and states beyond the 48 contiguous states would benefit from the analysis and were available in the data set.

## **JOURNAL ARTICLES**

**1)** *Using HIT to Reduce Barriers in Community Health: EHR & Telehealth Utilization in Federally Qualified Health Centers: Health Affairs*

**2)** *Using Geographical Information Systems (GIS) to Examine the Association of Broadband Availability and HIT adoption within Federally Qualified Health Center: Journal of the American Informatics Association*

## **JOURNAL ARTICLE**

**Title of Journal Article:** *Using HIT to Reduce Barriers in Community Health: EHR & Telehealth Utilization in Federally Qualified Health Centers*

**Name of Journal Proposed for Article Submission:** *Health Affairs*

The passage of the Affordable Care Act (ACA) and the mandate to expand access to health care to millions of Americans has increased the strain on an already overburdened and extremely costly healthcare delivery system. At present, the current healthcare system is struggling to provide access to medical services, particularly in remote areas, to those uninsured and under-represented.

Federally Qualified Health Centers (FQHCs) provide affordable, quality, accessible and cost-effective primary health care to all, regardless of their inability to pay. These centers provide an integrated, patient-centered model of care that coordinates medical, dental, mental health, substance abuse, and patient support services <sup>1</sup>. According to the Bureau of Primary Health Care (BPHC), and data from the 2018 Uniform Data System (UDS), more than 28 million individuals, depended on a Health Resources & Services Administration (HRSA) funded health centers for affordable, accessible primary care <sup>1</sup>. Patients are seen at 12,000 service delivery sites operated by almost 1,400 FQHCs located in every state, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and the Pacific Basin <sup>1</sup>.

Health centers have also shown the potential to improve health outcomes as important safety-net providers. A 2011 study demonstrated improved health outcomes and found that Medicaid patients, whose usual source of care was a community health

center or FQHC, were almost one-third less likely to have emergency department visits, inpatient hospitalizations, or preventable hospital admissions compared to patients who primarily frequented private, fee-for-service providers <sup>3</sup>. Regarding potential ability to reduce costs through services provided, Nocon et al. (2016) found that health center patients had 24% lower spending as compared to non-health center patients across all services including specialty care, inpatient admissions and inpatient care <sup>2</sup>. Even with the unique benefits offered by FQHCs, patients continue to have difficulty accessing affordable primary care as well as broader specialty services that other patients may receive living near larger health systems and hospitals <sup>6, 15, 66</sup>.

Health information technology (HIT) may aid in bridging that access gap and serving as a cost-effective means to overcome barriers related to accessing care, particularly for communities located in rural and remote areas <sup>4-8</sup>. While the Department of Health and Human Services simply defines HIT as the “exchange of health information in an electronic environment” <sup>67</sup>, the Robert Wood Johnson Foundation uses a broader definition that will be utilized and help guide this research where HIT is “a variety of electronic methods used to manage information about people’s health and healthcare, on both the individual and group level” <sup>16</sup>. Enacted in 2009, the Health Information Technology for Economic and Clinical Health (HITECH) Act and the American Recovery and Reinvestment ACT (ARRA), promoted the adoption of health information technology by healthcare delivery organizations with the purpose of facilitating patient-centeredness and improving health care delivery, quality and cost <sup>7-8</sup>. A 2013 study found a positive association between greater HIT capacity and quality of care within FQHCs <sup>8</sup>, while Lin

et al, noted that HIT utilization among health centers, specifically telehealth, could reduce the resource gaps between urban and rural areas <sup>6</sup>.

The Bureau of Primary Health Care, which funds FQHCs, requires grant recipients and look-alike clinics to report program data annually for key measures that evaluate access, quality, outcomes and financial cost and viability through HRSA's Uniform Data System in order to monitor the program's performance and identify areas for quality improvement <sup>86</sup>. This data is reported to Congress and is evaluated against state and national benchmarks from programs and initiatives such as Healthy People 2020, Centers for Disease Control and Prevention, and the National Quality Forum <sup>87</sup>.

In 2018, the Uniform Data System identified 1,362 FQHC parent organizations in 51 states and 7 U.S. territories as well as an additional 56 look-alike centers <sup>1</sup>. These clinics are most often situated in areas of high need and low accessibility to primary care. This means that clinics are often located in isolated or rural areas. The only way to effectively achieve the goal of improved access is with HIT, specifically electronic health records and telehealth. Both technologies have been demonstrated as effective means to overcome access barriers <sup>4-10</sup>.

While these technologies can improve access, their adoption in FQHCs has not been commonly evaluated outside of research done by HRSA's Office of Quality Improvement <sup>6</sup>. In 2017, over 96% of grantees reported having an EHR installed compared to only 43% reporting telehealth utilization. There is sparse evidence identifying the barriers to uptake of adoption among FQHCs, the level of utilization by patients and providers as well as the demographic distribution of adoption of HIT and the potential for spatial clustering among Federally Qualified Health Centers (FQHCs)



across the U.S. Barriers such as rurality <sup>15</sup>, provider and patient volume size <sup>6, 15</sup>, HIT costs and grant funding <sup>27, 73</sup>, and broadband density and speed <sup>15</sup> have individually begun to take shape as significant obstacles among private practice adoption across the nation. This paper will explore whether these most noted issues similarly impact an FQHCs' adoption of health information technology.

Overall, studies examining the impacts of HIT on patient outcomes within FQHCs found that though evidence supports the potential to improve the health of underserved populations and reduce health disparities; yet, the use of HIT remains relatively low in FQHC's compared to private clinics and larger hospital systems <sup>5-6,8</sup>. Therefore, this study will:

*AIM 1)* Identify how key structural influencers at FQHCs (patient volume, urban and rural status, implementation of a meaningful use program, telehealth modality), broadband access (provider network density and upload/download speed), state level policies (grant incentive payments and Medicaid expansion) and the process of adopting EHR (2a) impact providers (clinical decision-making support and clinical information exchange) and patients (e-prescribing, patient portals and after-visit summaries) and the process of adopting telehealth (2b) impact providers (communication with specialist outside the FQHC) and patients (communication with patients at remote locations outside the FQHC).

### Health Information Technology

Due to factors such as healthcare provider shortages, increases in chronic diseases and the geriatric population, advancements in technology are necessary to improve healthcare delivery <sup>32</sup>. Health Information Technology, which is the electronic exchange of health information, has played an important role in improving outcomes and increasing access to providers while achieving population health <sup>32</sup>. HIT encompasses several processes including the patient, provider and payer utilization of electronic health records; health information exchanges across systems, industries and geography; the detection of population and public health trends as well as remote monitoring, education/training and patient consultation <sup>8, 32</sup>.

The 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act and the American Recovery and Reinvestment Act of 2009 (Recovery Act-ARRA) were signed into law primarily to increase rate of EHR adoption among eligible professionals and hospitals defined by the Centers for Medicare and Medicaid Services (CMS). Eligible professionals (EP) are defined as physicians, practitioners and therapists who are paid under or based on Medicare Physician Fee Schedules (MPFS) and utilize certified information technology throughout their practice <sup>88</sup>. Through the authorization of Medicare and Medicaid incentive payments, EPs were expected to not only adopt electronic health records but also demonstrate meaningful use in regards to quality of care and cost efficiency <sup>26, 31</sup>. Meaningful use objectives set forth by the HITECH Act include the use of certified EHR to meet core and menu requirements such as e-prescribing, computerized order entry for medication orders, clinical decisions, medication reconciliation, and providing patients with electronic access to their health

information<sup>89</sup>. The HITECH Act also provided capital contributions towards EHR systems for health centers as well as funding the Regional Extension Center Program, which provided small practices or those serving disadvantaged populations with assistance in adoption, implementation and meeting meaningful use requirements<sup>26, 53</sup>. A year later, the Affordable Care Act of 2010, emphasized the importance of health information technology through the promotion of health IT related goals tied to health care quality and efficiency<sup>7</sup>.

Research has varied as to whether these policies have had weak<sup>31</sup> or strong<sup>7, 23, 26</sup> impacts on motivating healthcare providers to adopt health information technology. Vest and Gamm (2010) found that though policies such as HITECH and grant funding may have helped with the initial adoption of HIT, the benefits of adoption and implementation primarily carries over to patients and their communities and less to providers<sup>69</sup>. These researchers believed that current policies related to HIT excluded providers in certain professional areas, restricted exchanges to specific subpopulations due to the competitive nature of health care entities and limited availability of data elements<sup>69</sup>.

Burt and Sisk (2005) examined the relationships between HIT, physicians and practice characteristics<sup>73</sup>. While exploring practice size as measured by the number of physicians instead of number of patients or encounters, they found that “larger practices” were more likely to implement HIT than smaller practices due to their ability to spread the investment over more providers and services<sup>73</sup>. While the authors in the study were not able to obtain the number of patients seen in the individual practices by using National

Ambulatory Medical Care Survey (NAMCS) data <sup>73</sup>, the UDS allows for the capturing of such numbers.

### Electronic Health Records (EHRs)

Technology has been shown to promote better patient care and quality among the populations seeking care at FQHCs<sup>8</sup>, though much of the research has focused on the impact of EHRs <sup>22, 27</sup>. Frimpong et al (2013), found that an increased adoption and utilization of HIT increased the patient's perception of improved quality of care <sup>8</sup>. In their study, FQHCs were classified as either low, medium or high HIT capacity and survey variables supporting HIT capacity were defined by EHR-specific functionalities corresponding to the HITECH meaningful use objectives<sup>8</sup>. HIT capacity was considered high when clinics utilized functionalities such as decision-support, patient reminders, timely appointments made for specialist care and discharge summaries <sup>8</sup>.

Similar studies have also found that HIT demonstrated quality benefits using e-prescriptions, reminders and messaging functions <sup>21</sup>. The overall utilization of EHRs also demonstrated benefits associated with quality and efficiency by improving the organization of data, availability of progress notes and legibility of clinician notes. Increased use of EHRs also provided financial benefits and quality improvements when EHR documentation and care management was also analyzed <sup>27</sup>. Miller and Sim also noted that clinics utilizing basic electronic messaging improved the “availability, timeliness and accuracy of messages reducing dropped balls and safety problems” <sup>27</sup>. Advanced messaging has improved the coordination of care with outside providers increasing interoperability, and with patients in order to improve compliance and

promote better self-care <sup>24, 25, 27</sup>. Studies have also identified a correlation between HIT use service delivery and quality of care <sup>8, 20, 27</sup>. Utilization of HIT has also resulted in improved process measures <sup>8</sup>. Health Information Systems such as EHRs have been shown to improve clinical processes, and workflows, therefore reducing medication errors and resulting in quality improvement <sup>22</sup>. Implementation of HIT resulted in more advanced decision support through the electronic transmission of prescriptions and lab tests <sup>27</sup>. Though over 98% of FQHC reported having EHRs in place in a 2017 UDS study <sup>6</sup>, not all utilize them for patient services. This study will address the gap by looking at utilization of HIT that impact both patients and providers directly.

### Telehealth

Among research related to telehealth utilization, studies found that both patients and clinics benefitted from the increased use of telehealth <sup>6, 32</sup>. The American Telemedicine Association (ATA) defines “telehealth” as a broader encompassing term related to the remote provision of healthcare that includes patient care, education and monitoring <sup>48, 49</sup>. Telemedicine is described as the use of electronic communications to exchange health information from one site to another to improve patient health <sup>48</sup>. HRSA defines telehealth similarly as the “the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health and health administration” <sup>109</sup>. Researchers have used the terms interchangeably, however while telehealth characteristically refers to the comprehensive range of electronic health related services including “remote non-clinical services such as provider training, administrative meetings

and continuing medication education, in addition to clinical services”<sup>90</sup>, telemedicine specifically refers to remote clinical services<sup>48</sup>. Telemedicine services utilize current staff and have been shown to serve as a potential solution to alleviate shortages of health care providers through remote consultations by providers and nurses in other states and countries<sup>32</sup>. Telehealth raises the responsibility level of patients by empowering them to be more involved in their health and by allowing them the convenience of easier access to their primary care providers and specialists<sup>6, 32</sup>. The electronic sharing of images and consultations by video, also allows for a quicker turn-around in response to rarer health conditions with experts outside of the provider practice. This benefit allows public health providers and governments to make faster and better decisions regarding population potentially at risk<sup>32</sup>.

For the purposes of this study, the Health Resources Services Administration (HRSA) has specifically defined and differentiated telehealth from telemedicine due to its broader scope<sup>109</sup>. The Uniform Data System defines these utilizations of technology as “Telehealth” and captures this information in order to acknowledge the comprehensive nature of health centers and the methods used to expand services and improve their delivery of health care<sup>90</sup>. Similar to the use of this definition, Lin et al (2018), specifically analyzed key adoption factors, barriers and opportunities of telehealth in health centers. Our research will go further by exploring organizational factors, including FQHC structure, state and federal policies as well as broadband in determining potential barriers to adoption as well as exploring provider and patient impact, variables not available in the previous 2017 iteration of the UDS<sup>6</sup>.

### Barriers to HIT

There are barriers to adoption of HIT observed in the literature such as disparities in income of health care patients in addition to disparities in region and health center size<sup>9, 53</sup>. Literature supports the assertions that the lack of capital, dependence on public financing and lack of infrastructure contribute to a lower adoption rate of these telehealth services<sup>5, 53</sup>. While evaluating health information technology and clinical benefits and barriers within physician practices, an earlier study reported that the achievement of quality improvement and financial benefits were associated with ensuring that the greatest number of providers utilize an EHR engaging in as many functionalities and tasks as possible<sup>27</sup>. This study also discovered that smaller practice sizes were associated with lower levels of adoption and implementation<sup>27</sup>. Smaller and solo practices were required to utilize more internal clinical staff and “physician champions” to help with associated HIT support such as installation, implementation and training, while also providing technical support when problems occurred<sup>27</sup>. Larger practices tended to have stronger organizational resources, which led to more internal technical support staff to assist with developing workflow and process changes, financial resources and HIT support staff<sup>27</sup>.

For FQHCs to adopt EHRs and telehealth, there must be enough internet bandwidth for their systems to optimally function, but there is no research that specifies what speeds must be within these centers. The Federal Communication Commission officially defines broadband as a minimum of 25 mbps download and 3 mbps upload, a definition recently updated from a 2010 standard of 4 mbps download and 1 mbps upload due to the advancements in technology and increased consumer demands<sup>84</sup>. Access to telecommunication services in the US has demonstrated early disparities and gaps<sup>64</sup>.

Smaller and more rural areas experienced higher premiums and long-distance charges for accessing Internet services due to the lack of adequate network presences <sup>64</sup>. And even as the newer generation of broadband developed in the late 1990s, the debate between access, and equity of services continued to emerge <sup>64</sup>. Broadband providers tend to be influenced geographically and socially, infiltrating areas with more profitable markets that exhibited higher returns on investment <sup>64</sup>. Interestingly to this point, the American Medical Informatics Association (AMIA) has acknowledged 'broadband internet service' as a social determinant of health arguing that the FCC should consider the "specific challenges related to inadequate access to affordable and consistent high-speed internet faced by vulnerable and underserved group attempting to access digital communications for health-related purposes" <sup>129</sup> But there is little to no research specifically delineating what specific broadband speeds FQHCs need to access and optimally utilize EHR, Telehealth system or both <sup>65</sup>. .

Since the implementation of the HITECH and ARRA, and the emphasis on meaningful use and expanding access and quality, health care providers in primarily small practices frequently cited financial reasons as barriers to adoption of EHR <sup>53, 118</sup>. indicating barriers such as "high start-up costs, lack of capital, concern that a system would soon become obsolete and a lack of adequate and reliable information about return on investment <sup>118</sup>. Providers in practices that primarily serve underserved and underrepresented populations, also cited clinical productivity and the uncertainty of the diverse costs associated with implementation as well <sup>118</sup>.

. The Department of Health and Human Services has therefore provided incentives and increased funding through the Federal Office of Rural Health Policy and



HRSA-funded Regional Telehealth Resource Centers which provide technical assistance supporting telehealth program development in critical areas that lack access to health care services, including specialty care. Funding has now led to supporting HRSA grantees in the implementation of “internet technical assistance, provider-to-provider (patient-to-provider) videoconferencing, store-and-forward diagnostic imaging as well as streaming media and closed-circuit communications through regional and national telehealth hubs” <sup>123</sup>.

But even with federal incentive programs supporting and funding adoption of HIT, 2018 research examining factors associated with telehealth within federally qualified health centers using 2016 UDS data found cost and technical issues as major barriers to adopting Telehealth, along with rurality, reimbursement policies and operational factors <sup>6</sup>. UDS reported data includes cost related area related to HIT/EHR system development and analysis, supplies and equipment but is not publicly available, listing this section of the Reporting Handbook as proprietary <sup>79,106</sup>. In 2017, only 117 FQHCs out of a total of 1,373 FQHCs reported data on costs associated with HIT/EHR implementation <sup>79,106</sup>. Therefore, due to the limited data reported and publicly available, cost in relation to technology adoption as a barrier to implementation is considered outside of what this study can address.

### Conceptual Model

Several models for telehealth implementation and evaluation exist in literature. The Institute of Medicine and Donabedian frameworks have served as “gold standards” for the development of evaluation and implementation HIT models <sup>60,61</sup>. These frameworks

have specifically guided research concerning issues of quality, accessibility, cost and acceptability of clinical telehealth <sup>61</sup>.

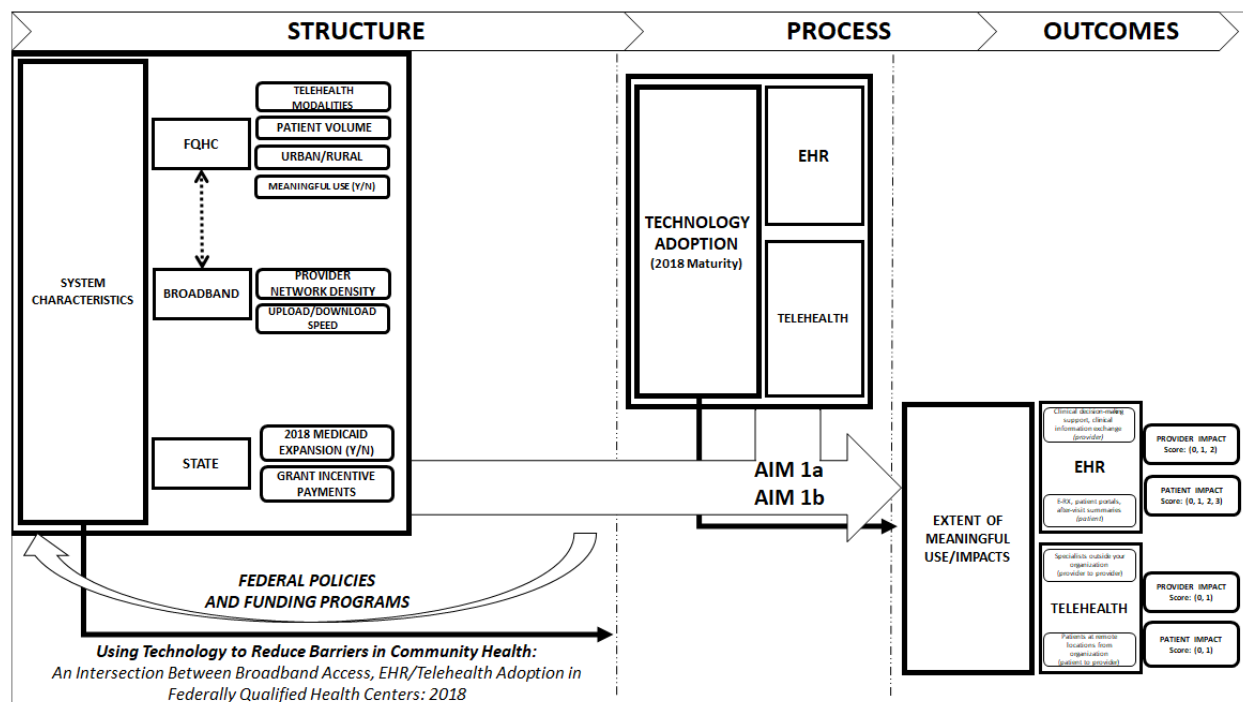


Figure 4: Adapted Donabedian Framework: AIM 1

The Donabedian Framework conceptualizes any health service as having three components, structure, (inputs), process (outputs) and outcomes <sup>63</sup>. Herbert et al. proposed a telehealth framework that expanded upon Donabedian <sup>60</sup>. The purpose of this modified framework was to “begin development of a body of knowledge around telehealth and to identify influential relationships among the success variables defined for telehealth” <sup>60</sup>. DeLone and McLean developed a Donabedian-influenced framework that considered structure measures with accessibility, availability, and quality of resources; process measures with delivery of health care services by clinicians and providers through system use and user satisfaction, and outcome measures with individual and organization impact

In this study, the Donabedian model will be adapted to develop a conceptual model (Figure 4) to analyze barriers of EHR and Telehealth adoption and resulting physician and patient impacts based on adoption of these technologies. Independent variables were included based on a review of existing literature as well as original contributions based on variables not previously examined.

### Public Health Significance

This research is important to public health as it addresses access to care in a period where an expanded population needs healthcare resources. FQHCs provide healthcare access to the underserved, and with more health information technology, these safety net clinics could better serve this population. Specifically, health centers have shown the potential to improve health outcomes as important safety-net providers<sup>3</sup> as well as lower overall spending when compared to non-health center patients<sup>2</sup>. Technology has been shown to promote better patient care and quality among patients using FQHC services<sup>8, 22, 27</sup> while also raising the accountability and patient involvement by empowering them to be more involved in their own health care<sup>6, 32</sup>.

This research will also inform policy and promote the meaningful use and utilization of health technologies to improve access and quality of care, an understanding of the distribution of broadband speeds and providers impact on FQHCs' adoption of telehealth and EHR. This will help direct federal and state funds towards improving the technical infrastructure in low adopting areas through spatial analysis of adoption. This work will potentially influence FCC policies on broadband fund allocations to ensure enough speed

is available where needed as well show characteristics of FQHCs, which will more readily adoption technology and for what primary uses.

Key factors such as the patient volume, rural/urban designation and broadband availability may have the potential to impact and inform adoption of HIT among health centers, therefore inciting changes in policy that emphasize structural and community factors rather than dollars to affect change that can benefit underserved populations.

## **RESULTS**

### *Structure*

**System Characteristics-FQHCs:** Table 4a and 4b presents a summary of the structural characteristics noted in literature that may possibly influence adoption of EHR or Telehealth and impact utilization by either patients or providers. On average, nearly 21,000 patients visited an FQHC in 2018 and more than half of these clinics were classified as urban (55.3%) with 44.7% parent organizations designated as rural. Among the 1,356 health centers surveyed 77.6% (1,052) participated in the CMS EHR Incentive Program, commonly known as meaningful use which contributes to that fact HITECH investments may have contributed to the adoption of health technology and specifically EHR. Of the 584 clinics that utilized Telehealth services, most of the sites (32.2%) relied on real-time (videoconferencing) modalities with the next highest utilization of a single modality occurred in 4.4% of the sites using store-and -forward

telehealth to communicate electronically. Importantly, over 5% of the clinics utilized 2 or more different modalities within their organizations.

**System Characteristics-Broadband (FCC):** Regarding broadband variables of interest, the FCC reported that more than half of the census block codes containing clinics had 7 or more broadband providers and companies servicing their areas with only 1 clinic reporting that their areas had no broadband service providers. Average Upload and download speeds varied, but the highest speed ranges noted among clinic sampled in the study was around 100/3 mbps-100/10 mbps, (30.1%), well above the recommended speeds identified by the FCC, needed to sustain telecommunications. More importantly 1,332 of the 1,354 clinics reported speeds well above 25/3 mbps servicing the area near and around their parent sites.

**System Characteristics-State:** Based on the review of previous research, state policy was believed to influence, and drive adoption of health technologies and it was shown that in 2018 70.6% of the health centers were located in a Medicaid Expansion state. As noted by research by Lin et al, state level policies had the potential to impact a clinics investment in health technologies such as Telehealth. On average, approximately \$60,150 grant dollars were distributed to FQHCs in 2018, with the highest payment equaling to over \$2.5 million.

### *Process*

**Adoption of EHR and Telehealth:** HIT characteristics related to adoption was noted in Table 5. In 2018, 99.6% (1,351) FQHCs reported that they had adopted EHR while only

43.1% (584) health centers reported adopting telehealth in the same UDS reporting year, resulting in almost 60% of the health centers not utilizing telehealth related services and modalities to provide remote clinical care services.

### *Outcomes*

**EHR Outcomes-Provider Impact:** EHR outcomes related to clinicians were based on sites reporting “yes” to utilizing specific functionalities to facilitate care such as clinical decision-making support and clinical information exchange (Table 6). 98.4% (1334) of the reporting clinics noted that an EHR was used to computerized, clinical decision support such as drug allergy alerts, checks for drug-drug interactions and reminders for preventive screening tests within their organizations. Providers’ utilization of electronic clinic information exchange between other providers and health care settings, was ~~utilized~~ demonstrated in 84.1% (1,141) of the FQHC population, while 15.5% (220) reported that they either did not use this function or were not sure if their system was capable to perform it at all. EHR Impact scores were described in Table 8, noting that of the 1,356 health centers, 83.4% reported the highest impact of utilization at a score of 2, utilizing all functionalities related to providers optimal use of their EHR.

**EHR Outcomes-Patient Impact:** Table 6 describes outcomes related to patient were based on variables related to e-prescribing, patient portal use and after visit summaries. Over 90% of the population reported that these functions were utilized fully within their parent locations, with 98.5% (1,335) of the clinics using e-prescriptions, 93.0% (1,261) of the sites reported engaging patient portals and kiosks or secure messaging thorough the EHR to patients, and 97.1% (1,316) provided patients with electronic summaries of

office encounter when requested. Similarly, 90.9% (1233) of reporting clinics reported optimal utilization of all EHR Patient relation functionalities, with a derived impact score of a 3, with 101 (7.4%) noting that they used 2 out of 3 functionalities related to EHR patient communication and clinical care (Table 8).

**Telehealth Outcomes-Provider Impact and Score:** Table 7 summarizes the telehealth outcomes characteristics related to provider impact and utilization. Of the 584 total FQHCs who adopted telehealth, 19.9% (270) of the FQHC providers reported that telehealth technologies were used to communicate with specialists out of their organization such as specialists at referral centers. And based on the cumulative “yes” responses related to 25.7% (349) of the total telehealth adopting sites reported utilizing the clinics telehealth benefiting providers and clinicians’ communication to the fullest extent (Table 9).

**Telehealth Outcomes-Patient Impact and Score:** In 2018, 235 reported utilization of provider to patient telehealth functions by communicating with patient at remote locations from the organizations, such as through home telehealth, and satellite location (Table 7). The patient impact scores related to this variable also showed that out of 584 clinics, 23.2% (3,114) score optimally noting full impacts of this technology benefiting the patients seen in the clinic (Table 9).

### *EHR Impacts and Associations*

**EHR Provider Impact Score Analysis:** FQHCs with higher patient volumes ( $p < 0.007$ ), and CMS EHR grant incentive payments ( $p < 0.008$ ), were significantly more likely to have

a high EHR Provider Impact Score , while the clinics who were not eligible for the meaningful use program were less likely (0.000) to have providers fully utilize the EHR for computerized clinical decision support (alerts for drug allergies, checks for drug-drug interactions and preventative screening reminders) and clinical information exchange with other providers/health care settings such as hospitals, emergency rooms or specialties (Table 10) . The odds ratio for patient volume (OR = 2.18) demonstrated that there was a 118% increase in the odds of a clinic with a higher patient volume having providers fully utilizing their EHR for these functions compared to a clinic with a lower patient volume. Meaningful use (OR=0.48) demonstrated that clinic sites who answered no/not sure for having all providers eligible for the meaningful use program had less than a 50% decrease in the odds of having providers fully utilizing their EHR compared to clinics who answered yes. Grant incentives had an odds ratio slightly greater than 1 (OR = 1.00000443), which meant, cumulatively, the higher the payment the higher the odds of a provider fully utilizing their EHR.

**EHR Patient Impact Score Analysis:** FQHC characteristics such as patient volume ( $p < 0.001$ ), and meaningful use ( $p < 0.000$ ), as well as state level variables related to grant incentive payments ( $p < 0.002$ ), were also statistically related to a significant impact on a clinics utilization of patient related EHR functions (Table 11). While Meaningful use had positive associations with full EHR-patient related utilization (OR = 2.5), patient volume (0.999335) and grant incentive payments (0.973404) had a negative impact in regards to a clinics use of their EHR for e-prescription, patient portals, and, after visit summaries. EHR regression analysis results demonstrated little impact in full utilization



of provider or patient functions when rurality, broadband and Medicaid expansion were considered.

### *Telehealth Impacts and Associations*

**Telehealth Provider Impact Score Analysis:** Health centers with higher volumes were significantly more likely to fully utilize their telehealth technology to communicate with providers and clinicians outside of their facility (Table 12).

**Telehealth Patient Impact Score Analysis:** Inverse results were determined when analyzing Telehealth Provider Impact Scores. We found that health centers with higher volumes were significantly less likely to fully utilize their telehealth technology to communicate with patients outside of their facility as well (Table 13).

## **DISCUSSION**

The purpose of our research was to identify how structural influences within FQHCs, broadband infrastructure and state level policy and incentives as well as the process of adopting EHR and telehealth, increased the likelihood of fully utilizing pre-surveyed functionalities of these technologies, as recognized by the 2018 HRSA UDS, ultimately impacting the health care within the nation's federally qualified health centers. Understanding key factors related to full adoption and implementation of health communications, provides benefits to health center providers and patients, expanding the overall goal of realizing and achieving outcomes related to improved access and overall population health to underserved and underrepresented populations frequented

in the U.S health centers funded under the Bureau of Primary Health Care and HRSA in 2018.

#### EHR Provider-Related Impacts

In 2018, the three variables with significant p-values ( $\leq 0.05$ ) that most influenced a clinic's utilization of their EHR for provider related impacts such as clinical decision-making support and clinical information exchange were patient volume, meaningful use program eligibility and grant incentive payments. Patient volume and grant incentive payments demonstrated a positive influence associated with a provider's motivation to utilize their EHR. Possibly, as the patient volume increases, the more likely a clinician would depend on using the EHR functions to make clinical decisions due to the burden of keeping up with clinic workflows, compared to a provider working in a smaller practice with less of a demand on their time. Similar research noted that clinicians in larger practices had higher odds of participating in health information exchanges compared to solo and smaller practices but noted that providers in community health centers such as FQHCs, had significantly lower odds compared to these larger practices <sup>140</sup>. This trend was similarly noted regarding grant incentive payments, which noted that for every dollar more the clinic received in grants, the odds increased that their clinicians and staff would utilize provider related functions. Since grant incentives are tied to meaningful use, this aligns with the incentive of being an eligible provider through the CMS EHR grant program and the value-based model of care that is driving much of health care. Though referencing private practices and institutions, this finding contradicts a study by Gold et. al (2012) where they found that grant funding had not been found to be viable alternatives to

revenue streams involving the utilization of HIT due to the costly nature of its management

26.

Regarding the meaningful use variable, health centers who answered “no” identifying that their clinics lacked eligible providers who participated in the Centers for Medicare and Medicaid Services (CMS) EHR incentive program known as Meaningful Use, were significantly less than 50% likely to have providers who fully utilize provider related EHR functions. Functional EHR requirements related to meaningful use include the use of computerized provider order entry (CPOE) such as medications, labs, imaging and referrals, clinical decision making, medications reconciliation, and medication reconciliation <sup>141</sup>. In this case, there is less of an incentive for these clinicians to utilize their technology. Even though a clinic may have an EHR system implemented, their system may not be certified demonstrating that their EHR has been used in ways that can be significantly measured and quantified. Meaningful use eligibility requires certification and program attestation and for those clinics that lacked providers who qualified, it would make sense for their utilization of EHR to its full capability to be decreased. Their providers may also not be qualified under CMS as eligible providers enrolled the Incentive program, meaning that they have not completed the attestation certification process to allow for incentive payments. On a state level, Kim et al (2015) noted that while more than half of California’s clinical practices had implemented EHRs, most community health centers, such as FQHCs, engaged in EHR interoperability only after the introduction of HITECH and meaningful use incentives <sup>142</sup>.

## EHR Patient-Related Impacts

Comparably, the three variables with significant p-values ( $\leq 0.05$ ) that most impacted a provider's utilization of their EHR for functionalities directly benefiting the care delivery of a patient (e-prescribing, patient portals, and after-visit summaries) were also patient volume, meaningful use program eligibility and grant incentive payments. But while patient volume and grant incentives positively motivated a provider to use ~~provider-related~~provider related EHR capabilities, these variables negatively influenced a provider from using patient benefiting functions.

When examining a clinics' motivation to utilize patient related EHR functions, it was noted that the higher the patient volume, the less likely the clinic would utilize their direct ~~patient-related~~patient related EHR capabilities. This could be because if there was a higher patient volume at a clinic, the large practices would have the need and, in some instances, the funding for more FTEs to support the demand of clients. These clinics usually have nurse educators, more providers and support staff, to provide enough of the education and the resources needed so that the providers had better opportunities to provide these related services to their patients through the course of their clinic encounter and experience. In many cases, while orders may be placed by a provider, an exit nurse may complete these pending orders, so that a provider may continue seeing patients. An exit nurse is sometimes available to provide the necessary discharge paperwork, print out after-visit summaries, answer questions, and provide general patient education. In this case, it would be up to the clinical staff to continue to advocate for the patient's involvement in their clinical care and access these functions remotely as needed, especially at times when a patient may have follow up questions, access to a patient

portal may assist in supporting patients' concerns outside of the clinic hours. These results contradicted similar state-based research noting that patient engagement, specifically utilizing the EHR for electronic after-visit summaries, was 2.45 times more likely in larger multi-site centers <sup>142</sup>. A 2017 study noted that productivity challenges of providers related to "increased patient loads, increased clerical burdens" impacted EHR utilization <sup>143</sup>.

The higher the grant incentive payment, the less likely, the clinic was also to utilize their EHR to support patient related functions, which could also be related to the clinic's ability to higher more support staff to support the needs of their patient population, leading to less of a reliance on technology by these patients.

Clinics who were not eligible for meaningful use were more than 2.5x more likely to have providers fully utilizing their EHR for patient related functions. There was little to no evidence to support this finding but could be related to the limitation of the data set to report specific satellite clinic data noting some providers who are eligible for the meaningful use program. While the survey reported whether a clinic had 1) no providers..., 2) some providers..., 3) all providers... or were 4) not sure of providers participating in the meaningful use incentive program, this data was still aggregated to the parent organization level and could ultimately be underrepresenting the accurate count of meaningful use eligible clinicians and therefore patient related utilization.

Clinics that answered "no" to meaningful use eligibility were significantly more likely to utilize EHR functions that impacted patients. Therefore, though the patient related functions of EHR are requirements for certifications of EHRs and demonstration of Meaningful use, they alone are not enough to qualify for the Incentive Program.

Research demonstrated that obtaining meaningful use, would require changes to future information clinical systems and a culture change for many established clinicians and practices <sup>141</sup>. Carman et al (2013) noted that patient engagement with EHR were established by the clinician and staff, and were ultimately, related to a patient's motivation, knowledge and education level, attitude and their beliefs about the patient's role, experience within the health care system, health literacy, and health status <sup>138</sup>. This supports the idea that patients were more likely to feel the need to engage and find answers regarding their own health through technology.

#### Telehealth Provider-Related Impacts

Variables that ultimately influenced a providers' utilization of their telehealth to communicate with outside providers at referral centers was significantly associated with patient volume in that the higher the patient volume the odds increase that the clinician would prefer to utilize their technology to consult with providers. This would be supported by the idea that the higher the case load the more the possibility of complicated patients and since most FQHCs offer primary care services to uninsured and underserved populations, the providers would benefit from accessing expertise outside of their facilities.

#### Telehealth Patient-Related Impacts

Patient volume also impacted a clinics' utilization of their telehealth to communicate with patients at remote locations from the organization. Inversely, as the patient volume increase, the probability of the provider to use their telehealth for this

function decreased by 65%. Not surprisingly, the more volume a clinic has, the less time a provider may have to communicate or consult with the patient directly. And this could also be applicable on the account of the patient. Since a higher volume in the clinic would detract a provider from potentially engaging in telehealth to communicate with patients, the patient is more likely to choose to instead not engage in telehealth communications and walk into the clinic instead. Therefore, the burden is on the clinic and the administrators to encourage dedicated clinic time towards, telehealth communications with patients especially in rural areas and locations where more vulnerable and elderly patients access care.

In summary, while several characteristics, such as CMS grant incentives and meaningful use, were identified as significant factors influencing full utilization of health technology within health centers, only the variable related to patient volume, our indicator of clinic size, was found to impact both EHR and telehealth utilization by providers as well as patients within 2018 reporting FQHCs. Specifically, as the number of patients within a clinic increased, the odds increased that the clinic would utilize EHR and Telehealth provider functions at the highest impact scores, demonstrating that the higher patient counts may account for how likely a provider is to use technology to complete tasks. This could be due to the fact that the more patients a clinic has, the more unlikely a provider is to be able to interact with every patient, to provide counseling and provide management, therefore would be more dependent on communicating through EHR or access outside provider assistance for consulting purposes. Studies supporting this theory note that providers in larger practices had higher rates of not only adopting but also using EHR capabilities to engage patients. They found that this was also due to

greater access to financial resources that supported managerial and IT oversight and a stronger infrastructure <sup>73, 137</sup>. Ultimately research showed that “without successful integration of HIT into clinical workflow, clinicians in ambulatory settings will continue to resist adoption and implementation of the technology” <sup>143</sup>.

As was noted in a similar study and evaluation of potential barriers to HIT adoption <sup>6</sup>, broadband characteristics had no impact on utilization of these technologies and though not statistically significant, demonstrated trends towards the notion that high speeds were not necessary for adoption, but instead average FCC recommended speeds of at least 25/3 mbps were enough to sustain health telecommunications. Based on this research, broadband provider density and speed did not explain enough of the variation to be significant and could be because there may not be enough data to properly detect and predict our dependent outcomes. Similarly, metropolitan status related to rurality, demonstrated a p-value (0.069) trending towards significance but due to the possibility that this study is an observational study, future research should examine these variables closer by conducting an experimental study to assess causation.

Among the variables identified potentially impacting the adoption of EHR and telehealth, factors related to patient volume and policy related financial incentives ultimately impacted the utilization of technology at the highest level. The problem is therefore more related to clinic capacity and the lack of financial support for sustaining technology.

**Strengths:** Ultimately the purpose of this research was not to evaluate population data and evaluate improvements in the overall health of FQHC patients, but instead to evaluate the technological tools that have the potential to improve the health of this



specific population of patients. While other studies have focused on clinical outcomes such as diagnosis and mortality in relation to the adoption of HIT, our study focused on those processes that may influence national policy changes related to adoption.

We ultimately examined intermediate processes impacting the usefulness of technology in healthcare due to the fact the adoption of health technology is inevitable. As healthcare needs change and the population becomes older, the costs associated with providing care will continue to strain our healthcare system. But the adoption of EHR and telehealth does not necessarily correlate with full utilization of all meaningful functionalities of that technology. Therefore, our aim was to go a step further than an analysis of adoption trends among FQHCs and instead to examine variables identified by past research, representing influencers of adoption, and their impact on a health centers' utilization of their adopted technologies. Another contribution of this paper was to document how different structural components of FQHCs including internal and external influences can influence EHR and telehealth adoption compared to other analysis that noted self-reported reasons as to the lack of adoption of HIT within their centers <sup>6</sup>.

**Limitations:** Although this study provides a contribution towards understanding the adoption patterns of HIT by comparing influential structural variables across the US, there are several limitations regarding utilizing the UDS and FCC datasets.

**UDS:** The UDS data is self-reported by individual health centers at the parent organization level. Critical variables that may potentially allow for an analysis of the structure of individual organizations are collapsed and not available at the parent-organizational level. Therefore, future UDS modernization efforts and research should

focus on sources of patient-level data within FQHCs, currently there is no data available reflecting this unit of analysis outside of the Health Center Patient Survey (HCPS: 2014) which does not capture the same variables as the UDS.

Our study also has a limitation when including a single urban or rural designation for health center organizations even if some of the satellite delivery sites may not be in rural areas. This potential discrepancy is likely to be a consequence of variations in definitions of rural and urban designation. Whitacre and Williams (2014) evaluated EMR adoption and measured rurality by using street addresses to define rurality at the county level. Though their study was limited to the state of Oklahoma, they categorized physician offices located within a Metropolitan Statistical Area (MSA) that consisted of a community of a population of 50,000 or greater as urban <sup>15</sup>. Therefore, future research using UDS should be evaluated rurality using street addresses rather than self-reported data.

**FCC:** Broadband data itself has been criticized for several reasons. According to the FCC, the choice of specific broadband technology may depend on factors that include whether a facility is in a rural or urban area, how the broadband is packaged with other services such as phone, price and availability <sup>83</sup>. The UDS ask specifically if the individual parent organization has an Office of the National Coordinator (ONC) for Health IT EHR, as well as the name of the vendor, but does not go into detail regarding the specific broadband technology available to the facility that may ultimately impact connectivity. There is also limited data regarding where exactly within a ZIP code, broadband is available therefore demonstrating a lack of geographic specificity <sup>81</sup>. Other critiques include that there have been “measurement errors and sample selection bias”

that have contributed to some overestimation of a carriers service area <sup>100</sup>. Ultimately, as noted in a similar research study analyzing broadband availability and EMR adoption on the state level, this data had improved significantly from earlier efforts to document broadband provision and it served as the best available data set representing this information <sup>15</sup>.

**Future Studies and Policy Implications:** Subsequent research should focus on evaluating the impact of patient mix within FQHCs and that clinics' incentives to adopt HIT. It would be beneficial to explore the influences potential payor reimbursements would have on HIT utilization as well as the impact of state and federal policies on the patient mix. Due to limitations of the data set, the patient mix variable is associated at the parent organization level and may not necessarily reflect the mix at the satellite site clinics.

And because the UDS also requires the reporting of health outcomes related to prenatal care, hypertension, and Diabetes, future research can then examine how significant variables associated with higher levels of patient and provider utilization impact final health outcomes in this patient population. The question would focus on whether higher utilization Impact Score are associated with better outcomes, or if a clinic can minimally utilize their health technology and continue to have positive outcomes.

A more robust comparative study should also be done on several aspects of this research in the future, once the UDS is modernized and site level data has been included. Follow up studies can also analyze potential patient volume threshold where it

is determined at what volume does adoption usually occur for EHR and telehealth. But volume can easily be increased in more urban areas, but rural areas with limited access and patients possibly living many miles away, have a limitation in that volume does not usually change drastically over time. How does a business justify the expense and staffing support and overall maintenance of technology for ~100 patients per year? Future research can also focus on a time and trend analysis on changes in patient volume and the level of utilization over time, ultimately determining if growth in clinic volume over time led to adoption and full utilization or does the initial investment of adoption cause substantial growths in patient volume.

Policies and laws can assist low volume clinics by changing how technologies are reimbursed. If telehealth modalities are incentivized, though the volume of patients actively being encountered in the clinic may not change, “virtual visits”, a new measure being captured in the 2019 UDS survey, can indirectly increase volume in an otherwise limited growth environment, while improving care and access. Therefore, models such as Project ECHO Telehealth and OCHIN EHR Collaboratives, serve as linkages where multiple FQHCs can utilize the same platforms creating network models rather than a single clinic adoption model especially in low volume areas.

## **CONCLUSION**

This research is important to public health as it addresses access to care in a period where an expanded population needs healthcare resources. FQHCs provide healthcare access to the underserved, and with more health information technology, these safety net clinics could better serve them through the provision of accessible primary care where upstream disease management can occur. Future research and

policy might focus on addressing implementation barriers and specifically research on design and implementation of successful telehealth programs. Research on barriers and overcoming them would help increase the understanding of the unique needs of the health center populations. This study shows that health centers play vital roles in providing quality care to a wide variety of patients and through the adoption of telehealth, serve as access points for high quality and accessible health care.

Table 4a: **Structural** Characteristics and Descriptive Statistics for *Categorical* Variables

<b>STRUCTURE: System Characteristics of FQHCs, Broadband and State-Level Policies/Incentives [CATEGORICAL]</b>					
	<b>N</b>	<b>Frequency</b>	<b>Percentage %</b>	<b>Missing</b>	<b>Missing %</b>
<b>FQHC Characteristics</b>					
<b>Telehealth Modality</b>	<b>584</b>			<b>772</b>	<b>56.9%</b>
Real-Time telehealth		436	32.2%		
Store-and-Forward telehealth		59	4.4%		
Remote Patient Monitoring		7	0.5%		
Mobile-Health		4	0.3%		
2 Modalities		63	4.6%		
3 Modalities		12	0.9%		
4 Modalities		3	0.2%		
<b>Patient volume</b>					
<b>Metropolitan Status</b>	<b>1356</b>			<b>0</b>	<b>0</b>
Rural		606	44.7%		
Urban		750	55.3%		
<b>Meaningful Use</b>	<b>1356</b>			<b>0</b>	<b>0</b>
Yes		1052	77.6%		
No		266	19.6%		
Not sure		38	2.8%		
<b>Broadband Characteristics</b>					
<b>Provider Network Density</b>	<b>1356</b>			<b>0</b>	<b>0</b>
0		1	0.1%		
1-2		3	0.2%		
3-4		21	1.5%		
5-6		180	13.3%		
7-8		450	33.2%		
9-10		436	32.2%		
11+		265	19.5%		
<b>Average upload/download speed</b>	<b>1356</b>			<b>0</b>	<b>0</b>
0.2/0.2 - 4/1 mbps		6	0.4%		
10/1 - 10/3mbps		14	1.0%		
10/10 - 25/1 mbps		4	0.3%		
25/3 - 25/10 mbps		142	10.5%		
25/25 - 100/1 mbps		8	0.6%		
100/3 - 100/10 mbps		408	30.1%		
100/25 - 100/100 mbps		69	5.1%		
250/3 - 250/10 mbps		346	25.5%		
250/25 - 250/100 mbps		165	12.2%		
>250/100 - 1000/25 mbps		144	10.6%		
1000/100 - >1000/100 mbps		50	3.7%		
<b>State/Political Characteristics</b>					
<b>Medicaid Expansion State</b>	<b>1331</b>			<b>25</b>	<b>1.8%</b>
Yes		957	70.6%		
No		374	27.6%		
<b>Grant Incentive Payments</b>					

Table 4b: **Structural** Characteristics and Descriptive Statistics for *Continuous* Variables

<b>STRUCTURE: System Characteristics of FQHCs, Broadband and State-Level Policies/Incentives [CONTINUOUS]</b>					
	<b>N</b>	<b>Mean</b>	<b>Standard Deviation</b>	<b>Min</b>	<b>Max</b>
<b>FQHC Characteristics</b>					
<i>Telehealth Modality</i>					
<b>Patient volume</b>	<b>1356</b>	20,892.62	25,306.71	136	232,430
<i>Metropolitan Status</i>					
<i>Meaningful Use</i>					
<b>Broadband Characteristics</b>					
<i>Provider Network Density</i>					
<i>Average upload/download speed</i>					
<b>State/Political Characteristics</b>					
<i>Medicaid Expansion State</i>					
<b>Grant Incentive Payments</b>	<b>1356</b>	\$60,149.81	161,251.95	\$0	\$2,645,023

Table 5: **Process** Characteristics and Descriptive Statistics

<b>PROCESS: HIT Characteristics related to Adoption of EHR/Telehealth</b>					
	<b>N</b>	<b>Frequency</b>	<b>Percentage %</b>	<b>Missing</b>	<b>Missing %</b>
<b>HIT Characteristics</b>					
<b>Adopted EHR</b>	<b>1356</b>			<b>0</b>	<b>0</b>
Yes		1351	99.6%		
No		5	0.4%		
<b>Adopted Telehealth</b>	<b>1356</b>			<b>0</b>	<b>0</b>
Yes		584	43.1%		
No		772	56.9%		

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Table 6: **EHR OUTCOME** Characteristics and Descriptive Statistics

<b>OUTCOME: EHR IMPACTS</b>					
	<b>N</b>	<b>Frequency</b>	<b>Percentage %</b>	<b>Missing</b>	<b>Missing %</b>
<b>Provider Impact</b>					
<b>Clinical Decision-Making Support</b>	<b>1351</b>			<b>5</b>	<b>0.4%</b>
Yes		1334	98.4%		
No		9	0.7%		
Not Sure		8	0.6%		
<b>Clinical Information Exchange</b>	<b>1351</b>			<b>5</b>	<b>0.4%</b>
Yes		1141	84.1%		
No		197	14.5%		
Not Sure		13	1.0%		
<b>Patient Impact</b>					
<b>e-Prescribing</b>	<b>1351</b>			<b>5</b>	<b>0.4%</b>
Yes		1335	98.5%		
No		12	0.9%		
Not Sure		4	0.3%		
<b>Patient Portals</b>	<b>1351</b>			<b>5</b>	<b>0.4%</b>
Yes		1261	93.0%		
No		87	6.4%		
Not Sure		3	0.2%		
<b>After-Visit Summaries</b>	<b>1351</b>			<b>5</b>	<b>0.4%</b>
Yes		1316	97.1%		
No		31	2.3%		
Not Sure		4	0.3%		

Table 7: **Telehealth OUTCOME** Characteristics and Descriptive Statistics

<b>OUTCOME: Telehealth IMPACTS</b>					
	<b>N</b>	<b>Frequency</b>	<b>Percentage %</b>	<b>Missing</b>	<b>Missing %</b>
	<b>584</b>				
<b>Provider Impact:</b> (Provider to Provider)		270	19.9%	0	0%
<b>Patient Impact:</b> (Patient to Provider)		235	17.3%		
<b>BOTH:</b> Provider and Patient Impact		584	5.80%		

Table 8: **EHR Impact Score** Characteristics and Descriptive Statistics

EHR Impact Score	N	Frequency	Percentage %	Missing	Missing %
EHR Provider Impact Score					
0	1356	12	0.9%	0	0.0%
1		213	15.7%		
2		1131	83.4%		
EHR Patient Impact Score )					
0	1351	6	0.4%	5	0.4%
1		11	0.8%		
2		101	7.4%		
3		1233	90.9%		

Table 9: **Telehealth Impact Score** Characteristics and Descriptive Statistics

TELEHEALTH IMPACT SCORE	N	Frequency	Percentage %	Missing	Missing %
Telehealth Provider Impact Score					
0	584	235	17.3%	772	56.9%
1		349	25.7%		
Telehealth Patient Impact Score					
0	584	270	19.9%	772	56.9%
1		314	23.2%		



Table 10: EHR Provider Impact Score Regression

EHR Provider Impact Score		Coefficient (B)	Std. Error	df	Wald Chi-Square	P-value	OR (95% CI)
FQHC CHARACTERISTICS	Intercept	1.637	0.2465	1	44.119	0.000	(1.154 , 2.120)
	Patient volume	1.64E-05	6.09E-06	1	7.204	0.007 **	(4.412E-6 2.830E-5)
	Metropolitan Status						
	Urban	-0.169	0.1724	1	0.962	0.327	(-0.507, 0.169)
	Rural	0 <sup>a</sup>					
	Meaningful Use						
	No/Not Sure	-0.734	0.174		17.81	1.000	( -1.075, -0.393)
	Yes	0 <sup>a</sup>					
	Adoption Level						
	EHR only	0.135	0.1691	1	0.64	0.424	(-0.467 , 0.196)
BROADBAND	Telehealth only	-0.543	1.2069	1	0.203	0.652	(-2.909 , 1.822)
	Both	0 <sup>a</sup>					
	Provider Network Density						
	0-4	1.722	1.0867	1	2.511	0.113	(-0.408 , 3.852)
	5-8	0.061	0.1652	1	0.137	0.711	(-0.263 ,0.385)
	9+	0 <sup>a</sup>					
STATE	Average upload/download speed						
	less than 25/1 mbps	-0.926	0.5514	1	2.823	0.93	(-2.007 , 0.154)
	between 25/3 mbps - 100/100 mbps	0.119	0.0166	1	0.512	0.474	(-0.207, 0.444)
	greater than 250/3 mbps	0 <sup>a</sup>					
	Medicaid Expansion State						
	No	-0.75	0.1729	1	0.187	0.665	(0.264 , 0.187)
	Yes	0 <sup>a</sup>					
	Grant Incentive Payments	4.43E-06	1.68E-06	1	6.969	0.008**	(7.710E-6, 1.140E-6)

a. Set to zero because this parameter is redundant

Table 10a: EHR Provider Impact Score Odds Ratio

Significant EHR Provider Impact Score Odds Ratios		Odds Ratio	P-value	OR (95% CI)
Intercept		5.14	0.000	(3.17 , 8.33)
Patient volume		2.18	0.007 *	(1.000135, 1.005524)
Meaningful Use				
No/Not Sure		0.48	0.000**	( 0.34, 0.67)
Yes		0 <sup>a</sup>		
Grant Incentive Payments		1.00000443	0.008*	(1.0000048, 1.57709815)

Table 11: EHR Patient Impact Score Regression

EHR Patient Impact Score		Coefficient (B)	Std. Error	df	Wald Chi-Square	P-value	OR (95% CI)
FQHC CHARACTERISTICS	Intercept	-1.745	0.3469	1	25.294	0.000	(-2.425, -1.065)
	Patient volume	0.000	1.24E-05	1	12.084	0.001 **	(-6.747E-5, -1.882E-5)
	Metropolitan Status						
	Urban	0.007	0.2261	1	0.001	0.974	(-0.436, 0.450)
	Rural	0 <sup>a</sup>					
	Meaningful Use						
	No/Not Sure	0.918	0.2221	1	17.091	0.000**	(0.483, 1.353)
	Yes	0 <sup>a</sup>					
	Adoption Level						
	EHR only	0.307	0.2332	1	1.732	0.188	(-0.150, 0.764)
BROADBAND	Telehealth only	-19.534	33219.3711	1	0	1.000	(-65128.305, 65089.237)
	Both	0 <sup>a</sup>					
	Provider Network Density						
	0-4	-1.177	1.1144	1	1.115	0.291	(-3.361, 1.007)
	5-8	-0.256	0.2191	1	1.365	0.243	(-0.263, 0.385)
	9+	0 <sup>a</sup>					
	Average upload/download speed						
STATE	less than 25/1 mbps	0.399	0.713	1	0.313	0.576	(-0.999, 1.796)
	between 25/3 mbps - 100/100 mbps	-0.207	0.2193	1	0.889	0.346	(-0.637, 0.223)
	greater than 250/3 mbps	0 <sup>a</sup>					
	Medicaid Expansion State						
	No	-0.308	0.2355	1	1.709	0.191	(-0.770, 0.154)
	Yes	0 <sup>a</sup>					
	Grant Incentive Payments	-2.06E-05	6.49E.06	1	10.041	0.002**	(-3.333E-05, -7.856E-6)

a. Set to zero because this parameter is redundant

Table 11a: EHR Patient Impact Score Odds Ratio

Significant EHR Patient Impact Score Odds Ratios	Odds Ratio	P-value	OR (95% CI)
Intercept	0.17	0.000	(0.09, 0.34)
Patient volume	0.999335	0.001 **	(0.999928, 0.958530)
Meaningful Use			
No/Not Sure	2.5	0.000**	(1.62, 3.87)
Yes	0 <sup>a</sup>		
Grant Incentive Payments	0.973404	0.002**	(0.997572, 0.9999957)

Table 12: Telehealth Provider Impact Score Regression

Telehealth Provider Impact Score		Coefficient (B)	Std. Error	df	Wald Chi-Square	P-value	OR (95% CI)
FQHC CHARACTERISTICS	Intercept	-0.895	0.2315	1	14.942	0.000	(-1.349 , -0.441)
	Patient volume	9.28E-06	3.23E-06	1	8.262	0.004 **	(2.951E-6 , 1.560E-5)
	Metropolitan Status						
	Urban	0.351	0.1932	1	3.301	0.069	(-0.028 , 0.730)
	Rural	0 <sup>a</sup>					
	Meaningful Use						
	No/Not Sure	-0.118	0.24	1	0.242	0.62	(-0.588 , 0.352)
	Yes	0 <sup>a</sup>					
	Adoption Level						
	EHR only				1 <sup>b</sup>		
BROADBAND	Telehealth only	-1.143	1.1365	1	1.011	0.315	(-3.370 , 1.085)
	Both	0 <sup>a</sup>					
	Provider Network Density						
	0-4	-0.679	0.8295	1	0.67	0.413	(-2.305 , 0.947)
	5-8	0.074	0.1901	1	0.15	0.81	(-0.299 , 0.446)
	9+	0 <sup>a</sup>					
	Average upload/download speed						
STATE	less than 25/1 mbps	-0.51	0.7044	1	0.525	0.469	(-1.891 , 0.870)
	between 25/3 mbps - 100/100 mbps	0.044	0.1834	1	0.058	0.346	(-0.315 , 0.404)
	greater than 250/3 mbps	0 <sup>a</sup>					
	Medicaid Expansion State						
	No	0.302	0.193	1	2.456	0.117	(-0.076 , 0.681)
	Yes	0 <sup>a</sup>					
	Grant Incentive Payments	-4.88E-07	4.73E-07	1	1.064	0.302	(-1.414E-6 , 4.388E-7)

a. Set to zero because this parameter is redundant

b. No values reported (missing data)

Table 12a: Telehealth Provider Impact Score Odds Ratio

Significant Telehealth Provider Impact Score		Odds Ratios		
Odds Ratios		Odds Ratio	P-value	OR (95% CI)
Intercept		0.409	0.000	(0.260, 0.640)
Patient volume		1.00000157	0.004 **	(1.001515, 1.103409)

Table 13: Telehealth Provider Impact Score Regression

Telehealth Patient Impact Score		Coefficient (B)	Std. Error	df	Wald Chi-Square	P-value	(95% CI)
FQHC CHARACTERISTICS	Intercept	1.17	0.2262	1	0.504	0.478	( 0.75, 1.83)
	Patient volume	0.65	3.68E-06	1	10.232	0.001 **	(0.96, 0.99)
	Metropolitan Status						
	Urban	1.09	0.1909	1	0.206	0.65	( 1.75, 1.59)
	Rural	0 <sup>a</sup>					
	Meaningful Use						
	No/Not Sure	1.14	0.2314	1	0.319	0.57	(0.72, 1.79)
	Yes	0 <sup>a</sup>					
	Adoption Level						
	EHR only				1 <sup>b</sup>		
BROADBAND	Telehealth only	4.99	1.1478	1	1.961	0.161	( 0.53, 47.3 )
	Both	0 <sup>a</sup>					
	Provider Network Density						
	0-4	1.00	0.6548	1	0	0.999	(0.68, 1.41)
	5-8	0.97	0.1875	1	0.019	0.891	( 0.74, 1.56)
	9+	0 <sup>a</sup>					
	Average upload/download speed						
STATE	less than 25/1 mbps	0.76	0.6075	1	0.202	0.653	(0.78, 1.59)
	between 25/3 mbps - 100/100 mbps	1.12	0.181	1	0.364	0.547	( 0.73, 1.50)
	greater than 250/3 mbps	0 <sup>a</sup>					
	Medicaid Expansion State						
	No	0.71	0.1922	1	3.092	0.079	(0.49, 1.04 )
	Yes	0 <sup>a</sup>					
	Grant Incentive Payments	0.99	5.18E-07	1	0.134	0.715	(0.72, 1.00)

a. Set to zero because this parameter is redundant

b. No values reported (missing data)

Table 13a: Telehealth Provider Impact Score Odds Ratio

Significant Telehealth Patient Impact Score			
	Odds Ratio	P-value	OR (95% CI)
Intercept	1.17	0.478	( 0.75, 1.83)
Patient volume	0.65	0.001 **	(0.96, 0.99)

## **JOURNAL ARTICLE**

**Title of Journal Article:** *Using Geographical Information Systems (GIS) to Examine the Association of Broadband Availability and HIT Adoption within Federally Qualified Health Centers*

**Name of Journal Proposed for Article Submission:** *Journal of the American Medical Informatics Association*

Health centers have shown the potential to achieve population health, improve outcomes and reduce costs but serving as important safety-net providers to the nation's insured, underinsured and uninsured <sup>1-3</sup>. Since the passage of the Affordable Care Act (ACA), the challenge to expand health care access to millions of additional Americans has increased the burden on an already costly health delivery system. Over the last 50 years, Federally Qualified Health (FQHC) centers have served as champions, providing affordable, quality care, regardless of an individual's ability to pay for services. More than 28 million patients sought care in a federally qualified health center in 2018 according to the Bureau of Primary Health Care <sup>1</sup>. These centers coordinate medical, dental, and mental health, providing an integrated, patient-centered model of care <sup>1</sup>.

### *Federally Qualified Health Centers: Impact and Characteristics*

Studies have identified cost effective care associated with patients that frequent FQHCs <sup>2</sup>, lower spending compared to non-health centers patients across all health and medical services <sup>2</sup>, as well as improved outcomes, where this population of patients were less likely to have ER visits or preventable hospital admissions <sup>3</sup>. As health care

becomes more accountable, focusing on value and quality, community clinics will continue to emerge as viable options, not only to provide care to the underrepresented and uninsured populations they primarily serve, but to expand the reach of their services to population beyond their own communities. The public health significance focuses on the importance of expanding healthcare resources in a growing model of care to an aging population with changing healthcare needs. Technology such as EHR and Telehealth, continues to emerge as vehicles to promote sufficient patient care and quality outcomes, especially among FQHC patient populations <sup>8, 22, 27</sup>, while also raising and impacting provider and patient accountability and involvement in their health care <sup>6,32</sup>.

While evaluating health information technology and clinical benefits and barriers within physician practices, an earlier study reported that the achievement of quality improvement and financial benefits were associated with ensuring that the greatest number of providers utilize an EHR engaging in as many functionalities and tasks as possible <sup>27</sup>. This study also discovered that smaller practice sizes were associated with lower levels of adoption and implementation <sup>27</sup>. Smaller and solo practices were required to utilize more internal clinical staff and “physician champions” to help with associated HIT support such as installation, implementation and training, while also providing technical support when problems occurred <sup>27</sup>. Larger practices tended to have stronger organizational resources, which led to more internal technical support staff to assist with developing workflow and process changes, financial resources and HIT support staff <sup>27</sup>.

Federally Qualified Health Centers are required as grant recipient clinics to report program data annually for key measures that evaluate access, quality, outcomes and

costs through the Bureau of Primary Health Care (BPHC) Health Resources and Services Administration's (HRSA) Uniform Data System (UDS) in order to monitor a health centers' performance and <sup>86</sup>. Patient volume is determined based on the unduplicated numbers of individuals encountered by each parent organization, an approach used as a common size metric in studies involving patient level analysis and HIT <sup>94-99</sup>. Previous studies have not evaluated patient volume as an independent variable related to FQHCs and adoption of Technology.

### Broadband Availability and HIT Adoption

There is little to no research specifically delineating what specific broadband speeds FQHCs need to access and optimally utilize EHR, Telehealth system or both <sup>65</sup>. The National Broadband Plan (BDP) analyzed connectivity for three types of providers: small practices, large practices and federally funded providers (although the federally funded provider category may overlap with the other two categories). Regarding federally funded providers such as FQHCs, the need to understand connectivity is important since accessibility for vulnerable populations is directly related to government funding and costs. <sup>65</sup>. Based on a BDP analysis, a rural health clinic with at least 5 practitioners would require an average bandwidth of at least 10 mbps in order to utilize EHR and general web-based activities such as billing, scheduling and web browsing and allow for video consultations, remote monitoring and non-real-time image downloads for 3 of the 5 providers <sup>65</sup>. Bauer et al., noted that broadband speed is also considered a metric in characterizing quality and can be directly related to capacity and ultimate performance <sup>63</sup>.

High-speed internet connectivity is essential especially for applications requiring

the transmittal of signals carrying health information, video and images between providers, that are potentially separated by large distances <sup>65</sup>. When considering that most federally funded clinics communicate and may consult with larger hospitals and academic medical centers, it's important to consider that these larger systems may require between 100 mbps to greater than 1 gbps to maintain the same types of services <sup>65</sup>. While researching most EHR system requirements, consensus has shown that “business-grade internet connectivity” is required <sup>127</sup>. *Eyefinity EHR* © provided the most extensive definition for minimum and recommended bandwidth speeds that can be used generally as a definition for multi-provider and practices, while considering that the number of practice users\* includes ***clinicians, staff and patients***, simultaneously using the system at a single practice location: <sup>127</sup>

NUMBER OF PRACTICE USERS*	MINIMUM BANDWIDTH SPEED	RECOMMENDED BANDWIDTH SPEED
1-5	5 mbps download 3.5 mbps upload	10 mbps download 5 mbps upload
6-10	10 mbps download 5 mbps upload	20 mbps download 10 mbps upload
11-15	20 mbps download 10 mbps upload	30 mbps download 15 mbps upload
16-20	30 mbps download 15 mbps upload	50 mbps download 20 mbps upload
21+	50 mbps download 20 mbps upload	100 mbps download 25 mbps upload

**Table 14:** Recommended EHR Implementation Speeds

Current research has evaluated and identified estimated broadband speeds required for adoption of EHR either by number of providers utilizing the technology within the clinical setting, or specific within critical access hospitals which serve underserved rural patient populations as well <sup>65, 115</sup> but information regarding telehealth has not been found. An article evaluating factors influencing the adoption of EMR since the



implementation of government incentives, found that the “amount of bandwidth needed is a function of how many users/FTEs a clinic anticipates needing access simultaneous as well as the installed applications that the different HIT technologies may include” <sup>117</sup>.

The UDS does not require that the number of FTEs within FQHC entities be reported annually and views this data as proprietary information, allowing clinics to not report it at their discretion <sup>90, 106</sup>. Though publicly available at the state level, this limitation of the dataset prevents adequate comparisons to other studies that determine average speeds for adoption, based on FTEs <sup>15, 65, 115</sup>. Whitacre and Williams (2014) used state level data to assess average upload/download speeds impact on adoption of EHR among FQHCs in rural vs urban areas of Oklahoma <sup>15</sup>. Using data provided by the National Broadband Map in collaboration with the FCC, they found that speed data and broadband availability varies across states <sup>15,116</sup>. And though their research focused on identifying rural and urban differences and the role of broadband availability, they found no statistical relationships between electronic medical record adoption and measures of broadband availability related to speed or provider density. Ultimately this study concluded that “policy focused primarily of broadband availability for private practices were likely misguided” <sup>15</sup>.

For FQHCs to adopt EHRs and telehealth, there must be enough internet bandwidth for their systems to optimally function, but there is no research that specifies what speeds must be within these centers. The Federal Communication Commission officially defines broadband as a minimum of 25 mbps download and 3 mbps upload, a definition recently updated from a 2010 standard of 4 mbps download and 1 mbps upload due to the advancements in technology and increased consumer demands <sup>84</sup>. Access to

telecommunication services in the US has demonstrated early disparities and gaps <sup>64</sup>. Smaller and more rural areas experienced higher premiums and long-distance charges for accessing Internet services due to the lack of adequate network presences <sup>64</sup>. And even as the newer generation of broadband developed in the late 1990s, the debate between access, and equity of services continued to emerge <sup>64</sup>. Broadband providers tend to be influenced geographically and socially, infiltrating areas with more profitable markets that exhibited higher returns on investment <sup>64</sup>. Interestingly to this point, the American Medical Informatics Association (AMIA) has acknowledged 'broadband internet service' as a social determinant of health arguing that the FCC should consider the "specific challenges related to inadequate access to affordable and consistent high-speed internet faced by vulnerable and underserved group attempting to access digital communications for health-related purposes" <sup>129</sup> But there is little to no research specifically delineating what specific broadband speeds FQHCs need to access and optimally utilize EHR, Telehealth system or both <sup>65</sup>. .

Since the implementation of the HITECH and ARRA, and the emphasis on meaningful use and expanding access and quality, health care providers in primarily small practices frequently cited financial reasons as barriers to adoption of EHR <sup>53, 118</sup>. indicating barriers such as "high start-up costs, lack of capital, concern that a system would soon become obsolete and a lack of adequate and reliable information about return on investment <sup>118</sup>. Providers in practices that primarily serve underserved and underrepresented populations, also cited clinical productivity and the uncertainty of the diverse costs associated with implementation as well <sup>118</sup>.

. The Department of Health and Human Services has therefore provided incentives and increased funding through the Federal Office of Rural Health Policy and HRSA-funded Regional Telehealth Resource Centers which provide technical assistance supporting telehealth program development in critical areas that lack access to health care services, including specialty care. Funding has now led to supporting HRSA grantees in the implementation of “internet technical assistance, provider-to-provider (patient-to-provider) videoconferencing, store-and-forward diagnostic imaging as well as streaming media and closed-circuit communications through regional and national telehealth hubs” <sup>123</sup>.

But even with federal incentive programs supporting and funding adoption of HIT, 2018 research examining factors associated with telehealth within federally qualified health centers using 2016 UDS data found cost and technical issues as major barriers to adopting Telehealth, along with rurality, reimbursement policies and operational factors <sup>6</sup>. UDS reported data includes cost related area related to HIT/EHR system development and analysis, supplies and equipment but is not publicly available, listing this section of the Reporting Handbook as proprietary <sup>79,106</sup>. In 2017, only 117 FQHCs out of a total of 1,373 FQHCs reported data on costs associated with HIT/EHR implementation <sup>79,106</sup>. Therefore, due to the limited data reported and publicly available, cost in relation to technology adoption as a barrier to implementation is considered outside of what this study can address.

### Geographical Information Systems (GIS) and HIT

Research findings vary as to primary barriers to adoption of HIT within FQHCs , and the effect location has played on implementation <sup>6, 44</sup>. Several factors such as cost, reimbursement and technical issues were commonly described as potential barriers to adoption of EHR and Telehealth <sup>6, 22</sup>. Technical issues such as inadequate broadband infrastructure has specifically been cited by FQHCs in rural and urban areas as a reason for not adopting technology <sup>6, 22, 48</sup>. Lin et al found evidence that the lack of broadband, or insufficient bandwidth, was not a commonly reported barrier to adoption due to the availability of broadband funding awareness of the Federal Communication's Rural Health Care Program. This program has the potential decrease the numbers of FQHCs without internet service <sup>6</sup>. But other studies have found that though physicians' practices are in areas with documented broadband activity <sup>6</sup>, they lacked adequate bandwidth required for EHR interoperability <sup>44</sup>. With the growing demand and complexity of HIT such as telehealth, more broadband speed will be necessary. Modalities such as real-time videoconferencing and store-and-forward, for example, use higher bandwidth <sup>6</sup>. The increased utilization of mobile devices and mHealth, which allows patients to have access to their providers from home, also requires adequate broadband speeds in communities where patients live. <sup>6</sup>.

Geographical Information Systems (GIS) is used to map spatial variations in healthcare services and has assisted in identifying gaps indicating where health care services are needed <sup>38-40, 46</sup>. Studies have shown the disparities in health outcomes across populations and how geographical disparities in access to technology has led to worsening outcomes <sup>41, 42</sup>. Luther et, a <sup>41</sup>. used GIS zip code mapping of communities

with high and low primary care access. They found that areas with more minority populations had a higher prevalence of mortality related to cancer, heart disease and stroke <sup>41</sup>. Interestingly, they also found that minorities in high primary care access areas had lower rates of these conditions compared to those in low primary care access areas <sup>41</sup>. Parker and Campbell (1998) also noted that both socioeconomic and geographical aspects of accessibility impacted health care outcomes <sup>46</sup>. Postcode data was geocoded using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) software and showed that the utilization of health services decreased as the patients' distance from the service increased <sup>46</sup>. Dulin et al used census-based geographic data geocoded using ArcGIS to create data points and maps examining attributes of populations and their primary care needs to identify areas that would benefit from increased access to community health organizations <sup>39</sup>. Research by Soares, Dewalle and Marsh applied patient-level GIS data to prospectively model optimal telemedicine locations for pediatric specialty services in a rural area using data provided by an EHR <sup>48</sup>. The Connect2Health<sup>FCC</sup> Task Force uses GIS enabled tools to explore the intersection between broadband access, health information technology and health through their project *Mapping Broadband Health in America* by allowing users to geographically overlay and analyze broadband and health data at the national, state and county level <sup>35</sup>. This mapping tool has been used to link broadband access and disease prevalence such as diabetes as well as telehealth <sup>12</sup>.

The effectiveness of FQHCs and their adoption of HIT, therefore, relies on accurate measures of access and speed of broadband networks so that resources can be allocated appropriately <sup>45</sup>. Further, studies need to focus on how geographic variability

of broadband speeds and internet providers has impacted the adoption of telehealth and EHR. Therefore, this study will:

*AIM 1)* Utilize ArcGIS to spatially describe and map adoption of HIT and broadband availability at the zip code level and then examine spatial clustering of adoption of EHRs and telehealth with patient volume variables to provide a correlation analysis comparing FQHC organizations and locations with adoption of HIT.

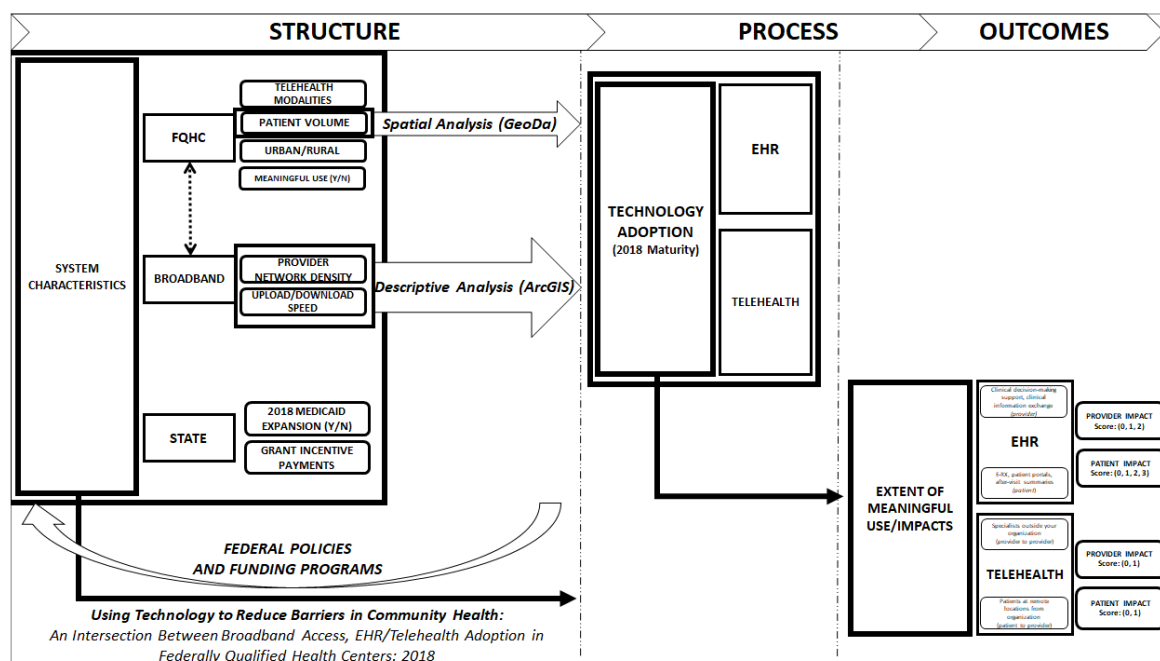


Figure 5: Modified Donabedian Framework: AIM 2

## RESULTS

The results of this research included a Descriptive Analysis and a Spatial Analysis. An ArcGIS descriptive analysis consisted of a general proportion of broadband speed and broadband provider density variables associated with HIT

adoption at the zip code level. The GeoDa spatial analysis focused on adoption patterns of telehealth and EHR in relation to FQHC patient volume.

*Descriptive Analysis (Adoption of HIT, Patient Volume and Broadband Characteristics)*

Results from ArcGIS descriptive analysis is depicted in figures 6-9 and Appendix B HRSA Region Map 1-10 (Speed), and HRSA Region Map 1-10 (Broadband Density). Figure 6 presents the distribution of FQHCs clinic Locations by zip code demonstrating denser numbers bicoastally. FQHC Patient Volume was depicted in Figure 7 and demonstrated that more clinics have lower patient volumes compared to higher volumes. More of the higher volumes appear to be noted in major cities and states along the west coast (California) as well as east coast (New York). Figure 8 showed that broadband provider density varied across the zip codes containing FQHC point locations. On average, it appears that most FQHC related zip codes, had at least 5-8 broadband providers servicing the area. Broadband provider speeds were also depicted descriptively at the zip code level and demonstrated that most FQHCs were located in zip codes with at least 25/3 mbps broadband speeds (Figure 9). HRSA Regional Maps were also descriptively produced in ArcGIS, and demonstrated no obvious correlations

between broadband speed, broadband provider density and whether an FQHC adopted EHR, telehealth or both technologies.

#### *Spatial Analysis (Adoption of HIT and FQHC Patient Volume)*

Results from GeoDa spatial analysis was depicted in figures 10-12. Among the different variables, the correlation study focused on adoption patterns of telehealth and EHR in relation to the volume of patients served the nation's FQHCs.

Figure 10 showed that there are 22 clinics that form a high-high cluster where there was a high adoption of EHR technology surrounded by clinics with high clinic volumes and 27 clinic locations, demonstrating low-low clustering. There were 233 clinics significant at a p-value of  $\leq 0.05$ , which demonstrated significant local spatial clustering, but at 999 permutations, the pseudo p-value was not significant at 0.411 though the Moran's I of 0.003 demonstrated a positive cluster globally.

Figure 11 represents another bivariate analysis where patient volume was compared to the adoption of telehealth among FQHCs in 2018. There were 8 health centers demonstrating high-high clustering of high clinic patient volume surrounded by clinics with high adoption of telehealth. The Moran's I was -0.010 and the global pseudo p-value was 0.172.

Adoption of both Telehealth and EHR compared to the volume of patients seen within the FQHCs was also analyzed by bivariate LISA and showed significant local clustering as well (Figure 12). This cluster map noted high-high clustering of high adoption of both technologies surrounded by clinics with high FQHC patient volume among 8 clinics



while there were 47 clinics that demonstrated low-low clustering. The Moran's I was 0 with an insignificant global pseudo p-value of 0.497

## **DISCUSSION**

Descriptively, FQHCs were distributed throughout the US in 2018, with higher concentrations of clinics noted along the east coast, south and west coast. There were several states and areas in the Midwest region without health centers represented within the map. There were many areas with low speeds of less than 5 broadband providers, where technologies were adopted. Multiple areas were noted where both technologies were adopted with moderate speeds and broadband provider density (Appendix B). Therefore, there were no obvious associations noted between adoption of a specific technology and speed or broadband provider density which supports results noted in similar studies where broadband characteristics demonstrated no significant impact on HIT adoption <sup>6, 15</sup>. Overall, spatial clustering was noted among our variables suggesting relationships between and FQHC's patient volume and their ultimate adoption of telehealth and EHR, but more research would be needed to further expand upon this exploratory and descriptive study.

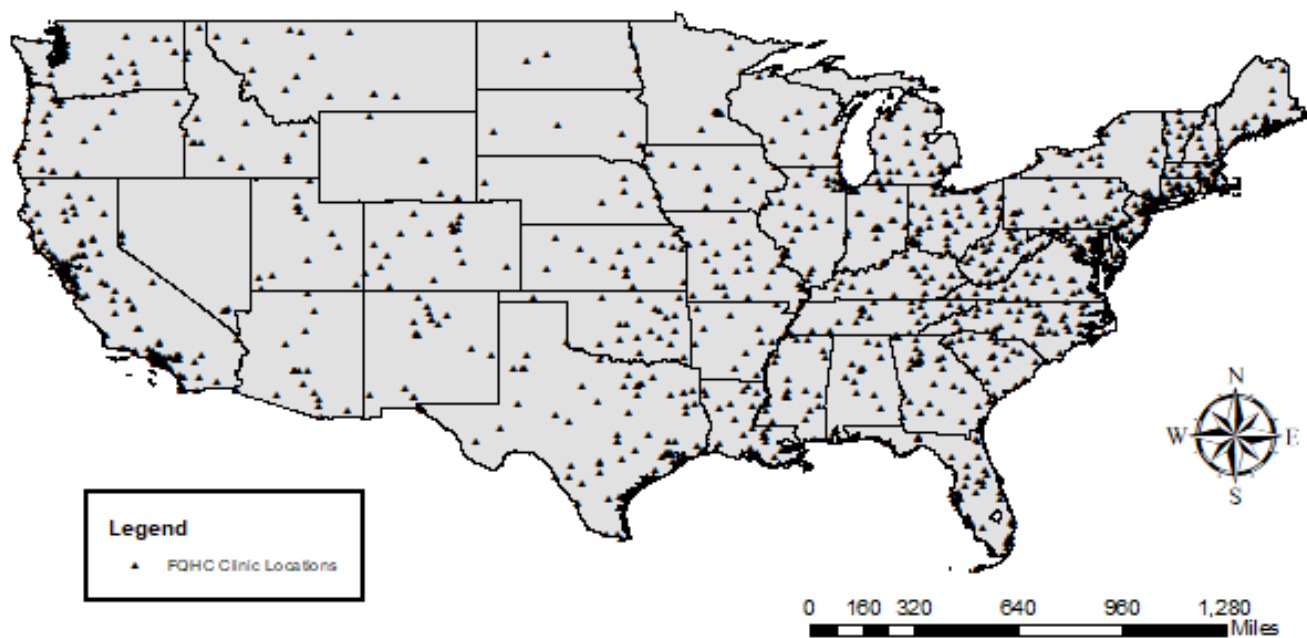
A more granular level of analysis should also be done using census block code data as well. A correlation study analyzing HIT adoption and other continuous various such as CMS EHR incentive payments should also be done to analyze the policies and incentive programs that may potential drive improve health care delivery in the U.S. Future analysis can also focus on adoption of both technologies and whether clustering or dispersion patterns change over time. Changes in policies and influencing state to

state relationships have the potential to help change clusters that may appear as outliers in one period, to significant clustering in future periods.

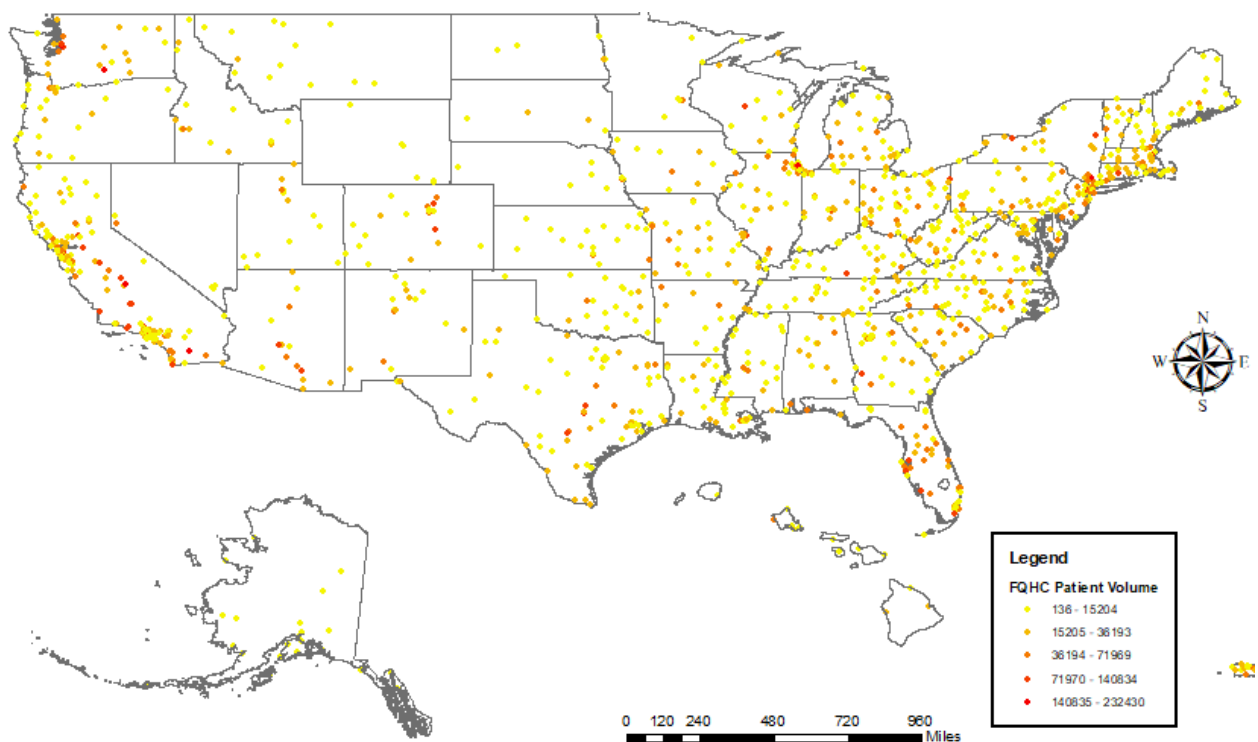
Spatial analysis and descriptive mapping cannot infer causation. Inferences can also not be made as to one variable directly impacting another but can instead suggest relationships. The data used in this analysis was analyzed at the Zip Code level, therefore making assumptions of the association of an area's broadband availability, patient volume and a health center's HIT adoption practices. Importantly, this UDS dataset utilized parent organization level aggregated data, therefore assumptions are also made as to the adoption habits and of the individual and associated clinic satellite sites that are not specifically counted among the 1,300 + clinic locations. The accuracy of the k-nn value is also a limitation due to the non-specific and limited data sources discussing its uses among contiguous and non-contiguous U.S states and territories.

## **CONCLUSION**

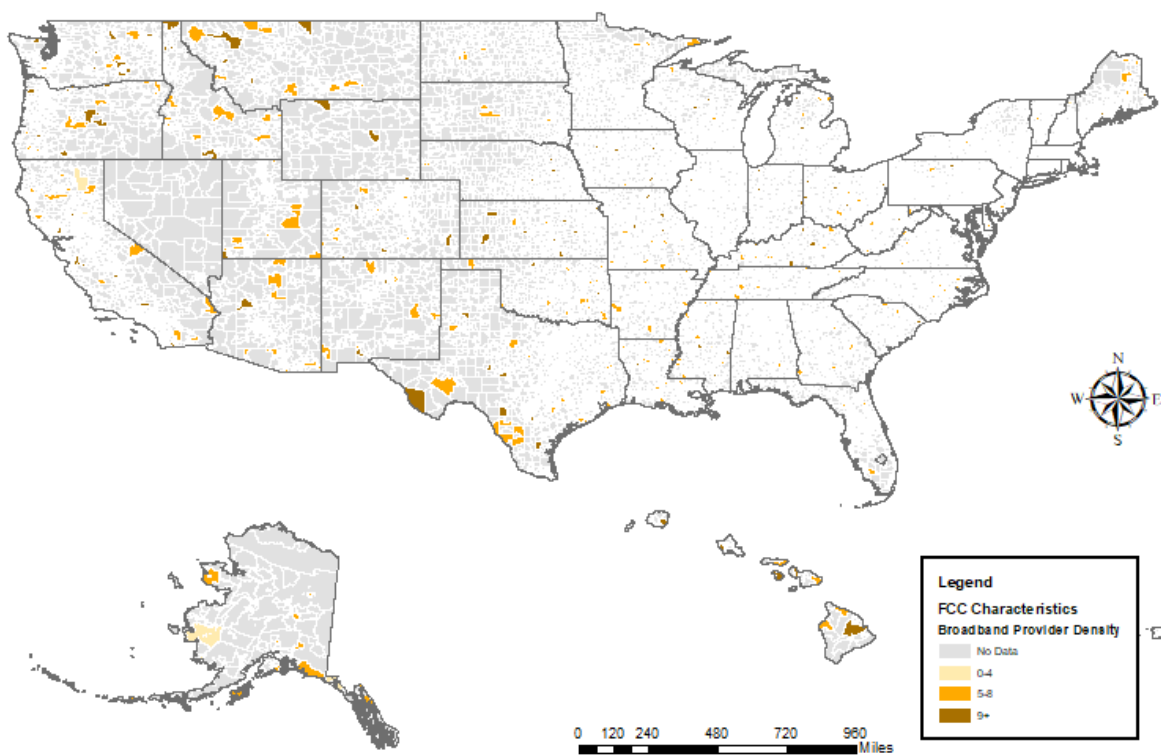
The purpose of this study was to descriptively and spatially explore relationships and clustering patterns. Research on health center characteristics, and systems that influence health technologies assists in determining barriers to providing quality care and improving access therefore potentially influencing policy and structures in order to enhance patient experiences.



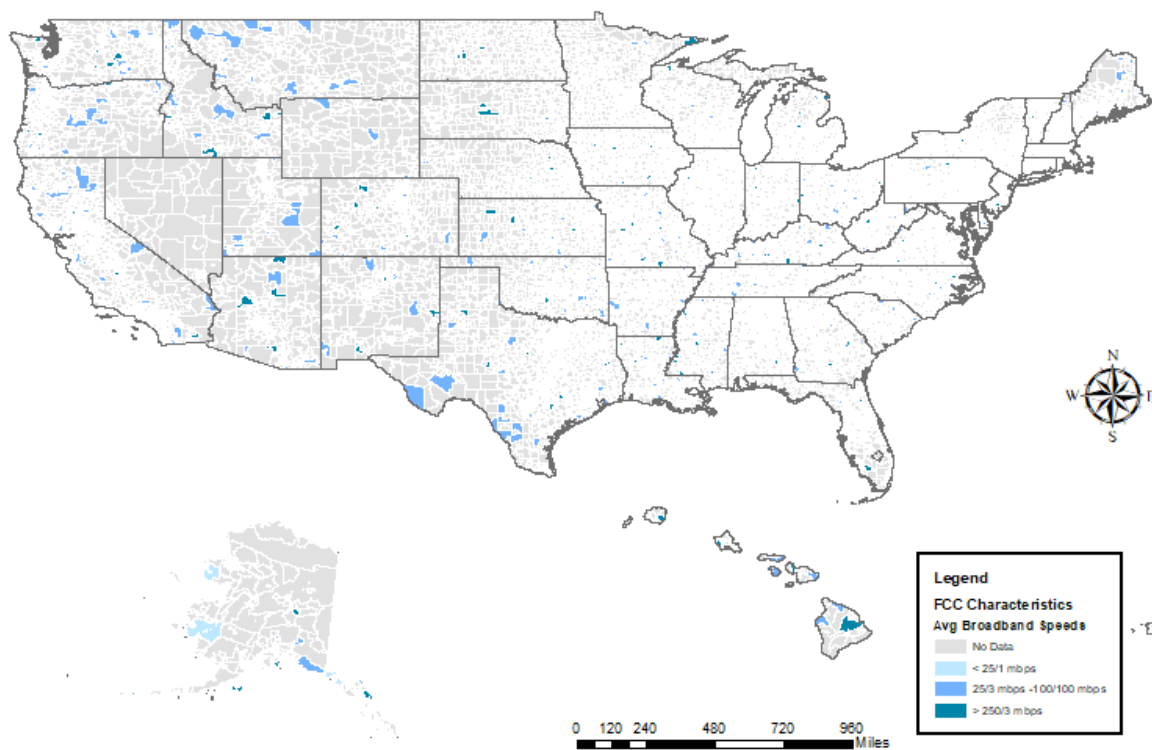
**Figure 6:** FQHC Clinic Locations by Zip Code



**Figure 7:** FQHC Clinic Locations by Patient Volume

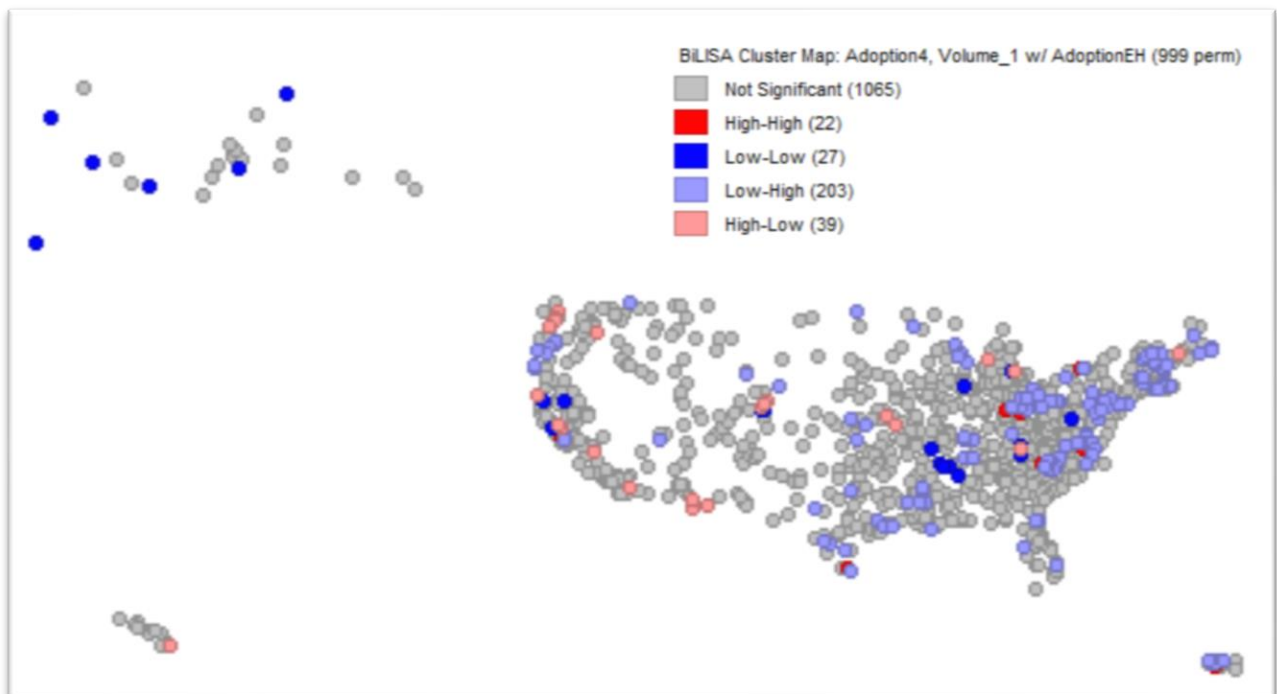
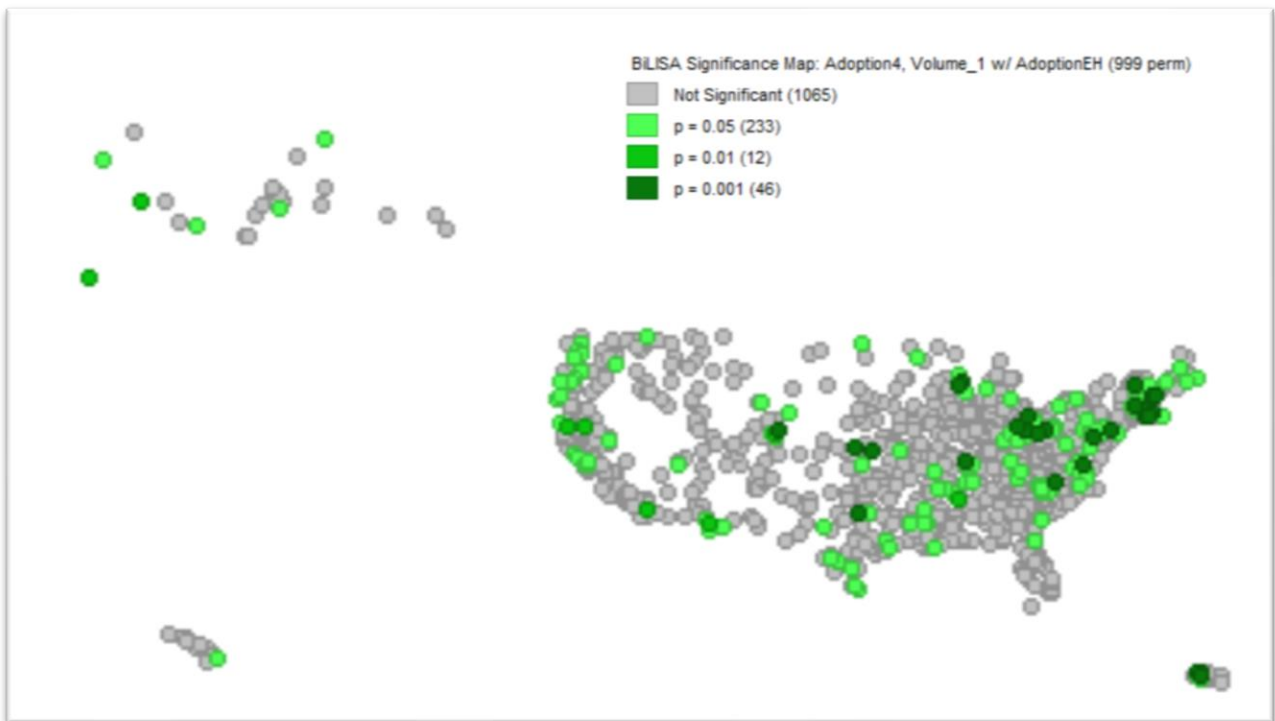


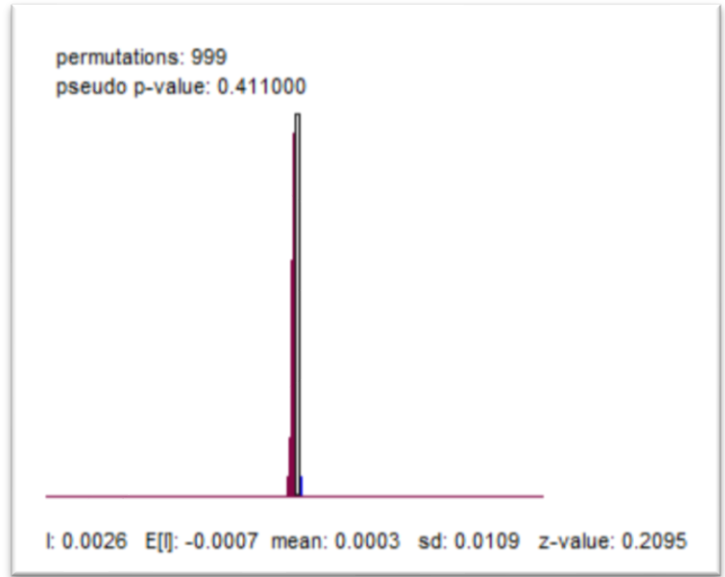
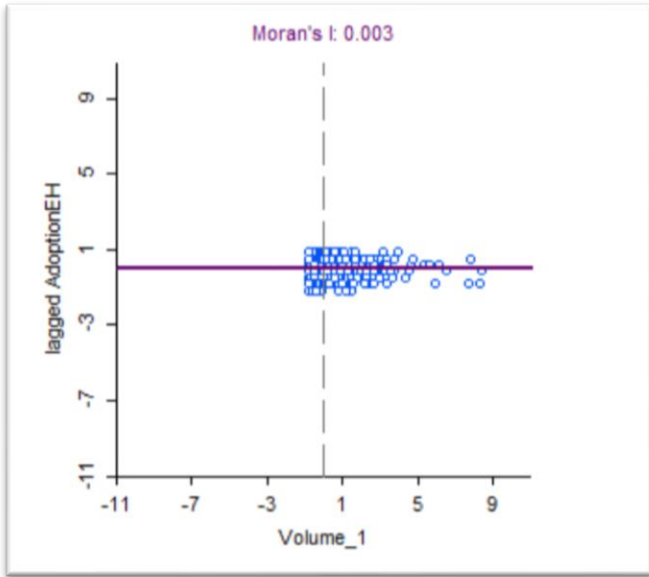
**Figure 8:** Broadband Provider Density and FQHC Zip Code locations



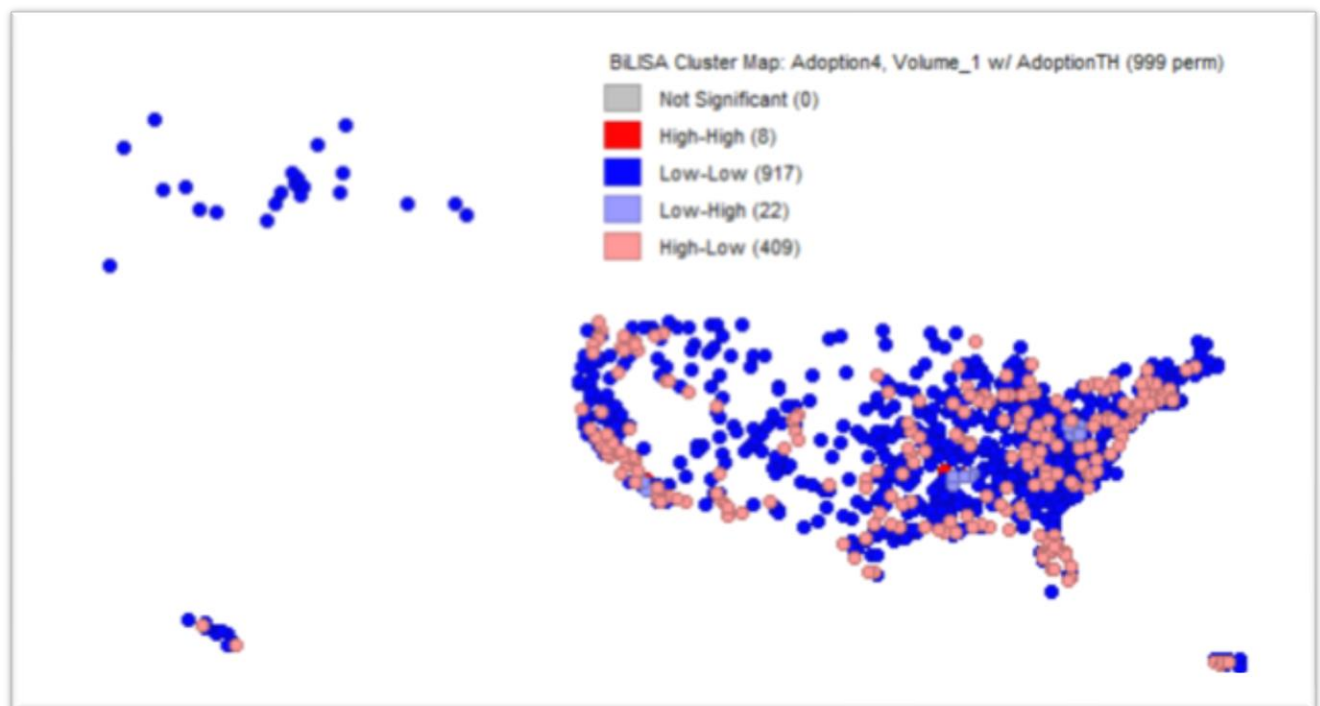
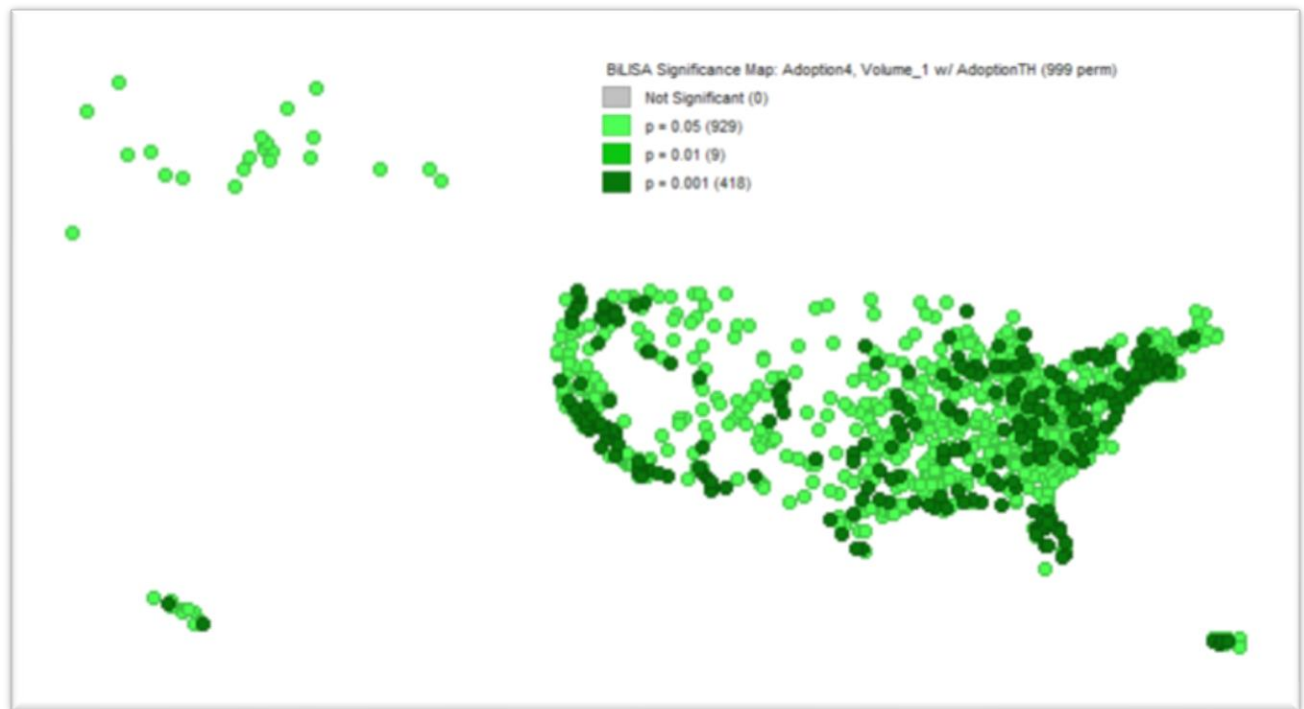
**Figure 9:** Broadband Provider Speeds and FQHC Zip Code locations

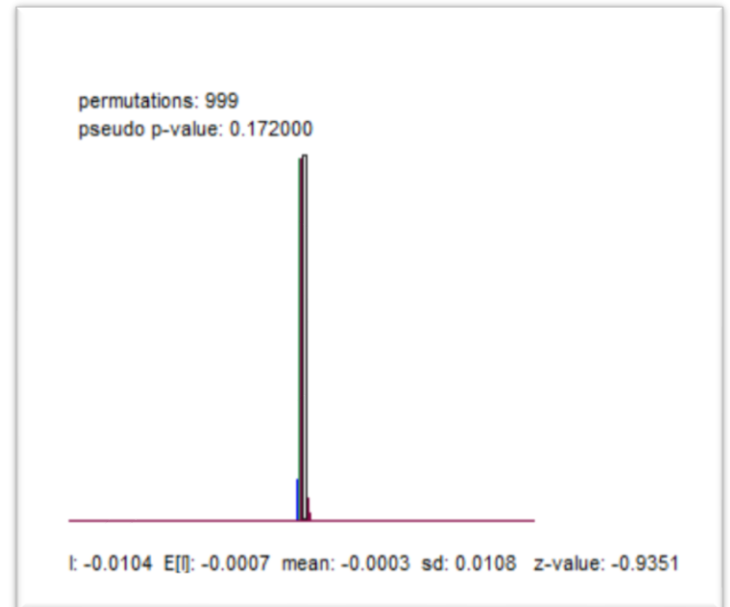
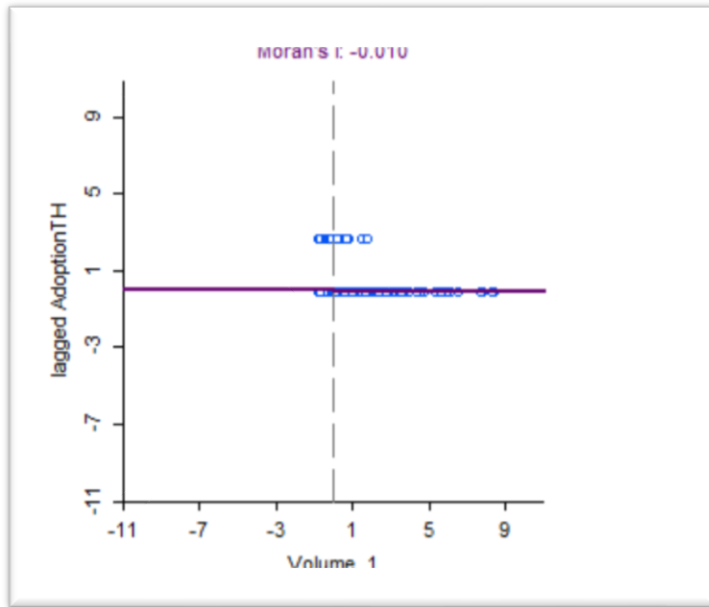
**Figure 10:** Adoption of EHR by Patient Volume/ FQHCs/Zip Code GeoDa Analysis (Bivariate Moran's I)





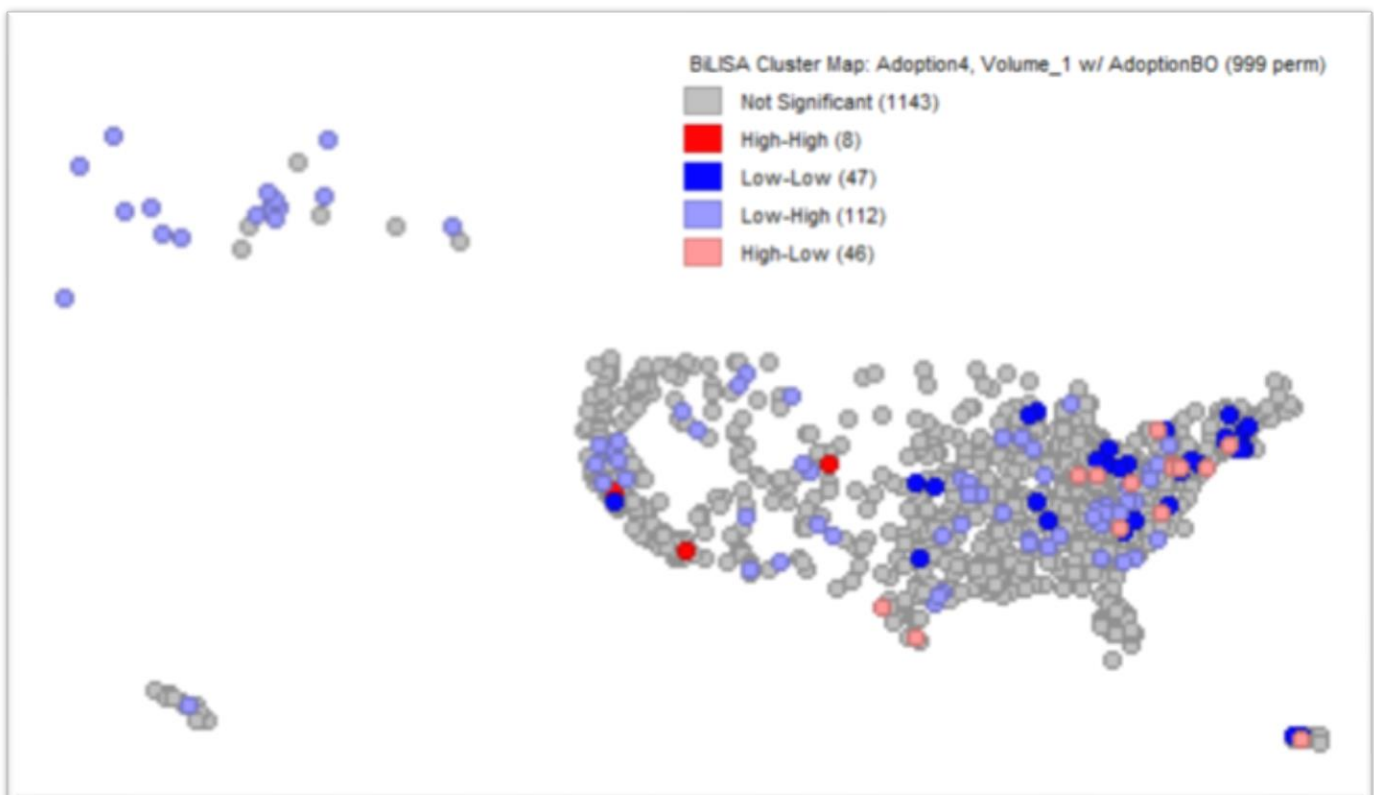
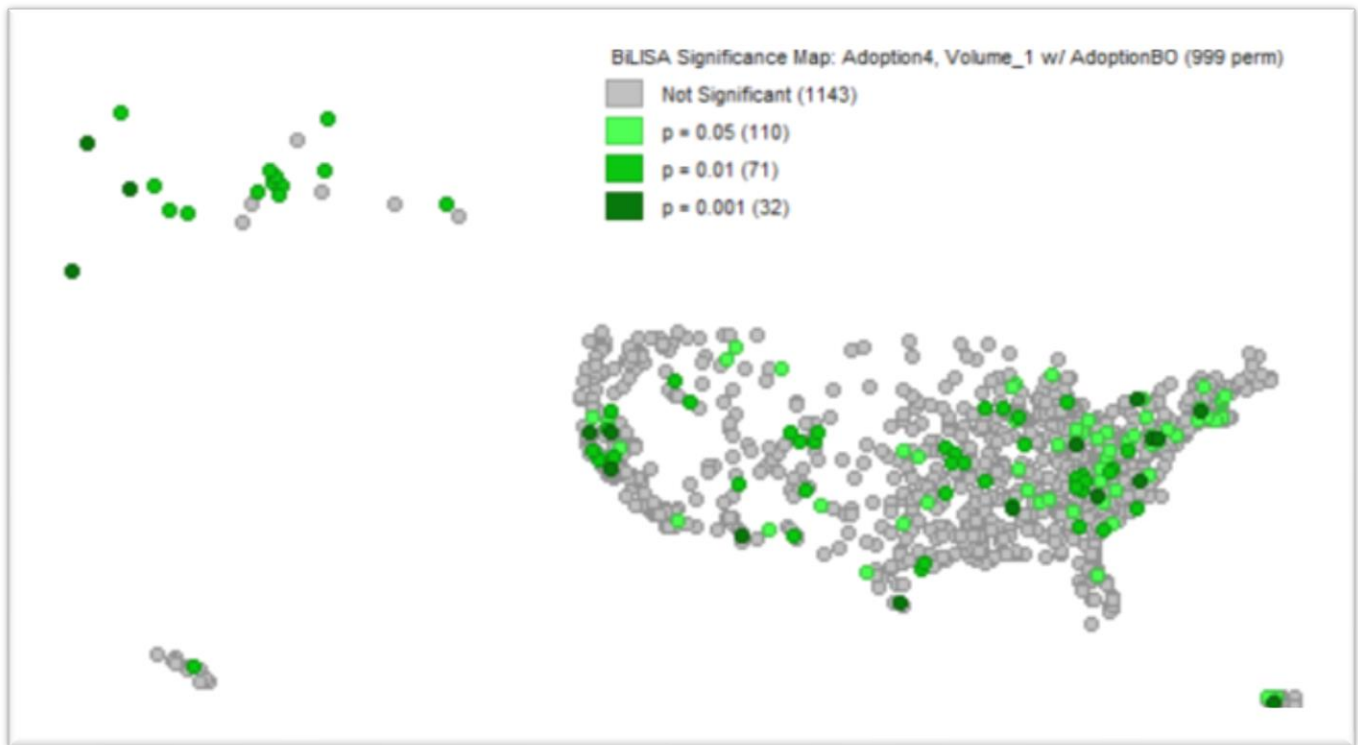
**Figure 11:** Adoption of Telehealth by Patient Volume/ FQHCs/Zip Code GeoDa Analysis (Bivariate Moran's I

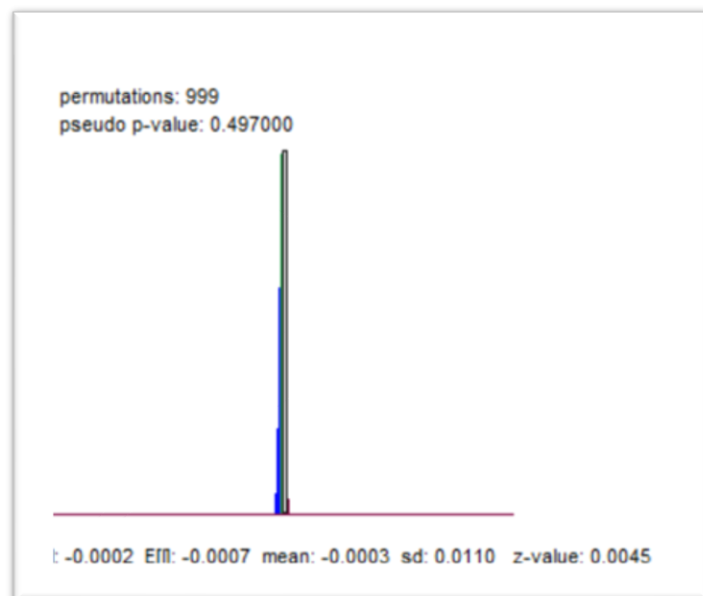
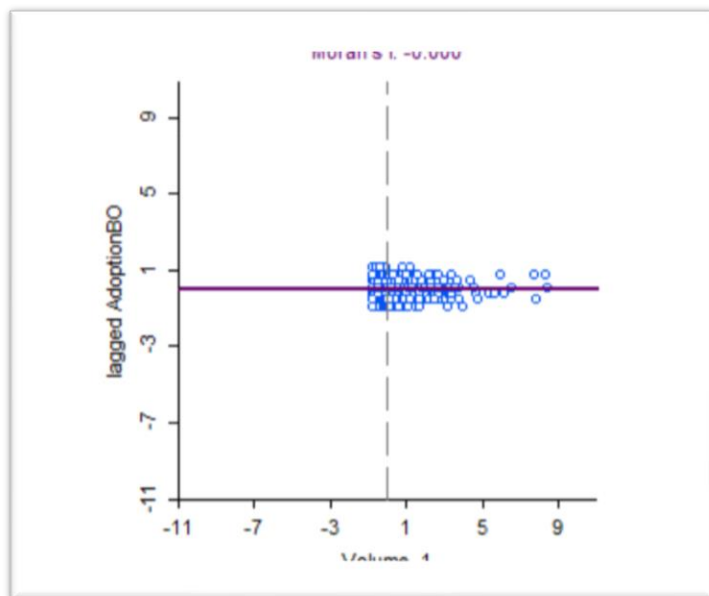






**Figure 12:** Adoption of EHR and Telehealth by Patient Volume/ FQHCs/Zip Code GeoDa Analysis (Bivariate Moran's I)





## **CONCLUSION (CUMULATIVE)**

This research is important to public health as it addresses access to care in a period where an expanded population needs healthcare resources. FQHCs provide healthcare access to the underserved, and with the utilization of health information technology, these safety net clinics could better serve them through the provision of accessible primary and specialty care. The purpose of this study was to descriptively and spatially explore relationships and clustering patterns comparing health center characteristics and systems that influence the adoption and utilization of health technologies. This assists in determining barriers to providing quality care and improving access therefore potentially influencing policy and structures in order to enhance patient experiences.

Ultimately the purpose of this research was not to evaluate population data and evaluate improvements in the overall health of FQHC patients, but instead to evaluate the technological tools that have the potential to improve the health of this specific population of patients. While other studies have focused on clinical outcomes such as diagnosis and mortality in relation to the adoption of HIT, our study focused on those processes that may influence national policy changes related to adoption. We examined intermediate processes impacting the usefulness of technology in healthcare due to the fact the adoption of health technology is inevitable. As healthcare needs change and the population becomes older, the costs associated with providing care will continue to strain our healthcare system. But the adoption of EHR and telehealth does not necessarily correlate with full utilization of all meaningful functionalities of that technology. Therefore, our aim was to go a step further than an analysis of adoption trends among FQHCs and

instead to examine variables identified by past research, representing influencers of adoption, and their impact on a health centers' utilization of their adopted technologies. Another contribution of this paper was to document how different structural components of FQHCs including internal and external influences can influence EHR and telehealth adoption compared to other analysis that noted self-reported reasons as to the lack of adoption of HIT within their centers <sup>6</sup>.

As the research *demonstrated*, broadband was not found to be a significant factor in full FQHC utilization of HIT in 2018 even though there has been increasing policy initiatives and FCC broadband rural health grants to eliminate this technology gap. The results instead point to a necessary shift in policy where upstream structural problems related to capacity and funding should instead be addressed and focused on. Many clinics located in rural areas have smaller patient volumes with no real ways to expand in their restrictive environments and locales, therefore lack the business motivation to justify paying an on-going cost for an IT staff member to help with support and maintenance when there are not many patients to manage. Though the benefits of HIT in improving outcomes has been demonstrated in the literature, clinics do not have the incentive to take on those costs. Policy should focus on discovering options on either increasing clinic sizes especially in areas where the population may be limited or allow for continuous funding to assist clinics in managing technology.

Although this study provided a contribution towards understanding the adoption patterns of HIT by comparing influential structural variables across the US, there were several limitations regarding utilizing the UDS and FCC datasets. The UDS data is self-reported by individual health centers at the parent organization level meaning that

critical variables that may allow for an analysis of the structure of individual organizations are collapsed and not available at the aggregated level. Therefore, future UDS modernization efforts and research should focus on sources of patient-level data within FQHCs. The UDS also used a single urban or rural designation for health center organizations even if some of the satellite delivery sites may not be in rural areas. This potential discrepancy is likely to be a consequence of variations in definition of rural designation. Whitacre and Williams (2014) evaluated EMR adoption and measured rurality by using street addresses to define rurality at the county level. Though their study was limited to the state of Oklahoma, they categorized physician offices located within a Metropolitan Statistical Area (MSA) that consisted of a community of a population of 50,000 or greater as urban <sup>15</sup>. Therefore, future research using UDS should be evaluated rurality using street addresses rather than self-reported data.

According to the FCC, the choice of specific broadband technology may depend on factors that include whether a facility is located in a rural or urban area, how the broadband is packaged with other services such as phone, price and availability <sup>83</sup>. The UDS asked specifically if the individual parent organization had an Office of the National Coordinator (ONC) for Health IT EHR, as well as the name of the vendor, but does not go into detail regarding the specific broadband technology available to the facility that may ultimately impact connectivity. There is also limited data regarding where exactly within a ZIP code, broadband is available therefore demonstrating a lack of geographic specificity <sup>81</sup>. Other critiques include that there have been “measurement errors and sample selection bias” that have contributed to some overestimation of a carriers’ service area <sup>100</sup>. Ultimately, as noted in a similar research study analyzing broadband

availability and EMR adoption on the state level, this data had improved significantly from earlier efforts to document broadband provision and it serves as the best available data set representing this information <sup>15</sup>.

Subsequent research should focus on evaluating the impact of patient mix within FQHCs and that clinics' incentives to adopt HIT. It would be beneficial to explore the influences potential payor reimbursements would have on HIT utilization as well as the impact of state and federal policies on the patient mix. Due to limitations of the data set, the patient mix variable is associated at the parent organization level and may not necessarily reflect the mix at the satellite site clinics.

And because the UDS also requires the reporting of health outcomes related to prenatal care, hypertension, and Diabetes, future research can then examine how significant variables associated with higher levels of patient and provider utilization impact final health outcomes in this patient population. The question would focus on whether higher utilization Impact Score are associated with better outcomes, or if a clinic can minimally utilize their health technology and continue to have positive outcomes.

A more robust comparative study should also be done on several aspects of this research in the future, once the UDS is modernized and site level data has been included. Follow up studies can also analyze potential patient volume threshold where it is determined at what volume does adoption usually occur for EHR and telehealth. Policies and laws can assist low volume clinics by changing how technologies are reimbursed. If telehealth modalities are incentivized, though the volume of patients actively being encountered in the clinic may not change, "virtual visits", a new measure

being captured in the 2019 UDS survey, can indirectly increase volume in an otherwise limited growth environment, while improving care and access. Therefore, models such as Project ECHO Telehealth and OCHIN EHR Collaboratives, serve as linkages where multiple FQHCs can utilize the same platforms creating network models rather than a single clinic adoption model especially in low volume areas.

## **DISSEMINATION PLAN**

Upon the completion of this research (Appendix A), data and analysis from Aim 2 will be combined in an article format and submitted to Health Affairs with a proposed title of *Using HIT to Reduce Barriers in Community Health: EHR & Telehealth Adoption in Federally Qualified Health Centers*. In order to acknowledge the GIS and spatial informatics components, the plan will be to submit an article to the Journal of the American Medical Informatics Association under the proposed title of *Using Geographical Information Systems (GIS) to Examine the Association of Broadband Availability and HIT Adoption within Federally Qualified Health Centers*

## APPENDICES

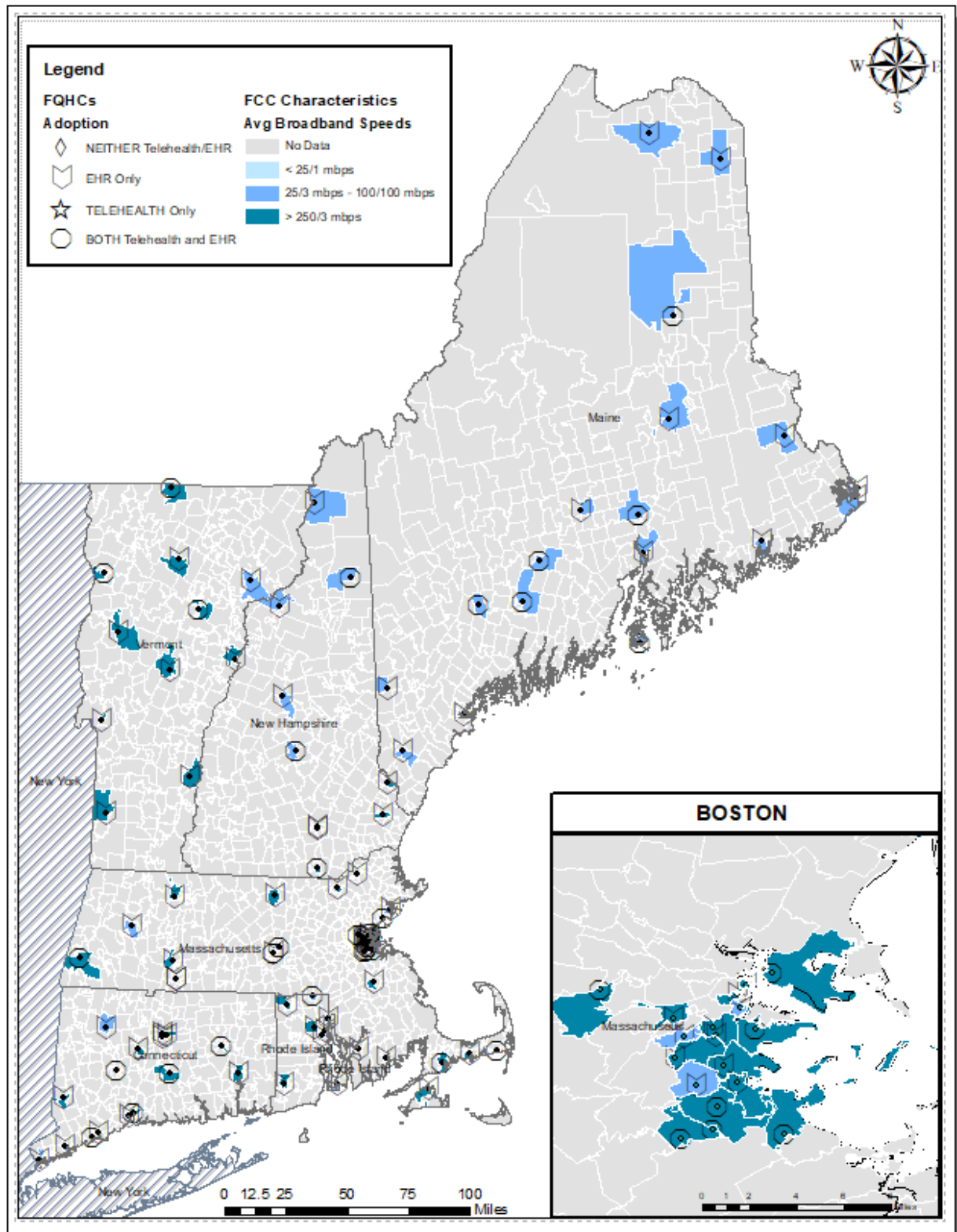
### Appendix A:

TASK #	TASK	2019 - 2020					
		Oct	Nov	Dec	Jan	Feb	Mar
1	DEFEND DISSERTATION PROPOSAL	✓					
2	ACQUIRE IRB APPROVAL		✓	✓			
3	SECURE THE DATA FROM HRSA, FCC & U.S. CENSUS BUREAU			✓			
4	COMPLETE DATA CLEANING			✓			
5	MERGE AND ORGANIZE DATA NEEDED FOR AIMS			✓	✓		
6	ANALYSIS AND DRAFT ARTICLE 1				✓	✓	
7	RESULTS AND CONCLUSIONS (ARTICLE 1)					✓	
8	ANALYSIS AND DRAFT ARTICLE 2				✓	✓	
9	RESULTS AND CONCLUSIONS (ARTICLE 2)					✓	
10	DEFEND COMPLETED DISSERTATON						✓

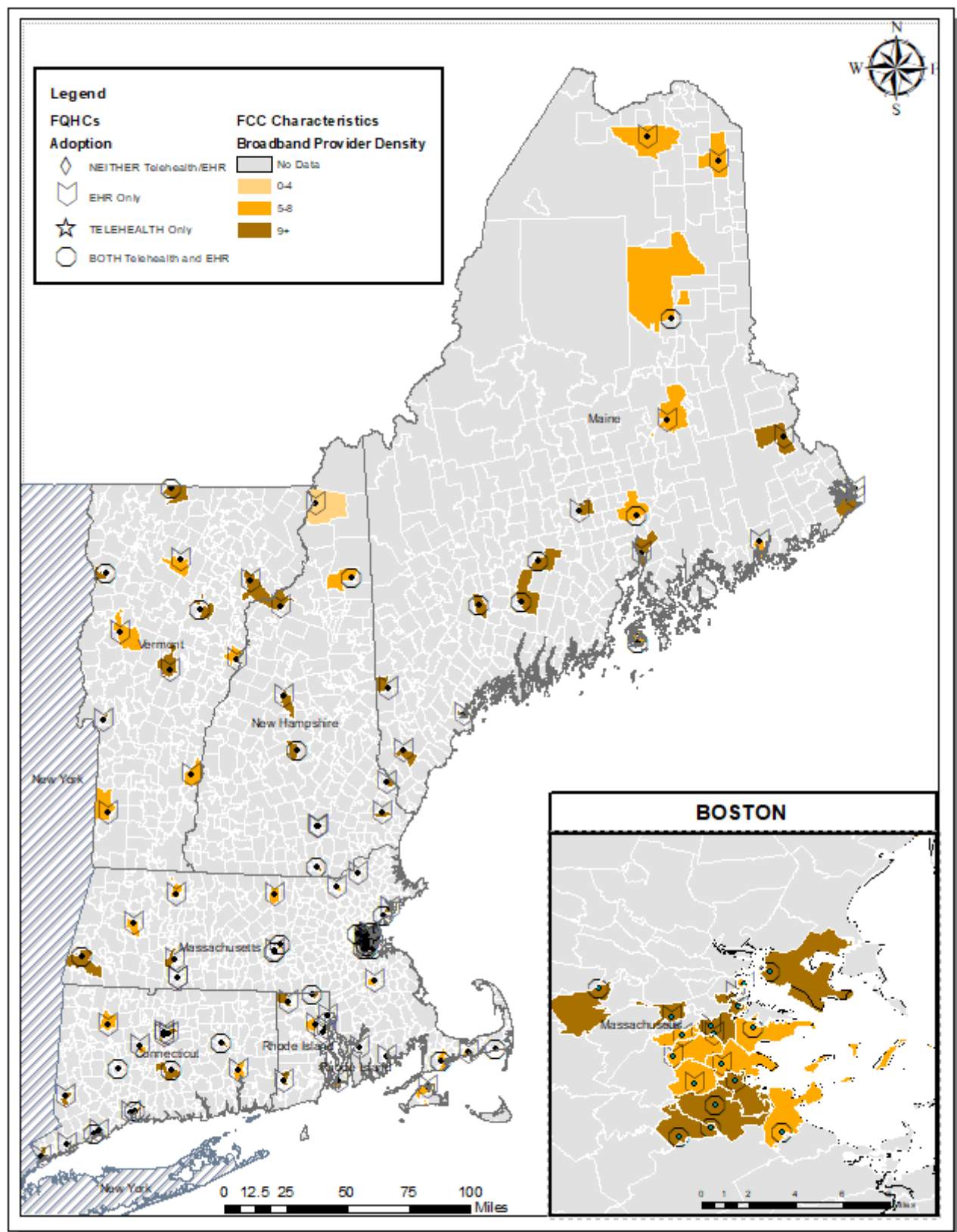


## Appendix B:

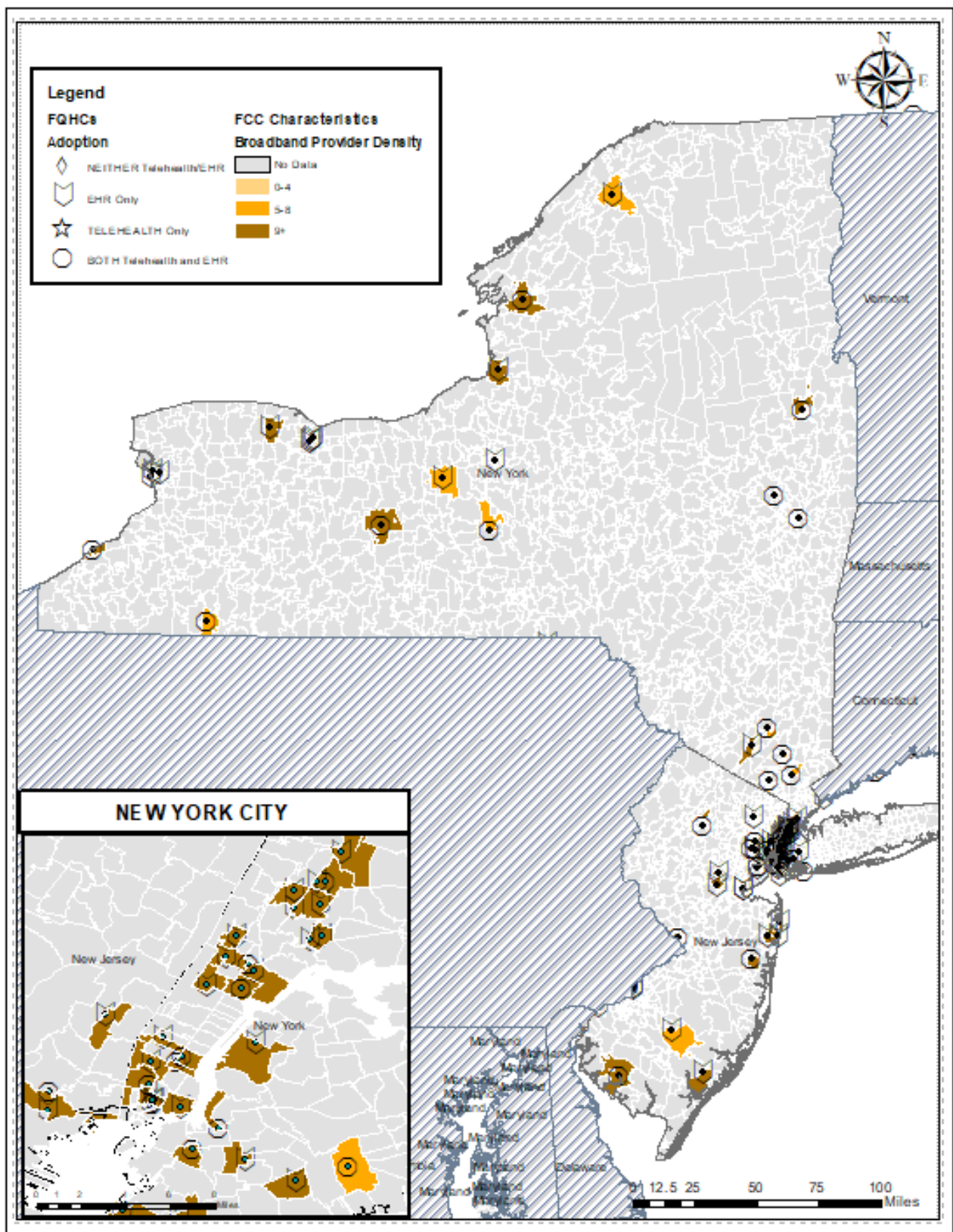
HRSA Region 1: FQHC Locations per Zip Code by Adoption Level and Broadband Speeds



**HRSA Region 1: FQHC Locations per Zip Code by Adoption Level and Broadband Provider Density**

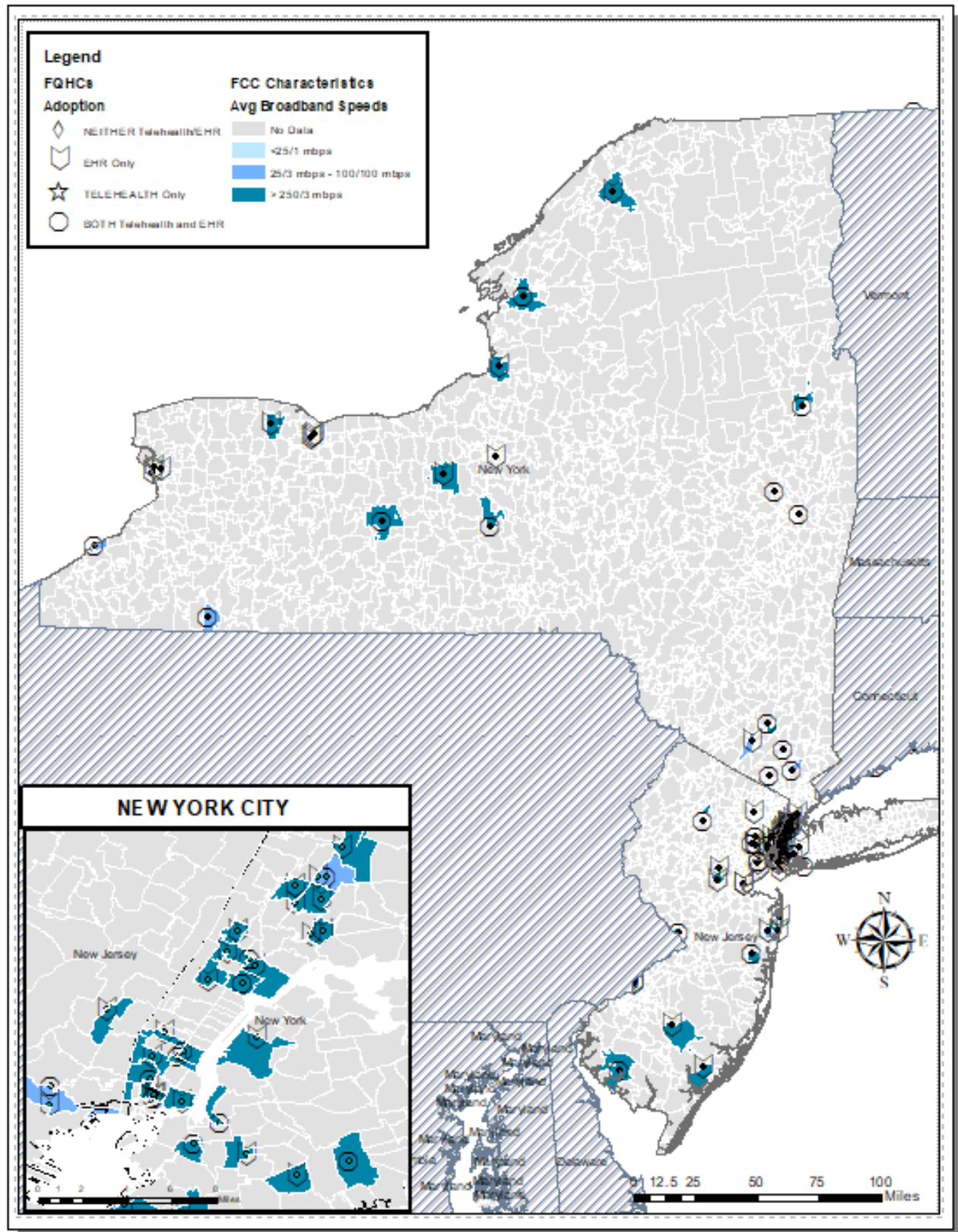


HRSA Region 2: FQHC Locations per Zip Code by Adoption Level and Broadband Density

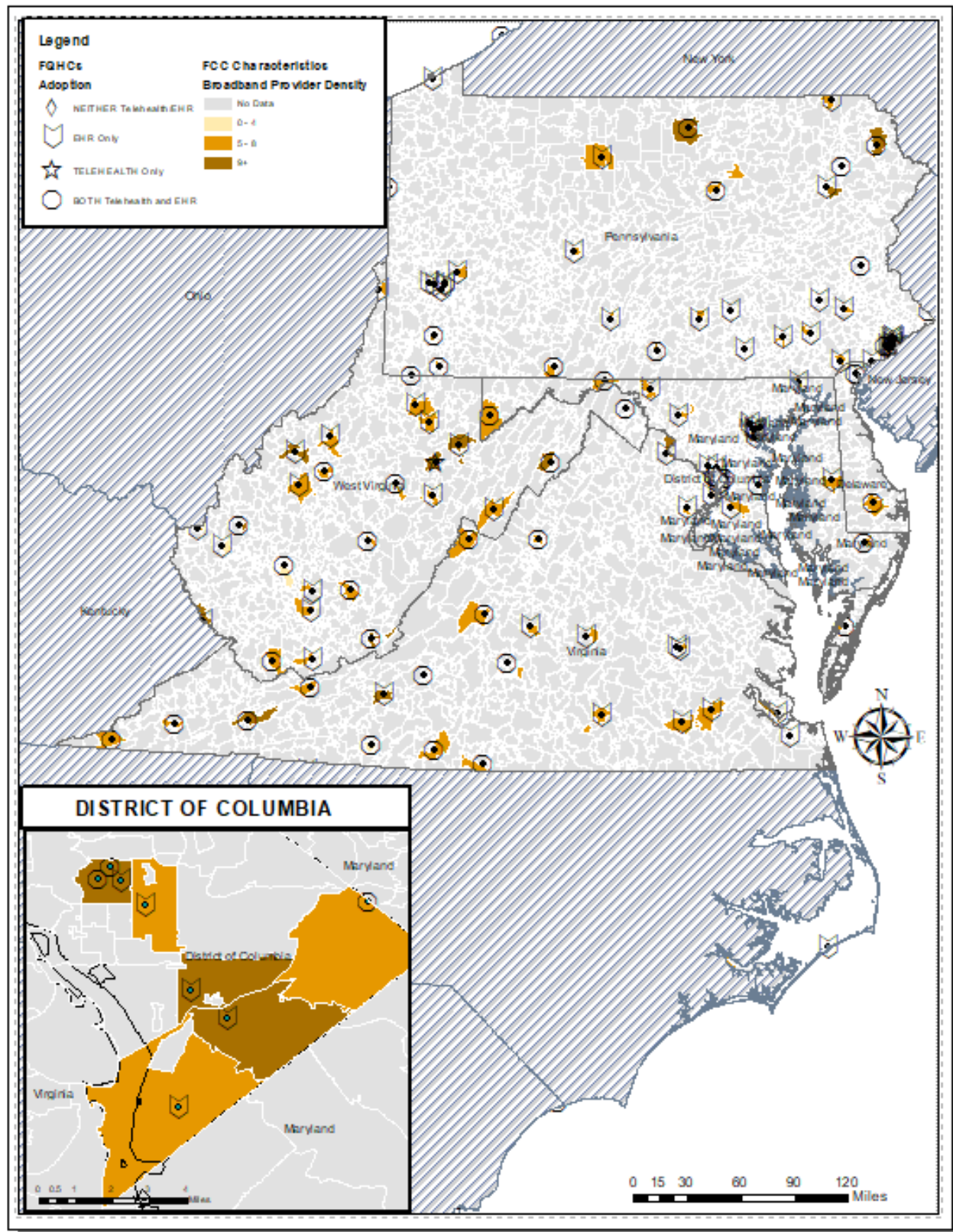




HRSA Region 2: FQHC Locations per Zip Code by Adoption Level and Broadband Speeds

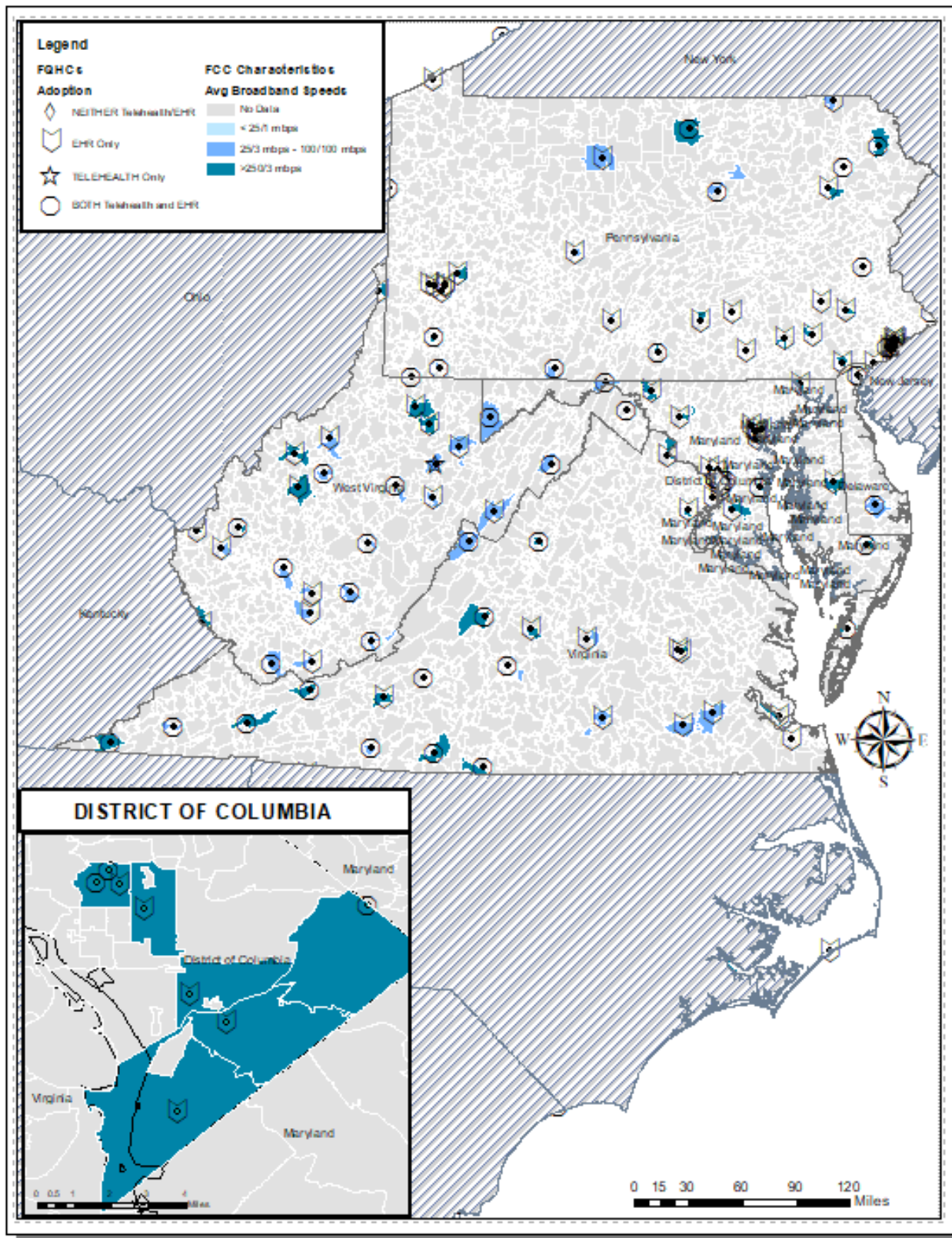


HRSA Region 3: FQHC Locations per Zip Code by Adoption Level and Broadband Density

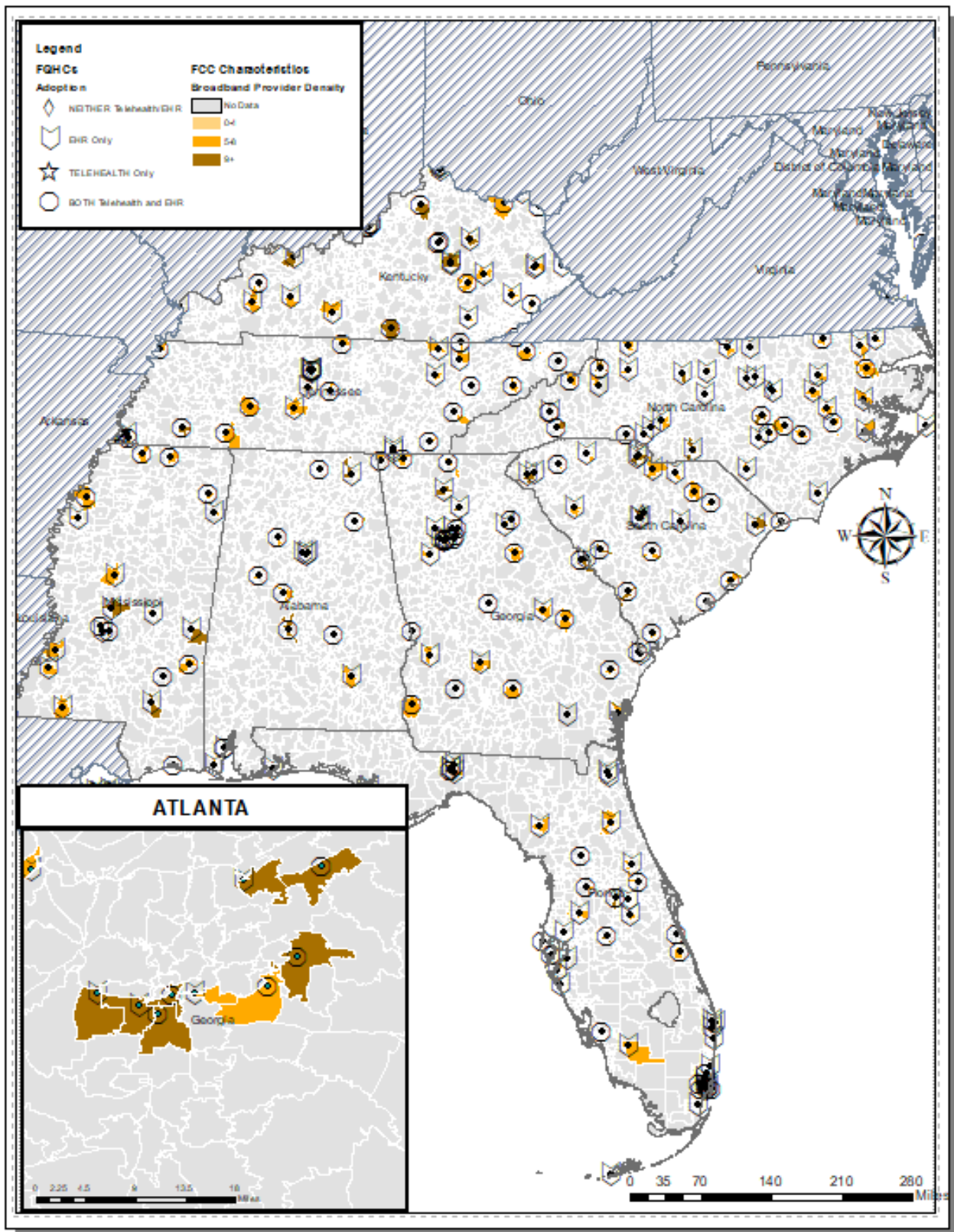




HRSA Region 3: FQHC Locations per Zip Code by Adoption Level and Broadband Speeds

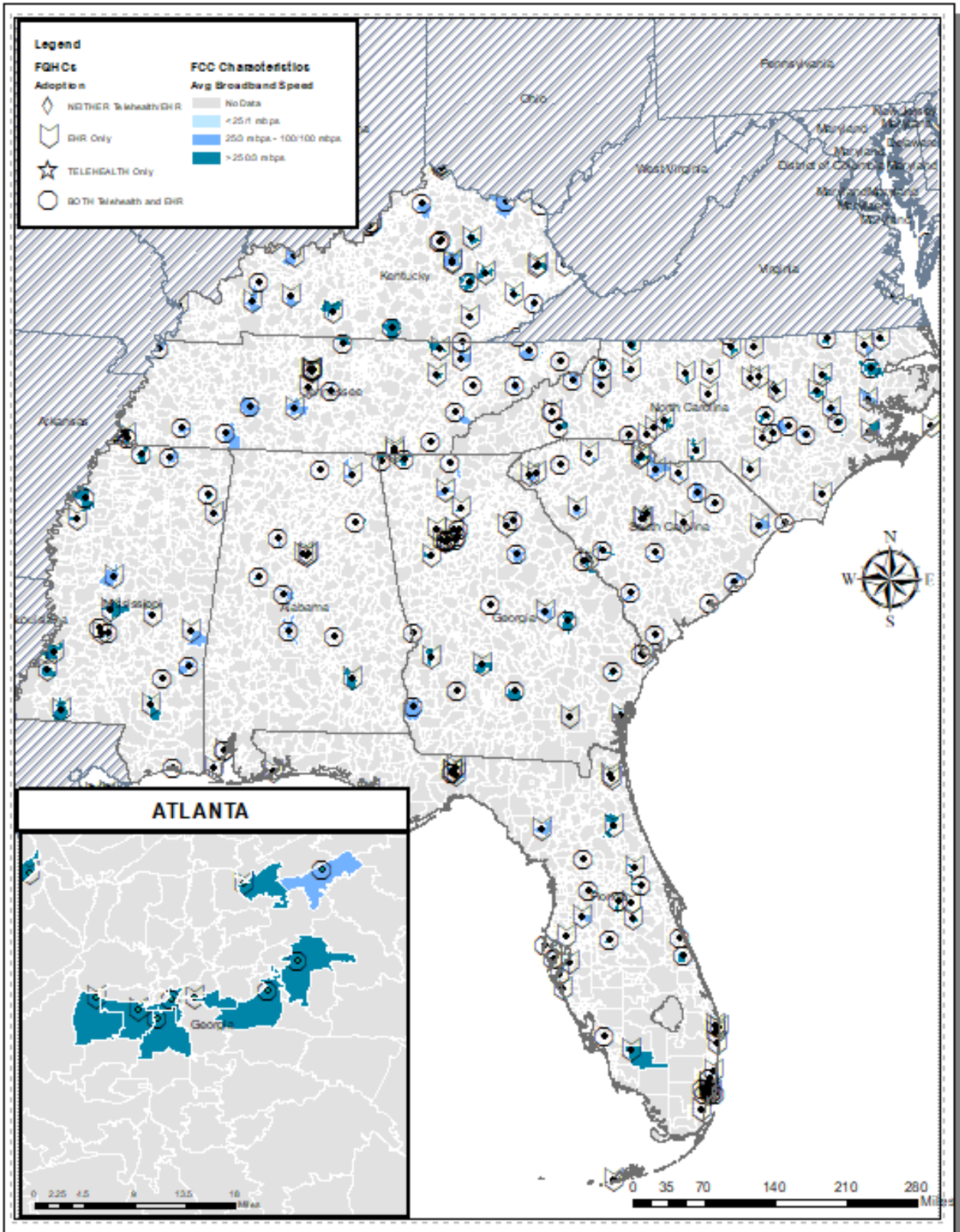


HRSA Region 4: FQHC Locations per Zip Code by Adoption Level and Broadband Density



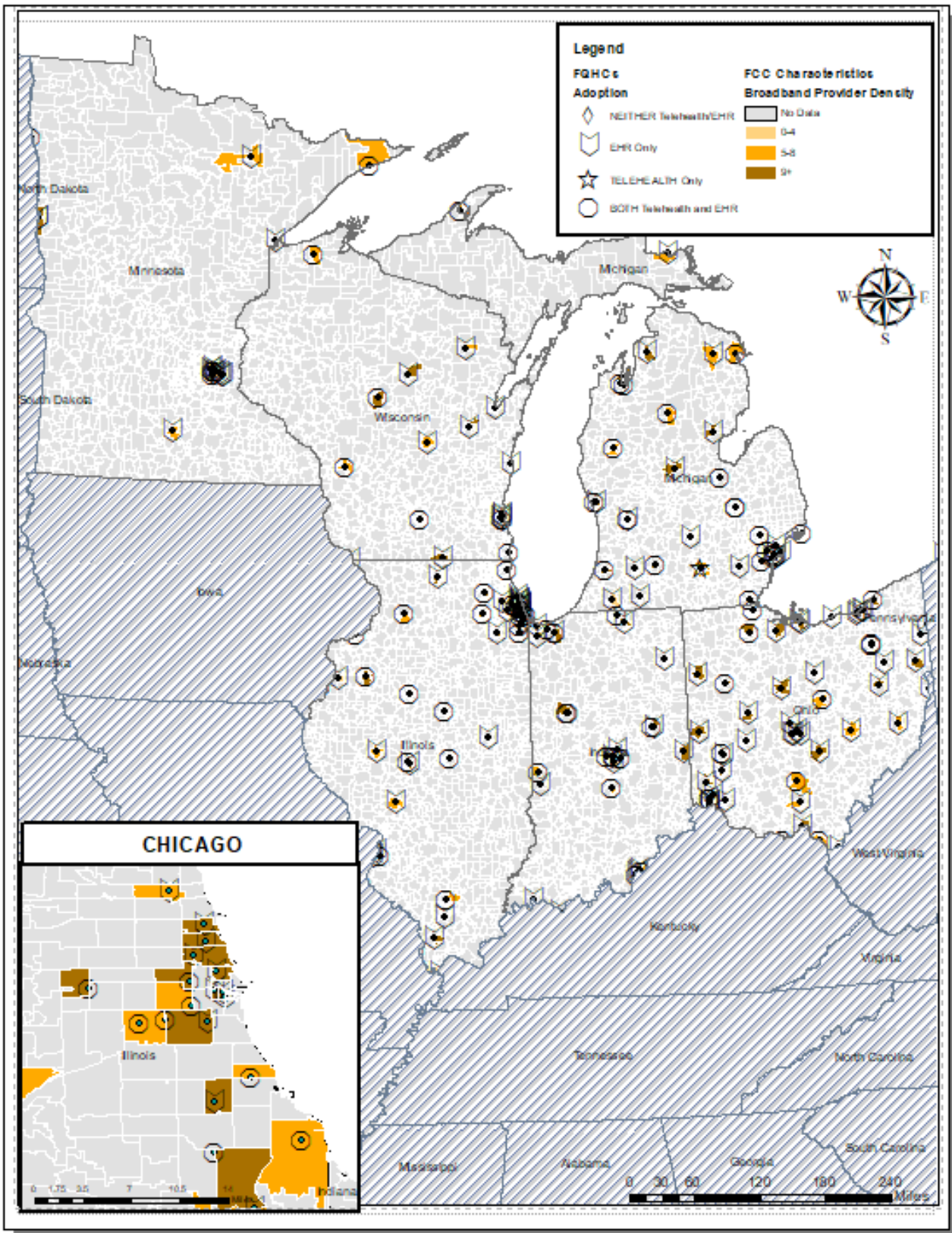


HRSA Region 4: FQHC Locations per Zip Code by Adoption Level and Broadband Speeds

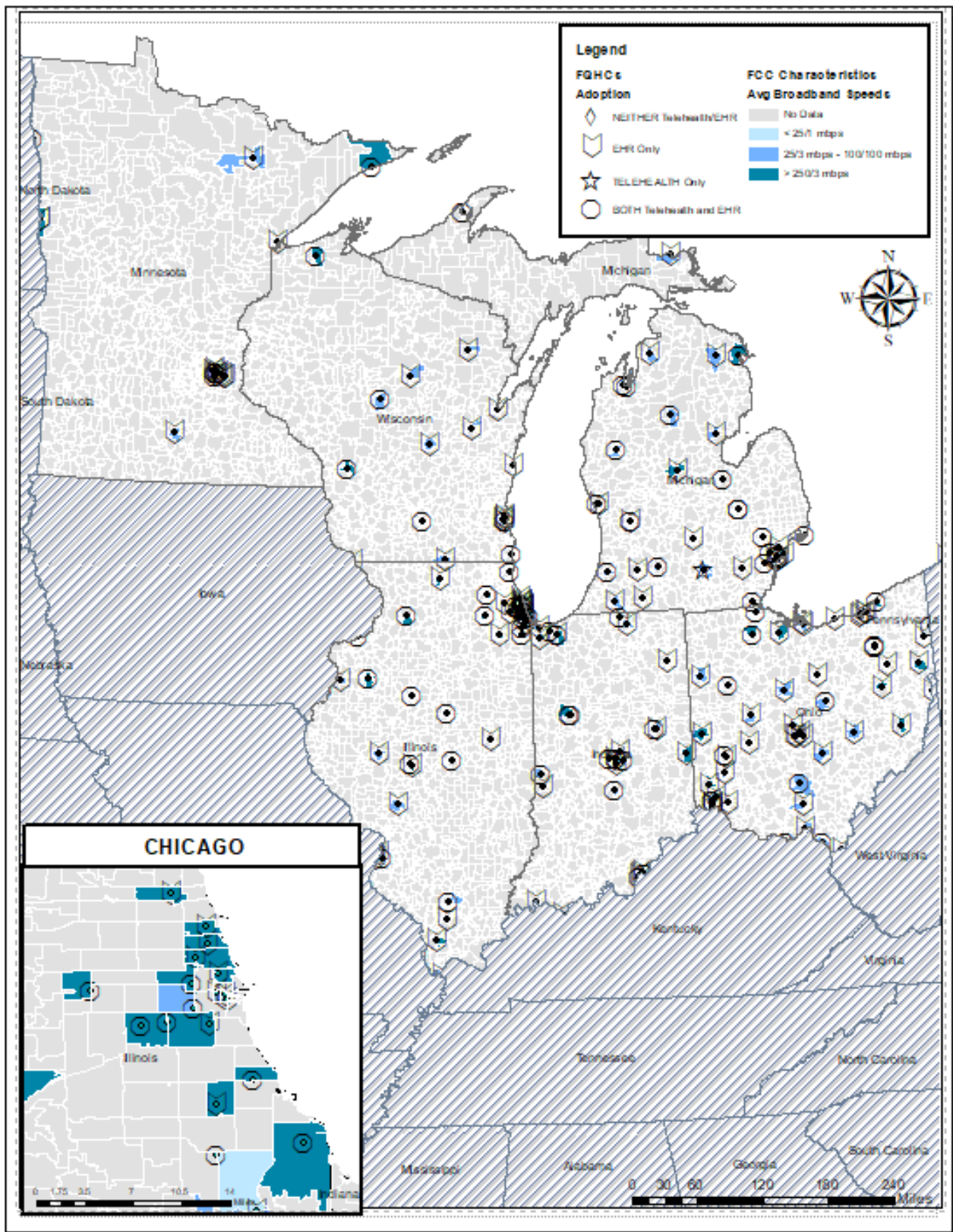




HRSA Region 5: FQHC Locations per Zip Code by Adoption Level and Broadband Density

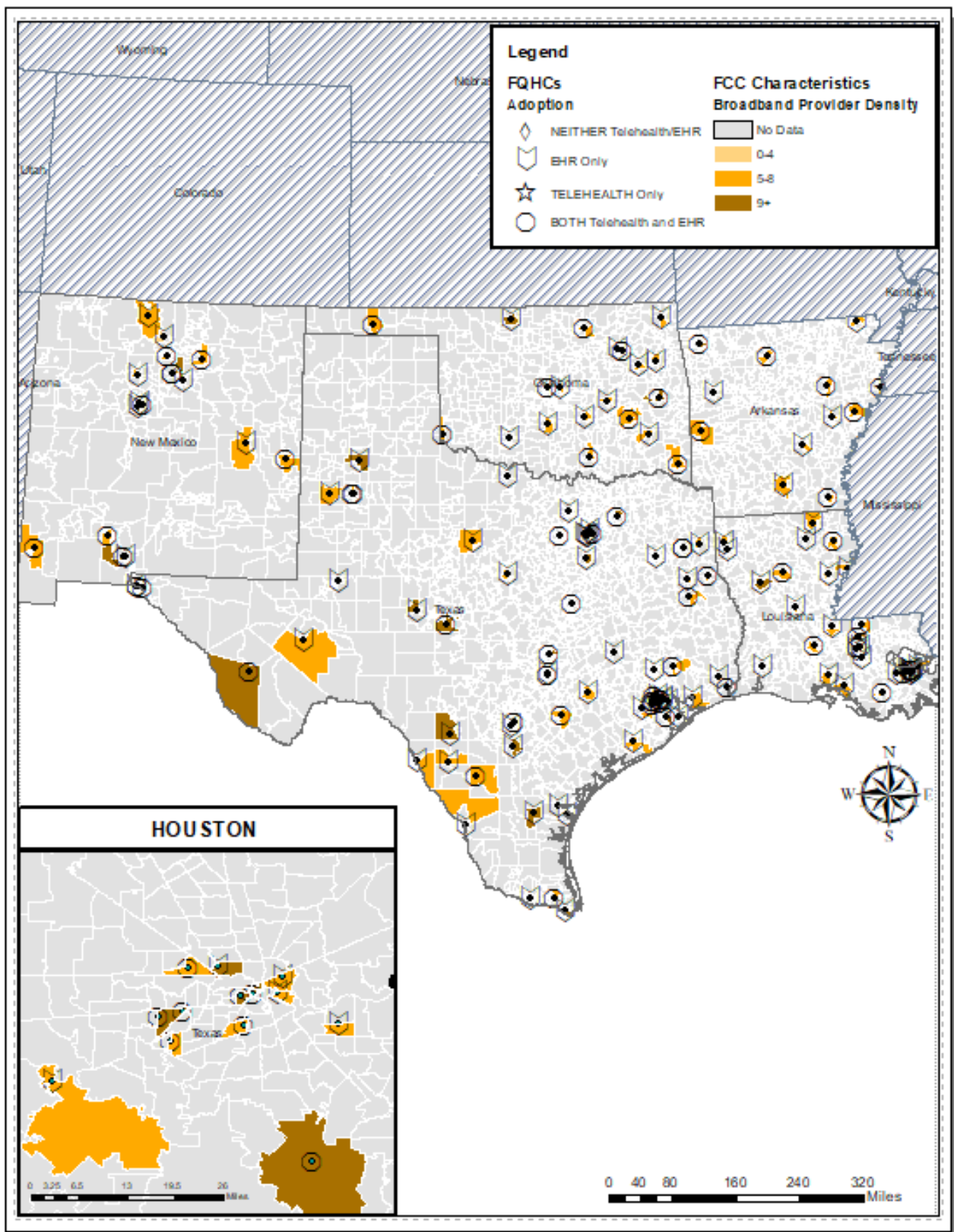


HRSA Region 5: FQHC Locations per Zip Code by Adoption Level and Broadband Speed

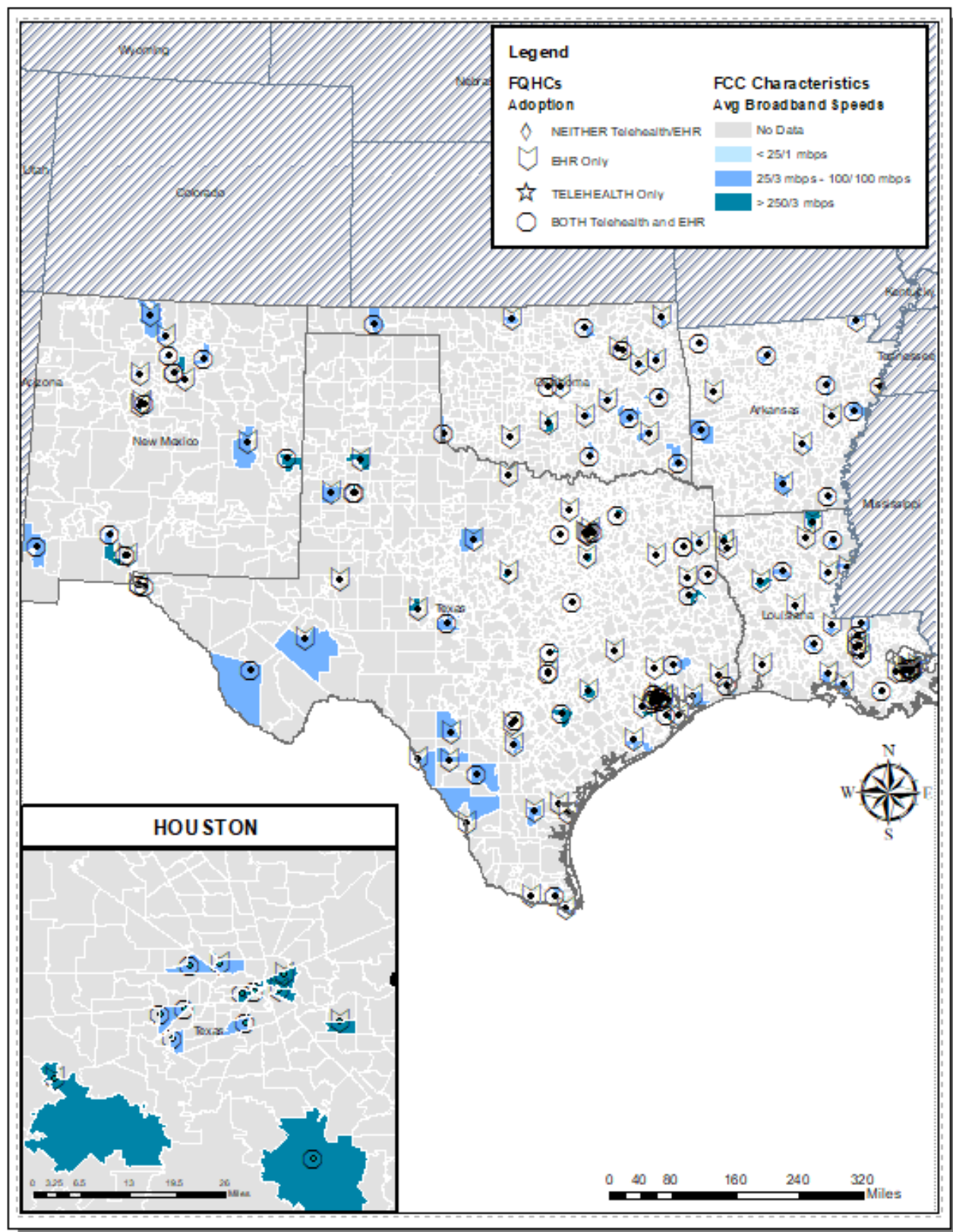




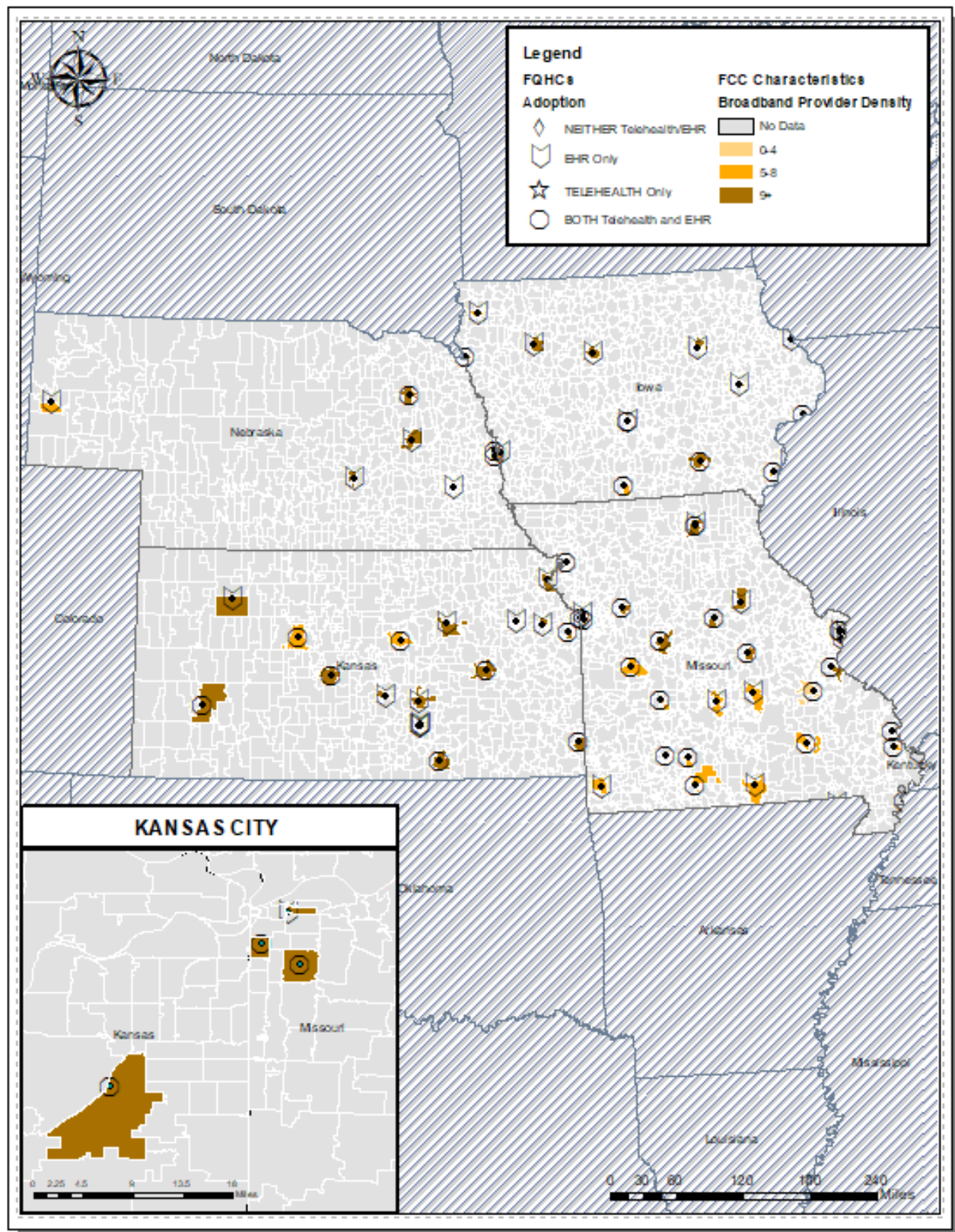
**HRSA Region 6:** FQHC Locations per Zip Code by Adoption Level and Broadband Density



**HRSA Region 6: FQHC Locations per Zip Code by Adoption Level and Broadband Speed**

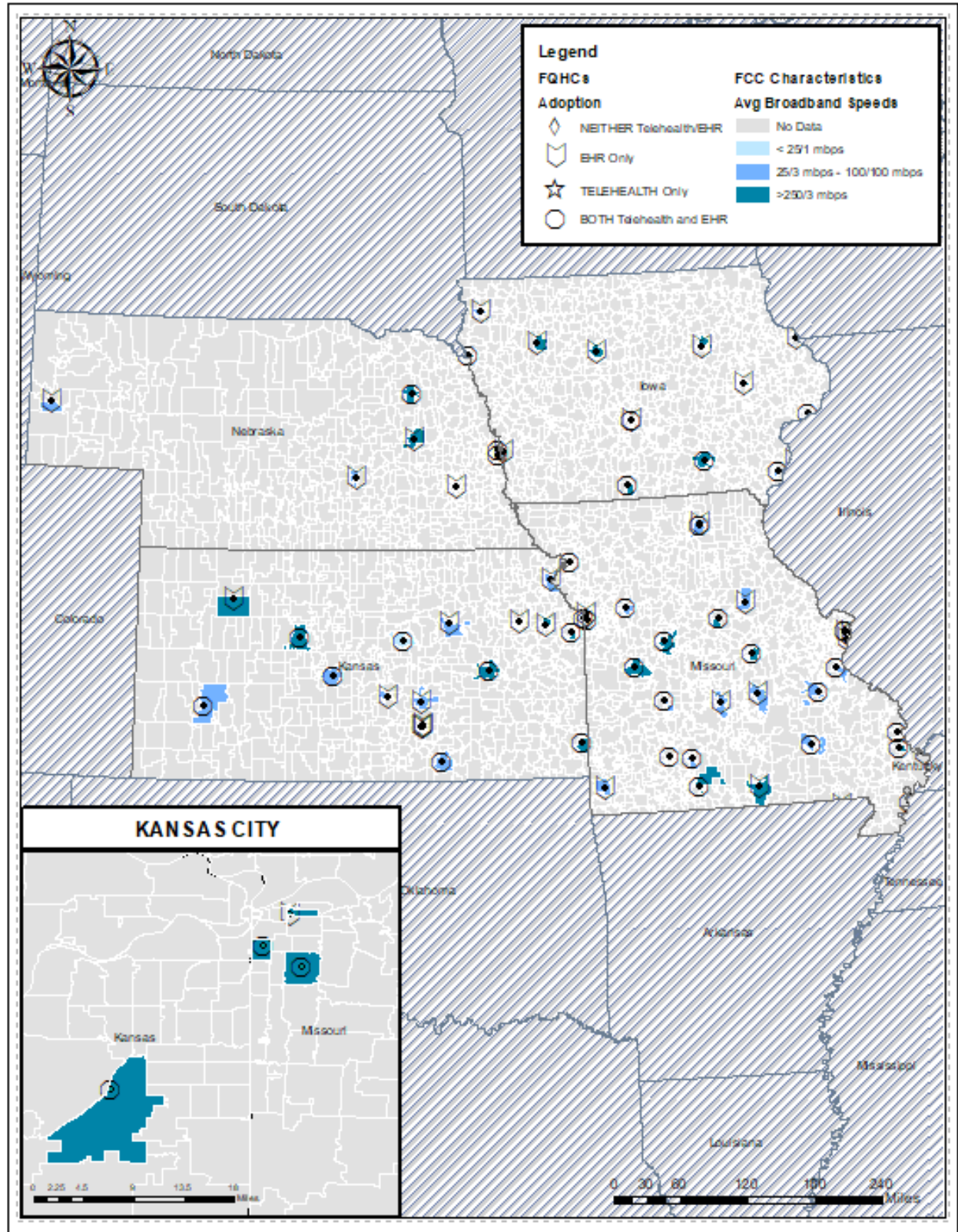


**HRSA Region 7: FQHC Locations per Zip Code by Adoption Level and Broadband Density**

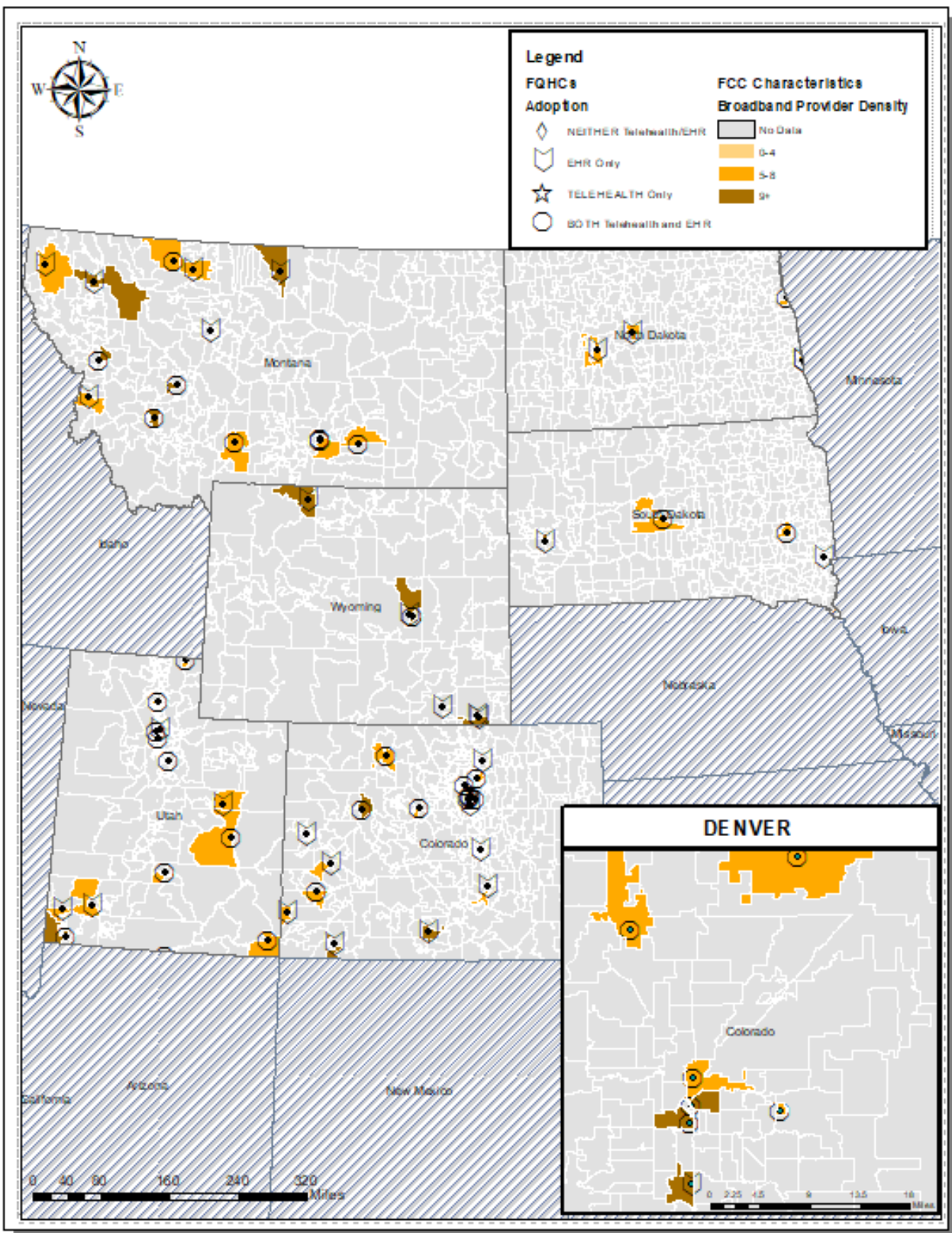




HRSA Region 7: FQHC Locations per Zip Code by Adoption Level and Broadband Speed

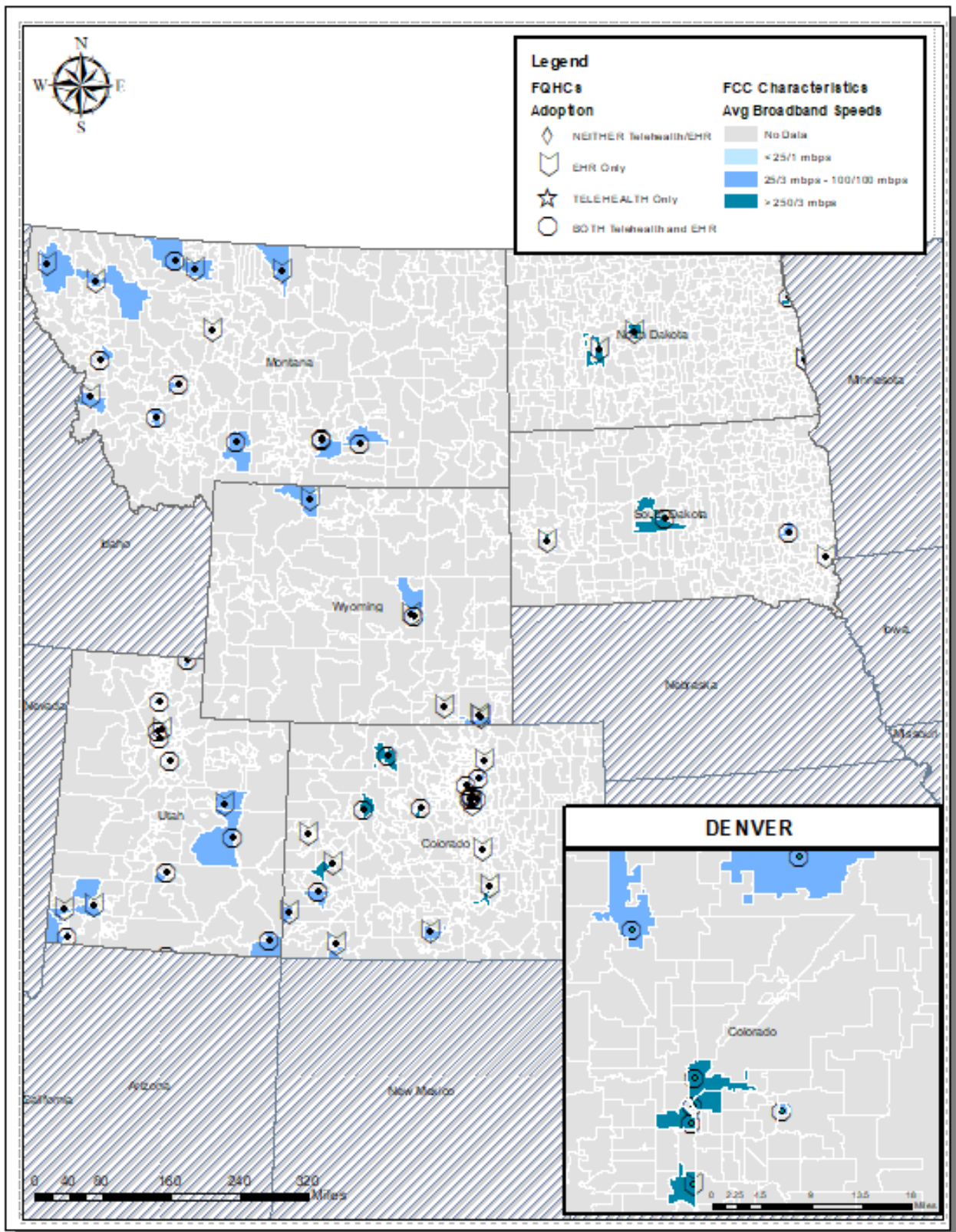


**HRSA Region 8:** FQHC Locations per Zip Code by Adoption Level and Broadband Density



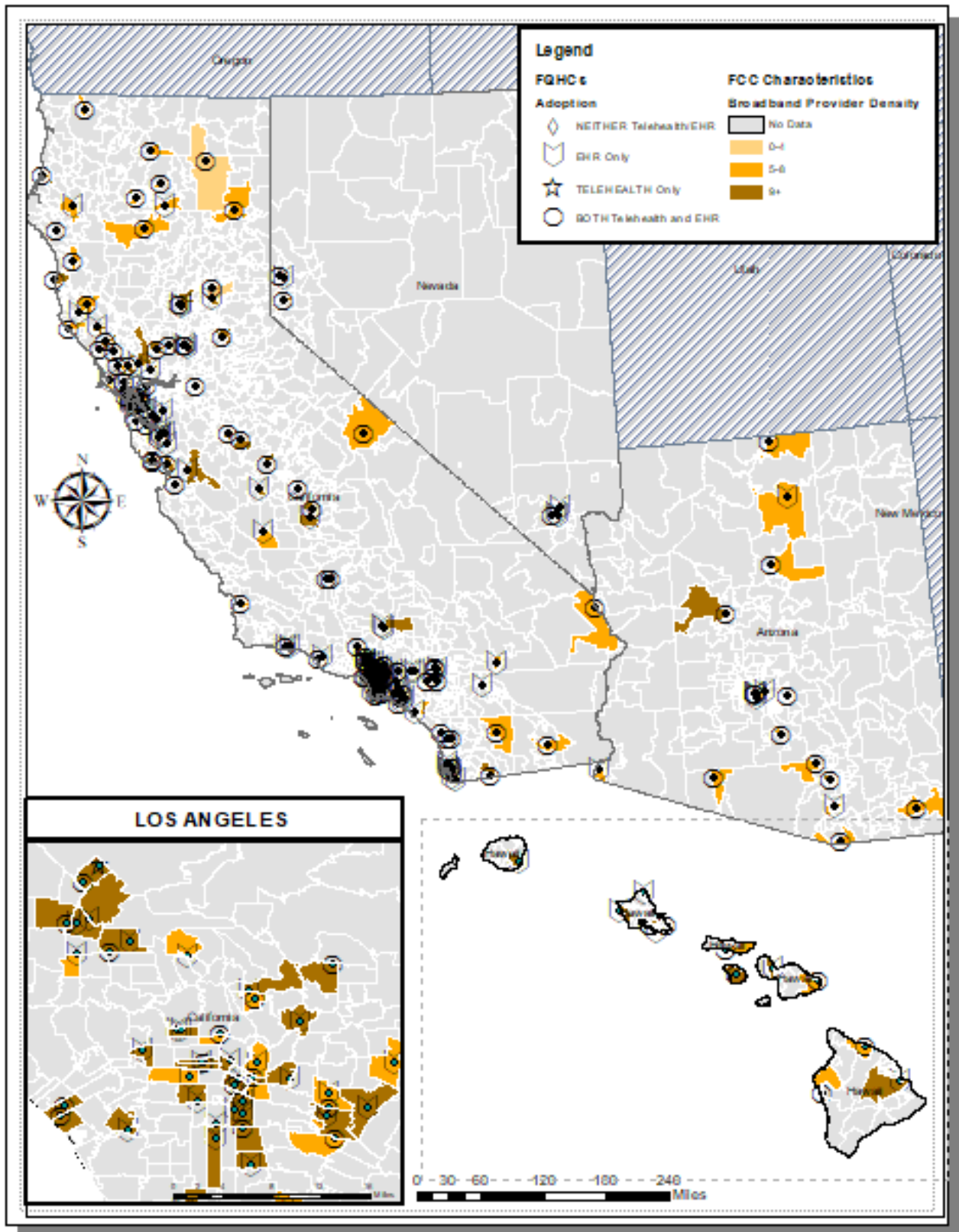


**HRSA Region 8: FQHC Locations per Zip Code by Adoption Level and Broadband Speed**

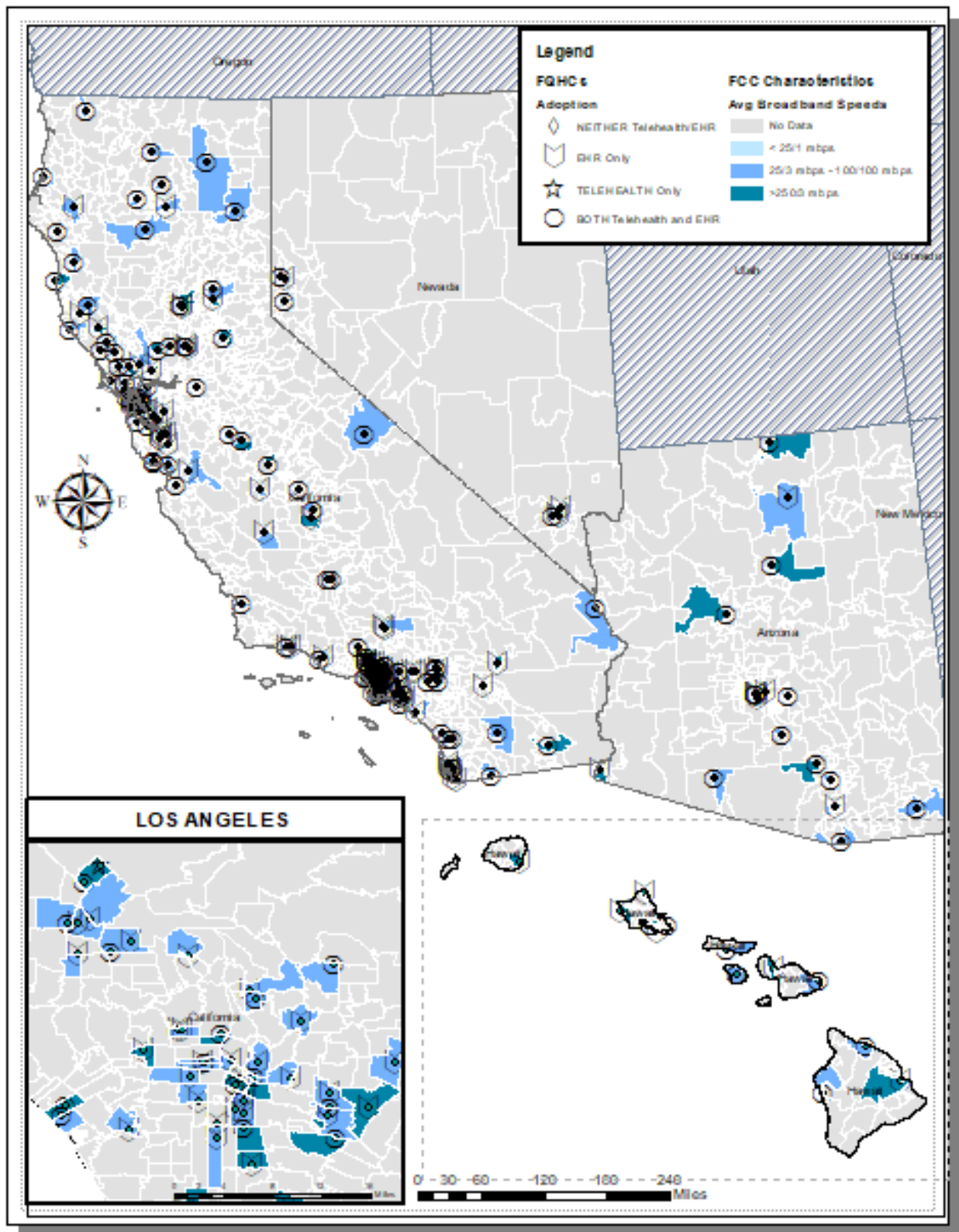




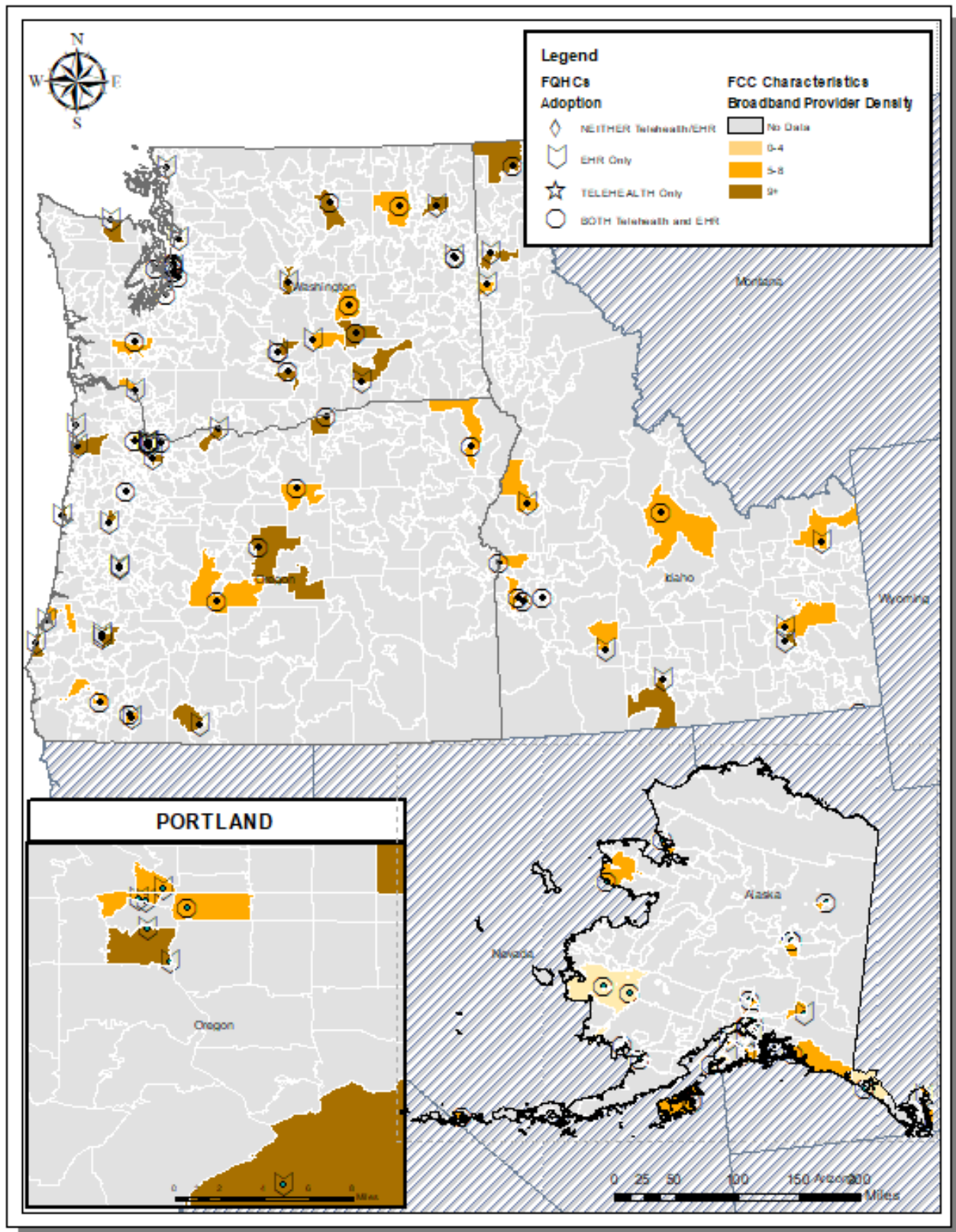
HRSA Region 9: FQHC Locations per Zip Code by Adoption Level and Broadband Density



HRSA Region 9: FQHC Locations per Zip Code by Adoption Level and Broadband Speed

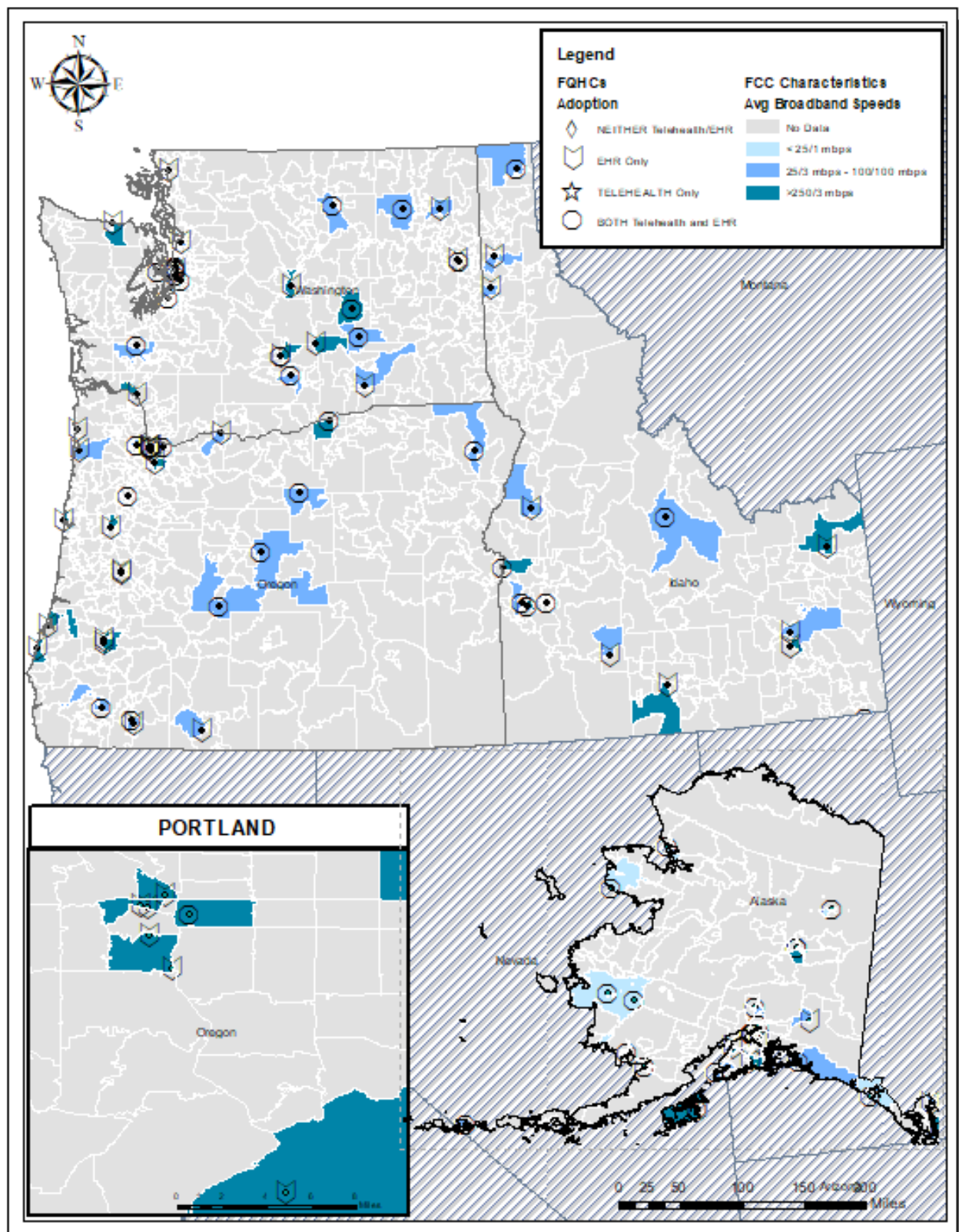


HRSA Region 10: FQHC Locations per Zip Code by Adoption Level and Broadband Density





HRSA Region 10: FQHC Locations per Zip Code by Adoption Level and Broadband Speed



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