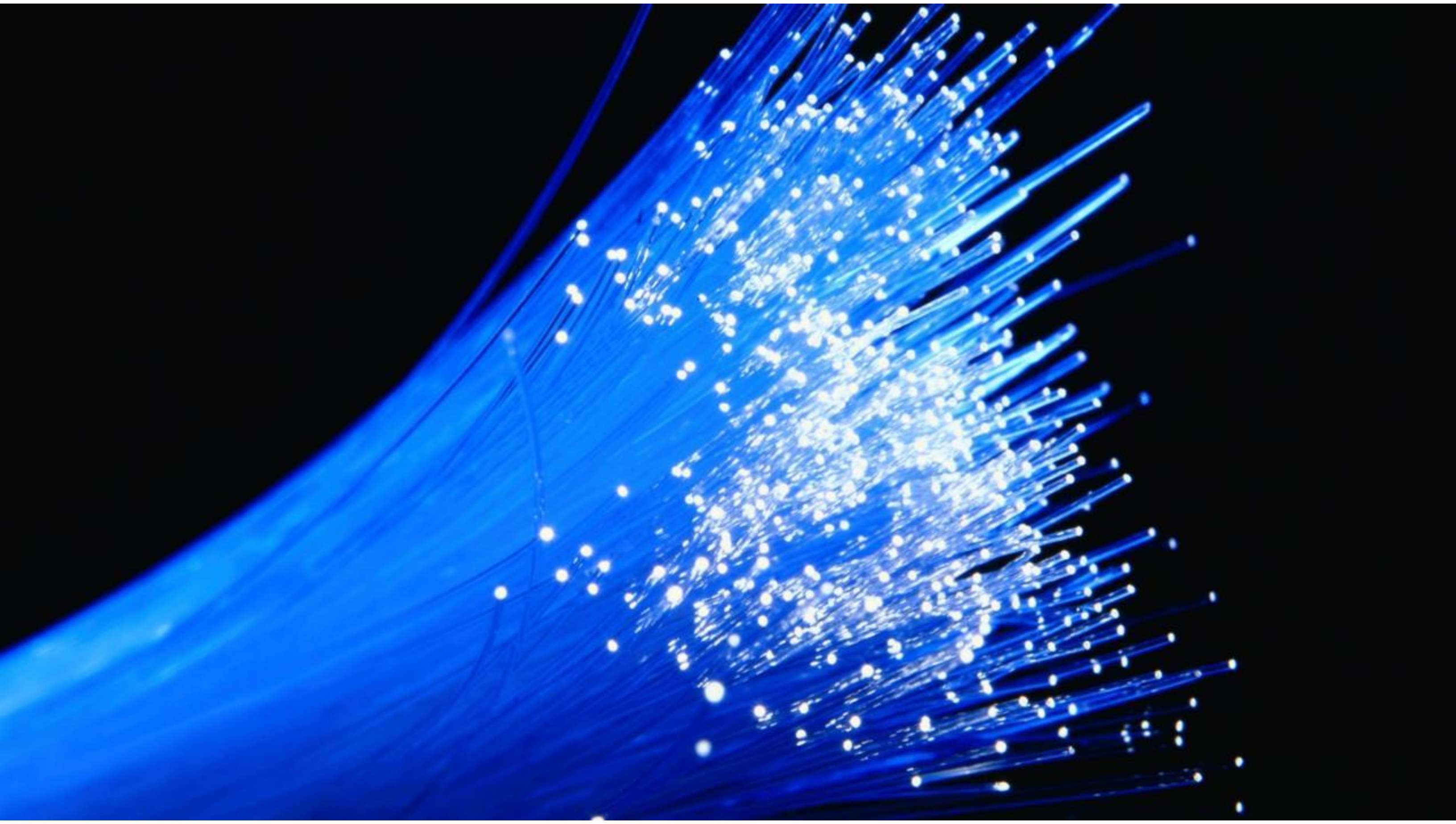

Broadband Access Study

Prepared for King County, Washington, in Response to the Proviso of Ordinance 18835, Section 118
December 2019

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1 Executive Summary

This report presents the research, findings, and recommendations of an assessment of broadband infrastructure and service conducted for King County by CTC Technology & Energy (CTC) in the summer and fall of 2019.

In parallel with CTC's work, King County contracted Pacific Market Research (PMR) to conduct a public research effort through a survey process. This survey includes insights from across the County on access and affordability as well as on attitudes, literacy, usage, and skills as they relate to digital engagement.[1]

1.1 King County's broadband challenges

The CTC and PMR studies were commissioned by King County in recognition that those who lack broadband face enormous disadvantages—and that those disadvantages will grow as our economy and society become more broadband-dependent in the coming decades.

The County's unincorporated areas are the most likely to suffer from lack of availability of broadband service because adequate broadband infrastructure does not currently exist. These are the County's **unserved** areas. Filling that gap will be costly and high-risk because building new broadband infrastructure requires massive capital investment, whether public or private, as well as ongoing operating risk.

To address these **unserved** areas, this report recommends grant and private sector partnership strategies that could serve to reduce the rural broadband challenge. The report recommends efforts to work with the private sector and to leverage State and federal competitive grant programs.

Even where broadband service is available in King County, there exist critical challenges related to affordability, digital literacy, and access to devices. These challenges—which PMR's research has shown to disproportionately impact lower-income members of the community and communities of color—put these **underserved** members of the community at huge disadvantage relative to others with respect to basic functions such as education, health care, small business development, and access to government services.

To address these **underserved** needs, this report recommends infrastructure and private sector partnership strategies designed to efficiently enable some underserved King County residents to access the broadband internet.

[1] PMR's full report is appended hereto as Appendix F and select findings of the PMR analysis are included herein.

1.2 CTC's tasks in fulfillment of County Proviso

Over the course of the engagement, CTC's engineers and analysts completed the tasks required by the County's Proviso. To that end, this report includes, but is not limited to:[2]

A. Definitions for "unserved" and "underserved" in terms of broadband internet access. Affordability, the number of service providers providing broadband Internet service and the quality of service offered shall be considered in the development of the definitions [see Section 2];

B. A description of the geographic areas in King County that are unserved or underserved according to the definitions developed in the report and any known barriers faced by the private sector in providing service in those areas [see Section 3 (unserved) and Section 4 (underserved)];

C. A description of existing and planned efforts by the Department of Information Technology related to expanding access to broadband service at the household level and community level in unserved or underserved areas [see Section 10 (unserved) and Section 11 (underserved)];

D. An evaluation of options for the County to expand broadband access at the household level and community level in unserved and underserved areas that includes a discussion of the potential costs to the County and estimated impact, as well as advantages and disadvantages related to each option [see Sections 5, 6, and 7(unserved), and Section 11 (underserved)]. The review shall consider, but not be limited to:

   1. Options available with the County's institutional network, noting any existing limitations and also including the timeline for the institutional network lease renewal [see Section 1.5.1, Section 11.1, and Section 12];

   2. Options available with the Community Connectivity Consortium, noting any existing limitations [see Section 1.4.1 and Section 12.1]; and

   3. Emerging technologies such as 5G wireless home service [see Section 8].

1.3 Summary of findings

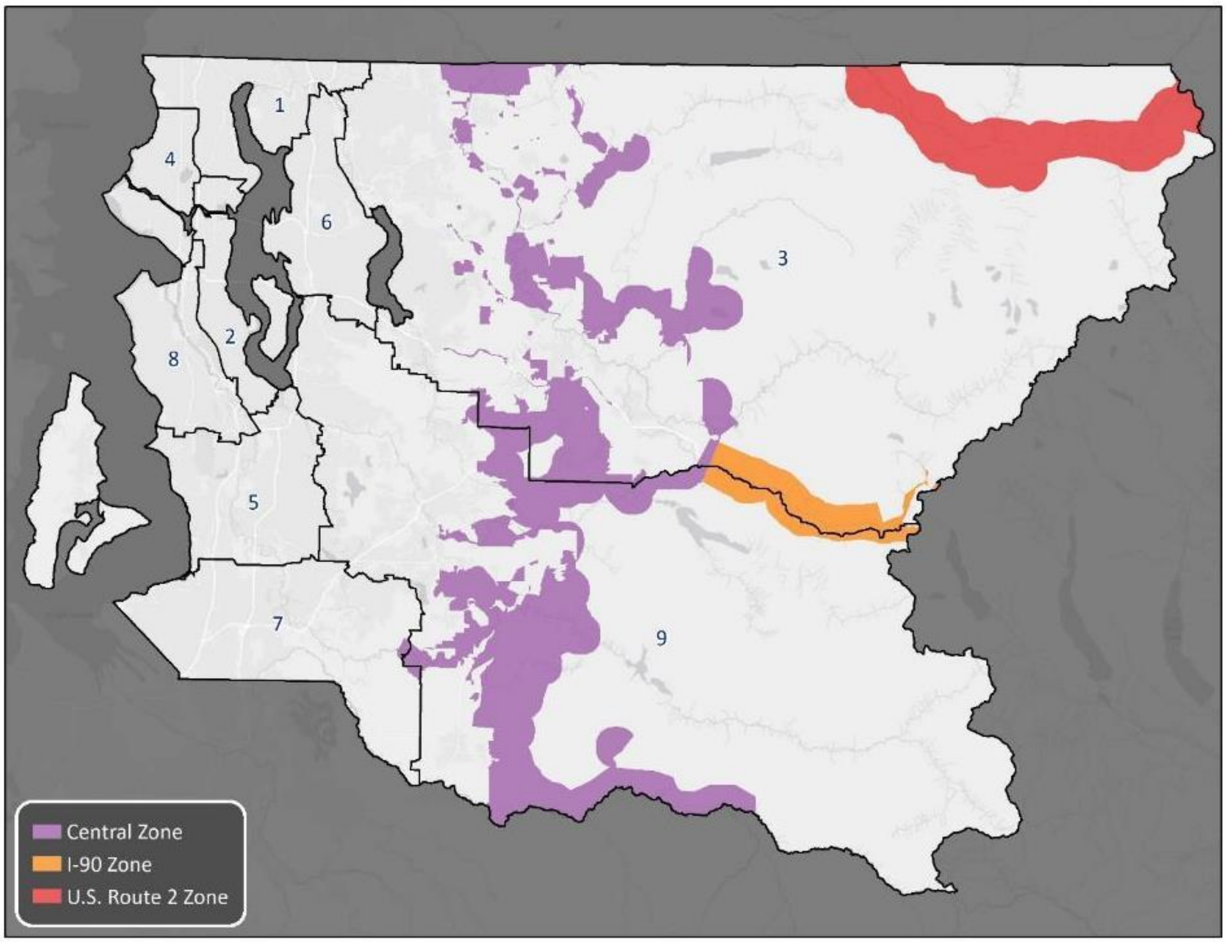
The following are the primary findings of CTC's work.

[2] King County Signature Report, Ordinance 18835, Section 118, King County Information Technology Services. Nov. 14, 2018. https://aqua.kingcounty.gov/council/clerk/OldOrdsMotions/Ordinance%2018835.pdf

1.3.1 Substantial geographic areas of King County are unserved with broadband

In brief summary, our analysis found that the County's unserved residents are clustered in three areas, which we have defined as the central zone, the Route 2 zone, and the I-90 zone (Figure 11). These three zones represent a substantial geographic area of the County, though a modest total population. For residents of these areas, there is no broadband service available and though they may be able to purchase lesser internet services, those services do not meet the federal, State, or County criteria for broadband internet.[3]

Figure 1: Overview of the County's Three Unserved Zones



1.3.2 Rural broadband gaps cannot be solved through private investment alone

Unincorporated King County faces the same challenges as other rural communities with respect to attracting broadband infrastructure investment. Even in the most affluent rural and semi-rural areas, the economics simply do not exist for broadband deployment based solely on

[3] See Section 2 for the County's definitions of served, unserved, and underserved. An area or address in King County is unserved with broadband if it cannot receive internet access with transmission speeds that, at a minimum and on a consistent and reliable basis, provide twenty-five megabits per second download and three megabits per second upload.

private sector investment. The private sector will not build costly wireline infrastructure to reach all homes and businesses in rural areas simply because the potential return on investment does not justify the investment.

The challenging economics result from the lack of density of homes—and, in many cases, the fact that homes are located on large parcels of land; long driveways or setbacks from the road greatly increase the cost to deploy wired infrastructure to those homes.

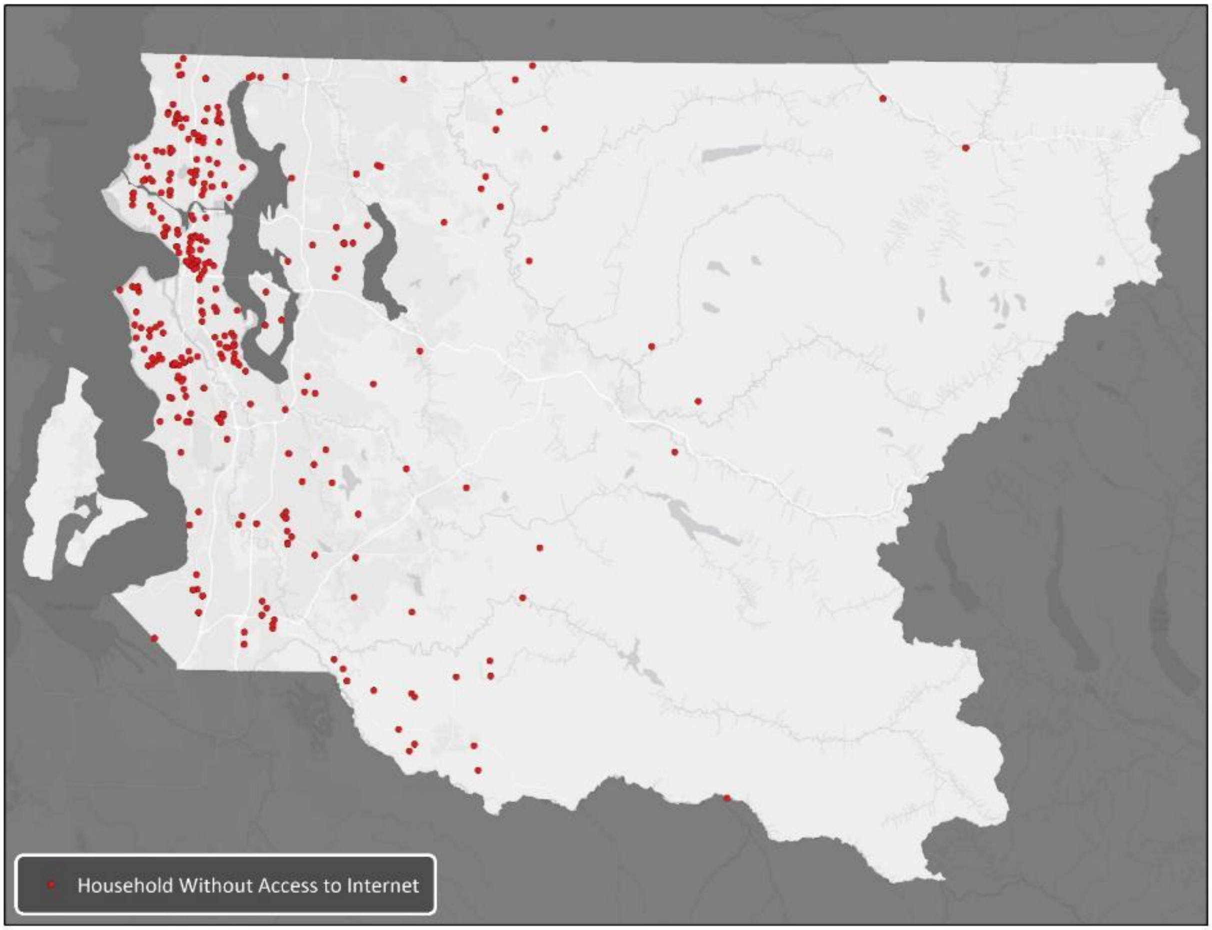
Given these underlying economic challenges, the only means of filling rural broadband gaps has been through public subsidy of various sorts. A wide range of federal subsidy programs support rural service, some more effectively than others, as do state grant programs in some states. When combined with—or incented by—local subsidy, state and federal funds can be sufficient to make viable otherwise infeasible rural broadband programs.

1.3.3 Based on the County's definition, 20 percent of members of the community are underserved and do not have home-based broadband

The County's definition of underserved identifies members of the community who do not use the internet for various reasons, even where it is available to them.[4] Because the term relates to whether and how members of the community are able to access the internet—and not to their geography—developing maps of underserved locations is particularly difficult. For example, responses to PMR's survey found households without access to the internet in many geographic areas of the County, including in areas that are defined as served in terms of availability.

[4] Income is frequently used as a proxy for broadband adoption (and is one element of the County's definition of underserved), based in part on the Pew Research Center's national data, which show that internet use for households earning less than $30,000 per year is far below that of higher-earning households. PMR survey data for King County align with those national data; according to the survey, 20 percent of King County households with income below that level do not have internet access where they live. See Section 4.2 for more details.

Figure 2: PMR Survey Finding – Households Without Access to Internet (Q1), Including Underserved



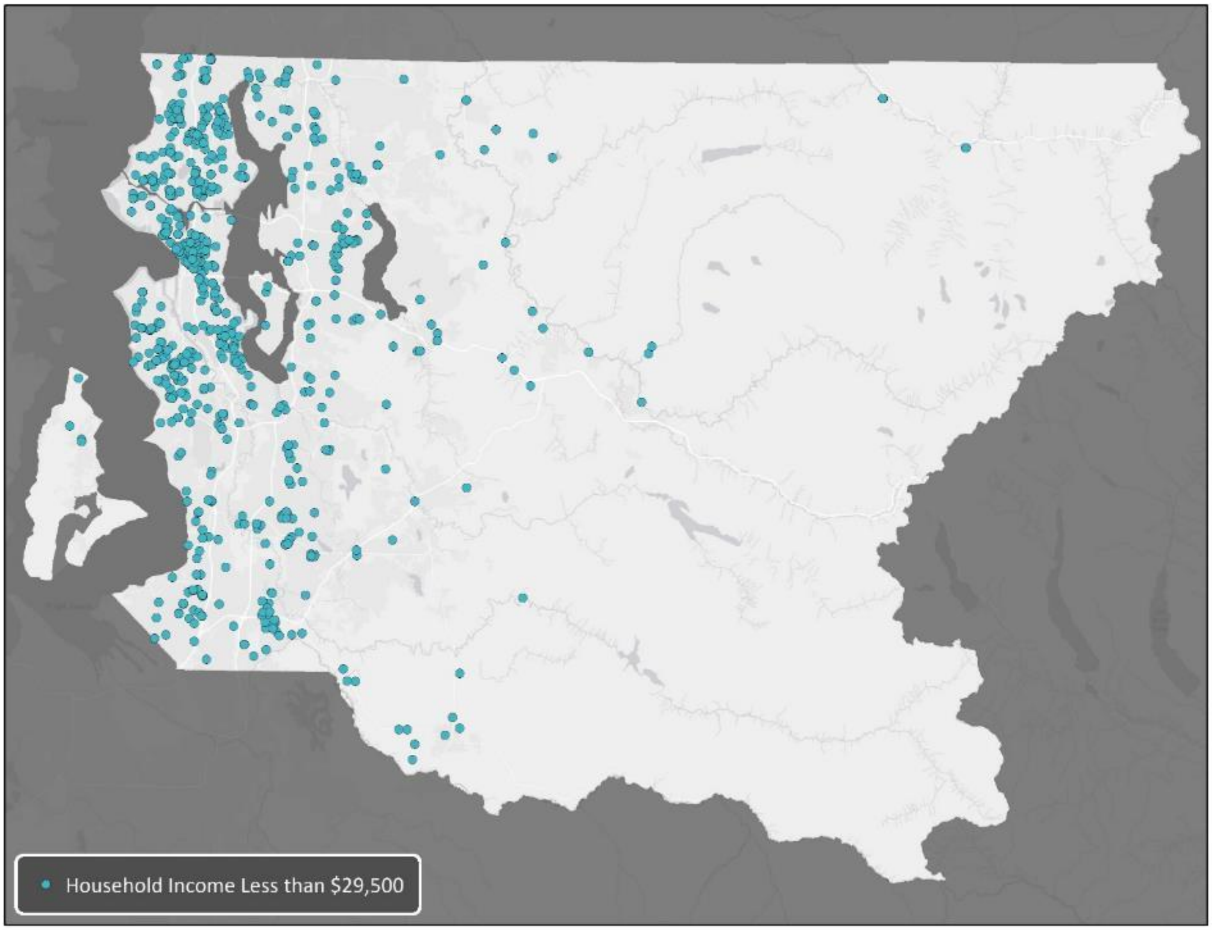
National data have long demonstrated a correlation between lack of broadband access and low income, and PMR's research finds the same for King County. Based on PMR's data, income is a significant factor in: (1) whether or not King County residents have access to the internet where they live; (2) whether that internet access has sufficient download speed; (3) whether that internet access is 'adequate' for their needs; (4) and whether they need to rely on cellular data for their internet access (instead of a fixed broadband connection).[5]

PMR's survey identified members of the community with household income below $29,500—which is an indicator of underserved status based on the County's definition of unserved (see map below). And PMR's survey found that King County households with income less than

[5] PMR's report of its extensive methodology, data, and analysis is attached as Appendix F.

$25,000 per year are significantly less likely to have internet access where they live (only 80 percent, compared to the County total of 96 percent).

Figure 3: PMR Survey Results – Household Income Less Than $29,500 (Underserved)



1.3.4 Federal and State policies have not solved these broadband challenges

Unfortunately, it does not appear that the County can rely on federal and State programs to address the needs of unserved and underserved populations of King County. Despite past, present, and emerging efforts to address these challenges, federal efforts have fallen short and State efforts have been, until very recently, quite modest.

For **unserved** parts of King County, the federal government's broadband funding programs have had limited impact—and have failed to deliver speeds that meet the federal (or County or State) definition of broadband to unserved members of the community. For example, the Federal Communications Commission (FCC) has awarded to CenturyLink, through the second round of its Connect America Fund (CAF II), ongoing subsidy to provide 10 Mbps down/1 Mbps up service to 1,827 locations from 2015 to 2021.[6] Last year, the FCC awarded the satellite company Viasat 10 years of support to provide 10/1 service for 166 locations in King County, through the FCC's CAFII auction. These awards not only *explicitly fail to require speeds that meet the FCC's own definition of broadband*, but also address only a portion of the total unserved locations in King County.

For **underserved** needs in King County, federal programs have been similarly modest in impact. The Lifeline program was created by Congress (and is administered by the FCC) to make service more affordable by providing a modest subsidy to telecommunications carriers for service to lower-income members of the community. While the Lifeline program has had some impact, as have low-cost internet options offered by companies like Comcast and Wave, there still exists a significant lack of use of broadband in King County that is correlated with lower incomes. In short, the adoption and use challenge within King County is related, in part, to the cost of service, and this has not been fully addressed by the federal program.

1.3.5 5G wireless will not solve the unserved and underserved broadband challenges

Despite considerable industry hype about next-generation "5G" wireless, it is doubtful that 5G will be deployed on a ubiquitous basis or comprehensively solve rural broadband challenges in King County. Indeed, the economics of 5G deployment suggest that this technology will extend primarily to densely populated, higher-income, and commercial areas, particularly in the initial years of deployment. As a result, 5G may serve to exacerbate rather than mitigate the existing broadband divides—including rural vs. urban—that already exist in King County and throughout the country. While incrementally improved mobile service may serve to increase the number of very price-sensitive consumers who shift to mobile only, this does not provide those lower-income members of the community with parity of access as compared to other members of the community. As a result, we would not assume that, in the short to medium term, 5G will address the concerns about unserved and underserved populations that led to the commissioning of this study.

1.3.6 Fiber-to-the-premises to fill gaps in unserved King County would cost an estimated $120 million but would have relatively low operating costs

Based on data gathered by CTC engineers through discussions with County stakeholders, an extensive desk survey, and an on-site survey of candidate fiber routes, CTC's engineers prepared a high-level network design for the deployment of a gigabit-capable fiber-to-the-premises (FTTP) network to homes and businesses in those unserved portions of the County. We then estimated the County's costs for deploying that network—and, for the sake of

[6] Future support for those locations will be auctioned in 2020 under the Rural Digital Opportunities Fund.

comparison, examined the potential costs for existing telecommunications providers in the County to expand their footprints to serve the unserved areas.

We developed a conceptual, high-level FTTP outside plant network design that is aligned with best practices in the industry, reflects the County's goals, and is open to a variety of electronic architecture options.[7] The design assumes a combination of aerial and underground construction based on the placement of the existing utilities.

The total estimated cost for the County to construct an FTTP network to serve these areas is summarized in the following table.

Table 1: Estimated FTTP Cost

Cost Component	Central	Route 2	I-90	Total Estimated Cost
Outside Plant	\$22 million	\$64 million	\$31 million	\$117 million
Central Network Electronics	800,000	100,000	100,000	1 million
FTTP Service Drop and Lateral Installations	800,000	150,000	50,000	1 million
Customer Premises Equipment	750,000	200,000	50,000	1 million
Total Estimated Cost:	*\$25 million*	*\$64 million*	*\$31 million*	*\$120 million*
Passings	4,190	940	90	5,220
Outside Plant Cost Per Passing	*\$5,140*	*\$67,740*	*\$329,770*	*\$22,190*

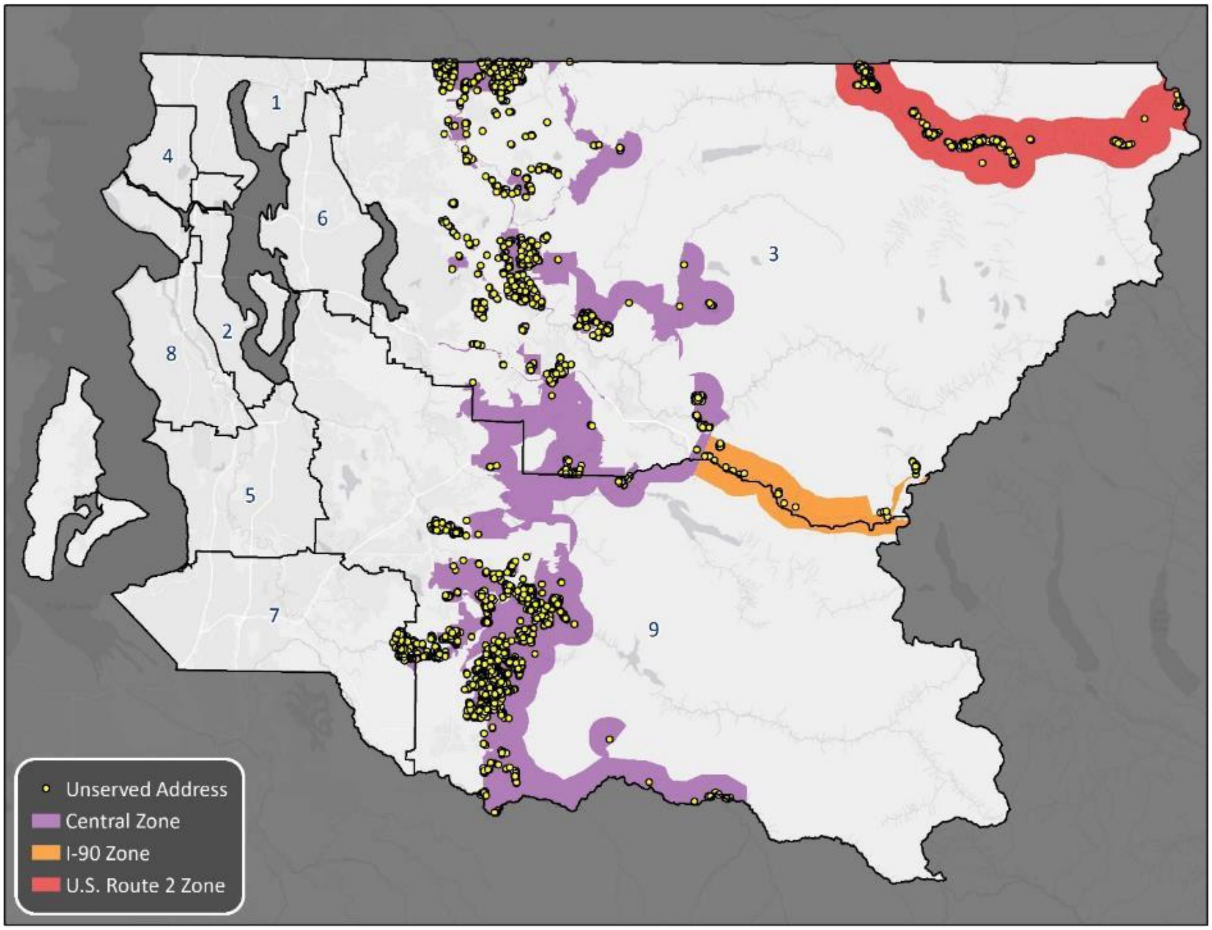
These remarkably high costs per home or business passed are a result of exactly the conditions one would expect: homes and businesses are remote from each other and, as a result, per unit (known as "per passing") costs are far higher than in more densely populated areas.

1.3.6.1 Connecting the Route 2 and I-90 zones will require more than 80 miles of fiber backbone construction

Figure 35 shows the unserved areas of the County, as described in Section 3. The zones were determined by our analysis of the unserved areas. The central zone is the majority of the unserved homes and businesses and are generally in close proximity to served areas. The high outside plant cost for the Route 2 and I-90 zones is because of the need for extensive fiber construction along the highways to serve these areas, which contain a small portion of the County's population.

[7] The network's outside plant is both the most expensive and the longest-lasting portion. The architecture of the physical plant determines the network's scalability for future uses and how the plant will need to be operated and maintained; the architecture is also the main determinant of the total cost of the deployment.

Figure 4: Unserved Areas of the County



Below are the total number of unserved homes per zone.

Table 2: Unserved Homes Per Zone

Phase	Passings
Central	4,190
Route 2	940
I-90	90
Total	*5,220*

1.3.6.2 Costs per passing range from $5,000 in the central zone to $330,000 in the I-90 zone

Assuming a take-rate (i.e., the percentage of residents and businesses that subscribe to the service) of 35 percent,[8] the network deployment will cost more than $120 million, inclusive of outside plant construction labor, materials, engineering, permitting, network electronics, drop installation, customer premises equipment, and testing.

Actual costs may vary due to factors that cannot be precisely known until the detailed design is completed, or until construction commences. These factors include costs of private easements; utility pole replacement and make-ready costs; variations in labor and material costs; subsurface hard rock; and the County’s operational and business model. Our analysis incorporated assumptions to address these items based on our experience in similar markets.

The estimated cost to construct the outside plant portion of the proposed FTTP network is approximately $117 million, or $5,200 per passing. Table 3 provides a breakdown of the estimated outside plant costs. (Note that the costs have been rounded.)

Table 3: Estimated Outside Plant Costs

Phase	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost per Plant Mile
Total	**329.0**	**$115,740,000**	**5,220**	**$22,190**	**$350,000**
Central	215.0	$21,525,000	4,190	$5,140	$100,000
Route 2	77.0	$63,544,000	940	$7,740	$825,000
I-90	37.0	$30,668,000	90	$329,770	$836,000

We note that the overwhelming majority of the outside plant cost (approximately 95 percent) for the Route 2 and I-90 zones is the cost of constructing new fiber to those zones from elsewhere in the County. We are not aware of any fiber that can be leveraged to reach the premises along Route 2 and I-90. Without that added cost, the unit construction costs in those zones would be more in line with the costs in the central zone.

[8] 35 percent is a common take-rate number used in cost analysis. However, the actual take-rate could vary significantly. Further market analysis would be required to determine a more accurate take-rate for the unserved areas of King County.

Incremental network electronics to serve the area will cost an estimated $1 million, or $200 per passing, also assuming a take-rate of 35 percent.[9] (These costs may increase or decrease depending on take-rate, and the costs may be phased in as subscribers are added to the network.) The network electronics consist of the core and distribution electronics to connect subscribers to the FTTP network at the core and the FTTP access electronics located at the customer premises. The electronics are subject to a seven- to 10-year replacement cycle, as compared to the 20- to 30-year lifespan of a County fiber investment.

Each activated subscriber would also require a fiber drop cable installation and customer premises electronics, which would cost roughly $1,160 per subscriber, or $2 million total—again, assuming a 35 percent take-rate. The drop installation cost is the biggest variable in the total cost of adding a subscriber. A short aerial drop can cost as little as $250 to install, whereas a long underground drop installation can cost upward of $5,000. We estimate an average of approximately $660 per drop installation.

1.3.6.3 Alternatively, cable companies could expand into the unserved central zone to serve 750 locations

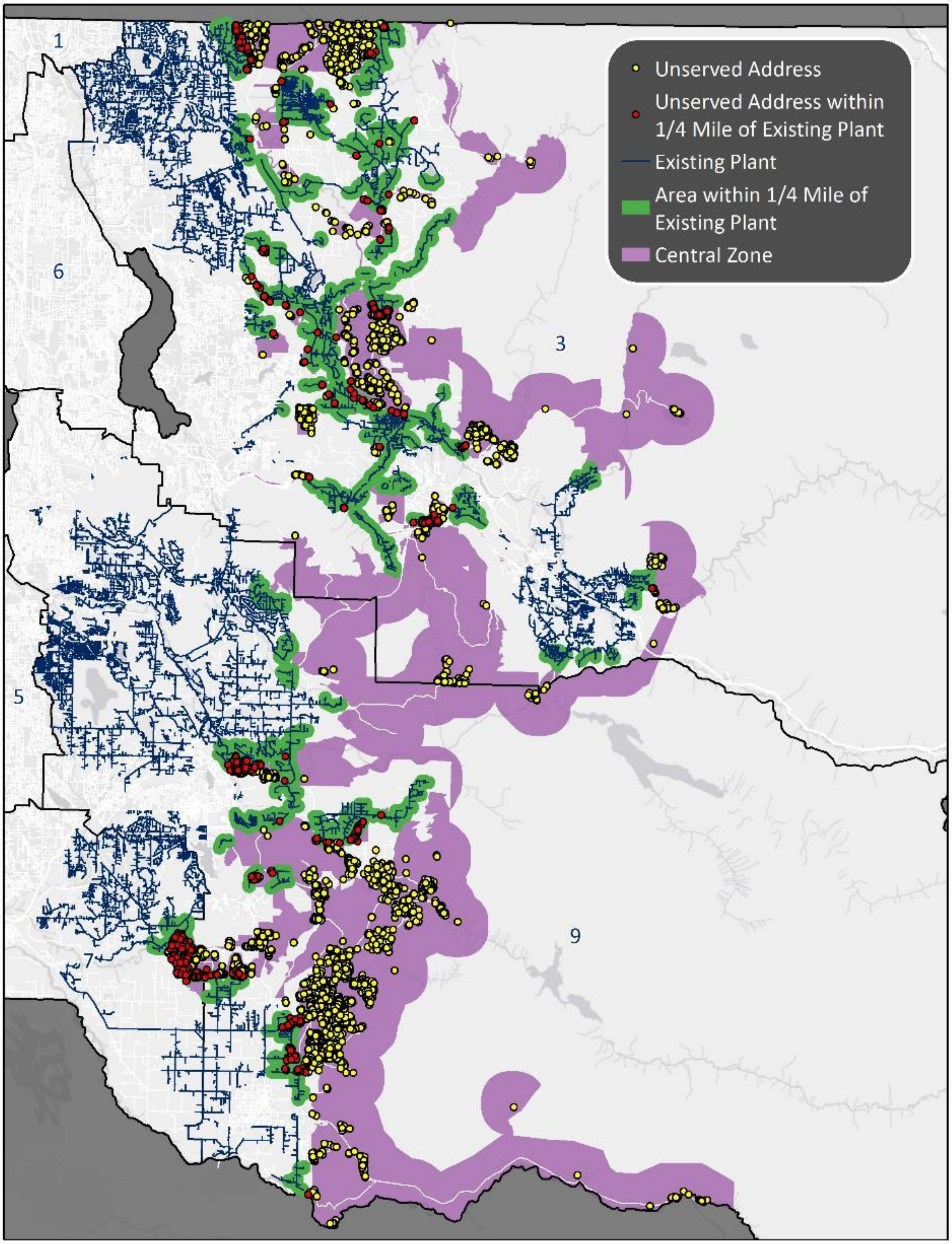
An alternate approach to serving unserved homes and businesses in the central zone would be to encourage existing providers to expand their fiber and coaxial systems to serve additional customers. This approach would be a means of enabling the cable companies to cost-effectively expand out from the edges of their existing footprints to serve the relatively denser portions of the County's unserved areas. (However, serving these areas in this way would make it that much more costly on a per-home basis to reach the remaining unserved areas in the future.)

A network expansion from the current cable company service area to one-quarter mile into the unserved central zone (Figure 36) would require 34 miles of fiber construction. The extensions would provide service to approximately 750 unserved homes and businesses, which is 14 percent of the County's unserved population. Since the providers have no conduit or aerial strand in the unserved areas, the unit cost would, like the FTTP estimate, be approximately $100,000 per mile.[10] Based on these assumptions, the total cost of network expansion would be $3.4 million, or $4,530 per passing. The costs do not include network electronics or drop installation, which would be required for each new subscriber.

[9] The take-rate affects the electronics and drop costs, but also may affect other parts of the network, as the County may make different design choices based on the expected take-rate. A 35 percent take-rate is typical of environments where a new provider joins the telephone and cable provider in a County. In CTC's financial analysis, we will examine how the feasibility of the project depends on a range of take-rates.

[10] For our comparative analysis, we have used the same cost per mile for the existing providers to expand their networks. However, those providers may have economies of scale that would decrease the cost of their network expansions in relation to a County-built FTTP network.

Figure 5: Central Zone Unserved Addresses Within One-Fourth Mile of Existing Plant



The following table compares the outside plant costs between the existing network providers expanding the networks one-quarter mile and the outside plant costs for the County to build the entire central zone.

Table 4: Comparison of County-Built FTTP to Network Expansion Costs

	County-Owned Central Zone FTTP Network	Existing Provider Quarter-Mile Expansion
Passings	4,190	750
Plant Miles	215	34
Passings Per Mile	19	23
Cost Per Mile	$100,000	$100,000
Outside Plant Construction Costs	$21.5 million	$3.4 million
Outside Plant Cost Per Passing	$5,140	$4,530

The network expansion area is approximately 20 percent more dense than the total central zone. This should be true given the areas closest to the existing providers are more likely to be denser than the areas farther away from them. Using the same per-mile construction costs for both networks, the existing providers would see an approximately 20 percent reduction in the cost to construct their network per passing. This also suggests that if the existing providers were to build these areas, the per-passing cost for the County to construct an FTTP network would increase as those denser, less-expensive portions of the unserved areas would now be served. In addition, there would be a smaller subscriber base of unserved residents—which would decrease the economies of scale for the operations of the County-built FTTP network.

1.3.7 Fixed wireless infrastructure covering 80 percent of unserved King County would have a lower capital cost than fiber, but extremely high ongoing operating costs

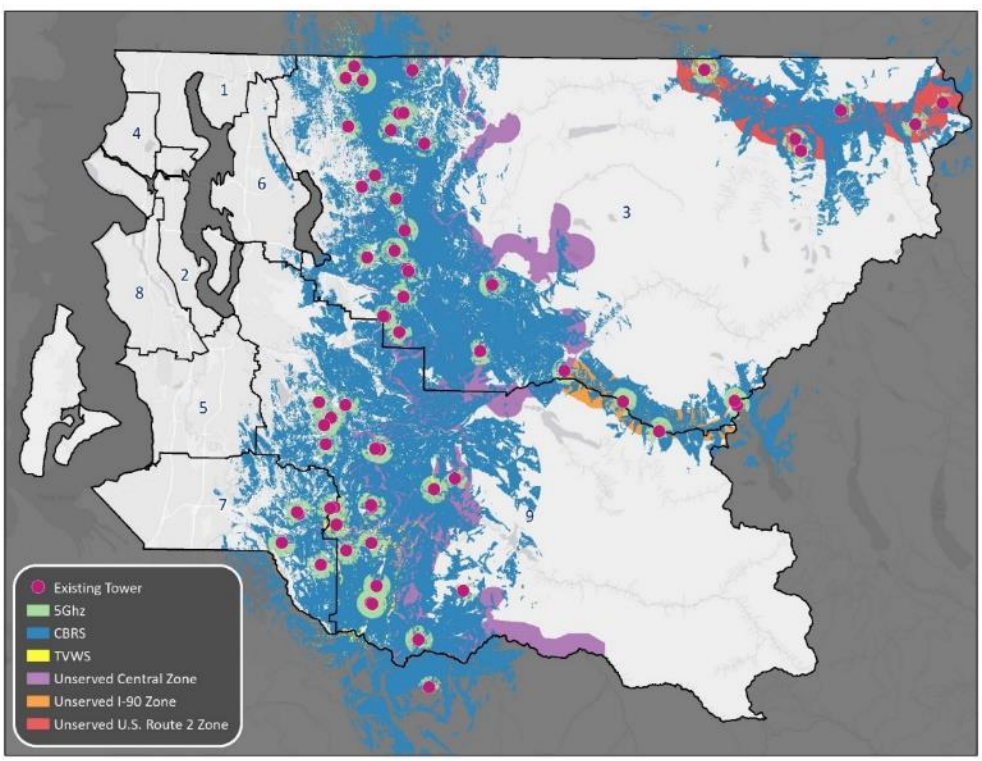
As with our analysis of fiber optic infrastructure, CTC's analysis of fixed wireless infrastructure divided the unserved area into three zones—the central County, along Route 2 in the County's northeast corner, and along the eastern portion of I-90. We developed three fixed wireless network models as options for serving the 5,216 unserved addresses in those zones: mounting equipment only on public safety towers; mounting equipment on public safety towers and other existing towers; and mounting equipment on public safety and existing towers, plus building new towers.

Our key findings are as follows:

- Although it would have clear technical limitations relative to a fiber optic network, a fixed wireless network using existing towers could serve about 80 percent of the County's unserved homes and businesses.

- Equipment mounted on public safety towers would enable coverage of approximately 36 percent of the unserved premises—and those towers would play a key role in reducing the cost of deploying a fixed wireless network. (The results of that analysis are confidential and have been provided under separate cover to King County.)
- A network based on the public safety towers that also includes equipment mounted on other existing towers could serve up to 78 percent of the unserved premises—for a total cost (assuming a 35 percent penetration rate) of about $16.5 million. The figure below illustrates this candidate network, which comprises equipment mounted on 64 towers. The red dots illustrate the tower locations, while the light green, blue, and yellow areas illustrate coverage with three types of wireless technologies. The purple, orange, and red shaded areas are the remaining unserved areas.
- Although it would be possible to serve more members of the community by building new towers, the high cost of new towers, combined with the very low number of homes served by each new tower, mean this approach would not be cost-effective. The map in Figure 10 (below) shows potential locations for these additional towers.
- Unlike a fiber-only solution, a fixed wireless solution could be implemented without long fiber optic backbone links, providing a feasible solution to serve the I-90 and U.S. 2 corridors.

Figure 6: Fixed Wireless Coverage Using Public Safety Towers and Other Existing Towers



The table below summarizes the cost and scope of the three scenarios.

Table 5: Cost and Coverage of Three Fixed Wireless Network Approaches

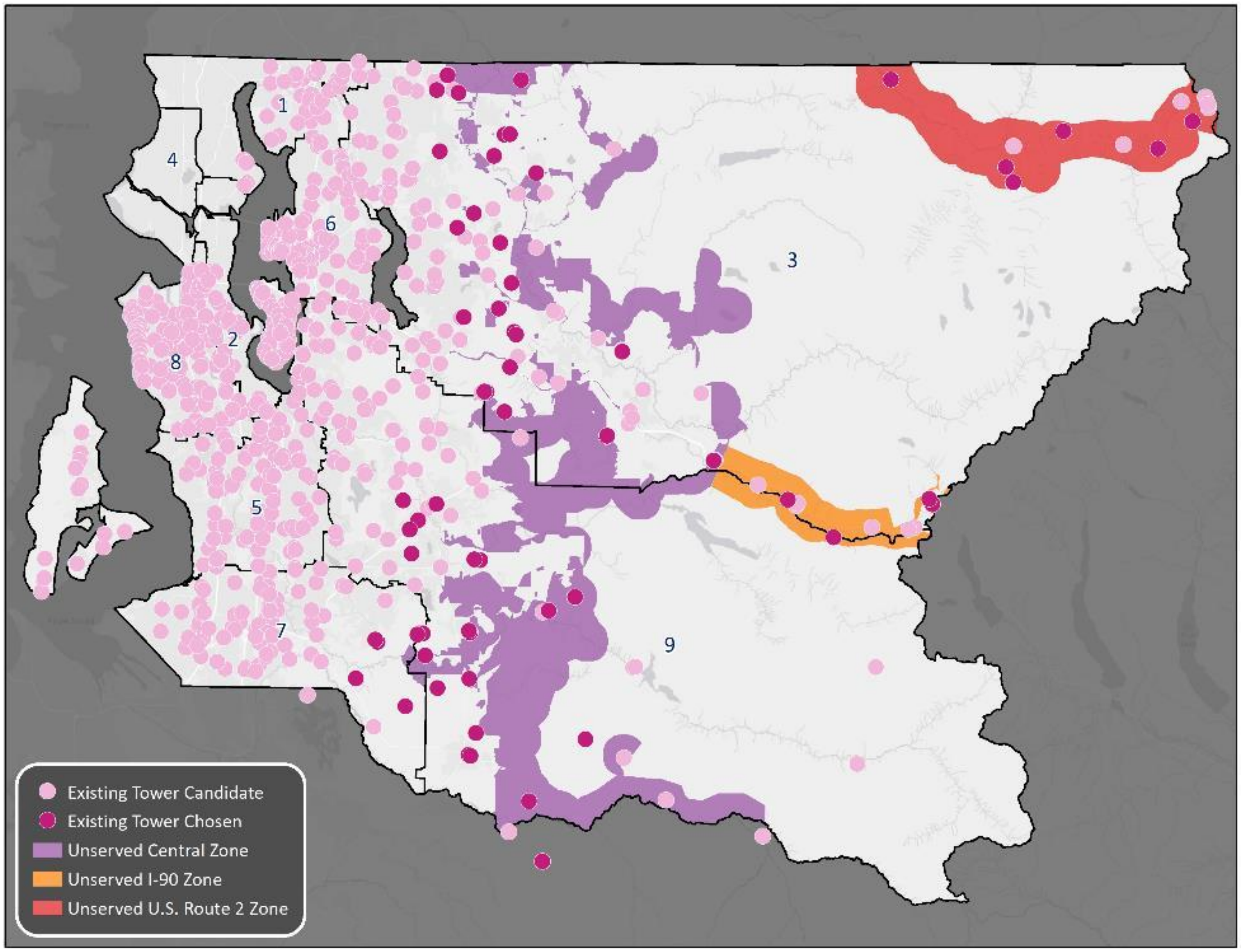
Option	Number of Towers	Passings Served	Percent of Unserved	Capital Cost with 35% Penetration[11]	Average Distribution Network Cost per Passing	Installation and Electronics per Customer
Public Safety Towers Only	16	1,899	36	$4,850,000	$1,900	$1,800
Public Safety and Other Existing Towers	64	4,069	78	$16,500,000	$3,050	$1,800
Public Safety, Other Existing, and New Towers	70	4,243	81	$19,000,000	$16,700	$1,800

1.3.7.1 Using existing towers would enable efficient deployment but would not extend service to all unserved members of the community

By eliminating towers that would not provide coverage in the unserved areas or were next to a tower that would provide similar coverage, CTC determined that, in an optimal model, 64 existing towers could be used to provide service to the unserved areas (see Figure 7).

[11] Includes subscriber equipment for 35 percent of addresses.

Figure 7: Existing Tower Candidates in a Fixed Wireless Network Solution



The fixed wireless network in this model uses the following spectrum:

TV White Space (TVWS)	500 MHz
Unlicensed	900 MHz, 2.4 GHz, 5 GHz
Citizens Broadband Radio Service (CBRS)	3.5 GHz

CTC analyzed the predicted coverage in the CBRS, 5 GHz unlicensed, and TVWS bands using the selected towers.[12] The CBRS band is predicted to connect the most addresses—primarily due to its spectrum properties, and the fact that FCC licensing rules allow CBRS antennas to be mounted higher than TVWS antennas. It also has the greatest broadcast power of the three technologies. In addition, CBRS is the only band that can be licensed.

[12] Section 6 provides details and risks regarding the use of these bands.

Of the frequencies examined, only CBRS and unlicensed technologies have channel widths (and therefore bandwidth) capable of delivering 25 Mbps down and 3 Mbps up. Because TVWS is not capable of delivering 25 Mbps down, we used that technology only in places where there is no 5 GHz or CBRS connectivity.

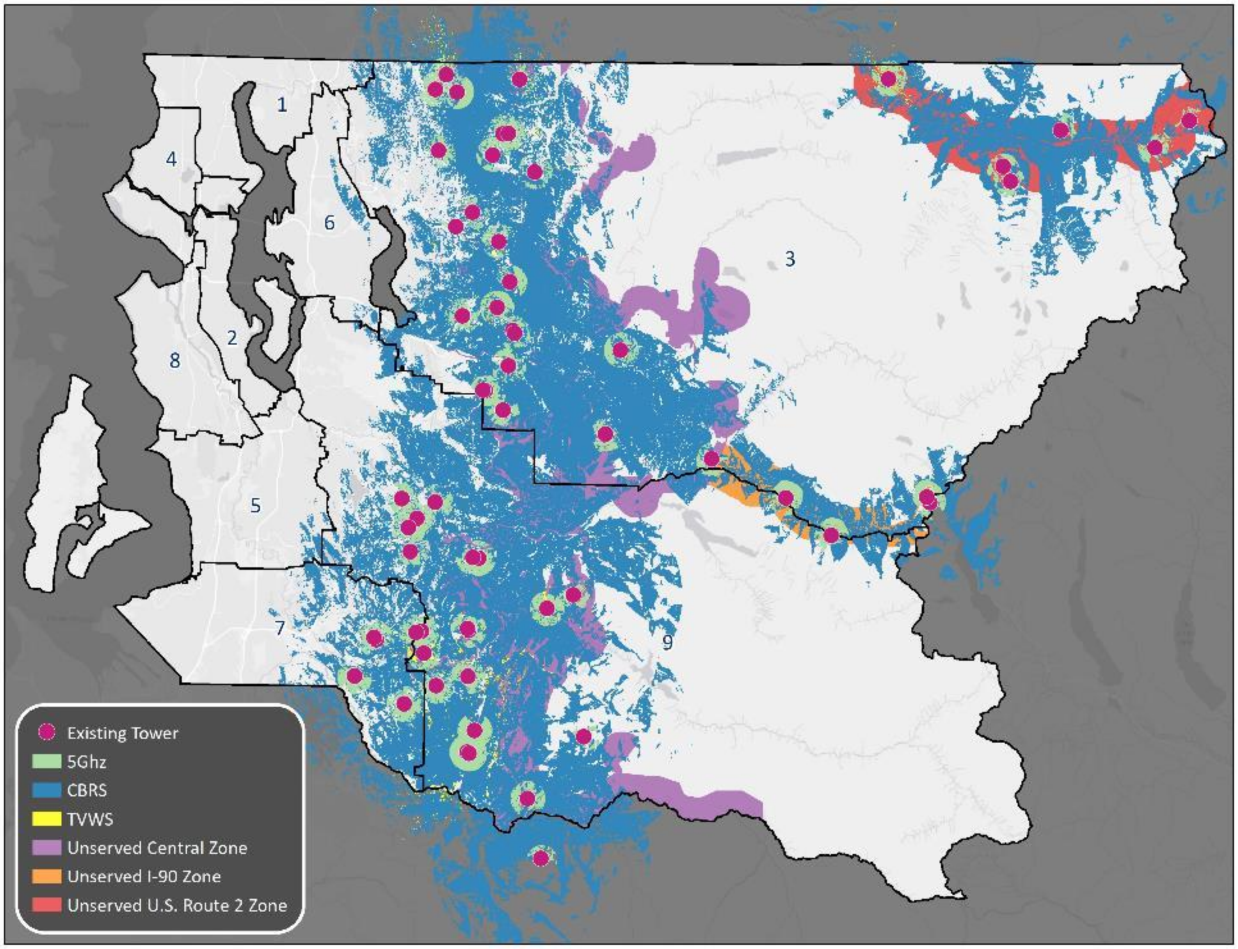
The results showed that there would still be 1,147 addresses in the unserved areas that would not be covered by the selected towers using any of the three frequency bands.

Table 6: Predicted Coverage with Existing Towers

Description	Number
Total addresses in unserved area	5,216
Addresses served by CBRS band	3,722
Additional addresses served by TVWS band	347
Addresses served by one or more band	4,069
Addresses not served by any of the three bands	1,147
Percent of addresses served by one or more of the bands	78%

The following figure shows the coverage areas in each band using the selected existing towers.

Figure 8: Coverage Using Existing Towers



The following table shows a summary of capital build costs using existing towers for each of the zones. Appendix E includes a full table.

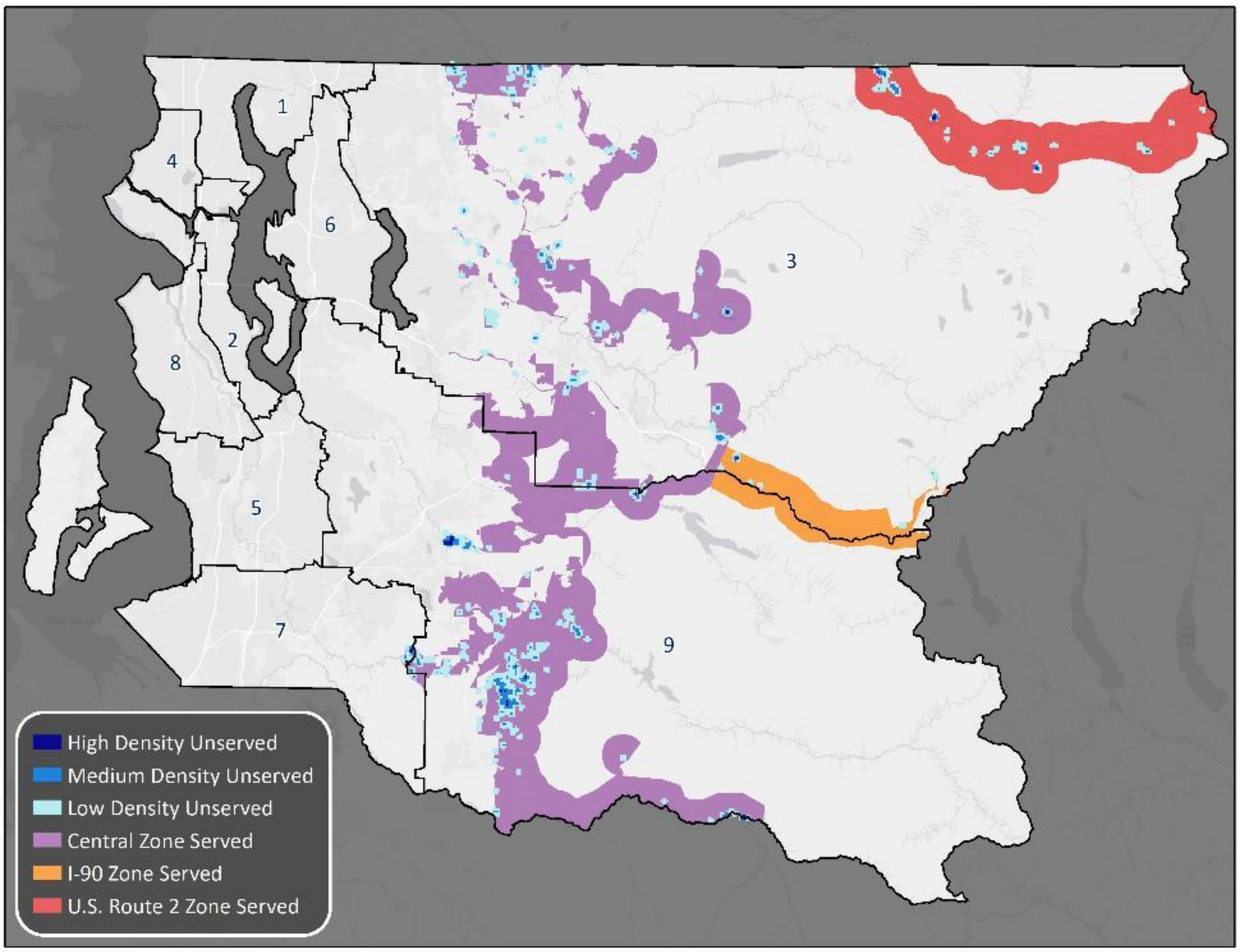
Table 7: Capital Cost Estimate for Fixed Wireless Using Existing Towers

	Central	U.S. Route 2	I-90
Network Core	$200,000	$200,000	$200,000
Access Point Equipment	$896,250	$123,750	$67,500
Backhaul	$885,000	$120,000	$75,000
Installation, Engineering and Design	$3,540,000	$480,000	$300,000
Site Acquisition	$5,900,000	$800,000	$500,000
Total Distribution Network Costs	$11,421,250	$1,723,750	$1,142,500
Total Addresses	3,215	789	65
Cost per Address (Distribution Network Only)	$3,552	$2,185	$17,577

1.3.7.2 Building additional towers would enable coverage for relatively few additional members of the community at a high cost per passing

The figure below is a heat map of the remaining unserved areas after considering coverage from existing towers. While many of the addresses are too far apart to feasibly build enough new towers to connect them all, new towers could be constructed to cover some of the remaining addresses. If the County were to build new towers, we recommend installing them in areas where most of the remaining addresses could be served—that is, focusing on the "High Density Unserved" areas in the map.

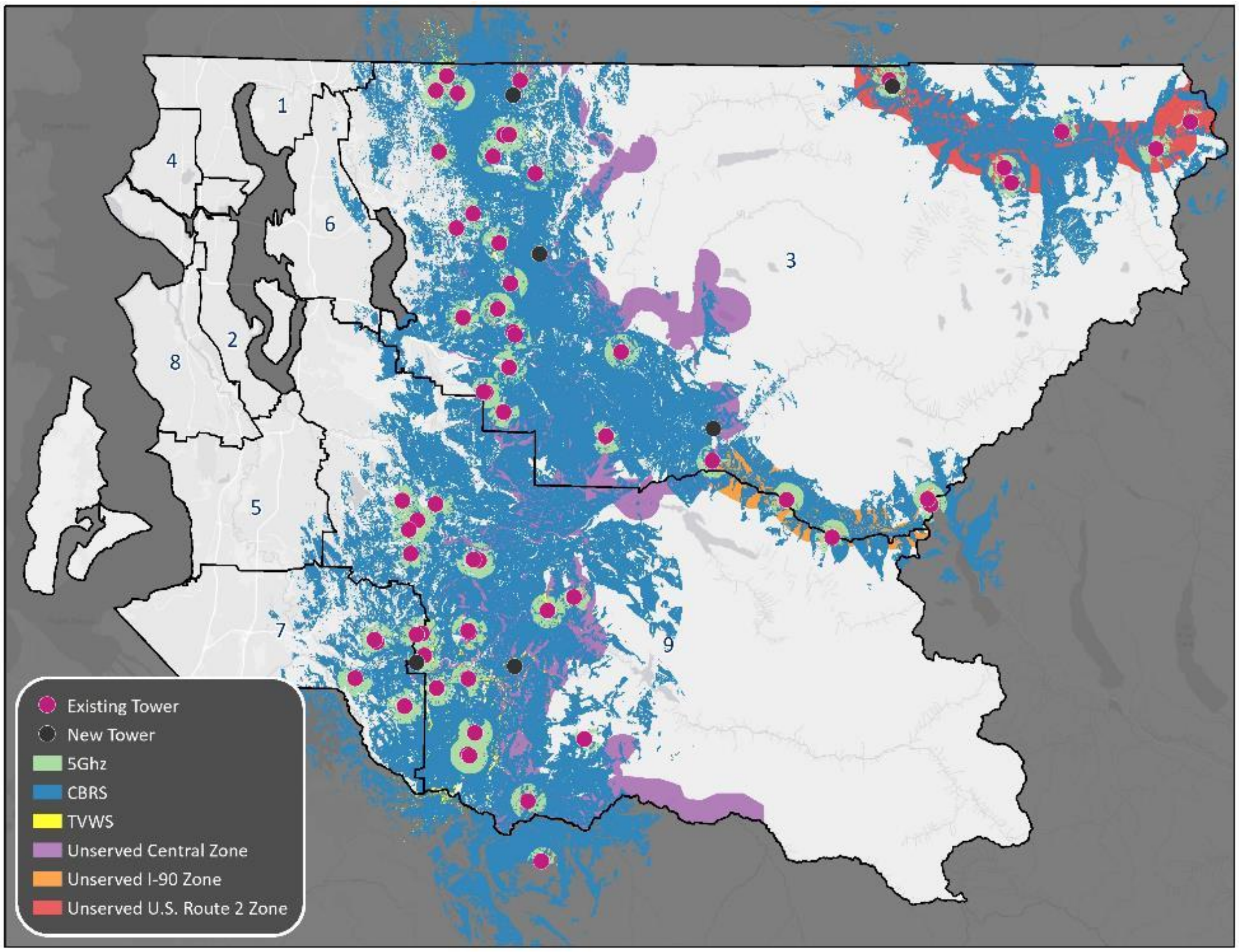
Figure 9: Unserved Addresses Remaining After Deployment of Fixed Wireless Network on Existing Towers



CTC determined 10 optimal locations for new towers based on their ability to reach most of the remaining addresses. However, we found that only six of the 10 locations were each able to cover more than five unserved addresses—which illustrates the difficulty of adding new towers that will cover a substantial number of addresses, and the low incremental value of these towers.

The following figure shows the resulting overall coverage after adding the six new towers (black dots). An additional 144 addresses would be served, leaving 1,003 addresses unserved in the County.

Figure 10: Total Fixed Wireless Coverage Using Existing and New Towers



The following table shows the costs for the six new towers using the same assumptions as above. No additional towers will be located in the I-90 zone.

Table 8: Capital Cost Estimate for Additional Towers with Fixed Wireless

	Central	U.S. Route 2	I-90
Access Point Equipment	$86,250	$18,750	$ –
Backhaul	$90,000	$30,000	$ –
Installation, Engineering and Design	$360,000	$120,000	$ –
Site Acquisition	$600,000	$200,000	$ –
Tower Build	$750,000	$150,000	$ –
Total Distribution Network Costs	*$1,886,250*	*$518,750*	*$ –*
Total Addresses	121	23	0
Cost per Address (Distribution Network Only)	*$15,589*	*$22,554*	*$ –*

1.3.8 Overall, a fiber investment would have higher capital costs than wireless but much lower operating costs—and would be a better investment over time

Based on engineering and cost-estimation of both a wired (fiber-to-the-premises) and a fixed wireless solution for unserved King County, we conclude that overall, FTTP represents a better broadband solution than fixed wireless for most unserved areas of King County. While FTTP has a higher initial capital cost per passing than a fixed wireless solution, the total cost of operations of FTTP over a 10-year period would be approximately half that of fixed wireless in the same unserved areas—primarily because of the need to replace wireless equipment at relatively short intervals and the cost of leasing space on commercial towers.

Table 9 illustrates the estimated costs of the FTTP and wireless solutions in the central zone, as well as the cost for cable companies to expand their existing plant to serve more homes in that zone (as described above in Section 1.3.6.3).

Table 9: Comparison of Costs for Solutions in the Central Zone

	Capital Costs (Distribution Only)	Duration of Capital Investment	Total Cost of Operations
County-Owned Central Zone FTTP Network	$21.5 million	30+ years	X
Existing Provider Quarter-Mile Expansion	$3.4 million	30+ years	Determined by provider
County-Owned Central Zone Fixed Wireless Network	$16.5 million	10 years	2X

1.3.8.1 Capital and operating costs require separate considerations

In two unserved parts of the County, we identified unique cost considerations:

1) In the areas that could be served from Puget Sound Emergency Radio Network (PSERN) towers, it may be possible that wireless equipment could be placed without paying a lease cost. If so, fixed wireless service to those areas, serving approximately 1,900 of the County's 5,216 unserved residences, may have a **comparable** overall cost over the first

decade of operations. (After 10 years, because of the lower cost of operations, FTTP would be less expensive to operate.)

2) In the I-90 and U.S. 2 corridors, where deploying FTTP would require the construction of 83 miles of new fiber at an estimated cost of $1.1 million per mile[13] to serve 90 and 940 passings, respectively, it would be less expensive to instead use a fixed wireless approach. However, in the event that fiber or other reasonably priced connectivity could be obtained in the corridor (e.g., from telecommunications providers that currently operate long-haul fiber), the analysis would change: it would become better from a cost perspective to use FTTP there, as well.

1.3.8.2 Fiber and fixed wireless each have technical advantages and challenges

Fiber optics, once constructed, is the highest-speed and most scalable technology. Current off-the-shelf technologies enable FTTP networks to provide capacity in excess of 1 Gbps to each subscriber, with new electronics making it possible to go to 10 Gbps or beyond in the coming years. Moreover, the FTTP network is not subject to interference from other signals or subject to line-of sight limitations.

Over time, maintenance and repair costs of fiber optic cables are low—approximately 1 percent of construction costs annually, or, in the central zone, $70 per passing per year. Equipment replacement occurs every seven years, but new equipment costs are only a small percentage of the capital cost of an FTTP network.

As discussed in Section 5, however, construction costs can be high and can vary based on the availability of space on utility poles and in the right-of-way. Construction can be delayed by utility pole owners, other utilities on the poles, and by the requirement for permitting in the right-of-way (including on bridges, water crossings, and expressway crossings).

By comparison, fixed wireless technology only provides an aggregate capacity between 100 and 250 Mbps. Using unlicensed and CBRS spectrum and innovations like higher-order multiple input, multiple output (MIMO) antennas, and the use of spatial multiplexing, these capacities could increase up to 750 Mbps in the King County environment.

It is important to note, however, that this is the aggregate capacity out of a single antenna or antenna array; in a point-to-multipoint architecture, this capacity will be shared among all users connected to a single base station. Even so, in most of the unserved environments in King County, download speeds in the tens or even low hundreds of Mbps per user may be possible.

[13] See Section 5.4.2 for more details.

Additionally, wireless eliminates the need for new cable construction, significantly reducing the time to build and the complexity of construction.

Wireless capital costs, especially where existing towers can be used as mounting structures, can be significantly lower than the cost of building new fiber optics (although capital costs for a wireless network are only a small part of its total cost). In King County's unserved areas, the cost of the distribution network (the antenna sites and the supporting network) is between $865 and $1,800 per passing. This is between 17 percent and 35 percent of the capital cost of the distribution network for FTTP in the central zone.

When taking into account the installation cost per subscriber, the wireless cost per passing is on average $2,665 to $3,600, which is between 42 percent and 57 percent the capital cost for FTTP in the central zone.

Given the limitations of line of sight and of the available spectrum, however, the wireless solution is not as scalable as a wireline solution. The spectrum available for fixed wireless broadband is limited and provides much lower bandwidth than what is available in an FTTP network. Homes and businesses that have substantial tree cover and terrain will get poorer performance than others.

Leasing space on a tower is costly. Leasing space for three sectors of antennas (as needed on each tower site) costs approximately $60,000 per year. This is a critical consideration, because the fixed wireless model uses 64 existing towers with an average 60 serviceable passings (potential customers) per tower, so the cost for tower leases alone exceeds $1,000 per year per passing.

Upgrading a wireless network requires replacement of the radios at the antenna site and at the user premises. Electronics may need to be replaced at five- to 10-year intervals due both to technological obsolescence and wear and tear—and unlike a fiber network, the electronics comprise almost all of the capital cost of the network, thus significantly increasing the ongoing cost.

Finally, permitting for new tower locations may require a public hearing process and may require months, and may be difficult to achieve if there is local opposition to the tower.

1.4 Summary of recommendations for unserved areas of the County

We recommend that the County select, through a competitive process, one or more partners who are committed to working with the County to deploy broadband to the three unserved areas, including through collaborative efforts to secure State and federal grant support.

Federal and State funding sources represent an important element of large-scale broadband deployments, though only for unserved areas where no broadband is currently available. While these programs tend to have restrictions that affect their potential breadth of impact, our analysis is that the programs have the potential to assist the County's efforts to greatly reduce the number of homes and businesses that are entirely unserved. These programs are described in some detail in Section 9 of this report and County eligibility is described in Section 10.2.

1.4.1 Select private partners to fill rural broadband gaps through partial County funding, supplemented with potential State and federal funds

1.4.1.1 A competitive process would allow companies or other interested entities to bid on one or more of the unserved areas

Through the bid process, the companies would propose the communications infrastructure and technology of their choice and describe how they will address the unserved gaps based on their infrastructure choice and their capabilities.

The County would then be in a position to select one or more potential partners with which to collaborate in applying for both State and federal grants, including the two different types of State of Washington broadband grants described herein and multiple federal grant programs.

The bidding process would be designed to enable the County to understand what its own financial commitment would have to be under a range of scenarios, including those in which different levels of State and federal funds can be secured, as well as the challenging scenario in which the County would be the only public entity providing funding to the private sector.

Public sector broadband capital grant programs have been developed in many states and localities across the country and there exist viable and tested procurement strategies by which the County could undertake this process. We therefore recommend this exploratory competitive process as a potential next step for King County to address the needs of the underserved areas.

1.4.1.2 Private carriers have suggested interest in this model

The outcome of our discussions with potential private partners indicates that there exists potential to build collaboration with the private sector that could fill identified broadband gaps.[14]

[14] Additionally, the interest expressed by the private sector suggests the feasibility of implementing a successful Dig-once policy in which joint-build opportunities are facilitated by the County to 1) reduce disruption associated with construction; 2) more efficiently utilize space in the right-of-way; and 3) achieve cost savings for both the County and commercial utility owners compared to separate construction initiatives.

Based on our conversations with a range of potential private collaborators for the County, as well as on our experience around the country, we anticipate that there do exist carriers that would agree to build and operate broadband facilities in currently unserved areas of the County so long as adequate grant funds are available to bridge the gap between an infeasible project and one that is economically viable. This is consistent with what we have observed throughout the country where local, state, and federal broadband funds have been made available to private carriers to address broadband gaps. In New York State, for example, Verizon has been the successful bidder for substantial state and federal funds to build robust broadband infrastructure in rural areas. Similarly, in Massachusetts and Virginia, Comcast has applied for and received state funds to deploy in unserved areas.

In King County, the preliminary indications from discussions we held with private carriers suggest that interested carriers would consider collaboration with the County (and, possibly, State and federal grant-makers) given the availability of upfront funds for the construction of infrastructure that would be owned by the carrier in return for enforceable commitments to build and operate broadband facilities. Together with County staff, CTC held very productive conversations with representatives of a range of entities, including Wave, CenturyLink, Frontier, T-Mobile, Verizon, and Comcast. While concerns about confidentiality and proprietary data made it difficult to share concrete information among the County and carriers, our preliminary conversations suggest there is sufficient potential interest on the part of the carriers that the County should consider a competitive process to elicit concrete proposals.[15]

1.4.2 Coordinate County initiatives with State efforts and State funding programs

In the past year the State of Washington has created a broadband office and begun development of new resources and tools. The creation of the new office is a very positive development that means new planning and coordination at the State level, offering an opportunity for King County to work with the State to meet shared goals. Given the potential for new coordination of local and State efforts, as well as the emergence of new grant opportunities at the State level, the County's efforts could unlock new State funding for unserved King County.

[15] CTC also evaluated the potential for collaboration with and investment by the Port of Seattle, the Community Connectivity Consortium (C3), the Pacific Northwest Gigapop, and the K-20 Network. Our conclusion is that, in all of these cases, there does not exist strategic alignment between the County's goals in this effort and those entities—although they are strong partners in serving other missions.

Washington already funds and manages a State rural broadband program through the Community Economic Revitalization Board (CERB).[16] In 2019, the legislature authorized an additional $18 million in funding through the Public Works Board for grants aimed at expanding broadband access in unserved areas throughout the State.[17] This program is still being designed, with the expectation that guidelines will be issued in early 2020. As with the CERB program, the County should track this program to see if this funding could be utilized to support broadband deployment in rural King County.

1.5 Summary of recommendations for underserved areas of the County

We recommend consideration of the following strategies, which involve improving affordability and access in underserved areas of the County.

1.5.1 Work with KCHA to deliver free broadband service to residents of public housing

The first recommendation reflects an understanding that the County's definition of underserved identifies those members of the community who do not use the internet for various reasons (including low income), even where it is available to them. As a result, underserved does not relate to geographic location. Rather it relates to whether and how members of the community are able to access the internet.

We recommend that the County work with the King County Housing Authority (KCHA) to capitalize on the relatively high population density of some low-income housing buildings—which represents an opportunity to leverage County communications capabilities and infrastructure to reach some underserved members of the community with much less investment per home than is required in less densely populated areas of the community.

In this model, the County or its contractor would provision free fixed broadband internet service using cost-effective Wi-Fi technology, potentially by building County-owned fiber to some buildings that are located in proximity to the fiber. Existing and future County broadband assets, such as the potential EasTrail fiber, could be leveraged for these purposes. Notably, County I-Net fiber is not available for these purposes given contractual restrictions on its use (i.e., I-Net fiber can only be used by government, non-profits, and educational organizations).

We recommend a free, rather than paid, service for a number of reasons. First, offering free service entails less operating cost and complexity than a paid service with respect to sales, marketing, billing, collections, and other elements of paid broadband service. Second, given

[16] "Community Economics Revitalization Board," Department of Commerce, State of Washington, https://www.commerce.wa.gov/building-infrastructure/community-economic-revitalization-board/ (accessed November 2019).

[17] "Public Works Board – Broadband Financing," Department of Commerce, State of Washington, https://www.commerce.wa.gov/building-infrastructure/pwb-broadband/ (accessed November 2019).

the significant cost barriers associated with low adoption of broadband, a free service has potential for far greater impact than a paid service.

1.5.2 Partner with the private sector to offer low-income mobile service

We recommend that the County consider developing a mobile service for low-income members of the community. This model is predicated on the understanding that parity in broadband service for the residents of low-income housing will not be achieved only through the fixed service described above.

The goal would not be for these members of the community to switch from fixed to mobile service, but rather that they would have access to both—which is the norm among most Americans who can afford it. Importantly, the approach we outline here would make this scenario feasible without the County going into the mobile business.

In this model, the County would partner with a mobile virtual network operator (MVNO), which would resell capacity from one of the mobile network operators that own nationwide infrastructure (like Verizon or AT&T). This would be a mobile product paired with the fixed product described above; the County's mobile service would be cost-effective because the County would purchase mobile service in bulk, and it would offload as much network traffic as possible to Wi-Fi within the buildings.

Both the fixed and the mobile service models are based on the County's potential to leverage its capabilities and assets to achieve a first-of-its-kind outcome for low-income members of the community.

1.6 Summary of recommendations applicable to both unserved and underserved needs

The following recommendations concern strategies that offer long-term incremental benefit to all areas of the County, addressing the needs of both unserved and underserved members of the community. These strategies do not represent opportunities for short-term transformation of either unserved or underserved challenges. Rather, these represent best practices that will, over time, enable the County to maximize its knowledge base and strategic options in the future.

1.6.1 Develop a broadband office to execute and coordinate strategies, including with regional stakeholders

CTC recommends that in order to effectively and efficiently execute the recommendations in this study, as well as to leverage broadband opportunities as they arise, the County establish a dedicated King County Broadband Office. We recommend that the Broadband Office be housed within the King County Department of Information Technology (KCIT) in light of KCIT's subject matter expertise and its management of the County's existing communications assets.

The Broadband Office would represent a new entity within KCIT, dedicated to achieving the County's public-facing broadband goals and executing strategy designed to serve the unserved and underserved—those whose needs are not met by private sector broadband services.

The Broadband Office could have responsibility to develop a regional broadband-focused coordinating entity to facilitate conversations and collaboration among all of the public entities within the County that are concerned with the broadband needs of unserved and underserved members of the community.

The Broadband Office could also be charged with developing ongoing mutual efforts and coordination mechanisms, particularly with other agencies of King County government that have significant stakes and assets associated with broadband (such as the County Department of Transportation), as well as tools for tight integration among agencies so as to be responsive to policy direction from County leadership. The Office could thus serve to ensure that no silos exist among the County agencies with responsibilities and authority related to broadband planning—or the assets and infrastructure that enable it. Absent this kind of coordinated multi-agency effort, national experience suggests that silos inevitably arise or are perpetuated, and that opportunities to efficiently plan across agencies and between the public and private sectors will be lost.

The Broadband Office could also serve as a clearinghouse and execution mechanism for taking advantage of new community-focused broadband opportunities, as well as State and federal broadband grant opportunities, as they arise.

1.6.2 Develop dig-once policies to efficiently add to County-owned assets over time

We recommend that the County develop a long-term "dig-once" strategy and policies to build conduit and fiber assets over time. Seeking to address the high capital cost of broadband network construction, dig-once strategies enable local communities to expand their own fiber and conduit assets and to encourage private providers to do the same.

Such policies open rights-of-way to fiber/conduit construction when other projects are underway, thus realizing efficiencies in network construction. Such policies also protect roads and sidewalks from life-shortening cuts and minimize disruption from construction. Even if private entities do not take advantage of the opportunity, the locality can use dig-once opportunities to install its own conduit and fiber at a reduced cost compared to standalone construction—which can be used by the locality itself or leased to private providers in the future.

At the same time, dig-once is rarely inexpensive—even though it is more cost-effective than standalone construction—and each opportunity must be carefully weighed to determine if it provides sufficient cost savings and is likely to meet some future need.

For these reasons, we recommend that the County develop an approach to dig-once that targets the following objectives:

- Protecting newly and recently paved roads and sidewalks
- Enhancing the uniformity of construction
- Ensuring efficient, non-duplicative placement of infrastructure in the public right-of-way (PROW)
- Reducing overall costs of all underground work in the PROW, both utility- and telecommunications-related, for public and private parties
- Facilitating private communications network deployment by reducing construction costs
- Leveraging construction by third-party entities for the deployment of a public communications network, or deployment of conduit that can be made available to other entities

There exist three general approaches to dig-once policies. In the first approach, some local governments require an excavator applying for a permit in the PROW to notify utilities and other relevant entities about the project and invite their participation.

In the second approach, localities with a "shadow conduit" installation policy require the excavator to install excess conduit for future use; depending on the policy, the excavator or the jurisdiction may then lease that excess capacity.

Finally, in the third approach, other localities undertake a longer-term process, coordinating multi-year plans with excavators.

In considering these and other strategies, we recommend the County take the following steps toward identifying the appropriate dig-once strategy:

- Analyze and prioritize known County projects suitable for additional construction based on a scoring mechanism that weighs estimated costs and potential benefits
- Develop a high-level estimate of the incremental costs for likely dig-once scenarios
- Survey potential dig-once partners to share the County's dig-once objectives and high-level cost models; identify likely geographic areas for future buildout requirements; refine technical specifications for dig-once infrastructure under varying buildout scenarios; and determine suitable parameters for a dig-once process that will encourage private investment in broadband infrastructure

The primary goal of this planning effort is to ensure that a dig-once strategy can be crafted that is attractive to private service providers—a strategy that results in processes that do not unduly burden construction timelines and that leads to the deployment of infrastructure meeting the technical and operational requirements of the commercial providers. Once the strategic framework is determined, the County can undertake more detailed planning efforts necessary to implement the strategy, such as:

- Developing a standard engineering specification for dig-once conduit
- Refining dig-once cost estimates and cost-sharing models
- Developing a procedure to systematically track and manage the construction and to create a repository of existing infrastructure

1.6.3 Continue and expand upon broadband data collection efforts in order to track progress over time and target investments

Through this project, and the research conducted by PMR, the County has developed a substantial and important set of data regarding the availability and use of broadband throughout the community. These datasets represent a baseline for understanding the current status of broadband availability and use in King County—and we recommend that they be maintained, periodically updated, and expanded.

The data developed by CTC in the preparation of this report include geographic information regarding infrastructure and services; a range of demographic information; and engineering, design, and cost estimate data. The data developed by PMR to prepare the PMR report include a wide range of survey data with insights regarding access and affordability, as well as attitudes, literacy, usage, and skills as they relate to digital engagement.

To supplement the existing datasets, we also recommend that the County develop an online speed test to build a long-term dataset that measures actual user experiences. A speed test represents a low-cost, high-impact step that will allow the County to measure progress over time in the actual user experience.

We recommend that the data be maintained and, as appropriate, periodically updated. There are three primary reasons for this data effort: First, the existing data represent a tool for measuring progress and changes in the scale of the unserved and underserved challenges in the County over time. Second, the information offers a data-driven means of targeting County investments to areas and populations with the most significant unserved and underserved challenges. Third, the data also serve as a corrective for inadequate federal data, which have tended to overstate the availability of broadband in unserved areas and underestimate the affordability challenge in underserved areas; while federal data collection will hopefully improve over time, the County's own efforts in this area will enable it to make data-driven policy that is not compromised by poor federal data.

1.6.4 Develop partnerships with wireless providers to fill unserved and underserved gaps

We recommend that the County undertake a competitive process in which the County exchanges with private wireless and infrastructure companies the use of public assets for wireless deployment in return for free services to underserved members of the community and/or for deployment of infrastructure and services to unserved areas of the County. The County would seek to develop public-private partnerships with wireless network operators (such as Verizon and AT&T) and wireless infrastructure companies such as Crown Castle. On the assumption that the FCC Order preempting local government authority with respect to placement of small cells and fees will not survive court challenge, the County could signal its openness to the wireless industry to negotiate contracts that offer strong terms and conditions for access to public assets in return for public goods that are of high policy value to the County, such as equitable deployment in low-income neighborhoods, deployment in unserved areas, and funding of programs to support digital inclusion initiatives.

2 King County Has Identified Two Primary Types of Broadband Challenges: Lack of Availability (Unserved) and Low Levels of Use (Underserved)

As a foundation for the analysis and recommendations in the broadband access study, this section presents the County's established definitions of key terms based on the key challenges identified for research and analysis.[18]

The County's definitions are as follows:

1. **Served:** An area or address in King County is ***served*** with broadband if it can receive internet access with transmission speeds that, at a minimum and on a consistent and reliable basis, provide twenty-five megabits per second download and three megabits per second upload and if none of the factors included in the definition of ***underserved*** are present. This definition generally aligns both with federal rules[19] and Washington law.[20]

2. **Unserved:** An area or address in King County is ***unserved*** with broadband if it cannot receive internet access with transmission speeds that, at a minimum and on a consistent and reliable basis, provide twenty-five megabits per second download and three megabits per second upload. This definition generally aligns both with federal rules[21] and Washington law.[22]

3. **Underserved:** An area of King County is ***underserved*** with broadband if the service offered meets any of the following criteria (regardless of speeds):

    a. It has been adopted by less than 80 percent of residential customers[23]

[18] The sources consulted in developing these definitions are listed in Appendix A.
[19] "2018 Broadband Deployment Report," Federal Communications Commission, Feb. 2, 2108, https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report (accessed May 17, 2019).
[20] "Expanding affordable, resilient broadband service to enable economic development, public safety, health care, and education in Washington's communities," HB 1498 – 2019-20, Washington State Legislature, https://app.leg.wa.gov/billsummary?BillNumber=1498&Year=2019&Initiative=false (accessed May 17, 2019).
[21] "2018 Broadband Deployment Report," Federal Communications Commission, Feb. 2, 2108, https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report (accessed May 17, 2019).
[22] "Expanding affordable, resilient broadband service to enable economic development, public safety, health care, and education in Washington's communities," HB 1498 – 2019-20, Washington State Legislature, https://app.leg.wa.gov/billsummary?BillNumber=1498&Year=2019&Initiative=false (accessed May 17, 2019).
[23] PMR measured adoption in terms of factors other than access that limit digital connectedness, including availability of devices and "financial, skill based, or attitudinal" issues.

b. It is priced at 20 percent or more above services of comparable speeds in other areas of King County

c. Service plans include data caps or other tiered pricing that effectively price it at 20 percent or more above services with comparable speeds in other areas of King County

d. If census or other data demonstrate that median annual household income in the area is less than $30,000, reflecting 2018 national Pew Research Center data showing the adoption rate (i.e., "internet use") for households earning less than $30,000 is approximately 81 percent, far below that of higher-earning households[24]

[24] "Internet Fact Sheet," Pew Research Center, Feb. 5, 2018, https://www.pewinternet.org/fact-sheet/internet-broadband/ (accessed May 15, 2019). We note, too, that 2019 national Pew Research Center data (released after the County established its definition) show the home broadband adoption rate for households earning less than $30,000 is approximately 56 percent—which, like the internet use level, is far below that of higher-earning households. See: "Internet Fact Sheet," Pew Research Center, June 12, 2019, https://www.pewinternet.org/fact-sheet/internet-broadband/ (accessed October 29, 2019).

3 King County's Unserved Are Located in Unincorporated King County Where Broadband Speeds Are Not Available

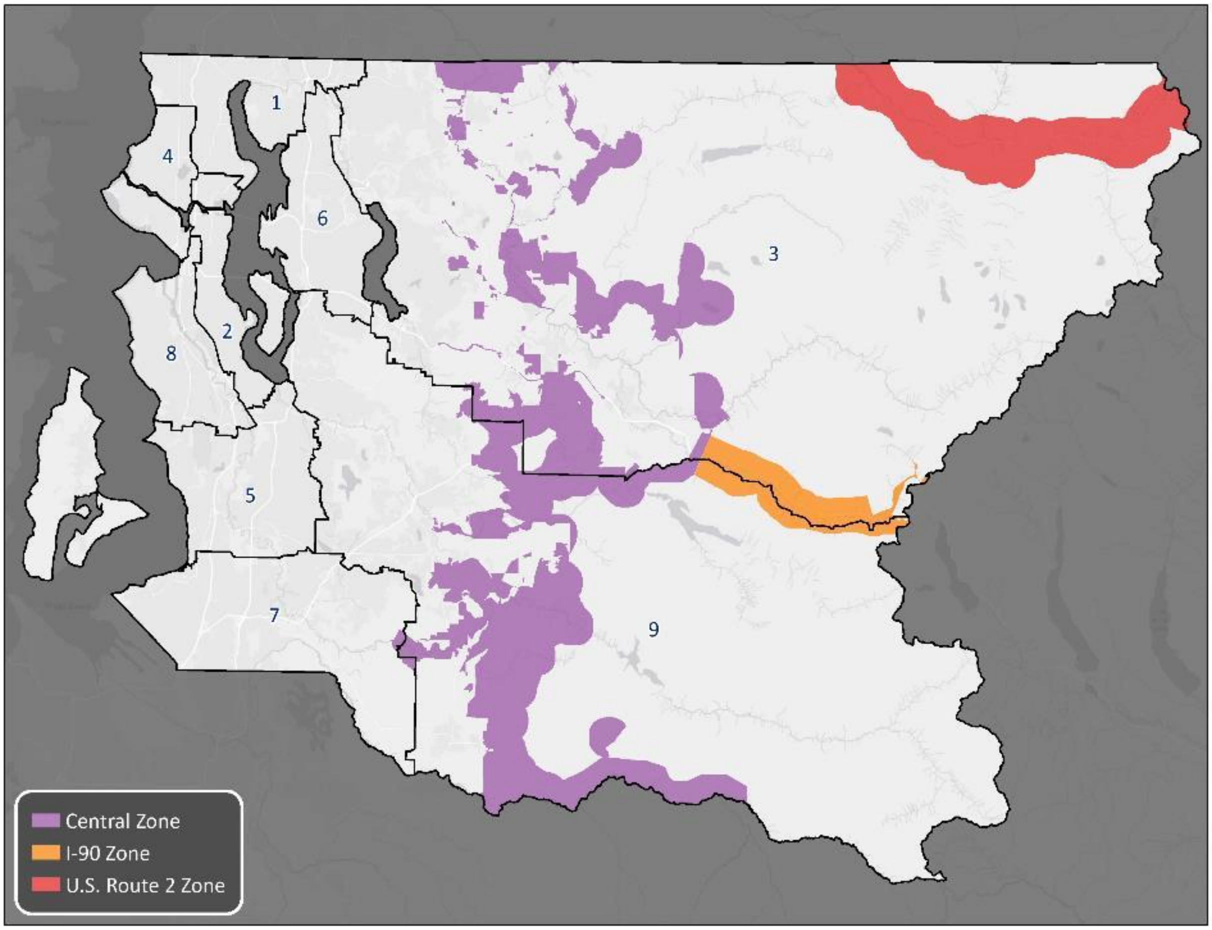
Based on the County's definitions, CTC conducted an extensive, multi-source, multi-layer analysis to determine what parts of the County's 2,116 square miles of land are unserved. In the sections below, we first document our data sources, then describe the methodical analysis that culminated in a map of the County's unserved areas.

In brief summary, we found that the majority of the population has broadband available, but that substantial areas of the rural parts of the County do not.

With respect to those areas that are served, it is important to note that *this widespread broadband service is thanks to the County's efforts and foresight in securing universal cable buildout obligations* as part of the cable television franchise agreements decades ago—the result of which is that Comcast's cable modem network extends to almost all residential neighborhoods of King County.

For the very low-density parts of the County, however, we found that the unserved members of the community are clustered in three areas, which we have defined as the central zone, the U.S. 2 zone, and the I-90 zone (Figure 11).

Figure 11: Overview of the County's Three Unserved Zones



3.1 CTC's analysis of a range of data sources demonstrates lack of fixed service

CTC evaluated a wide range of datasets in part because so much of the existing broadband availability data, particularly those gathered by the federal government, are inaccurate and overstate availability. For example, as both Microsoft and the U.S. Government Accountability Office have publicly pointed out, the Federal Communications Commission's (FCC) data overestimate broadband availability because they are insufficiently granular and are self-reported by carriers.

Accordingly, we evaluated, tested, and incorporated a wide range of complementary data sources. Our strategy was to aggregate datasets, understanding that all are flawed—but that by layering them, we could compare them to each other and glean insights that we could not identify with only federal government data.

We recognize that none of the individual datasets is perfect. (This is not an issue specific to King County; there is no perfect dataset for any jurisdiction in the nation.) For example, none of the sources has address-level details on where infrastructure exists, what services are available to members of the community (at what price), and who is utilizing the services. But by layering these data sources—understanding that separately they have different importance and usefulness for our analysis—we built a more accurate and useful picture of the unserved portions of the County.

To conduct our analysis, we:

- **Evaluated available FCC Form 477 data** about broadband services available in the County. These data are self-reported by carriers and there is tendency for these forms to overstate service availability, given that an entire census block is reported as being served if even one location in the block meets the FCC's requirement.

- **Evaluated Connect America Fund (CAF II) funding areas**. Evaluating the FCC's maps and data related to CAF II funding in the County provided useful data on areas deemed unserved or underserved by that program. Given the long buildout window for entities receiving CAF II funding, we note that unserved areas that are subject to an award may still be unserved for many years.

- **Evaluated the USDA Rural Utilities Service's map of served and unserved areas**, which is based on a range of different datasets. In our view the map is under-inclusive of the unserved portions of the County but provides another set of insights to add to our broader analysis.

- **Identified and analyzed relevant County datasets.** We worked with the County to identify and develop the most useful data, including information related to public safety infrastructure, C3, and the EasTrail project. We also analyzed service footprint information for Comcast and Wave, the two providers that have cable franchise agreements with the County. The cable franchise service footprint maps are a few years old—and were only provided for the unincorporated parts of King County.

- **Identified and analyzed relevant commercial datasets**. We reviewed a range of commercial datasets that provide insight into broadband infrastructure and availability. For example, we accessed commercial services that aggregate data about known backbone fiber routes in the United States. In addition, some companies, like Zayo, publish maps of their enterprise fiber in order to communicate where they can provide enterprise-level service. We incorporated these important datasets into our full analysis. These datasets are self-published by the commercial providers and may be inaccurate or incomplete due to the age of the data (and the fact that some commercial providers treat their route details as proprietary).

- **Reviewed existing cable franchise agreements throughout King County**, which told us where the cable companies are obligated to build—and where lower population density means that they have no obligation. As part of this review, we analyzed the County's GIS-based population density data to identify which streets in the County qualify for service under the franchise agreement requirements. While this analysis identifies areas where cable infrastructure is required, it does not guarantee the cable franchisee has met its obligations to build.

- **Conducted an extensive desk survey** using the County's GIS maps, Google Earth imagery, and other relevant sources. We used the desk survey to spot-check and verify the other datasets in order to develop a more accurate and comprehensive overview of service availability. This review did not encompass the entire County; it was focused on areas where the other datasets provided inconsistent information or lacked information altogether. The field verification was further limited by the availability of updated aerial and street-level imagery.

- **Conducted a week of field verification of the datasets we analyzed, as well as representative portions of the County selected for closer inspection.** A CTC outside plant engineer conducted field work to review our determinations of which areas of the County are unserved and to evaluate density requirements in representative portions of the unincorporated areas of the County. The field verification was more targeted than the desk review—focusing on specific areas that could not be addressed by the desk survey.

- **Evaluated existing survey results**, including the results of the County's "Survey of King County Residents on Technology Access and Adoption" and the City of Seattle's "2018 Technology Access and Adoption Survey."

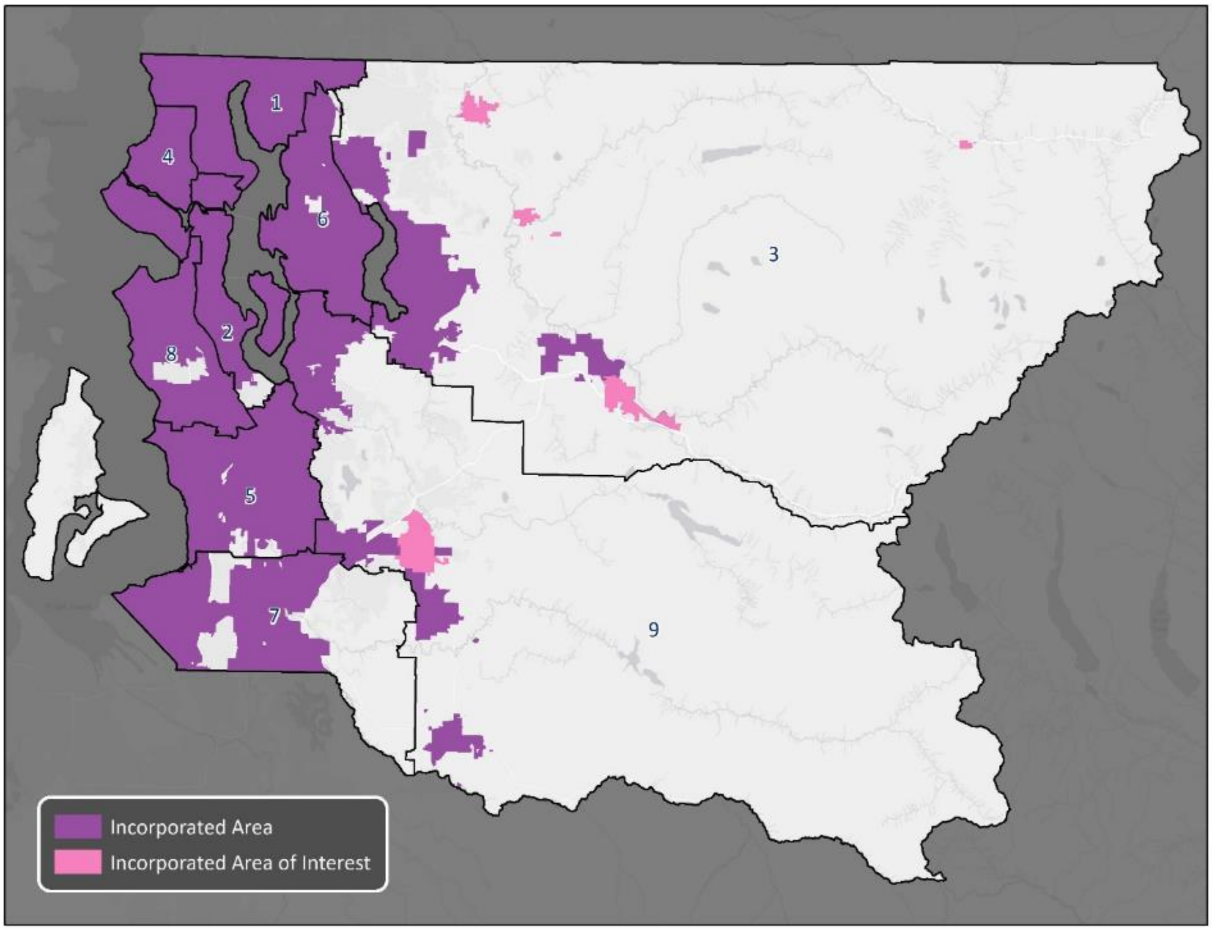
- **Reviewed broadband speed data collected by Measurement Lab (M-Lab)**, a consortium led by academic and public interest entities. The M-Lab broadband speed dataset is considered the most comprehensive and authoritative in the country and has no commercial elements, thus ensuring the independence of the data. That said, the data are aggregated by ZIP code, which limits the granularity of any analysis performed.

- **Reviewed speed test results submitted to the Washington State Broadband Office**. This dataset is somewhat dated (2014), but we included it under the assumption that if there were service in an area a few years ago, there likely is still service now.

3.2 GIS-based analysis confirmed fixed service availability and identified unserved areas

As a starting point we refined the focus of our analysis by eliminating areas of the County where existing service has already been verified or areas with minimal to no serviceable addresses. First, we divided the County into unincorporated and incorporated areas using County-provided GIS data (Figure 12).

Figure 12: Incorporated and Unincorporated Portions of King County



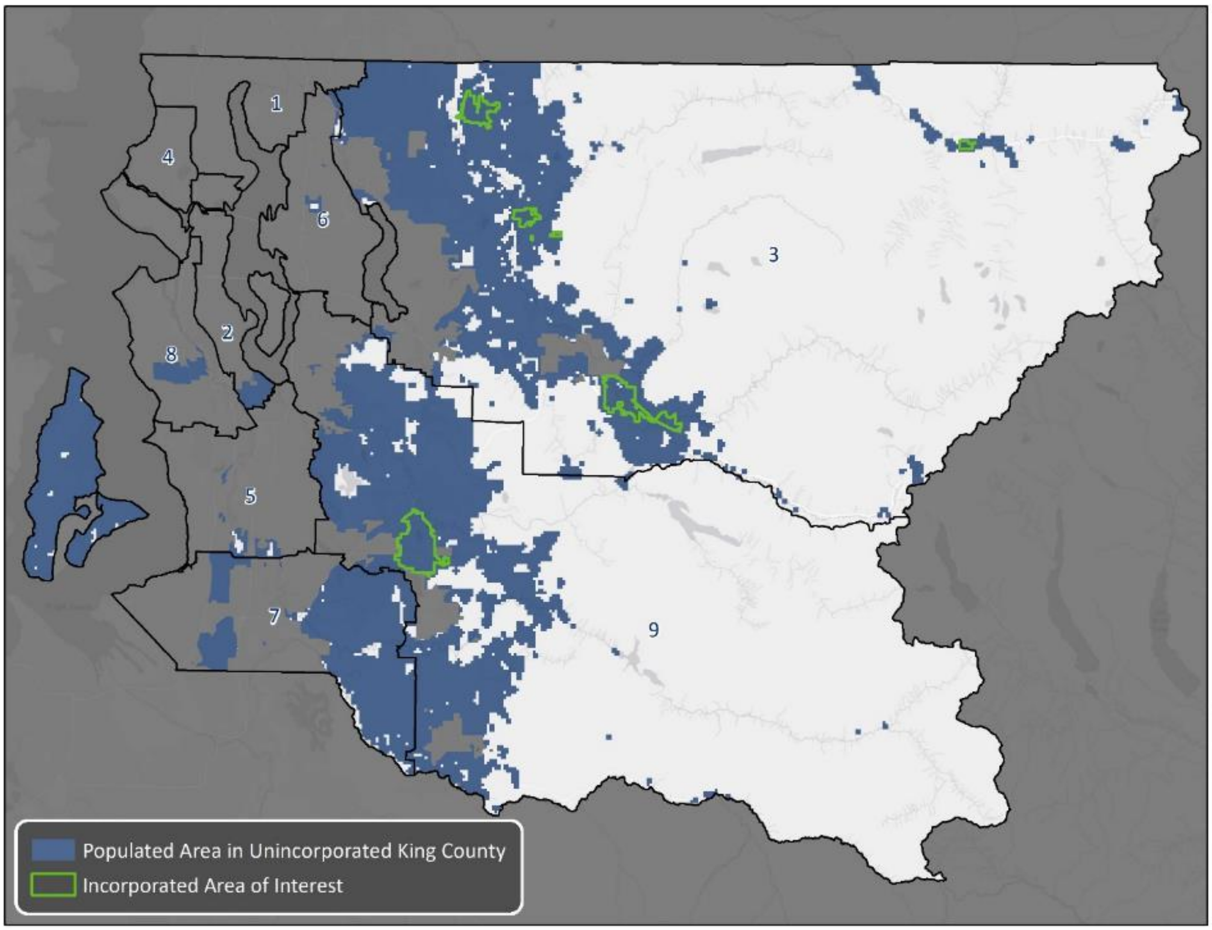
We made this decision based on an understanding that incorporated King County is largely served (due to population densities and build-out requirements in the cable franchise agreement agreements between cable operators and either the County or the individual jurisdictions), and that only unincorporated parts of the County and select incorporated areas might be unserved. The County provided CTC with the following list of incorporated areas to investigate as part of our analysis of unserved areas:

- Carnation
- Duvall

- Maple Valley
- North Bend
- Skykomish

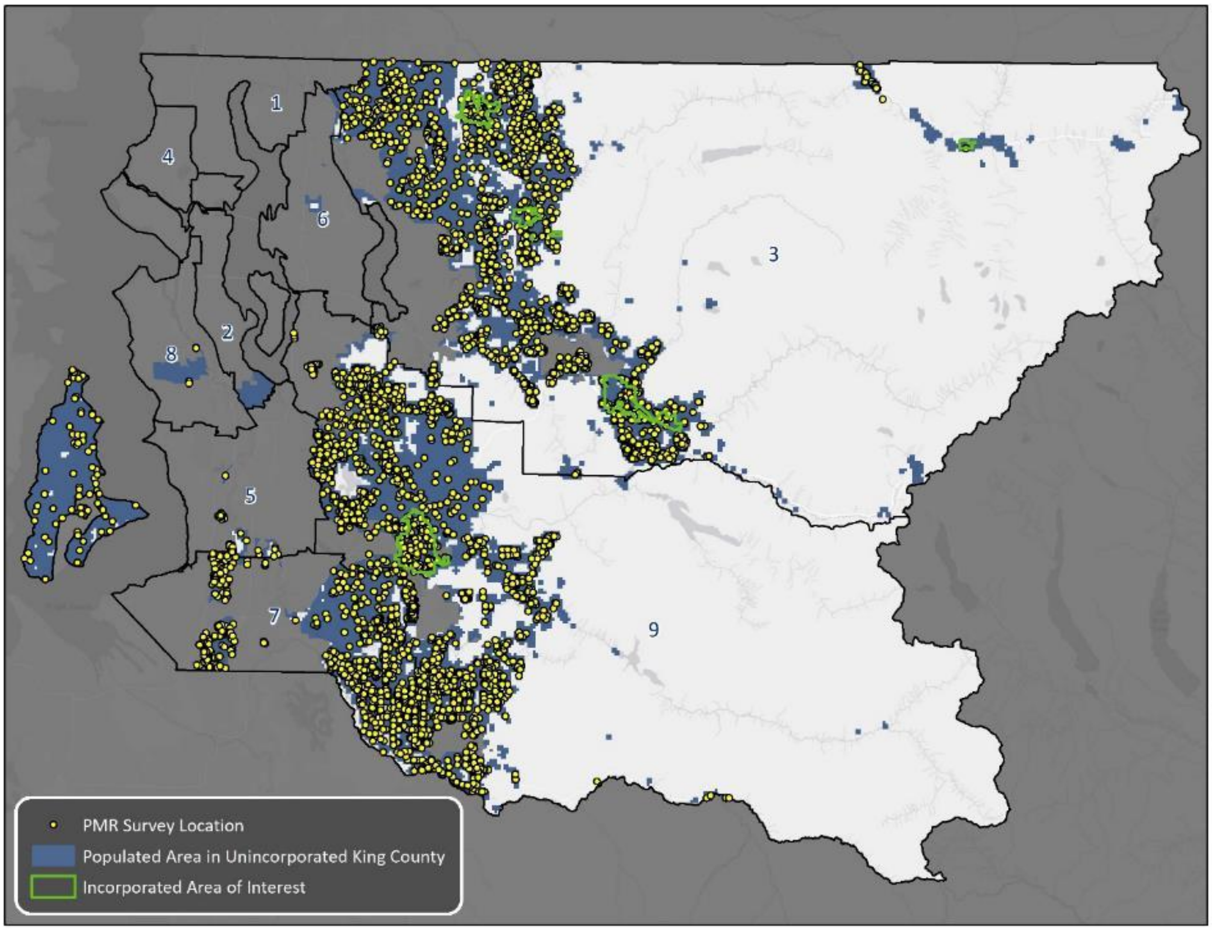
Focusing on unincorporated King County (and in the select incorporated areas), we sought to identify were serviceable addresses were located. The map below (Figure 13), which is based on a County-provided dataset, illustrates all addressable locations in unincorporated King County. The blue portions of the map represent area of possible population in King County.

Figure 13: Population Location in Unincorporated King County



We corroborated this analysis with PMR's survey location data, which show that the areas we identified as populated based on the County's address data align with the residential addresses identified by PMR (i.e., where surveys were mailed) (Figure 14).

Figure 14: Population and Residential Survey Locations

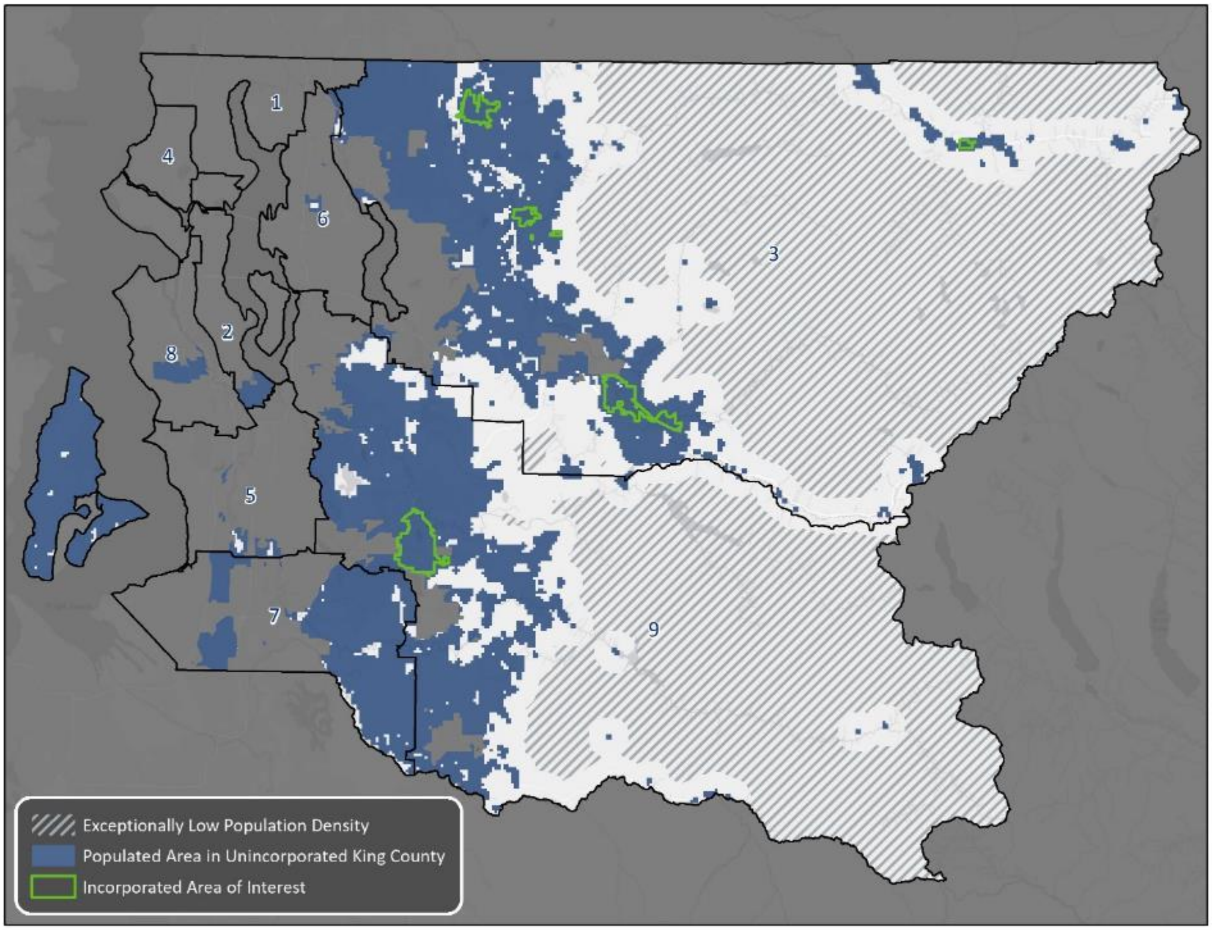


We then sought to exclude from our analysis parts of unincorporated King County that have extremely low population density and, in some cases, hold no population at all.[25] The map in

[25] For the purposes of our analysis, areas with extremely low population density could be excluded from consideration for fixed broadband service because while parts of the County with almost no population might need mobile or fixed broadband access for recreational or public safety uses, they would not require fixed broadband to serve pockets of residential premises

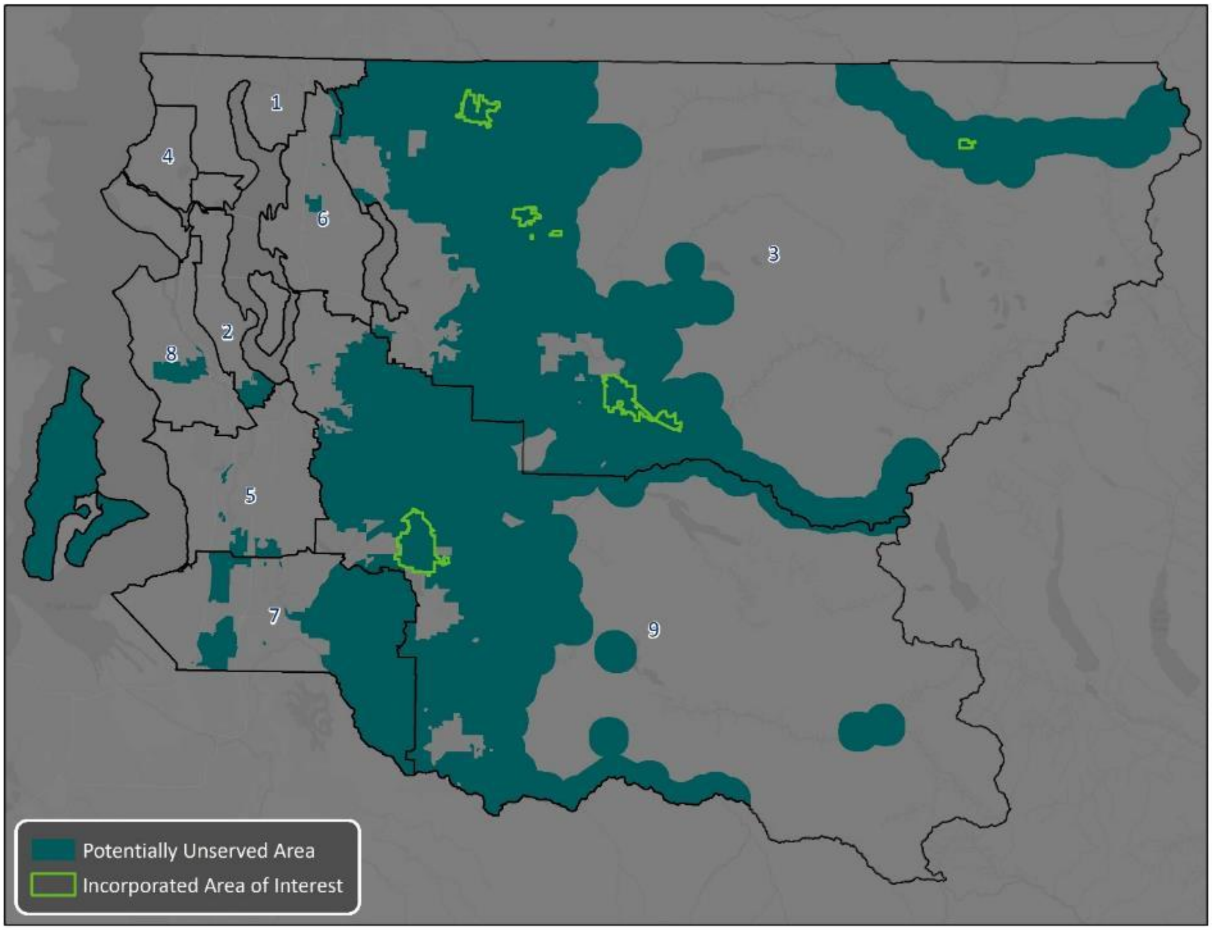
Figure 15 depicts the areas extremely low population density. These areas mostly are forested and mountainous land more than three miles from the nearest County-identified address.

Figure 15: King County Low-Population Areas



After completing this initial analysis, the remaining areas within the County represent the focus of our analysis—the potentially unserved members of the community (see the shaded areas in Figure 16). We note that Skykomish is one area identified as unserved—a finding supported by PMR's consumer survey results. (While all survey respondents in the Skykomish area reported being unserved, 88 percent reported purchasing non-broadband-speed internet access at their homes, which suggests a high level of interest in being served with broadband.)

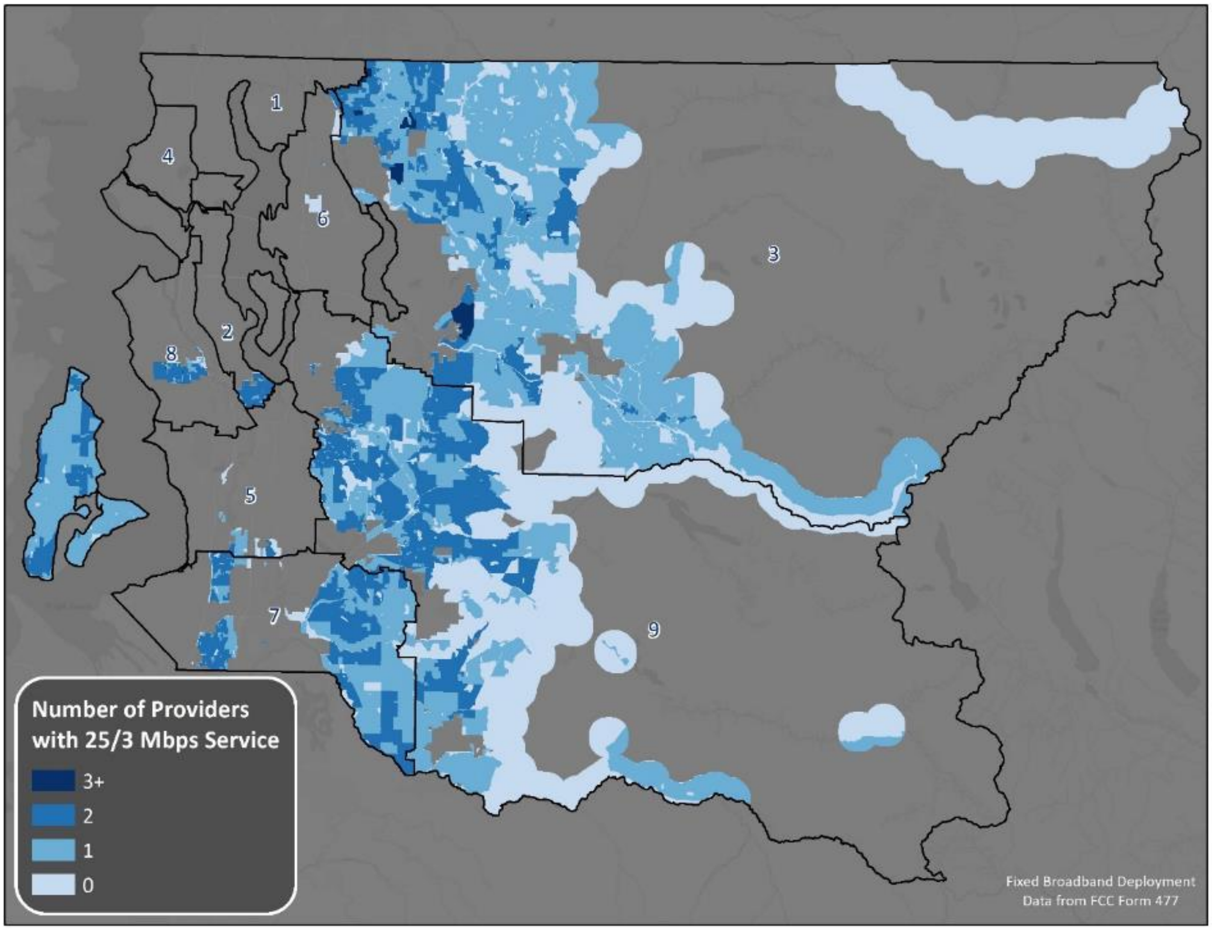
Figure 16: Potentially Unserved Areas



To further refine our identification of unserved areas, we overlaid the FCC's Form 477 data with the boundaries of potentially unserved members of the community to see where service has been reported (Figure 17).

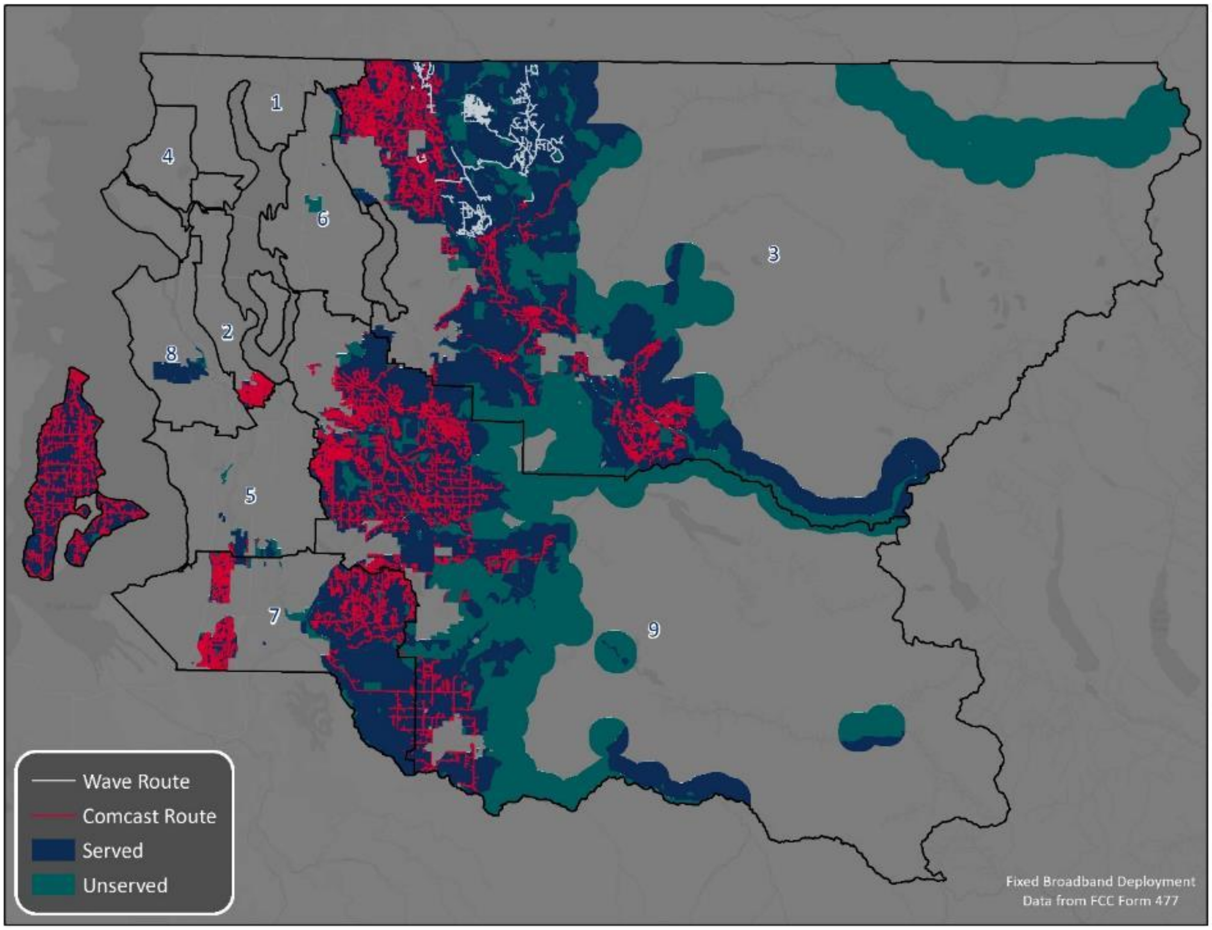
There is a tendency for the FCC's Form 477s to overstate service availability because an entire census block is reported as served if even one location in the block meets the FCC's requirement. In the case of this analysis, that overstatement is to our advantage; where we found census blocks within the County that are shown as being unserved, we can be confident that the residents there truly are unserved. For the areas shown as served we looked at additional data sources to determine the validity of the self-reported FCC 477 data.

Figure 17: Service Availability as Reported on FCC Form 477



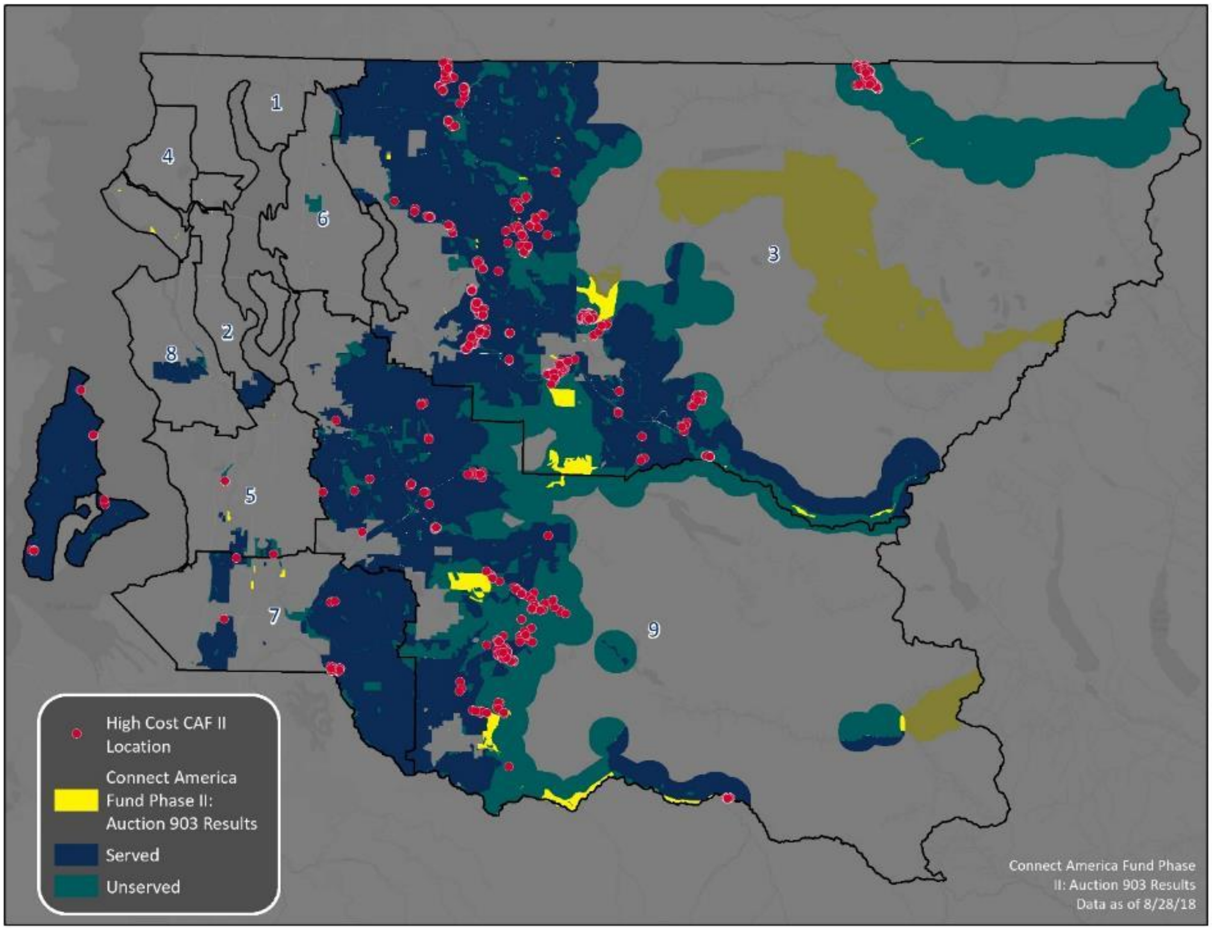
Once such dataset would be the cable franchisee service footprint. As part of their franchise agreement with King County, Comcast and Wave are required to report their respective cable television service footprints and are obligated to build cable infrastructure within their franchise areas above certain density requirements. Where Comcast or Wave has built infrastructure to offer cable television services, their networks are also capable of offering high-speed broadband data services that meet the County's definition of broadband.

Figure 18: Franchisee Service Footprint



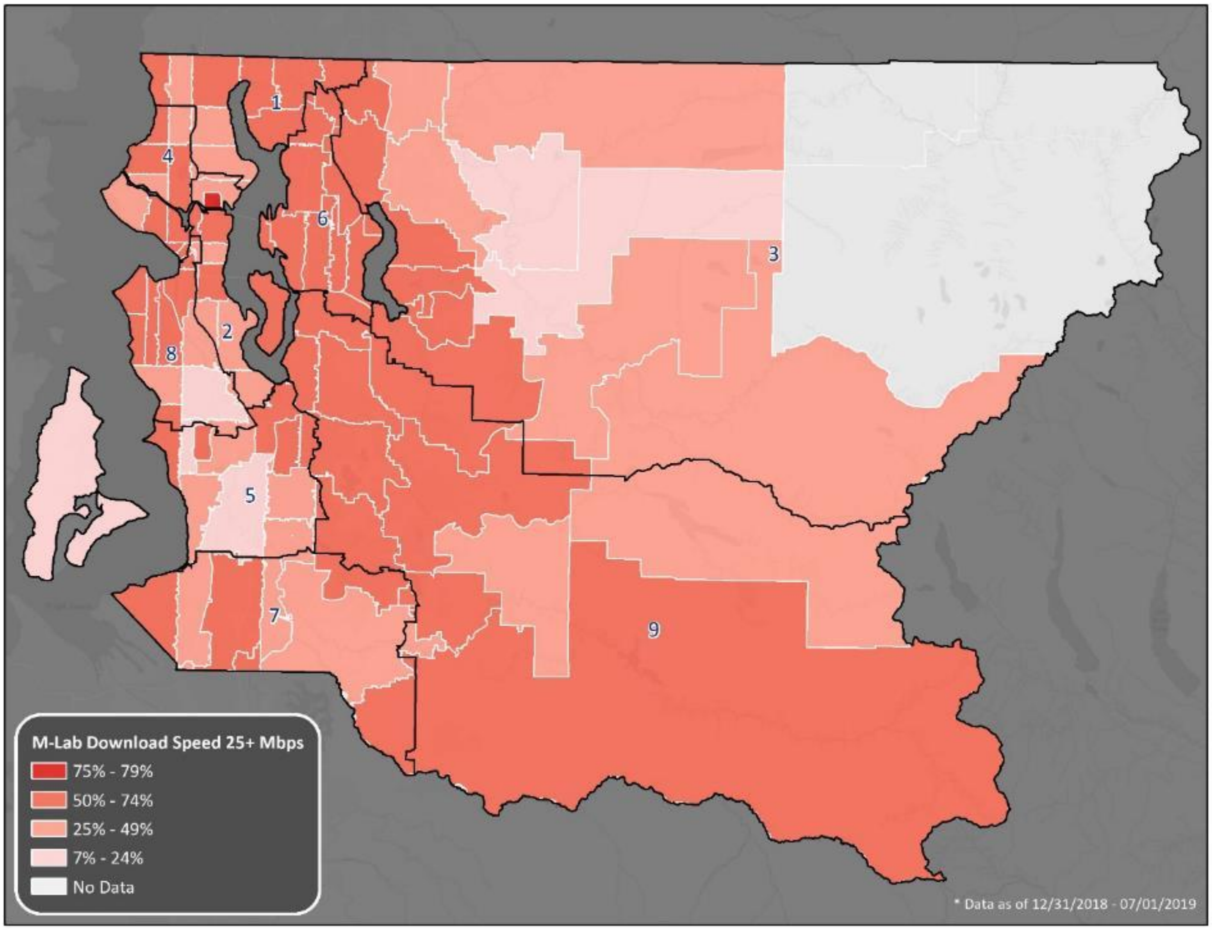
In the map below, red dots indicate locations that the FCC reports are eligible for FCC support in the Connect America Fund program. This is another datapoint identifying areas without service. The yellow areas are locations where the FCC has awarded ongoing support for 10/1 service. We note that the CAF II awards do not overlap with the identified areas of unserved, meaning there is still a need to provide service in the unserved areas we identified—the federal program has not addressed this need.

Figure 19: High-Cost CAF II Locations and Winners in Unserved Areas



As an additional data point for identifying unserved areas in the County we also evaluated the speed test data gathered by M-Lab for the first six months of 2019 (Figure 20). We used data as a snapshot of that time period detailing the percentage recorded download speeds greater than 25 Mbps for each ZIP code in the County. (M-Lab's data are aggregated by ZIP code; they cannot be mapped on a more granular level.) The most significant finding was that the northeastern corner of the County along U.S. 2 (i.e., ZIP codes 98288 and 98224) did not have any data reported showing downloads speeds meeting the County's broadband definition.

Figure 20: M-Lab Speed Test Results



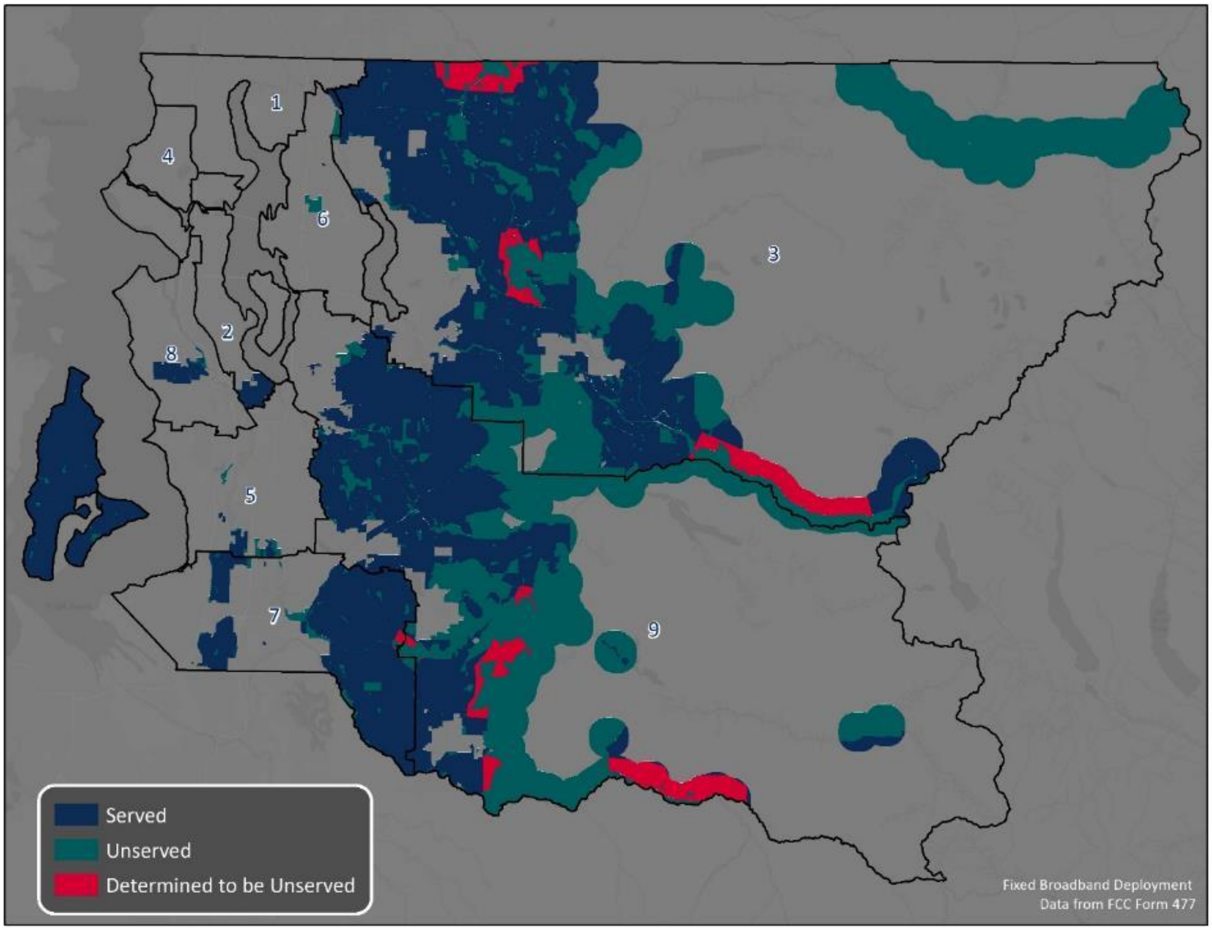
3.3 An extensive field survey confirmed the County's unserved areas

Based on the unserved areas defined through dataset analysis, a CTC outside plant engineer conducted an extensive desk survey (using Google Earth to visually inspect pole lines and rights-of-way for the presence of broadband infrastructure), then undertook a week-long field survey of likely unserved areas to visually confirm where broadband infrastructure exists and where it does not. The field survey established three key points:

1. Areas that we determined to be unserved based on data analysis are indeed unserved.
2. FCC Form 477 data overreport the availability of broadband service in unincorporated King County. Some areas reported as served are actually unserved.
3. Data reported by the County's cable franchisees are accurate. Cable infrastructure exists in all parts of the franchise areas that we surveyed.

The map below illustrates the field survey findings overlaid with the results of our analysis of the available datasets and our desk survey.

Figure 21: Field Findings of Served and Unserved Areas



The field survey entailed a ride-out of approximately 650 miles of roadways throughout King County targeting areas identified as likely to be unserved based on our analysis of the available datasets and our desk survey. Our field engineer examined the target areas for signs of existing aerial and underground wireline broadband infrastructure, including:

- Aerial fiber optic infrastructure indicative of hybrid fiber-coaxial (HFC) and/or FTTP service availability, including fiber optic splice enclosures serving as tie points for multiple feeder cables; fiber optic taps and/or FTTP service drop cables; FTTP distribution cabinets; and fiber feeder cables of varying strand counts attached to existing utility poles in the communications space[26]

- Aerial HFC distribution plant, including taps for coaxial cable service drops, cable television amplifiers, power supplies, and coaxial cables (trunk, distribution, and drop cables) attached in the communications space of utility poles
- Utility pole risers containing telecommunications cables for transition between aerial and underground infrastructure
- Utility markers located within the public ROW indicating the presence of underground fiber optic lines owned by commercial broadband operators (often providing contact information for reporting accidental damages)
- Utility manholes and communications handholes/vaults located in the public ROW with lid markings indicating underground infrastructure owned by commercial broadband operators[27]
- Pedestals for connection of underground FTTP or coaxial service taps
- Underground fiber optic and coaxial customer service drop entry points and related equipment visible from the public ROW, including FTTP Optical Network Units (ONUs), Network Interface Device (NID) enclosures, coaxial splitters, and aboveground service drop cable entry points and/or bonds to electrical ground

Where aerial infrastructure is prevalent, our survey found that most major roadways between and passing through the target survey areas have some type of fiber optic cable (generally the top attachment in the communications space), though much of this appears to be backbone cable that is not supporting local services.

Our findings are summarized as follows for the five main areas targeted by our field surveys as potentially unserved:

- **Duvall and areas north:** There is no cable television infrastructure until just north of the City limits. The area between Duvall and the northern County line is primarily rural land with few building structures. The City has mostly ubiquitous cable service availability, with fiber optic cables feeding the HFC plant from multiple directions. Communications

[26] Conversely, the presence of only middle mile and/or long-haul plant is characterized by larger-count fiber optic cables with few splice enclosures and a lack of smaller distribution and/or lateral cables extending from or lashed to these backbone cables.
[27] CTC did not open or enter existing manholes or handholes to inspect underground infrastructure, as field surveys were conducted without participation by representatives of any network operator.

services are mainly buried in the northern portion of the City and some areas of the City center.

- **Area between Carnation and Fall City:** This area is mostly farmland with no cable or fiber infrastructure.
- **South of Kent:** This is an industrial area that appears to be served with both cable television and fiber infrastructure.
- **Straight Ponds area (near SE Green Valley Road and 212th Way SE):** This area is not served by cable television, however there is fiber in this area that appears to be cable and telephone backbone infrastructure with only straight splices. Stated otherwise, the infrastructure passes through the area but there are no laterals for local services.
- **Area from north of Enumclaw to Kanaskat:** Within a large area along Veazie Cumberland Road SE and laterals to the east, there is no cable service or fiber of any type. All communications infrastructure is buried telephone service with aerial power service.

3.4 Several datasets demonstrate that mobile service is also unevenly available across the County

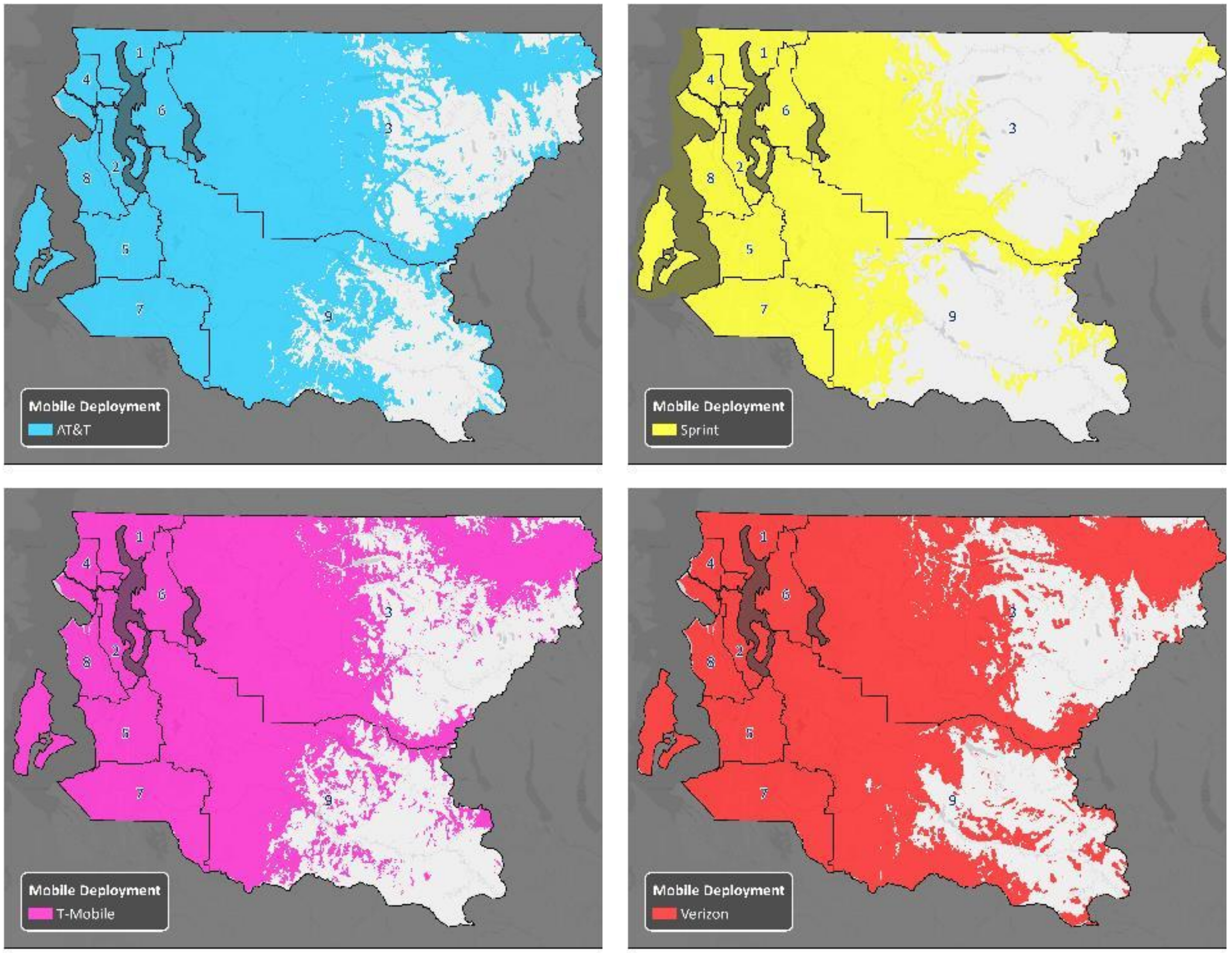
CTC's analysis of a range of datasets finds that mobile wireless service is better in the more populated areas and along the major highways than in the rural, less populated, or sparsely populated areas of King County.

The FCC's fixed broadband service reporting is overstated—but mobile service reporting is even worse. The FCC requires all facilities-based, fixed, and mobile broadband providers to complete Form 477 twice a year. Mobile providers must file maps of their coverage areas for each broadband technology, as well as details on their upload and download speeds. However, the FCC does not define the parameters for the maps nor the conditions under which the speed data is collected—only that "the data associated with each polygon should indicate the minimum advertised upload and download speeds associated with that network technology in that frequency band, and the coverage area polygon should depict the boundaries where, according to providers, users should expect to receive those advertised speeds."[28] As a result, the coverage maps and speeds submitted to the FCC are those *advertised* by the network providers, and thus the same as the maps on the respective carriers' websites.

The maps below illustrate the four major carriers' *reported* coverage in King County.

[28] https://www.fcc.gov/document/data-specification-form-477-data-collection

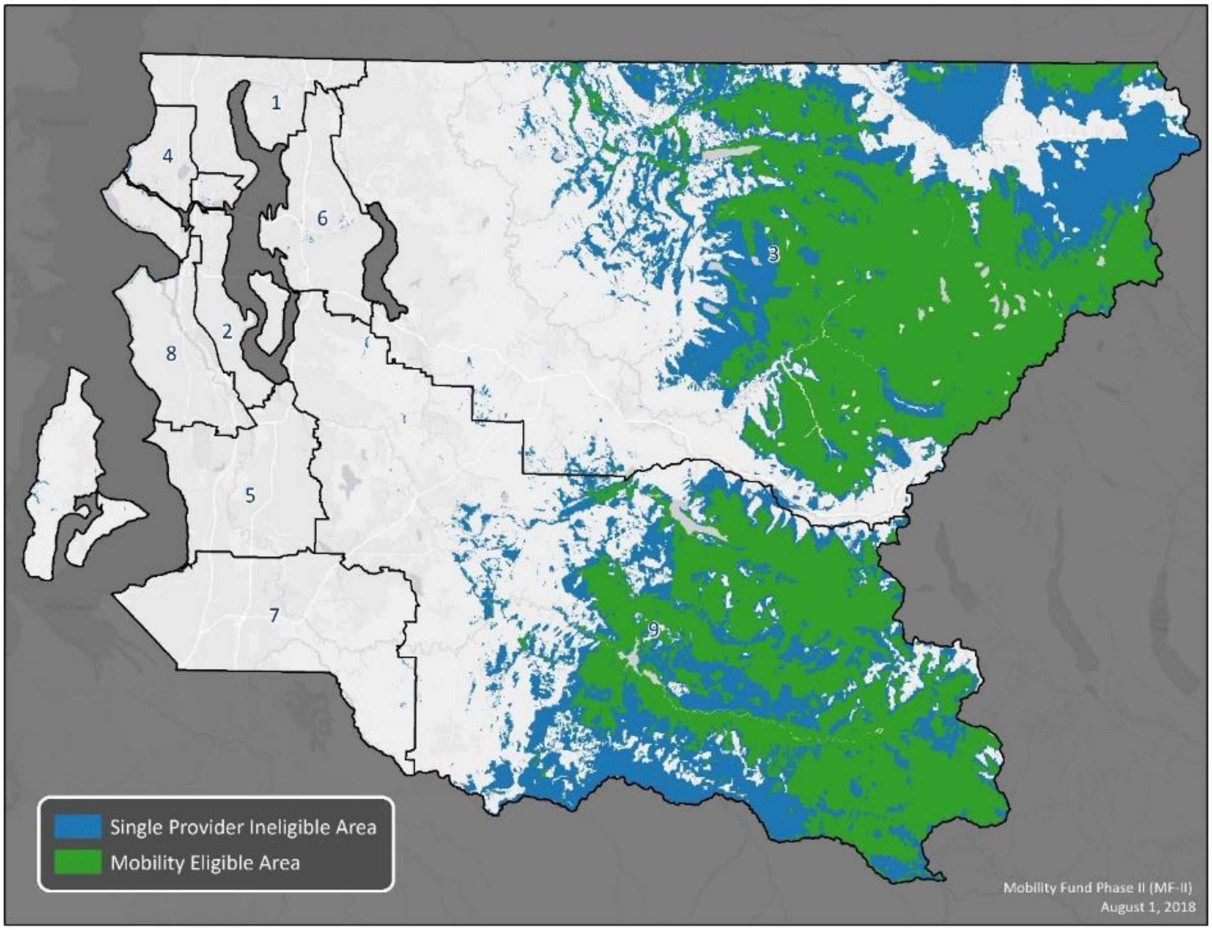
Figure 22: FCC Form 477 Reported Mobile Coverage Areas



FCC data indicate that the areas in the map below are unserved by 4G LTE wireless service and thus are eligible for Mobility Fund support.[29] The eligible areas are primarily in the unpopulated areas of the County.

[29] "Mobility Fund Phase II (MF-II)," Federal Communications Commission, https://www.fcc.gov/mobility-fund-phase-ii-mf-ii (accessed October 2019).

Figure 23: Unserved Areas Eligible for FCC Mobility Funding



CTC conducted additional analyses of wireless carrier performance based on publicly available data from private companies RootMetrics[30] and OpenSignal.[31] These data confirm that better call performance and speeds are available in the more populated areas of the County and along major roadways whereas the rural areas, especially along U.S. 2 and I-90 in eastern King County, experience slower speeds and are limited by older technologies such as 2G/3G.

These maps and reports provide consumers with a much better idea of network provider performance than do the carriers' maps or the FCC's coverage maps. The companies' independence of the carriers and frequent updates more reliably demonstrate performance.

[30] RootMetric's interactive map can be found at http://webcoveragemap.rootmetrics.com/en-US. Information provided in this report is based on data accessed on November 14, 2019.

[31] OpenSignal's maps can only be accessed using their mobile device application which is described on OpenSignal's website at https://www.opensignal.com/apps. Information provided in this report is based on data accessed on the company's mobile application on November 14, 2019.

RootMetrics sends researchers into the field to drive primarily main thoroughfares; they collect, analyze, and report on measurements every six months. In addition, they have recently enhanced their data with crowdsourced information from mobile device applications. The specific datasets available on their online maps measure call performance, maximum speed, and best technology available for each of the four major network providers.

According to RootMetics, call performance throughout most of King County is “good” (signal strength levels from -96 dBm to -50 dBm) even along U.S. 2 and I-90 to the east. However, zooming into these two area, performance along roadways off the highways goes from “good” to “poor” to “bad” (-116 dBm and below).

Potential download speeds (depends on device) are mostly categorized from “moderate” (5 to 20 Mbps) to “fast” (20 to 40 Mbps) with some roadways in the populated areas of the County at “faster” speeds (40 to 300 Mbps). As suspected, speeds are “slow” to “moderate” along U.S. 2 and I-90 to the east.

It is important to understand that not all roads or all indoor locations are being tested every six months and that the measurements only reflect the device being used and the weather conditions at the time of the test.

OpenSignal is a wireless infrastructure analysis company that gathers crowdsourced data from individuals across the world to evaluate wireless network provider performance. OpenSignal shares its data online.

According to OpenSignal’s website, data are based on both user-initiated tests and background automated tests from a range of smartphone applications. While both types of tests can be useful, user-initiated measurements reflect conditions when users choose to run the tests, whereas background tests can be run at regular intervals throughout the day and capture a much broader range of network performance metrics.

By combining data from user-initiated and background tests, OpenSignal strives to reproduce the user experience. Most of their measurements are from indoor locations (since that is where most people spend their time) providing a larger indoor capture rate than other forms of data collection like drive-testing.

OpenSignal’s maps substantiate other analyses showing “strong” (-99 dBm signal strength or better) in the populated areas and along the roadways in King County and average speeds of 17 to 40 Mbps. Along U.S. 2, however, signals are “weak” and there are not enough data points to provide an average speeds.

This is not surprising, but it is of concern for rural County residents. Note that there must be *some* signal level to execute one of these tests from an application on a Smartphone or other compatible wireless device. Therefore, the area of “no data collected” shows one of two things—no one with a signal ran a test while they were in that area or there is no signal in that area over which a test can be run. So these areas of “no data collected” may be an indicator of absent coverage or poor performance.

If the County is interested in more extensive investigation, we suggest further testing to fully assess the geographic scale and severity of any deficiencies in wireless carrier performance. Such testing would include an assessment of specific areas in a controlled environment using drive and walk-test equipment specially configured for collecting performance data from individual carriers.

4 King County's Underserved Residents Have Broadband Available But Limitations to Access

CTC's research found that broadband internet service is available to the great majority of the residential population of King County but that availability does not equate to ubiquity of access and adoption. Access to service remains a significant challenge for low-income members of the community.

4.1 CTC's analysis illustrates the geographic dispersion of King County's underserved residents

As part of our analysis of who in King County is "underserved" under the County's definitions of broadband,[32] we developed a series of maps that seek to illustrate the geographic dispersion of the underserved members of the community.

Because there does not exist a data source with granular data regarding residents' income levels,[33] we began our analysis with the U.S. Census Bureau's American Community Survey data. The map in Figure 24 illustrates the ACS-reported median household income of residents across the County; Figure 25 illustrates only those census block groups with income below $30,000. (We note that one of the census block groups identified in the latter map could include University of Washington dormitories; it stands to reason that the student population there would report low incomes—but that they are almost uniformly broadband adopters.)

[32]Under the County's definition, a community is ***underserved*** with broadband if the service offered meets any of the following criteria (regardless of speeds): (1) it has been adopted by less than 80 percent of residential customers; (2) it is priced at 20 percent or more above services of comparable speeds in other areas of King County; (3) service plans include data caps or other tiered pricing that effectively price it at 20 percent or more above services with comparable speeds in other areas of King County; or (4) census or other data demonstrate that median annual household income is less than $30,000, reflecting 2018 national Pew Research Center data showing the adoption rate for households earning less than $30,000 is approximately 81 percent, far below that of higher-earning households.

[33] Income is frequently used as a proxy for broadband adoption and does make up an element of the County's definition of underserved, based in part on the Pew Research Center's national data, which show that internet use for households earning less than $30,000 per year is far below that of higher-earning households. "Internet Fact Sheet," Pew Research Center, June 12, 2019, https://www.pewinternet.org/fact-sheet/internet-broadband/ (accessed October 29, 2019).

Figure 24: Median Household Income by Census Block Group (ACS Data)

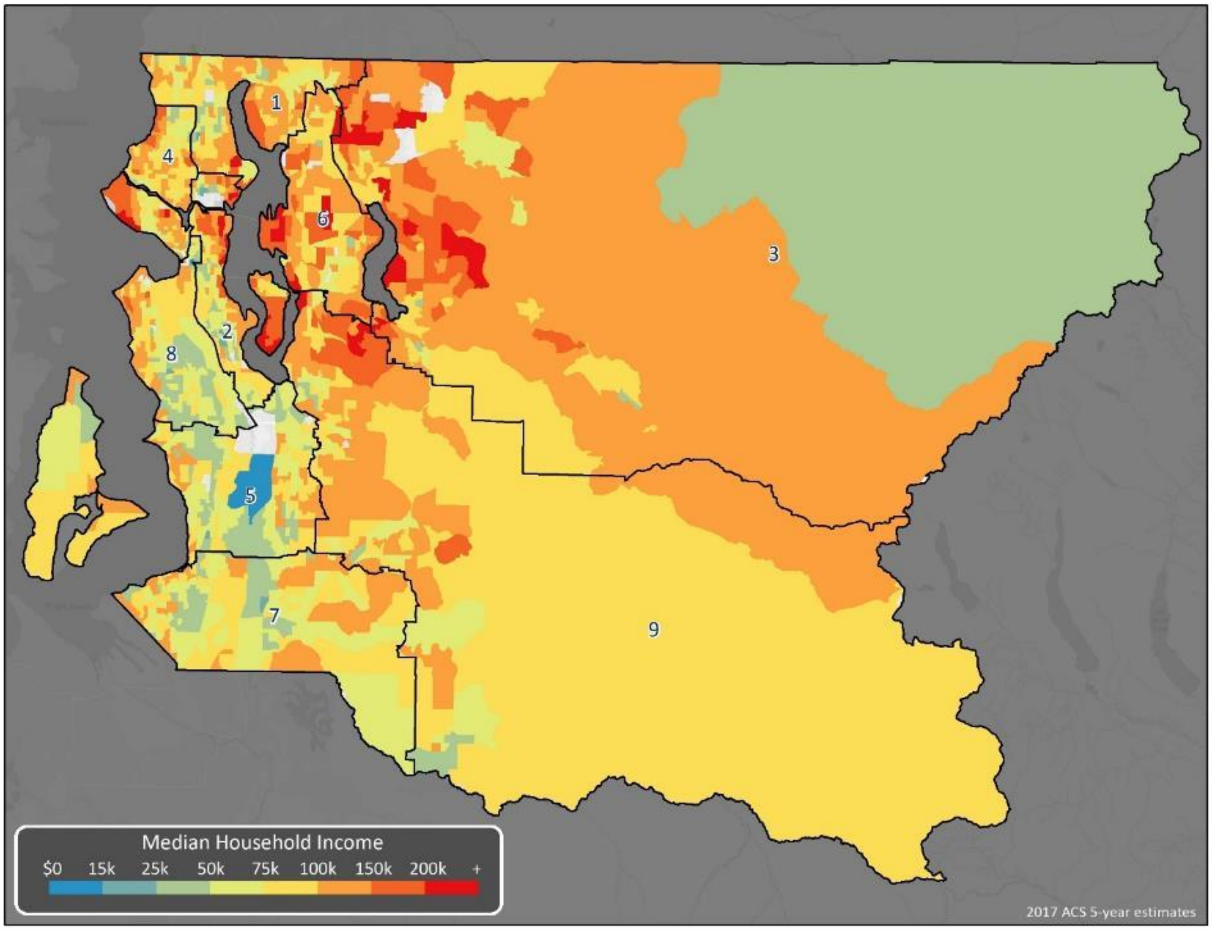
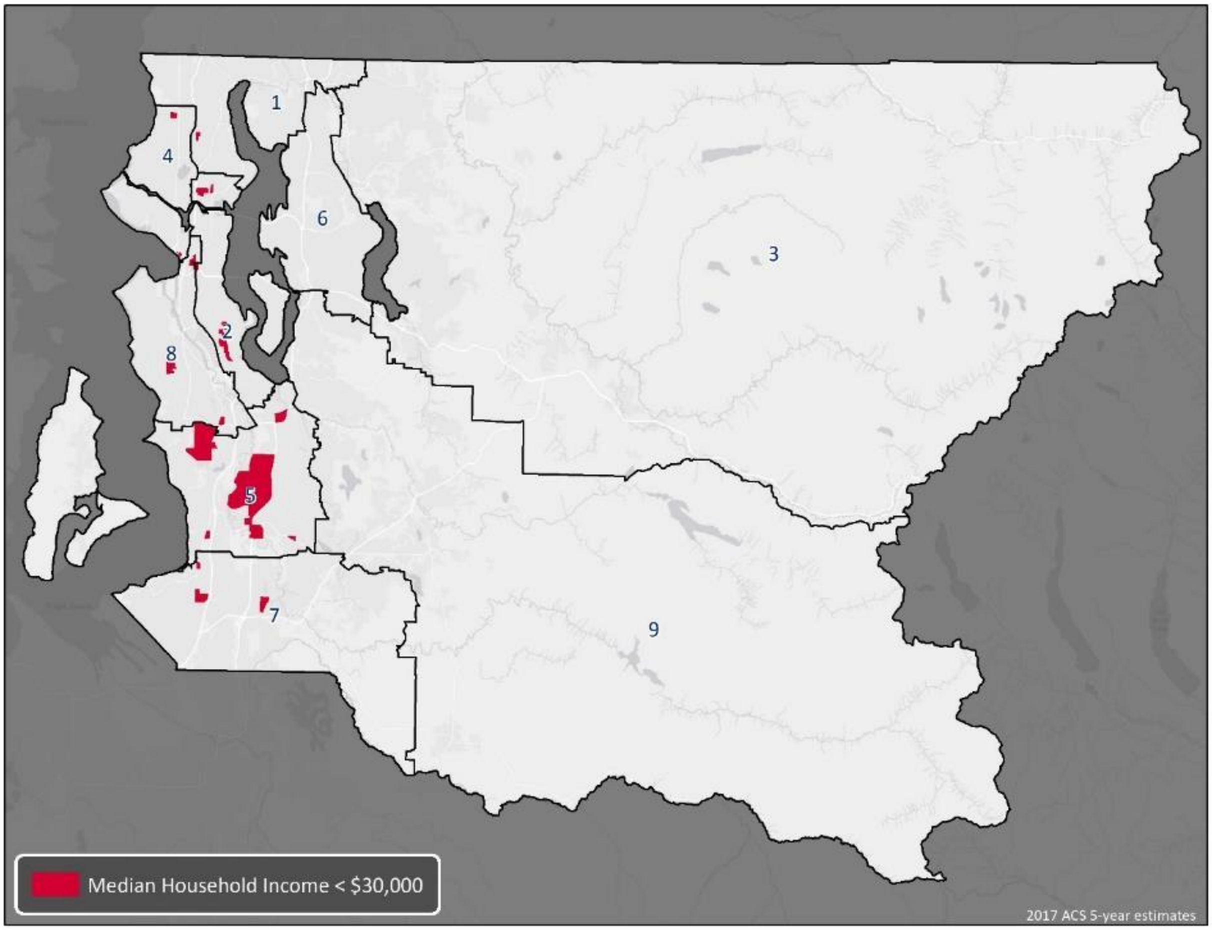
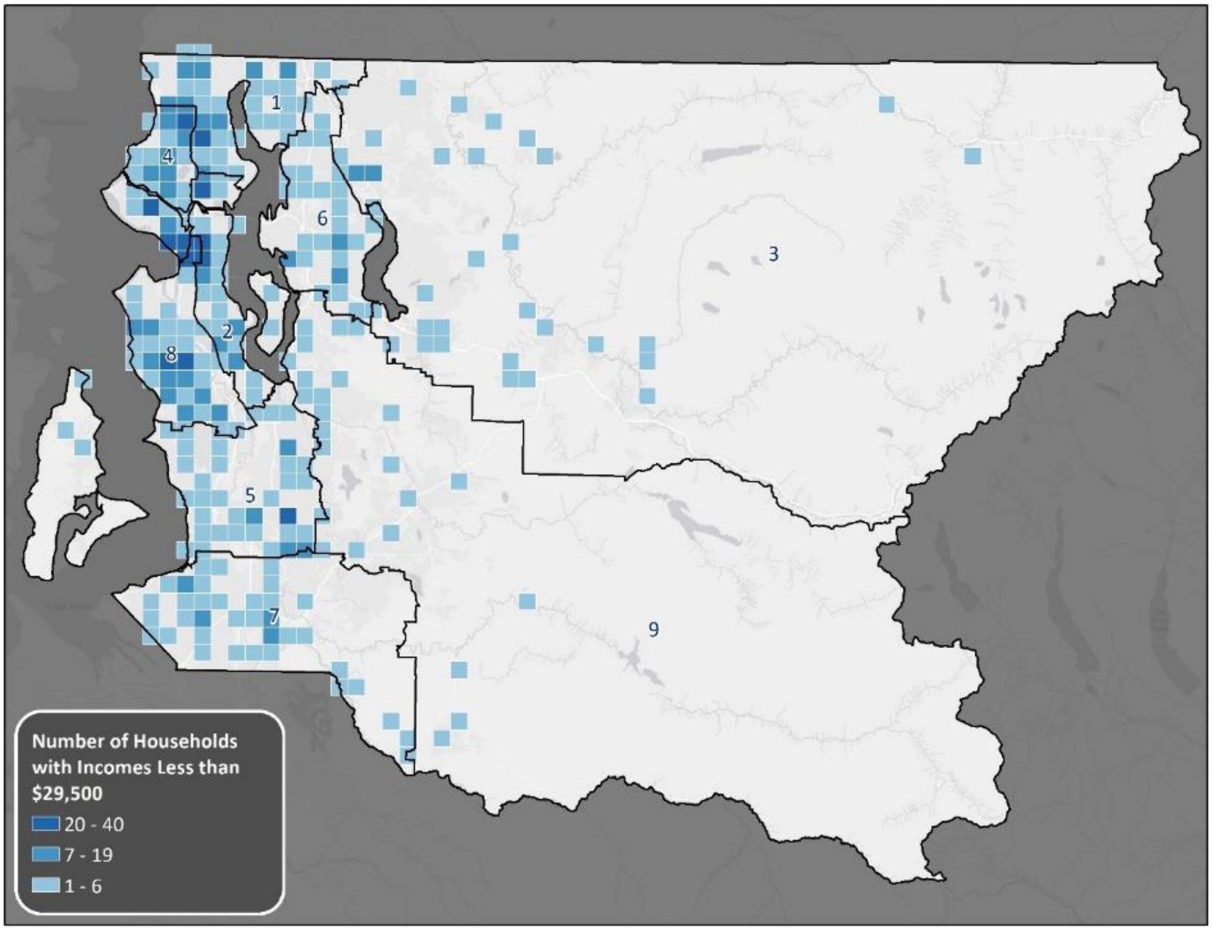


Figure 25: Median Household Income Below $30,000 by Census Block Group



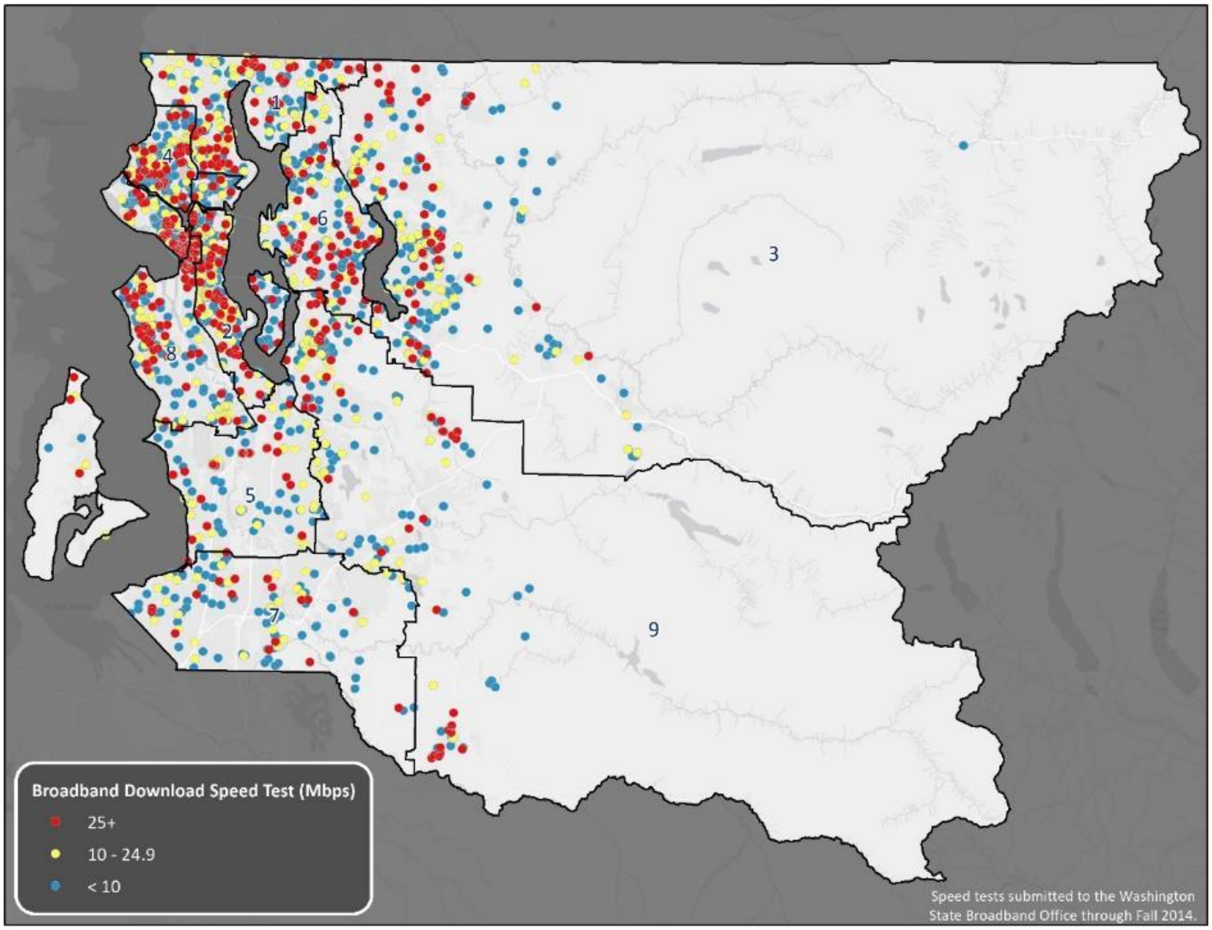
However, our analysis indicated that data at the census block group level are not granular enough to be meaningful, and actually create distortion by neglecting to show smaller areas of the County that are low-income. To refine our map of underserved areas, we analyzed PMR survey data to focus on members of the community with median household income of $29,500 or less (Figure 26).

Figure 26: Median Household Income Below $29,500 Based on PMR Survey Data (Underserved)



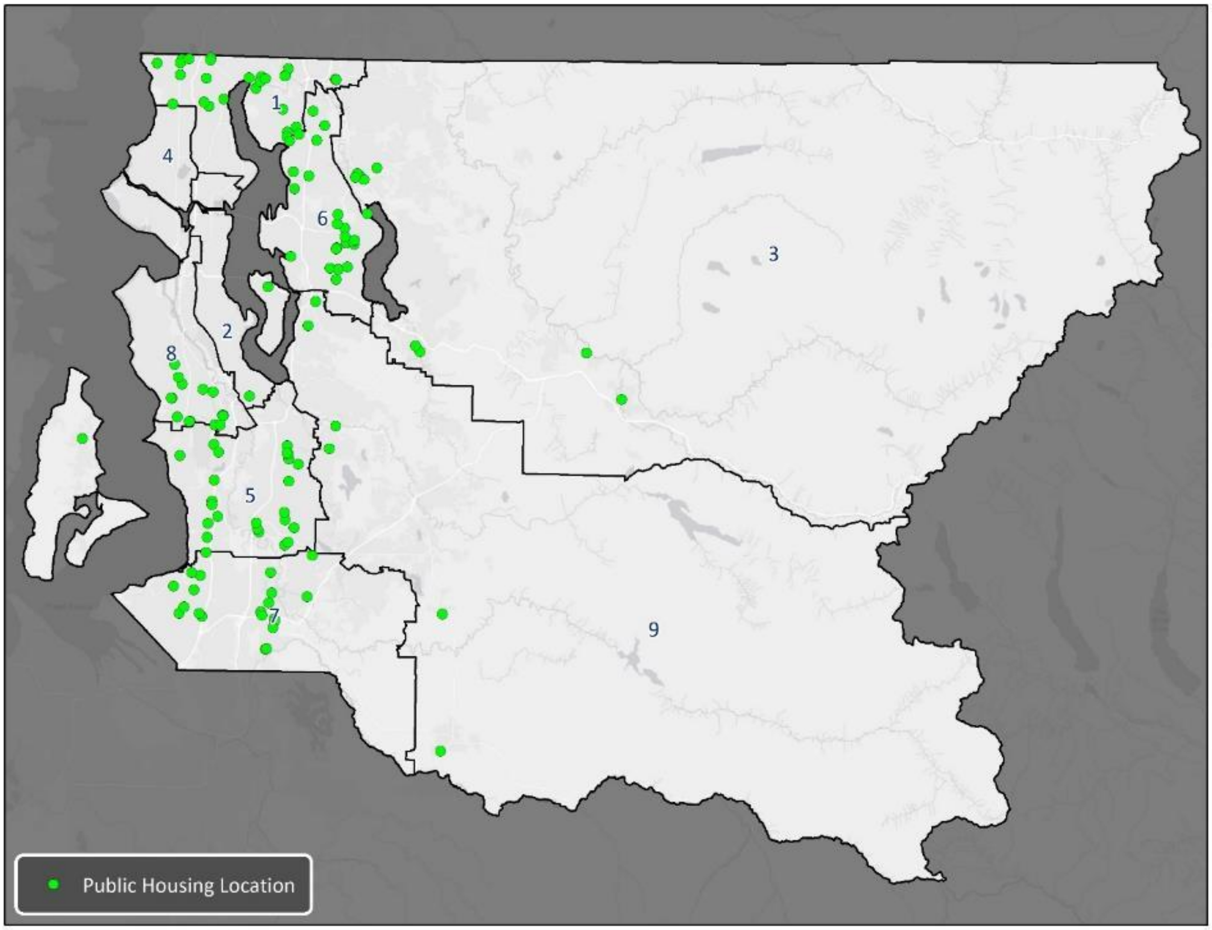
To support our income-based analysis, we also evaluated the most recent speed test data gathered by the Washington State Broadband Office (SBO), from late 2014 (Figure 27). These data points offer a snapshot of that time period: 25/3 service was available in substantial parts of the County, but many people appear to have been choosing to purchase slower service (see the yellow and blue points on the map). There are other potential reasons for slow speed test results, such as network congestion, but the data indicate that price sensitivity or other factors led members of the community to buy slower broadband services just a few years ago.

Figure 27: Speed Test Results from State Broadband Office (2014)



As a final piece of our analysis of potentially underserved members of the community, we identified the location of public housing buildings in King County; we can assume, based on income thresholds for residents who live there, that those locations also represent underserved addresses (Figure 28).

Figure 28: Public Housing Locations (Underserved)



4.2 PMR's survey data demonstrate that lower-income members of the community are less likely to purchase broadband internet

King County's survey findings are consistent with national data demonstrating that lower-income communities have less access to broadband internet.

National data have long demonstrated a correlation between lack of broadband access and low income, and PMR's research finds the same for King County. Based on PMR's data, income is a significant factor in: (1) whether or not King County residents have access to the internet where they live; (2) if that internet access has sufficient download speed; (3) if that internet access is 'adequate' for their needs; (4) and if they need to rely on cellular data for their internet access (instead of a fixed broadband connection).

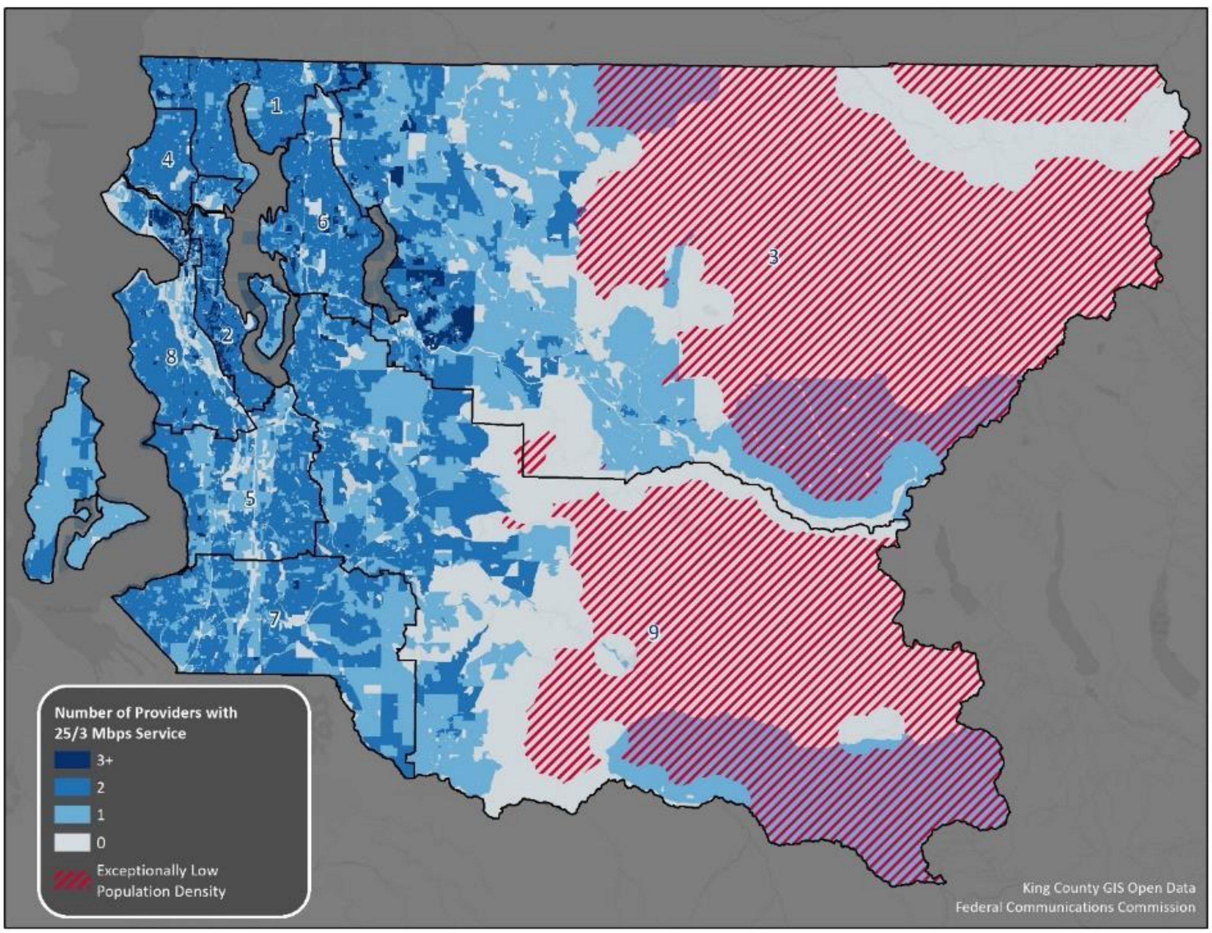
King County households with income less than $25,000 per year are significantly less likely to have internet access where they live (only 80 percent, compared to the County total of 96 percent).

These households are also significantly less likely to have adequate internet access (55 percent repot 'completely' or 'mostly' adequate internet where they live, compared to the County total of 76 percent).

Furthermore, these members of the community are significantly more likely to rely on cellular data (8 percent, compared to the County total of 4 percent) and significantly less likely to have a fixed broadband subscription where they live (64 percent, compared to the County total of 88 percent).

One reason for the lack of affordability may be lack of competition. Even though reasonable levels of broadband are provided by Comcast and Wave in the County's residential markets, competitive networks are not uniformly available across the County (see Figure 29).

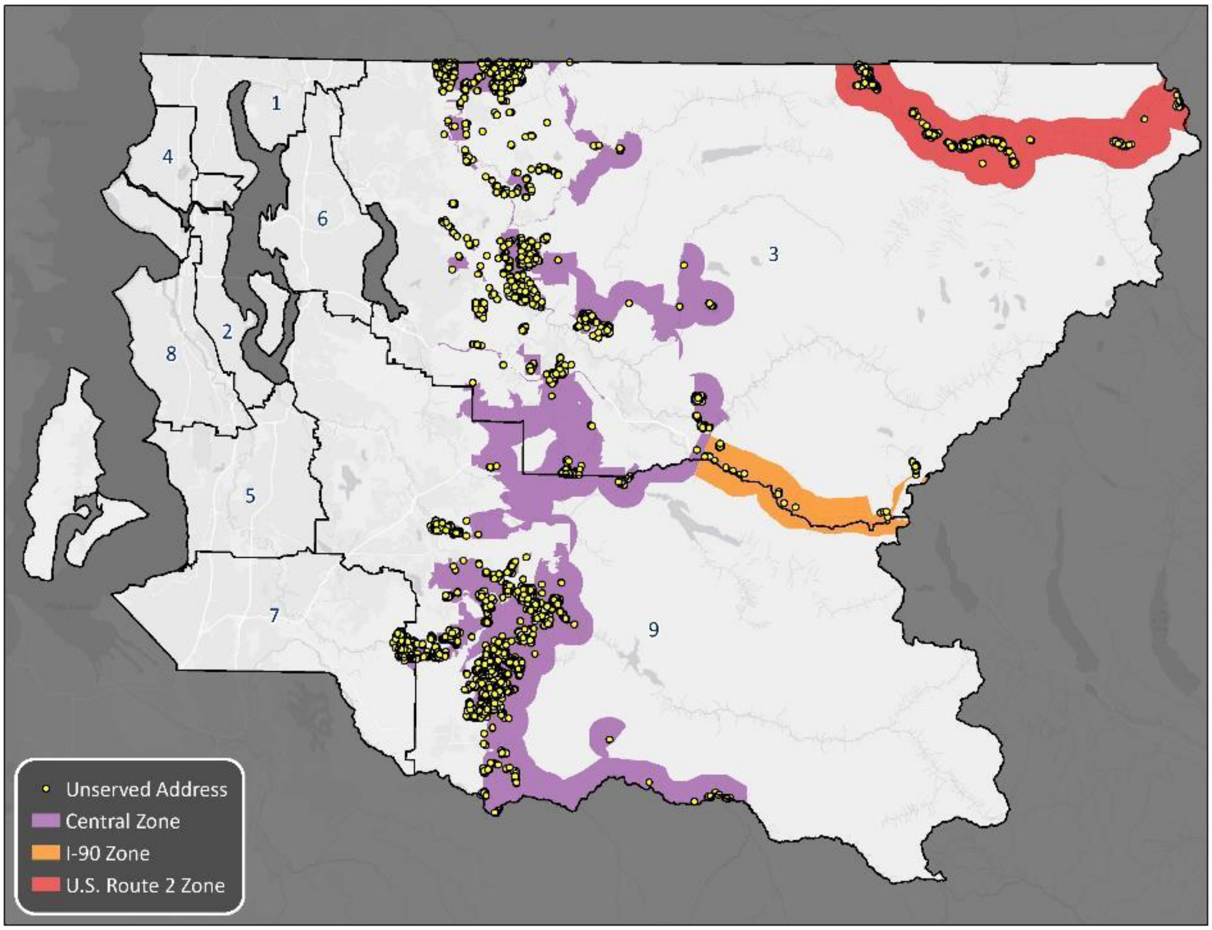
Figure 29: Number of Reported Broadband Providers



5 Fiber-to-the-Premises Infrastructure Could Fill Broadband Gaps in Unserved King County

As documented above, CTC's analysis identified three areas where the majority of unserved residents and businesses are located: the center of King County, along U.S. 2, and along I-90. Figure 30 shows the location of the unserved areas.

Figure 30: Unserved Areas of King County



Based on data gathered by CTC engineers through discussions with County stakeholders, an extensive desk survey, and an on-site survey of candidate fiber routes, CTC's engineers prepared a high-level network design for the deployment of a gigabit-capable fiber-to-the-premises (FTTP) network to homes and businesses in those unserved portions of the County. We then estimated the County's costs for deploying that network—and, for the sake of comparison, examined the potential costs for existing telecommunications providers in the County to expand their footprints to serve the unserved areas.

The total estimated cost for the County to construct an FTTP network to serve these areas is shown in the following table.

Table 10: Estimated FTTP Capital Cost

Cost Component	Central	U.S. 2	I-90	Total Estimated Cost
Outside Plant	$22 million	$64 million	$31 million	$117 million
Central Network Electronics	$800,000	$100,000	$100,000	$1 million
FTTP Service Drop and Lateral Installations	$800,000	$150,000	$50,000	$1 million
Customer Premises Equipment	$750,000	$200,000	$50,000	$1 million
Total Estimated Cost:	*$25 million*	*$64 million*	*$31 million*	*$120 million*
Passings	4,190	940	90	5,220
Outside Plant Capital Cost Per Passing	*$5,140*	*$67,740*	*$329,770*	*$22,190*

This cost estimate provides data relevant to assessing the financial viability of network deployment; it enables financial modeling to determine the approximate revenue levels necessary for the County to service any debt incurred in building the network.

5.1 Per-mile cost estimates are based on a customized network design

CTC engineers performed a survey of the County via Google Earth Street View followed by an on-site survey of targeted areas. The engineers reviewed available green space, necessary modifications to infrastructure on utility poles, and the need for utility pole replacement and factored these costs into the design and cost estimate.[34] From this analysis, we developed estimates of per-mile cost customized for King County for construction on utility poles and for underground construction where poles are not available.

Table 11 summarizes the conditions determined through our field and desk survey.

[34] Modifications and replacement of the utility poles is commonly referred to as "make-ready." The utility poles are getting modified to make space available for an additional attachment.

Table 11: Field Survey Findings in Unserved Areas

	Central	U.S. 2	I- 90
Aerial Construction	75%	90%	90%
Poles per Mile	51	46	41
Average Moves Required per Pole	1	1	1
Poles Requiring Make-Ready	15%	15%	15%
Cost Per Move	$350	$350	$350
Poles Requiring Replacement	2%	2%	2%
Average Pole Replacement Cost	$5,000	$5,000	$5,000
Intermediate Rock Underground	2%	2%	2%
Hard Rock Underground	1%	1%	1%

Make-ready is the work required to create space on an existing utility pole for an additional attachment. Existing attachments often have to be moved or adjusted to create the minimum clearance required by code to add an additional attachment. Each move on the pole has an associated cost (i.e., for contractors going out to perform the move). When a utility pole is not tall enough to support another attachment or the pole is not structurally capable of supporting the attachment, a pole replacement is required. The pole replacement cost is then charged to the new attacher.

Where utility poles do not exist, underground construction is required. One of the challenging variables with underground construction is the prevalence of rock. Softer stones and boulders (intermediate rock) require the use of a specialized boring missile that is more expensive than traditional boring. Where hard rock, such a granite is present, specialized rock boring machinery is required to directional bore new conduit. The cost of boring through rock is added to the cost of traditional boring.

CTC's outside plant engineer noted that the quality of the poles and pole attachments in the County varied, as they do in many cities and counties—but that overall, most of the poles have capacity for an additional attachment. In comparison to other communities where we have done similar outside plant work, the poles in King County tend to be average to above average in terms of feasibility of adding an additional attachment. (In some other communities the poles are so congested that adding additional attachments is not financially feasible.)

The figures below show samples of poles in various conditions that we identified during our field survey of the County's unserved areas. In the following figure, for example, make-ready is required on the pole because there are multiple cables in the communications space and a street light in the power space. This is an example of a pole that may require replacement if clearance cannot be achieved for an additional attachment.

Figure 31: Utility Pole Requiring Make-Ready

Tree trimming is required to attach an additional attachment on the utility poles in the following picture. Tree trimming is also an important maintenance function necessary to keep the pole line clear of tree limbs that could break and damage the wires on a utility pole.

Figure 32: Pole Line Where Tree Trimming Will Be Required

The following photo shows a low make-ready pole line that has only one existing attachment in the communications space. Where make-ready is low, the cost of aerial construction is cheaper than in high make-ready areas.

Figure 33: Typical Low-Make-Ready Pole Line in the Unserved Areas

5.2 The fiber-to-the-premises network design can support multiple subscriber models and classes of service

We developed a conceptual, high-level FTTP outside plant network design that is aligned with best practices in the industry, reflects the County's goals, and is open to a variety of electronic architecture options.[35] The design assumes a combination of aerial and underground construction based on the placement of the existing utilities.

Figure 34, below, shows a logical representation of the FTTP network architecture we recommend based on the conceptual outside plant design. The drawing illustrates the primary functional components in the FTTP network, their relative position to one another, and the flexibility of the architecture to support multiple subscriber models and classes of service.

The recommended architecture is a hierarchical data network that provides critical scalability and flexibility, both in terms of initial network deployment and its ability to accommodate the increased demands of future applications and technologies. The characteristics of this hierarchical FTTP data network are:

[35] The network's outside plant is both the most expensive and the longest-lasting portion. The architecture of the physical plant determines the network's scalability for future uses and how the plant will need to be operated and maintained; the architecture is also the main determinant of the total cost of the deployment.

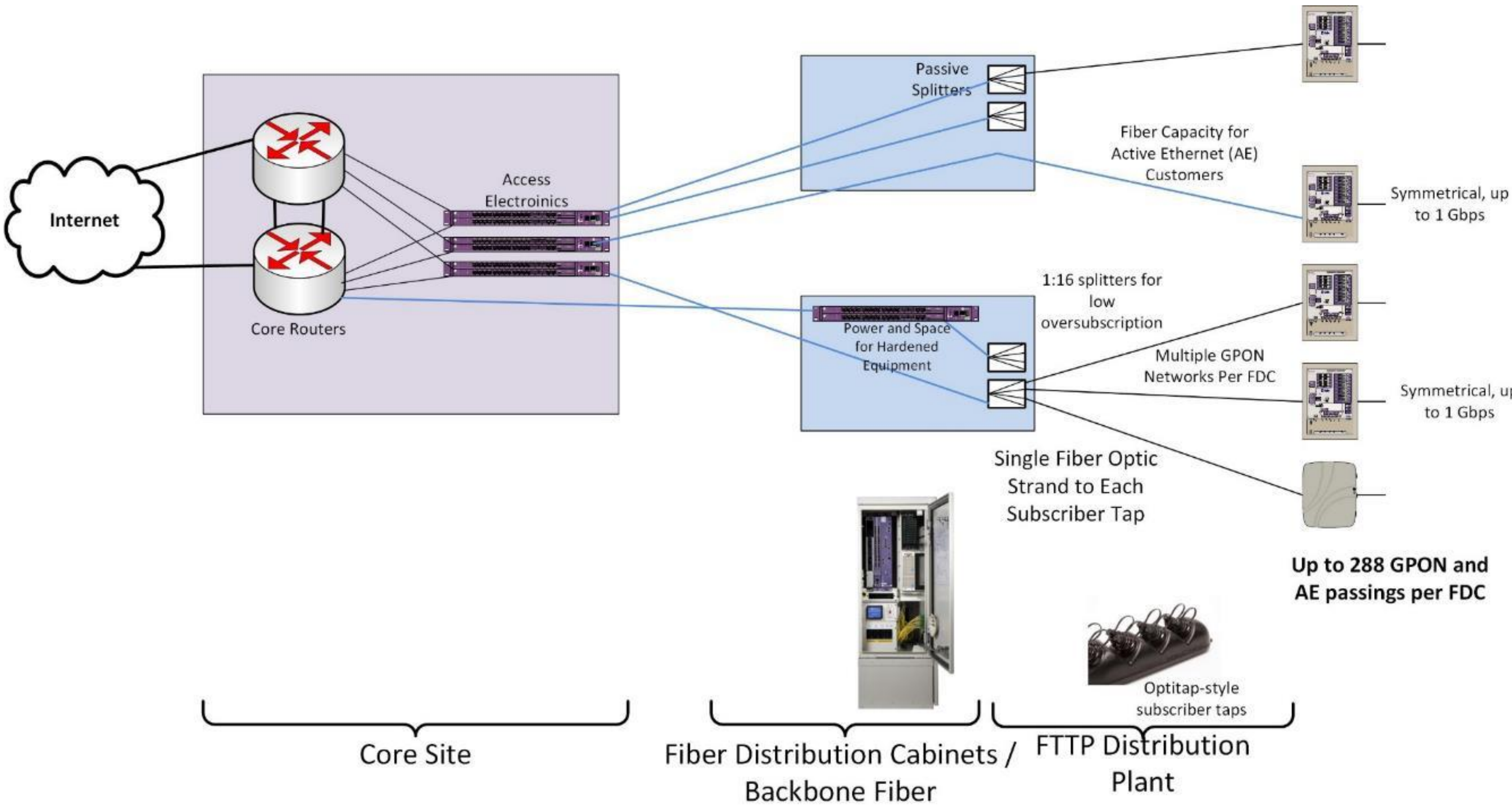
- **Capacity** – ability to provide efficient transport for subscriber data, even at peak levels
- **Availability** – high levels of redundancy, reliability, and resiliency; ability to quickly detect faults and re-route traffic
- **Failsafe operation** – physical path diversity in the network backbone to minimize operational impact resulting from fiber or equipment failure
- **Efficiency** – no traffic bottlenecks; efficient use of resources
- **Scalability** – ability to grow in terms of physical service area and increased data capacity, and to integrate newer technologies without new construction
- **Manageability** – simplified provisioning and management of subscribers and services
- **Flexibility** – ability to provide different levels and classes of service to different customer environments; can support an open access network or a single-provider network; can provide separation between service providers on the physical layer (separate fibers) or logical layer (separate Virtual Local Area Network (VLAN) or Virtual Private Network (VPN) providing networks within the network)
- **Security** – controlled physical access to all equipment and facilities, plus network access control to devices

This architecture offers scalability to meet long-term needs. It is consistent with best practices for either a standard or an open-access network model to provide customers with the option of multiple network service providers. This design would support the current industry standard Gigabit Passive Optical Network (GPON) technology. It could also provide the option of direct Active Ethernet (AE) services.[36]

The design assumes placement of manufacturer-terminated fiber tap enclosures within the PROW or easements, providing watertight fiber connectors for customer service drop cables, and eliminating the need for service installers to perform splices in the field. This is an industry-standard approach to reducing both customer activation times and the potential for damage to distribution cables and splices. The model also assumes that the County obtains easements or access rights to the gated communities and private drives within the communities to access the homes in those neighborhoods.

[36] The architecture enables the network to provide direct unshared Ethernet connections to 5 percent of customers, which is appropriate for a select group of high-security or high capacity commercial users (banks, wireless small cell connections). In extreme cases, the network can provide more customers with Active Ethernet with the addition of electronics at the fiber distribution cabinets on an as-needed basis.

Figure 34: High-Level FTTP Architecture



5.3 Connecting the U.S. 2 and I-90 zones will require more than 80 miles of fiber backbone construction

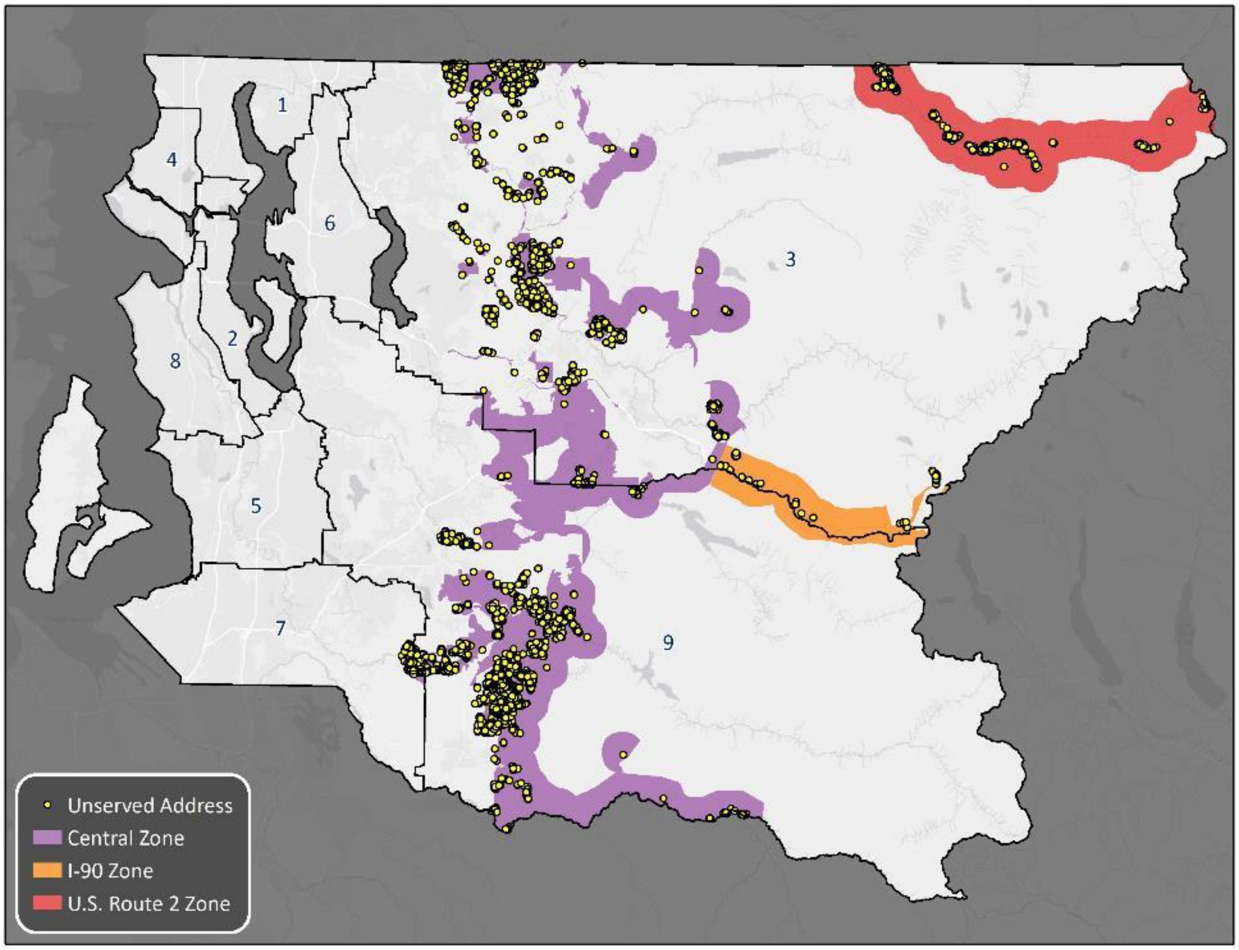
The network design and cost estimates assume the County will:

- Use existing County land to locate a core facility; the cost estimate includes the facility costs with adequate environmental and backup power generators to house network electronics, and provide backhaul to the internet[37]
- Construct approximately 83 miles of backbone network to connect the communities along U.S. 2 and Interstate 90
- Construct approximately 245 miles of fiber to connect the core to fiber distribution cabinets (FDC)
- Construct fiber optics from the fiber distribution cabinets (FDCs) to each of the 5,200 residence and businesses (i.e., from termination panels in the FDC to tap locations in the PROW or on County easements), and
- Obtain easements or access rights to private roads and roads of use where PROW do not exist.

Figure 35 shows the unserved areas of the County, as described in Section 3. The zones were determined by our analysis of the unserved areas. The central zone is the majority of the unserved homes and businesses and are generally in close proximity to served areas. The U.S. 2 and I-90 zones require extensive fiber construction along the highways to serve these areas, which contain a small portion of the County's population.

[37] Appendix B includes details on usable and available broadband infrastructure in the County, which could potentially be used to support network deployment.

Figure 35: Unserved Areas of the County



Below are the total number of unserved homes per zone.

Table 12: Unserved Homes Per Zone

Phase	Passings
Central	4,190
U.S. 2	940
I-90	90
Total	*5,220*

The FTTP network design was defined based on the following criteria:

- Fiber will be installed in the communications space of the electrical utility poles where poles are present, and in newly constructed conduit in other areas
- Fiber will vary between 12 and 288-count based on the need in the area

- Fiber will be installed in the PROW or in an easement on the side of the road
- The network will target up to 288 passings per FDC
- FDCs will support hardened network electronics and provide backup power and an active heat exchange[38]
- The distribution plant network routes will avoid crossing major roadways and railways

5.4 Costs per passing range from $5,000 in the central zone to $330,000 in the I-90 zone

Assuming a take-rate (i.e., the percentage of residents and businesses that subscribe to the service) of 35 percent,[39] the network deployment will cost more than $120 million, inclusive of outside plant construction labor, materials, engineering, permitting, network electronics, drop installation, customer premises equipment, and testing (Table 13).

Table 13: Estimated FTTP Cost

Cost Component	Central	U.S. 2	I-90	Total Estimated Cost
Outside Plant	$22 million	$64 million	$31 million	$117 million
Central Network Electronics	$800,000	$100,000	$100,000	$1 million
FTTP Service Drop and Lateral Installations	$800,000	$150,000	$50,000	$1 million
Customer Premises Equipment	$750,000	$200,000	$50,000	$1 million
Total Estimated Cost:	*$25 million*	*$64 million*	*$31 million*	*$120 million*
Passings	4,190	940	90	5,220
Outside Plant Cost per Passing	*$5,140*	*$67,740*	*$329,770*	*$22,190*

Actual costs may vary due to factors that cannot be precisely known until the detailed design is completed, or until construction commences. These factors include:

1. Costs of private easements;
2. Utility pole replacement and make-ready costs;
3. Variations in labor and material costs;

[38] These hardened FDCs reflect an assumption that the County's operational and business model will require the installation of provider electronics in the FDCs that are capable of supporting open access among multiple providers. We note that the overall FTTP cost estimate would decrease if the hardened FDCs were replaced with passive FDCs (which would house only optical splitters) and the providers' electronics were housed only at the hub facility.

[39] 35 percent is a common take-rate number used in cost analysis. However, the actual take-rate could vary significantly. Further market analysis would be required to determine a more accurate take-rate for the unserved areas of King County.

4. Subsurface hard rock; and
5. The County's operational and business model.

We have incorporated suitable assumptions to address these items based on our experience in similar markets.

5.4.1 Outside plant cost estimation methodology

As with any utility, the design and associated costs for construction vary with the unique physical layout of the service area—no two streets are likely to have the exact same configuration of fiber optic cables, communications conduit, underground vaults, and utility pole attachments. Costs are further varied by soil conditions, such as the prevalence of subsurface hard rock; the condition of utility poles and feasibility of aerial construction involving the attachment of fiber infrastructure to utility poles; and crossings of bridges, railways, and highways.

Our observations determined that the utilities are primarily aerial in unserved areas of the County, while most of the newly developed areas are all underground.

The assumptions and cost estimates were used to extrapolate a cost-per-passing for the outside plant infrastructure. This number was then multiplied by the number of passings in each area based on the County's estimation of the unserved population.

The actual cost to construct FTTP to every unserved premises in the County could differ from the estimate due to changes in the assumptions underlying the model. For example, if make-ready and pole replacement costs are too high, the network would have to be constructed underground—which could significantly increase the cost of construction. Further and more extensive analysis would be required to develop a more accurate cost estimate across the entire County.

5.4.2 Outside plant costs

The estimated cost to construct the outside plant portion of the proposed FTTP network is approximately $117 million, or $5,200 per passing. As discussed above, the model assumes a mixture of aerial and underground fiber construction, depending on the construction of existing utilities in the area. From our desk and field surveys our model determines an average fiber construction cost of $100,000 per mile for FTTP infrastructure. Our cost estimate is based on other FTTP construction projects of similar density, make-ready conditions, and aerial versus underground construction. Where fiber must be constructed along the highways, we used the number provided by representatives from the Puget Sound Emergency Radio Network (PSERN) for their fiber construction projects: $1.1 million per mile. The cost of constructing along the highways to reach the resident and businesses along U.S. 2 and I-90 significantly increases the cost of serving these customers. Table 14 provides a breakdown of the estimated outside plant costs. (Note that the costs have been rounded.)

Table 14: Estimated Outside Plant Costs

Phase	Distribution Plant Mileage	Total Cost	Passings	Cost per Passing	Cost per Plant Mile
Total	**329.0**	**$115,740,000**	**5,220**	**$22,190**	**$350,000**
Central	215.0	$21,525,000	4,190	$5,140	$100,000
U.S. 2	77.0	$63,544,000	940	$7,740	$825,000
I-90	37.0	$30,668,000	90	$329,770	$836,000

We note that the overwhelming majority of the outside plant cost (approximately 95 percent) for the U.S. 2 and I-90 zones is the cost of constructing new fiber to those zones from elsewhere in the County. We are not aware of any fiber that can be leveraged to reach the premises along U.S. 2 and I-90. Without that added cost, the unit construction costs in those zones would be more in line with the costs in the central zone.

We used the following cost assumptions when developing our fiber construction costs.

Table 15: Cost Estimate Assumptions

Description	Unit	Assumption
Total average cost per mile (Distribution Only)	$/mile	$100,000
Placement of 2-inch conduit using directional boring	$/foot	$15.00
Pull-box placement, 24"x36"x36" Tier 22	each	$1,050
Aerial cable installation per foot	$/foot	$1.50
Traffic control and work area protection per foot	$/foot	$1.00
Tree Trimming	$/foot	$1.00
Make-ready per foot	$/foot	$4.30
288-count cable	$/foot	$2.05
Aerial fiber installation materials	$/foot	$1.30

5.4.2.1 Aerial and underground construction approach

Aerial construction entails the attachment of fiber infrastructure to existing utility poles, which could offer significant savings compared to all-underground construction but increases uncertainty around cost and timeline. Under some circumstances, costs related to pole remediation and make-ready construction can make aerial construction cost-prohibitive in comparison to underground construction. However, as discussed in Section 5.1, our survey finds that the majority of poles likely have sufficient space and capacity, and that the amount of needed make-ready is mostly average.

We assume that the fiber will be strand-mounted in the communications space on the existing utility poles. Splice cases, subscriber taps, and drops will also be attached to the strand, which facilitates maintenance and customer installation.

While generally allowing for greater control over timelines and more predictable costs, underground construction is subject to uncertainty related to congestion of utilities in the PROW and the prevalence of subsurface hard rock—neither of which can be fully mitigated without physical excavation and/or testing.

While anomalies and unique challenges will arise regardless of the design or construction methodology, the relatively large scale of this project is likely to provide ample opportunity for variations in construction difficulty to yield relatively predictable results on average.

We assume underground construction will be done using an industry-standard approach for this type of environment, which consists primarily of horizontal, directional drilling to minimize public right-of-way impact and to provide greater flexibility to navigate around other utilities. The design model assumes a single 2-inch, flexible, High-Density Polyethylene (HDPE) conduit over underground distribution paths, and dual 2-inch conduits over underground backbone paths to provide scalability for future network growth.

Costs for aerial and underground placement were estimated using available unit cost data for materials and estimates on the labor costs for placing, pulling, and boring fiber based on construction in comparable markets. The material costs were known, with the exception of unknown economies of scale and inflation rates and barring any shortages or supply disruptions restricting material availability and increasing costs. The labor costs associated with the placement of fiber were estimated based on comparable construction projects and data provided by the County.

5.4.2.2 Outside plant cost components

The cost components for outside plant construction include the following tasks:

- ***Engineering*** – includes system level architecture planning, preliminary designs and field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction “as-built” revisions to engineering design materials.

- ***Quality Control / Quality Assurance*** – includes expert quality assurance field review of final construction for acceptance.

- ***General Outside Plant Construction*** – consists of all labor and materials related to "typical" underground or aerial outside plant construction, including conduit placement, utility pole make-ready construction, aerial strand installation, fiber installation, and surface restoration; includes all work area protection and traffic control measures inherent to all roadway construction activities.

- ***Special Crossings*** – consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate / controlled access highways.

- ***Backbone and Distribution Plant Splicing*** – includes all labor related to fiber splicing of outdoor fiber optic cables.

- ***Backbone Hub, Termination, and Testing*** – consists of the material and labor costs of placing hub shelters and enclosures, terminating backbone fiber cables within the hubs, and testing backbone cables.

- ***FTTP Service Drop and Lateral Installations –*** consists of all costs related to fiber service drop installation, including outside plant construction on private property, building penetration, and inside plant construction to a typical backbone network service "demarcation" point; also includes all materials and labor related to the termination of fiber cables at the demarcation point. The model only includes drop costs for the customers taking the service, an estimated 35 percent.

5.4.3 Central network electronics costs

Incremental network electronics equipment to serve the unserved area will cost an estimated $1 million, or $200 per passing, also assuming on an assumed take-rate of 35 percent.[40] (These costs may increase or decrease depending on take-rate, and the costs may be phased in as subscribers are added to the network.) The network electronics consist of the core and distribution electronics to connect subscribers to the FTTP network at the core and the FTTP access electronics located at the customer premises. Table 16, below, lists the estimated costs for each segment.

[40] The take-rate affects the electronics and drop costs, but also may affect other parts of the network, as the County may make different design choices based on the expected take-rate. A 35 percent take-rate is typical of environments where a new provider joins the telephone and cable provider in a County. In CTC's financial analysis, we will examine how the feasibility of the project depends on a range of take-rates.

Table 16: Estimated Central Network Electronics Costs

Network Segment	Subtotal	Passings	Cost per Passing
Core and Distribution Electronics	$700,000	5,200	$135
FTTP Access Electronics	$300,000	5,200	$65
Central Network Electronics Total	**$1.0 million**	**5,200**	**$200**

Please note that the electronics are subject to a seven- to 10-year replacement cycle, as compared to the 20- to 30-year lifespan of a County fiber investment.

5.4.3.1 Core electronics

The core electronics connect the FTTP network to the internet. The core electronics consist of high performance routers, which handle all the routing on both the FTTP network and to the internet. The core routers have modular chassis to provide high availability in terms of redundant components and the ability to "hot swap" line cards and modular in the event of an outage.[41] Modular routers also provide the ability to expand the routers as demand for additional bandwidth increases.

The cost estimate design envisions running networking protocols, such as hot standby routing protocol (HSRP), to ensure redundancy in the event of a router failure. Additional connections can be added as network bandwidth on the network increases. The core sites would also tie to the distribution electronics using 10 Gbps links. The links to the distribution electronics can also be increased with additional 10 Gbps and 40 Gbps line cards and optics as demand grows on the network. The core networks will also have 10 Gbps to ISPs that connect the FTTP network to the internet.

The cost of the incremental core routing equipment is approximately $600,000. In addition, the network requires OSS, such as provisioning platforms, fault and performance management systems, remote access, and other operational support systems for FTTP operations. For a network of this scale, an OSS system costs approximately $100,000 to acquire and configure.

5.4.3.2 Access electronics

The access network electronics at the FDCs connect the subscribers to the FTTP network by connecting the backbone to the fiber that goes to each premises. We recommend deploying access network electronics that can support both GPON and AE subscribers to provide flexibility within the FDC service area. These electronics are commonly referred to as optical line

[41] A "hot swappable" line card can be removed and reinserted without the entire device being powered down or rebooted. The control cards in the router should maintain all configurations and push them to a replaced line card without the need for reconfirmation.

terminals (OLT). We also recommend deploying modular access network electronics for reliability and the ability to add line cards as more subscribers join in the service area. Modularity also helps reduce initial capital costs while the network is under construction or during the roll out of the network.

The cost of the access network electronics for the network is estimated at approximately $300,000. These costs are based on a take-rate of 35 percent and include optical splitters at the FDCs for that take-rate.

An alternative design places the OLTs at the core location, with the FDCs containing only splitters. As the County examines more closely the specific electronics architecture, this alternative may be a suitable approach, which would reduce size of the FDCs and provide a small cost savings.

5.4.4 Customer premises equipment and service drop installation (per subscriber costs)

Customer premises equipment is the subscriber's interface to the FTTP network and for GPON networks is referred to an optical node terminal (ONT). For this cost estimate, we selected CPE that both terminates the fiber from the FTTP network and provides only Ethernet data services at the premises (however, there are a wide variety of additional customer premises equipment offering other data, voice, and video services). The customer premises equipment can also be provisioned with wireless capabilities to connect devices within the customer's premises. Using the assumed take-rate of 35 percent, we estimated the cost for subscriber customer premises equipment will be approximately $1 million.

Each activated subscriber would also require a fiber drop cable installation and customer premises electronics, which would cost roughly $1,160 per subscriber, or $2 million total—again, assuming a 35 percent take-rate.

The drop installation cost is the biggest variable in the total cost of adding a subscriber. A short aerial drop can cost as little as $250 to install, whereas a long underground drop installation can cost upward of $5,000. We estimate an average of approximately $660 per drop installation.

The other per-subscriber expenses include the labor to install and configure the electronics, and the incidental materials needed to perform the installation. The numbers provided in Table 17, below, are averages and will vary depending on the type of premises and the internal wiring available at each premises.

Table 17: Per Subscriber Cost Estimates

Construction and Electronics Required to Activate a Subscriber	Estimated Average Cost
Drop Installation and Materials	$660
Subscriber Electronics (ONT)	$200
Electronics Installation	$200
Installation Materials	$100
Total	**$1,160**

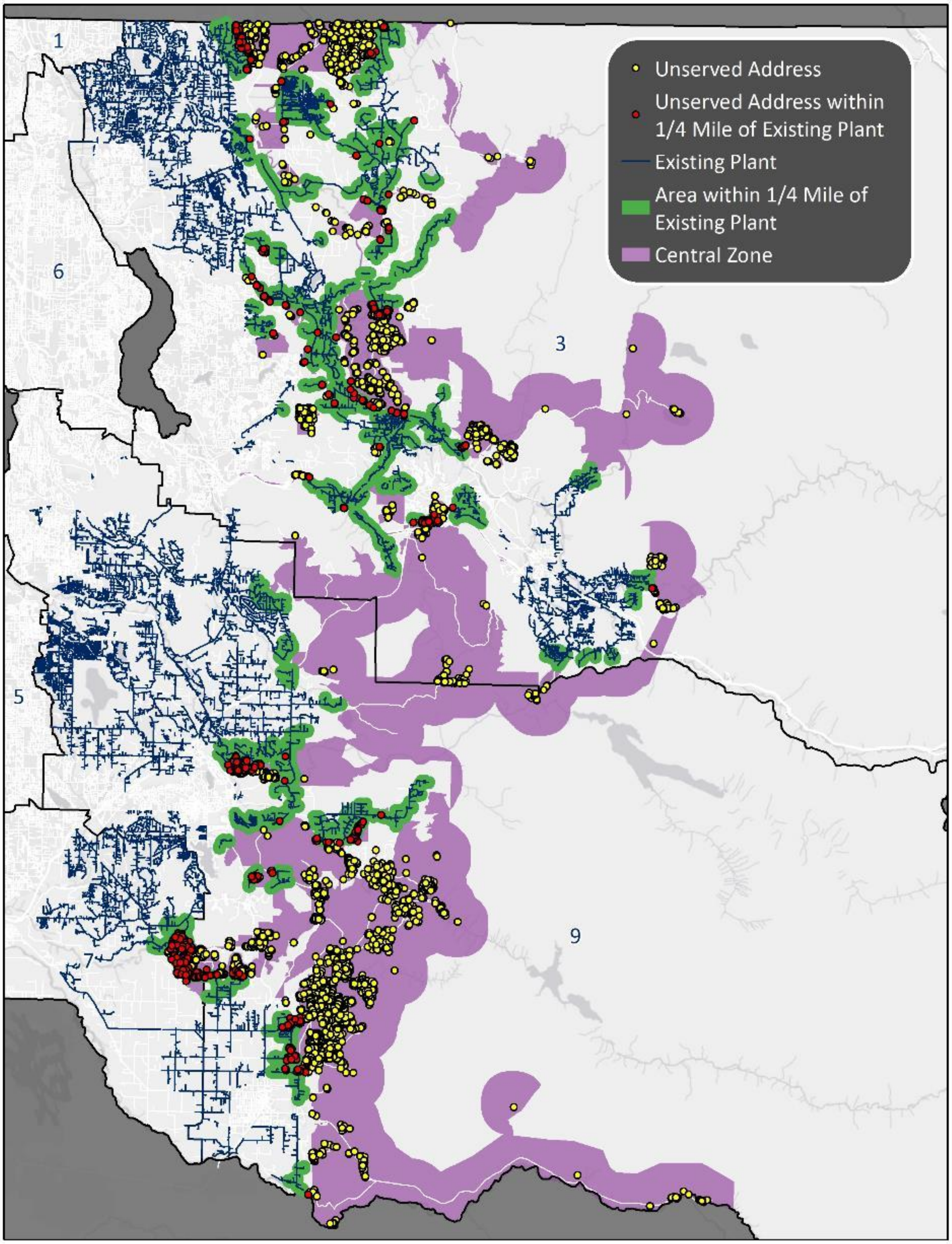
5.5 Cable companies could expand their networks into the unserved central zone to serve 750 new homes and businesses for $3.4 million or $4,500 per passing

An alternate approach to providing service to unserved homes and businesses in the central zone would be to encourage the existing providers to expand their fiber and coaxial systems to serve additional customers. This approach would be a means of enabling the cable companies to cost-effectively expand out from the edges of their existing footprints to serve the relatively denser portions of the County's unserved areas. (However, serving these areas in this way would make it that much more costly on a per-home basis to reach the remaining unserved areas in the future.)

A network expansion from the current cable company service area to one-quarter mile into the unserved central zone (Figure 36) would require 34 miles of fiber construction. The extensions would provide service to approximately 750 unserved homes and businesses, which is 14 percent of the County's unserved population. Since the providers have no conduit or aerial strand in the unserved areas, the unit cost would, like the FTTP estimate, be approximately $100,000 per mile.[42] Based on these assumptions, the total cost of network expansion would be $3.4 million, or $4,530 per passing. The costs do not include network electronics or drop installation, which would be required for each new subscriber.

[42] For our comparative analysis, we have used the same cost per mile for the existing providers to expand their networks. However, those providers may have economies of scale that would decrease the cost of their network expansions in relation to a County-built FTTP network.

Figure 36: Central Zone Unserved Addresses Within One-Fourth Mile of Existing Plant



The following table compares the outside plant costs between the existing network providers expanding the networks one-quarter mile and the outside plant costs for the County to build the entire central zone.

Table 18: Comparison of County-Built FTTP to Network Expansion Costs

	County-Owned Central Zone FTTP Network	**Existing Provider Quarter-Mile Expansion**
Passings	4,190	750
Plant Miles	215	34
Passings Per Mile	19	23
Cost Per Mile	$100,000	$100,000
Outside Plant Construction Costs	$21.5 million	$3.4 million
Outside Plant Cost Per Passing	$5,140	$4,530

The network expansion area is approximately 20 percent more dense than the total central zone. This should be true given the areas closest to the existing providers are more likely to be denser than the areas farther away from them. Using the same construction costs for both networks, the existing providers would see an approximately 20 percent reduction in the cost to construct their network per passing. This also implies that if the existing providers were to build these areas, the cost for the County to construct an FTTP network would increase by approximately 20 percent per passing as those denser portions of the unserved areas would now be served. In addition, there would be a smaller subscriber base of unserved residents—which would decrease the economies of scale for the operations of the County-built FTTP network.

6 Fixed Wireless Infrastructure Could Cover 80 Percent of the County's Unserved Areas From Existing Towers

As with our analysis of fiber optic infrastructure, CTC's analysis of fixed wireless infrastructure divided the unserved area into three zones—the central County, along U.S. 2 in the County's northeast corner, and along the eastern portion of I-90 (see Figure 37). We developed three fixed wireless network models as options for serving the 5,216 unserved addresses in those zones: mounting equipment only on public safety towers; mounting equipment on public safety towers and other existing towers; and mounting equipment on public safety and existing towers and building new towers.

Our key findings are as follows:

- Although it would have clear technical limitations and much higher operating costs relative to a fiber optic network, a fixed wireless network could serve about 80 percent of the County's unserved homes and businesses.
- Equipment mounted on public safety towers would enable coverage of approximately 36 percent of the unserved premises—and those towers may play a key role in reducing the cost of deploying a fixed wireless network.
- A network based on the public safety towers that also includes equipment mounted on other existing towers could serve up to 78 percent of the unserved premises—for a total cost (assuming a 35 percent penetration rate) of about $16.5 million. Figure 37 (below) illustrates this candidate network, which comprises equipment mounted on 64 towers. The red dots illustrate the tower locations, while the light green, blue, and yellow areas illustrate coverage with three types of wireless technologies. The purple, orange, and red shaded areas are the remaining unserved areas.
- Although it would be possible to serve more residents by building new towers, the high cost of new towers, combined with the relatively low number of homes served by each new tower, mean this approach would not be cost-effective.
- Unlike a fiber-only solution, a fixed wireless solution could be implemented without long fiber optic backbone links, providing a feasible solution to serve the I-90 and U.S. 2 corridors.
- As illustrated in Figure 37 and Table 19 below, fixed wireless technology can be a technically feasible approach to providing broadband to the County's unserved addresses. However, there are technological limitations relative to a fiber optic solution, as well as higher operational costs and a shorter technology (and therefore

equipment) lifetime. Fixed wireless does have the benefits of lower capital costs and reduced time to deploy, and new developments continue to improve reliability and speed.

Figure 37: Fixed Wireless Coverage Using Public Safety Towers and Other Existing Towers

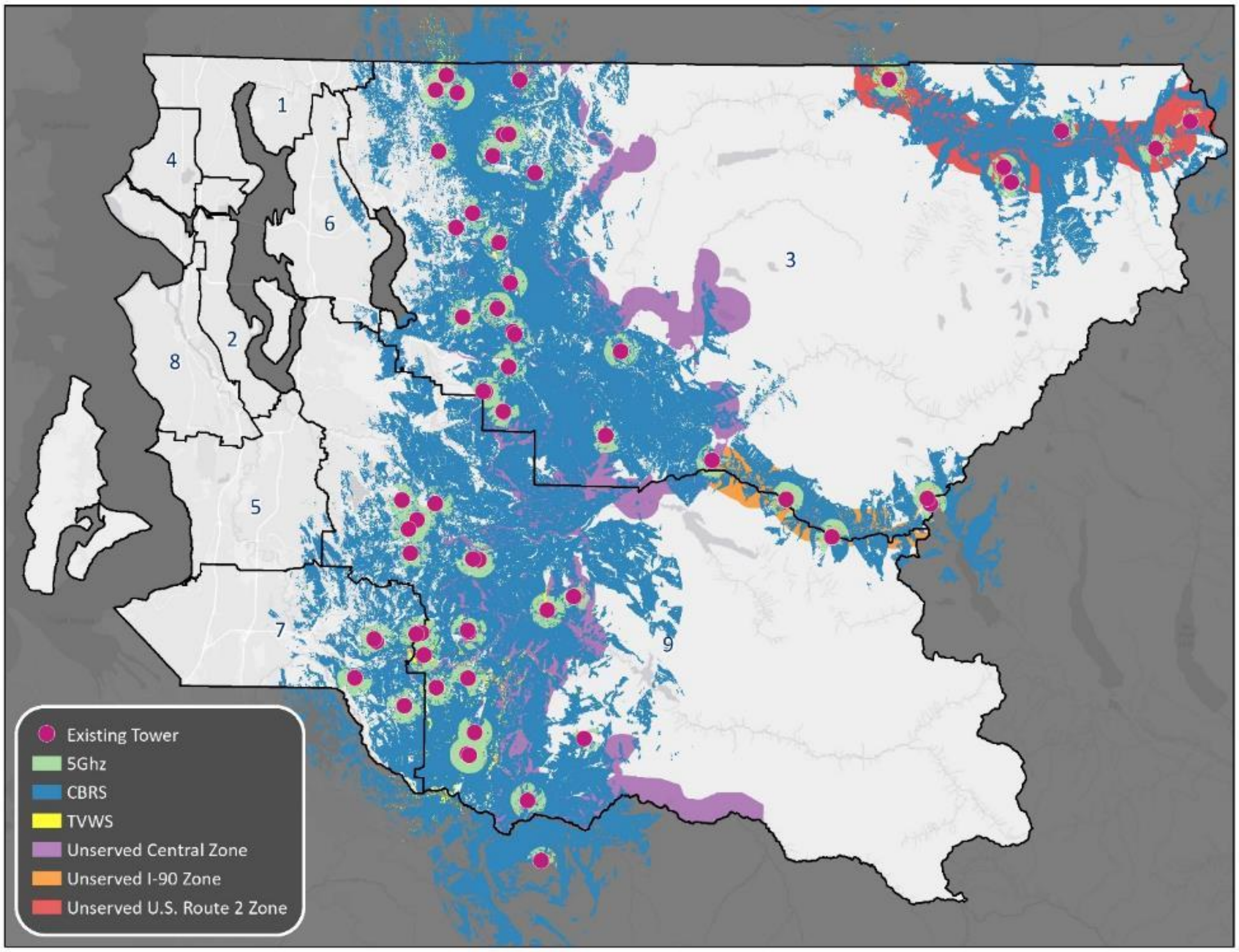


Table 19 summarizes the cost and scope of the three scenarios.

Table 19: Cost and Coverage of Three Fixed Wireless Network Approaches

Option	Number of Towers	Passings Served	Percent of Unserved	Capital Cost with 35% Penetration[43]	Average Distribution Network Cost per Passing	Installation and Electronics per Customer
Public Safety Towers Only	16	1,899	36	$4,850,000	$1,900	$1,800
Public Safety and Other Existing Towers	64	4,069	78	$16,500,000	$3,050	$1,800
Public Safety, Other Existing, and New Towers	70	4,243	81	$19,000,000	$16,7000	$1,800

Although it is possible to serve more addresses by adding new towers, we found that each new tower would be able to serve fewer than 30 additional addresses, compared to an average of more than 60 addresses served by each of the existing towers.

In addition, the cost of each new tower and accompanying equipment would be approximately $425,000, compared to approximately $225,000 for adding equipment to an existing tower. Taken together, the cost per address in an area served by a new tower would be more than five times higher than in an area that can be served by equipment added to an existing tower.

In our third scenario, we identified six new tower locations that would serve the largest number of additional addresses. Adding the six towers would enable the County to serve 174 new addresses, but at a high per-address cost. The capital cost of those six new towers and associated electronics would be an estimated $2.5 million; this does not include equipment at the subscriber premises. Since any additional towers beyond these six would each reach significantly fewer addresses, they were not considered in the model.

The following sections:

- Provide a high-level introduction to fixed wireless connectivity (including technologies, basic architecture, spectrum, and elements of costs)
- Describe the use of public safety towers and other available structures within the County in a fixed wireless solution for the unserved homes and businesses

[43] Includes subscriber equipment for 35 percent of addresses.

- Analyze the potential for adding sites that would enhance the fixed wireless network's coverage

6.1 Fixed wireless networks can deliver broadband speeds

Broadband speeds in compliance with the FCC's definition (i.e., 25 Mbps download, 3 Mbps upload—which is also the definition of "served" approved by King County for this project) are more readily available from fixed wireless networks than in the past, owing to the recent introduction of the Citizens Broadband Radio Service (CBRS) spectrum into the market and new wireless technologies. While wireless internet service providers (WISP) are typically not able to offer connection speeds on a market-wide basis comparable to cable or fiber networks built to each premises, a fixed wireless connection may be a desirable solution if cable or fiber is not cost-effective. This is especially true in low-density rural areas where there are few homes and businesses per mile, and therefore the cost of building wired networks is often high.

As opposed to an underground or aerial cable, wireless broadband is provided from access point antennas on towers or rooftops. The customer antenna may be on the home or business or on a mast on the customer premises (Figure 38).

Figure 38: Example Fixed Wireless Network with Antennas on a Monopole and Customer Premises

6.1.1 Fixed wireless networks can use various technologies and spectrum bands

The fixed wireless networks in our model use the following spectrum:

TV White Space (TVWS)	500 MHz
Unlicensed	900 MHz, 2.4 GHz, 5 GHz
Citizens Broadband Radio Service (CBRS)	3.5 GHz

Of these bands, only CBRS and 5 GHz technology have channel widths capable of delivering 25 Mbps down and 3 Mbps up. For unlicensed spectrum, there exists the potential for others to be operating on the same, adjacent, or other interfering frequencies. Precautionary measures should be taken to mitigate different types of interference; such efforts include checking for a clean frequency in the area of interest and appropriate antenna and antenna pattern choice.

TVWS delivers service over unused television frequencies (known as white space). TVWS bands have much better non-line-of-sight transmission qualities than the other bands; however, due to its narrower bandwidth, TVWS is not capable of delivering 25 Mbps down, and therefore should only be considered in cases where other connectivity is not available or feasible. Also, because white space technology is still in an early phase of development, compatible equipment is far more expensive than other off-the-shelf wireless equipment. Finally, because King County has a metropolitan area and many existing broadcast television channels, the potential TVWS spectrum is significantly more limited than in more remote areas.

Most fixed wireless networking solutions require the antenna at the subscriber location to be in or near the line of sight of the base station antenna. This can be especially challenging in mountainous regions. It is also a problem in areas with dense vegetation or multiple tall buildings. WISPs often need to lease space at or near the tops of radio towers; even then, some customers may be unreachable without the use of additional repeaters. And because the signal is being sent through the air, climate conditions like rain and fog can impact the quality of service.

In addition, there is a tradeoff in these bands between capacity and the ability to penetrate obstructions such as foliage and terrain. The higher frequencies have wider channels and therefore the capability to provide the highest capacity. However, the highest frequencies are those most easily blocked by obstructions. Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-point networks may have limited network capacity, particularly upstream, making the service inadequate for applications that require high-bandwidth connections. A medium-sized business, then, would likely need a point-to-point solution with dedicated bandwidth, while small businesses and residences could be served by a less expensive point-to-multipoint solution. The models in this document assume point-to-multipoint equipment, which is typical for a residential or small business connection.

6.1.2 Fixed wireless network deployment costs depend on a range of factors

The following factors will determine the costs associated with a fixed wireless network:

- **Wireless equipment used:** Different wireless equipment has different aggregate bandwidth capacity and use a range of different spectrum bands, each with its own unique transmission capabilities.

- **Backhaul connection**: Although the bottleneck tends to be in the last-mile connection, if a WISP cannot get an adequate connection back to the internet from its tower, equipment upgrades will not be able to increase available speeds beyond a certain point.

- **Future capacity and lifespan of investment:** Wireless equipment generally requires replacement every five to 10 years, both because exposure to the elements causes deterioration, and because the technology continues to advance at a rapid pace, making decade-old equipment mostly obsolete. The cost of deploying a wireless network is generally much lower than deploying a wireline network, but the wireless network will require more regular investment.

- **Availability of unobstructed line of sight:** Most wireless networking equipment require a clear, or nearly clear, line of sight between antennas for optimum performance. WISPs often lease space near the tops of radio towers, to cover the maximum number of premises with each base station.

- **Use of public safety infrastructure**: Public safety infrastructure must be built to public safety grade guidelines and is therefore more costly that commercial infrastructure. "'Public Safety Grade' is a conceptual term that refers to the expectation of emergency response providers and practitioners that their equipment and systems will remain operational during and immediately following a major natural or manmade disaster on a local, regional, and nationwide basis. [The term] is used to refer to network hardening or network sustainability."[44]

6.2 Choosing the best-fit spectrum for a given tower location can improve coverage and reduce deployment costs

CTC examined the three most suitable candidate frequency bands (and the associated technologies) for fixed wireless services: CBRS, unlicensed 5 GHz, and TVWS.

Because each band needs its own set of equipment, we sought to identify the most effective bands for each tower location with the understanding that if one or more bands can be

[44] Definition of public safety grade from the National Public Safety Communications Council (NPSTC) report *Defining Public Safety Grade Systems and Facilities* which is under consideration to contribute to a future public safety grade standard.

eliminated from specific sites, then the overall cost of deployment and operations will be reduced.

The CBRS band is predicted to connect the most addresses—primarily due to its spectrum properties, and the fact that FCC licensing rules allow CBRS antennas to be mounted higher than TVWS antennas. It also has the greatest broadcast power of the three technologies. In addition, CBRS is the only band that can be licensed.

Of the frequencies examined, only CBRS and unlicensed technologies have channel widths (and therefore bandwidth) capable of delivering 25 Mbps down and 3 Mbps up. Because TVWS is not capable of delivering 25 Mbps down, we used that technology only in places where there is no 5 GHz or CBRS connectivity.

6.3 Cost-effective fixed wireless service depends on precise tower selection

To examine the potential for existing towers to provide service to the County's unserved addresses, we analyzed multiple commercial and government databases and identified approximately 1,500 existing tower locations in King County. Of these towers, we selected 64 that could potentially provide fixed wireless service to the unserved addresses (based on their locations, height, and ownership).

CTC's engineers assessed the potential coverage that would be enabled by equipment mounted on each of the selected tower sites; using CloudRF software, we estimated how many of the unserved address would be within the predicted coverage area of each of the three fixed wireless frequency band options (CBRS, 5 GHz, and TVWS). We based our analysis on the following assumptions:

- Antennas would be placed at 80 percent of a tower's height for 5 GHz and CBRS, and at the maximum allowable height of 30 meters for TVWS
- Broadcast power would be at the FCC's maximum allowable level for all three bands
- Channel bandwidth would be 20 MHz for 5 GHz, 10 MHz for CBRS, and 6 MHz for TVWS
- Subscriber equipment antenna would be placed at 4.57 meters (15 feet) above ground level
- Ground elevation and clutter resolution is 30 meters

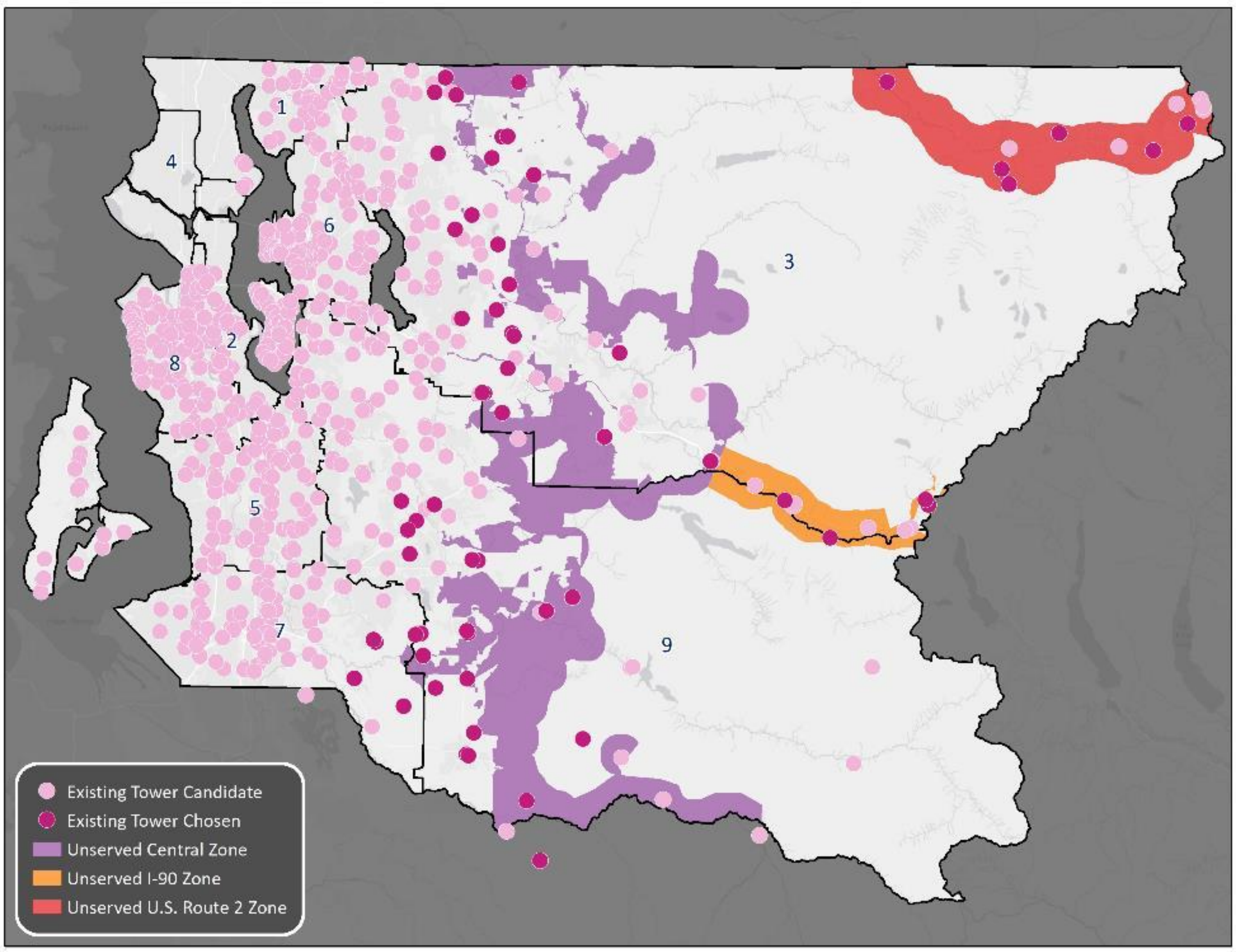
6.4 Coverage and cost estimates vary by number and type of towers used for fixed wireless network

CTC evaluated the potential fixed wireless coverage feasible with equipment mounted at public safety sites within the County and estimated the cost to build a fixed wireless solution using these sites. The results of that analysis are confidential and have been provided under separate cover to King County. In the sections below, we describe the coverage and costs of the other two scenarios.

6.4.1 Using existing towers, a fixed wireless network could cover about 80 percent of unserved residents for $16.5 million

By eliminating towers that did not provide coverage in the unserved areas or were next to another tower that would provide similar coverage, CTC determined that 64 existing towers could be used to provide service to the unserved areas (Figure 39).

Figure 39: Existing Tower Candidates in a Fixed Wireless Network Solution



CTC then conducted a high-level wireless analysis to determine how the unserved addresses could be served using fixed wireless spectrum and technologies.

There are various propagation models used for the RF analysis, the most popular being line of sight (LOS), cost 231, Okumura Hata, and Longley-Rice (also called irregular terrain (ITM) model). For our analysis we used Longley-Rice. Longley-Rice is the most conservative model considering atmospheric conditions, ground elevation, the environment in which deployments are done, obstacles between the Base station and the mobile station, and ground clutter.

The RF coverage analysis for each spectrum was modeled using the online service CloudRF. CloudRF was chosen due to its ability to create coverage maps in a GIS layer than can be overlaid on the unserved address points, and therefore identify which of the address would be covered by the wireless model. Propagation maps were generated such that the signal levels would achieve a minimum throughout of 25 Mbps download and 3 Mbps upload throughput speeds at the cell edge.

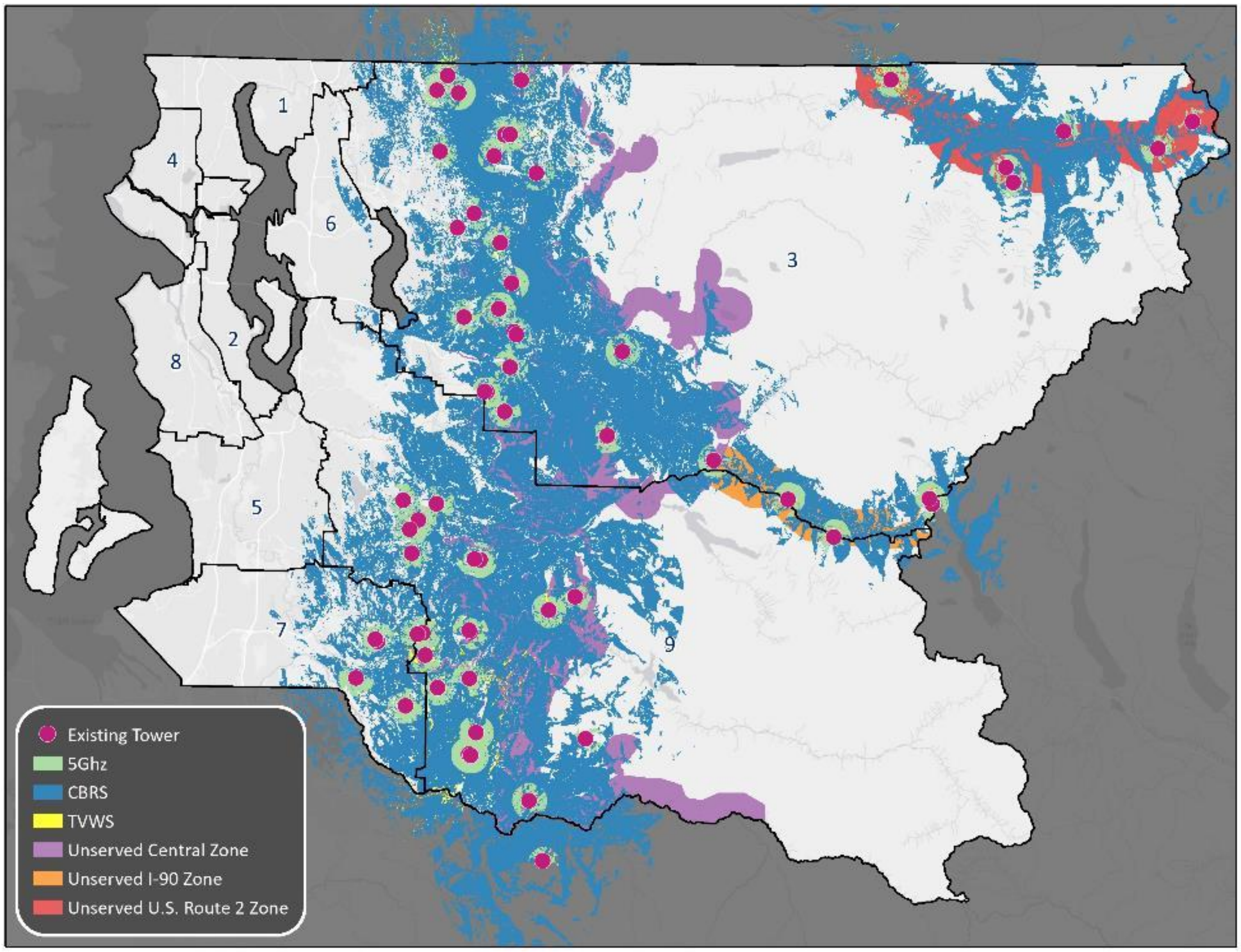
The results showed that there would still be 1,147 addresses in the unserved areas that would not be covered by the selected towers using any frequency band (Table 20).

Table 20: Predicted Coverage with Existing Towers

Addresses	Number
Total addresses in unserved area	5,216
Addresses served by CBRS band	3,722
Additional addresses served by TVWS band	347
Addresses served by one or more band	4,069
Addresses not served by any of the three bands	1,147
Percent of addresses served by one or more of the bands	78%

Figure 40 shows the coverage areas in each band using the selected existing towers.

Figure 40: Coverage Using Existing Towers



Almost all addresses that have 5 GHz coverage also have CBRS coverage. Although no more addresses are reached by adding 5 GHz than by just deploying CBRS, there may be some cases where CBRS capacity is at a maximum and 5 GHz could be deployed to offload some of the traffic.

Because CBRS covers the most addresses, and delivers 25 Mbps, we recommend it be deployed at all towers; 5 GHz can be used selectively to add capacity at sites, and TVWS can be used selectively to pick up additional addresses at select locations.[45]

Table 21 and Table 22 (below) summarize our cost breakdowns for using existing towers to provide coverage to unserved residents and businesses. (Full tables are in Appendix E.) Our assumptions are as follows:

[45] Determining which band would be deployed at each tower site is beyond the scope of this analysis.

- All covered addresses will require the installation of subscriber equipment (100 percent take-rate)
- Towers will be configured with three sectors for each frequency used
- All selected towers will have CBRS deployed
- 25 percent of the towers will also have 5 GHz deployed
- 25 percent of the towers will also have TVWS deployed
- Cost of installation and customer premises equipment per customer is $1,800
- Towers will be connected to backhaul using microwave links; 10 percent of the sites will require an additional hop
- Existing shelters at each tower location have room for additional equipment
- To support a fixed wireless network, it is necessary to set up a core network to manage functions such as authentication, billing, security, and connections to the internet; in each of the cases outlined below, CTC assumes $200,000 for equipment and setup of a core network
- High-level engineering/design and site acquisition costs including for items such as structural analysis, plan review, permits, escorts to sites, backhaul path design, building modifications, and site preparation

Table 21: Capital Cost Estimate for Using Existing Towers with Fixed Wireless

	Central	U.S. Route 2	I-90
Network Core	$200,000	$200,000	$200,000
Access Point Equipment	$896,250	$123,750	$67,500
Backhaul	$885,000	$120,000	$75,000
Installation, Engineering and Design	$3,540,000	$480,000	$300,000
Site Acquisition	$5,900,000	$800,000	$500,000
Total Distribution Network Costs	$11,421,250	$1,723,750	$1,142,500
Total Addresses	3,215	789	65
Cost per Address (Distribution Network Only)	$3,552	$2,185	$17,577

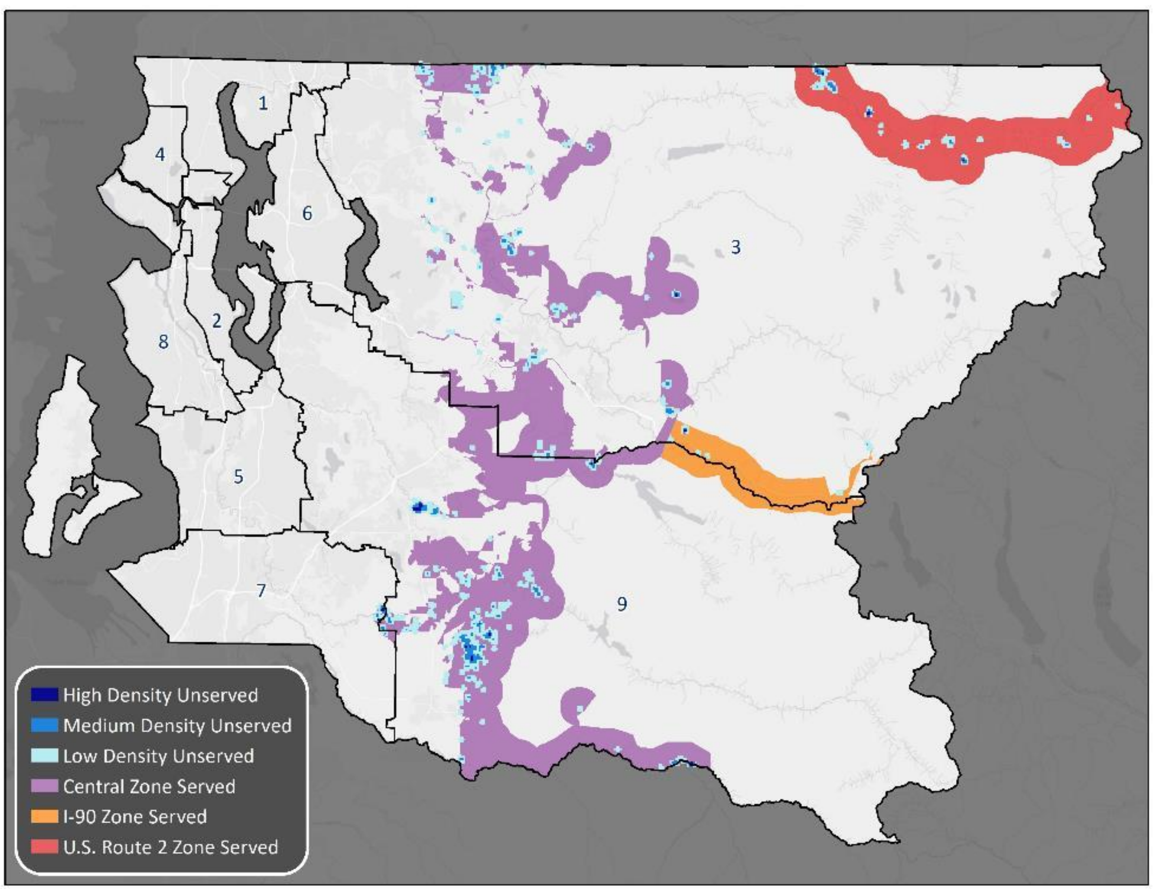
Table 22: Total Cost Estimate for Using Existing Towers with Fixed Wireless at Different Penetration Rates

Item	Cost
Total Cost (Distribution Only)	$13,887,500
Total Cost (35% Penetration)	$16,450,970
Total Cost (60% Penetration)	$18,282,020
Per Address (Distribution Only)	$3,413
Per Customer (35% Penetration)	$11,551
Per Customer (60% Penetration)	$7,488

6.4.2 Building additional towers would enable coverage for relatively few additional residents at a high cost per passing

Figure 41 is a heat map of the remaining after considering coverage from existing towers. While many of the address are too far apart to feasibly build enough new towers to connect them all, new towers could be constructed to cover some of the remaining addresses. If the County were to build new towers, we recommend installing them in areas where the most remaining addresses could be served—that is, focusing on the "High Density Unserved" areas in the map.

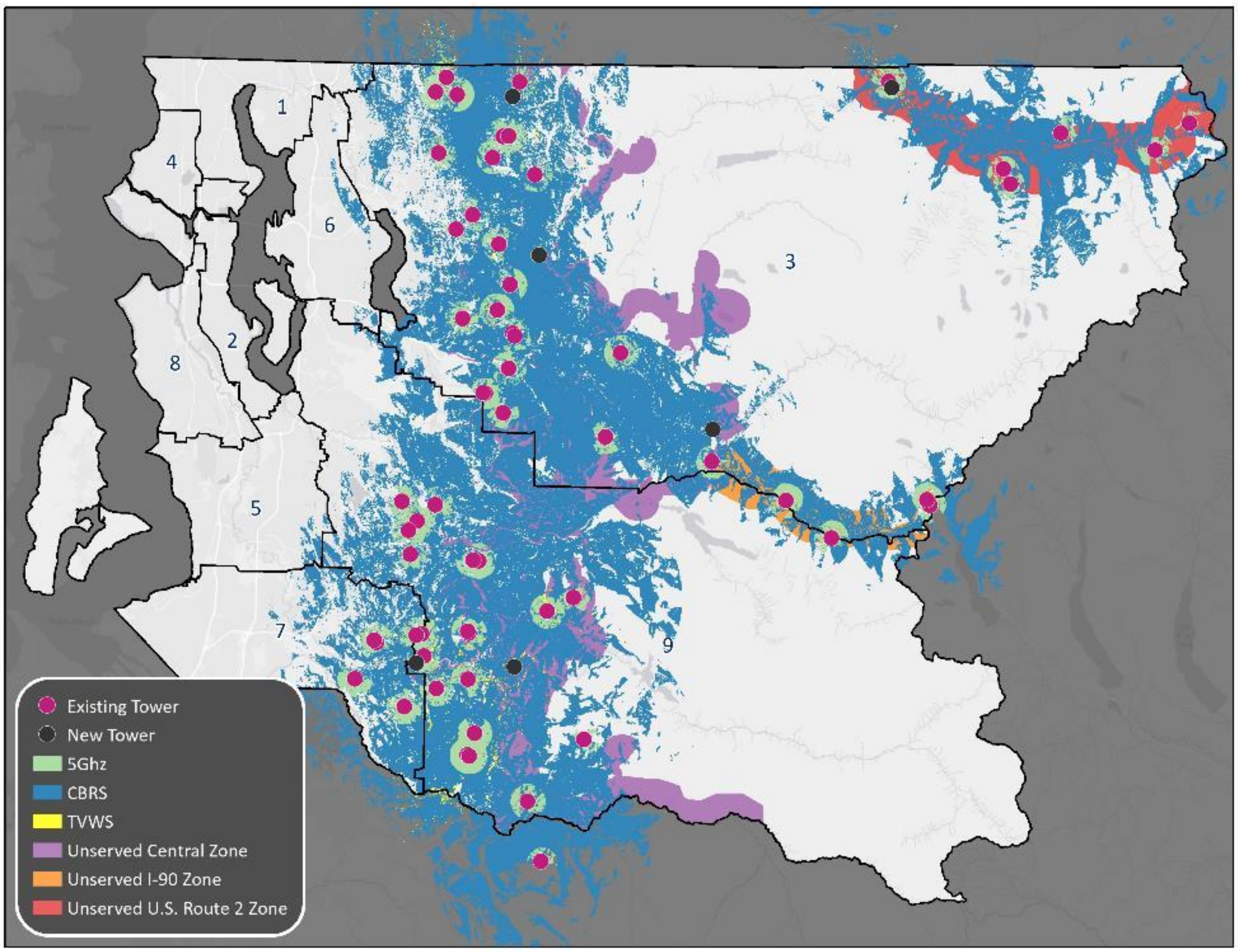
Figure 41: Unserved Addresses Remaining After Deployment of Fixed Wireless Network on Existing Towers



CTC determined 10 optimal locations for new towers based on their ability to reach the most addresses. However, we found that only six of the 10 locations were able to cover more than five unserved addresses—which illustrates the difficulty of adding new towers that will cover a substantial number of addresses, as well as their relatively low incremental value.

Figure 42 shows the resulting overall coverage after adding the six new towers to the fixed wireless network composed of the 64 existing towers. An additional 144 addresses would be served, leaving 1,003 addresses unserved in the County.

Figure 42: Total Fixed Wireless Coverage Using Existing and New Towers



The following tables show the incremental costs for the six new towers using the same assumptions as above.

Table 23: Capital Cost Estimate for Six Additional Towers with Fixed Wireless

	Central	U.S. Route 2	I-90
Access Point Equipment	$86,250	$18,750	$ –
Backhaul	$90,000	$30,000	$ –
Installation, Engineering and Design	$360,000	$120,000	$ –
Site Acquisition	$600,000	$200,000	$ –
Tower Build	$750,000	$150,000	$ –
Total Distribution Network Costs	$1,886,250	$518,750	$ –
Total Addresses	121	23	–
Cost per Address (Distribution Network Only)	$15,589	$22,554	$ –

Table 24: Total Cost Estimate for Additional Towers with Fixed Wireless at Different Penetration Rates

Item	Cost
Total Incremental Cost (Distribution Only)	$2,405,000
Total Incremental Cost (35% Penetration)	$2,495,720
Total Incremental Cost (60% Penetration)	$2,560,520
Incremental Cost per Address (Distribution Only)	$16,701
Incremental Cost per Customer (35% Penetration)	$49,518
Incremental Cost per Customer (60% Penetration)	$29,635

7 Fiber-to-the-Premises Is a Clearly Preferable Technical Solution with Significantly Lower Operating Costs as Compared to a Fixed Wireless Solution

Overall, FTTP represents a better broadband solution than fixed wireless for most unserved areas of King County. While FTTP has a higher capital cost than a fixed wireless solution, the total cost of operations of FTTP over a 10-year period would be approximately half that of fixed wireless in the same unserved areas. In addition, the duration between required capital investments (i.e., equipment replacement) for a fiber solution is typically 30 years or more, whereas fixed wireless equipment is typically replaced every 10 years. Table 25 illustrates the estimated costs of the FTTP and wireless solutions in the central zone, as well as the cost for cable companies to expand their existing plant to serve more homes in that zone.

Table 25: Comparison of Costs for Solutions in the Central Zone

	Capital Costs (Distribution Only)	Duration of Capital Investment	Total Cost of Operations
County-Owned Central Zone FTTP Network	$21.5 million	30+ years	X
Existing Provider Quarter-Mile Expansion	$3.4 million	30+ years	Determined by provider
County-Owned Central Zone Fixed Wireless Network	$16.5 million	10 years	2X

7.1 Capital and operating costs require separate considerations

In two unserved parts of the County, we identified unique cost considerations:

3) In the areas that could be served from public safety towers, it may be possible that wireless equipment could be placed without paying a lease cost. If so, fixed wireless service to those areas, serving approximately 1,900 of the County's 5,216 unserved residences, may have a **comparable** overall cost over the first decade of operations. (After 10 years, because of the lower cost of operations, FTTP would be less expensive to operate.)

4) In the I-90 and U.S. 2 corridors, where deploying FTTP would require the construction of 83 miles of new fiber at an estimated cost of $1.1 million per mile[46] to serve 90 and 940 passings, respectively, it would be less expensive to instead use a fixed wireless approach. However, in the event that fiber or other reasonably priced connectivity could be obtained in the corridor (e.g., from telecommunications providers that

[46] See Section 5.4.2 for more details.

currently operate long-haul fiber), the analysis would change: it would become better from a cost perspective to use FTTP there, as well.

7.2 Fiber and fixed wireless each have technical advantages and challenges

Fiber optics, once constructed, is the highest-speed and most scalable technology. Current off-the-shelf technologies enable FTTP networks to provide capacity in excess of 1 Gbps to each subscriber, with new electronics making it possible to go to 10 Gbps or beyond in the coming years. Moreover, the FTTP network is not subject to interference from other signals or subject to line-of sight limitations.

Over time, maintenance and repair costs of fiber optic cables are low—approximately 1 percent of construction costs annually, or, in the central zone, $70 per passing per year. Equipment replacement occurs every seven years, but new equipment costs are only a percentage of the capital cost of an FTTP network.

As discussed in Section 5, however, construction costs can be high and can vary based on the availability of space on utility poles and in the right-of-way. Construction can be delayed by utility pole owners, other utilities on the poles, and by the requirement for permitting in the right-of-way (including on bridges, water crossings, and expressway crossings).

By comparison, fixed wireless technology provides an aggregate capacity between 100 and 250 Mbps. Using unlicensed and CBRS spectrum and innovations like higher-order multiple input, multiple output (MIMO) antennas, and the use of spatial multiplexing, these capacities will likely increase to as fast as 750 Mbps in the King County environment.

It is important to note, however, that this is the aggregate capacity out of a single antenna or antenna array; in a point-to-multipoint architecture, this capacity will be shared among all users connected to a single base station. Even so, in most of the unserved environments in King County, download speeds in the tens or even low hundreds of Mbps per user may be possible. Additionally, wireless eliminates the need for new cable construction, significantly reducing the time to build and the complexity of construction.

Wireless capital costs, especially where existing towers can be used as mounting structures, can be significantly lower than the cost of building new fiber optics (although capital costs for a wireless network are only a small part of its total cost). In King County's unserved areas, the cost of the distribution network (the antenna sites and the supporting network) is approximately $3,500 per passing. This is approximately 70 percent of the per-passing capital cost of the distribution network for FTTP in the central zone.

When taking into account the installation cost per subscriber, including labor, materials, and electronics, the wireless cost per passing is approximately $5,200, which is approximately 80 percent of the per-passing capital cost for FTTP in the central zone.

Given the limitations of line of sight and of the available spectrum, however, the wireless solution is not as scalable as a wireline solution. The spectrum available for fixed wireless broadband is limited and provides much lower bandwidth than what is available in an FTTP network. Homes and businesses that have substantial tree cover and terrain will get poorer performance than others.

Leasing space on a tower is costly. Leasing space for three sectors of antennas (as needed on each tower site) costs approximately $60,000 per year. This is a critical consideration, because the fixed wireless model uses 64 existing towers with an average 60 serviceable passings (potential customers) per tower, so ***the cost for tower leases alone exceeds $1,000 per year per passing***.

Upgrading a wireless network requires replacement of the radios at the antenna site and at the user premises. Electronics may need to be replaced at five- to 10-year intervals due both to technological obsolescence and wear and tear—and unlike a fiber network, the electronics comprise almost all of the capital cost of the network, thus significantly increasing the ongoing cost.

Finally, permitting for new tower locations may require a public hearing process and may require months, and may be difficult to achieve if there is local opposition to the tower.

8 Finding: 5G Is Unlikely to Solve the Entire Availability and Affordability Challenge in King County

While there exists considerable optimism among some policymakers about the potential of emerging 5G wireless technologies to bridge broadband gaps, particularly in rural areas, it is unlikely that King County's currently-unserved areas are likely to be served in the near-term with 5G service. There is little indication in the current moment that high-speed wireless products are likely to be deployed at scale in the next few years.

8.1 New 5G fixed wireless is likely to be deployed only in select areas

Verizon, T-Mobile and, to a lesser extent, AT&T, have all announced plans to use their 5G network to provide a fixed-wireless (FW) service to homes and businesses that competes with wired service providers offerings. T-Mobile and AT&T are currently testing fixed-wireless service in rural and underserved areas using their existing 4G network,[47] while Verizon is pushing ahead with 5G FW. Verizon has already launched 5G fixed-wireless in limited areas of Sacramento, Houston, Indianapolis and Los Angeles at the end of 2018.[48] A year later, the company announced an overhauled version of its fixed-wireless service is now available in parts of Chicago.[49]

While 5G technology is clearly capable of delivering a service that competes with fixed broadband offerings, the economics of building out the infrastructure necessary to support such a service is extremely challenging. Telecom financial analysts at MoffetNathanson did extensive analysis of Verizon's fixed-wireless pilot in Sacramento and found that each mmWave small cell Verizon had installed served an average of 27 homes (excluding nodes that serve multiple dwelling units).[50] The researchers caution that this average is likely overly conservative, but even if each node eventually serves three times as many homes, it is still difficult to figure out how Verizon will make sufficient returns to justify the investment. At 84 homes served per node, New Street Research estimated that in order to serve 30 million homes (Verizon's initial projection), the company will need to spend $35 billion over 15 years, in order

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[47] "T-Mobile begins limited home internet pilot," *T-Mobile,* March 21, 2019, https://www.t-mobile.com/news/home-internet-pilot (accessed October 2019);
Eric Scarborough, "Connecting Rural America: Delivering Fixed Wireless Internet through New Technologies," *AT&T*, September 26, 2018, https://about.att.com/story/2018/fixed_wireless_rural_america.html (accessed October 2019).

[48] Dan Jones, "Verizon's Home-Grown 5G Arrives Today," *Light Reading,* October 1, 2018, https://www.lightreading.com/mobile/5g/verizons-home-grown-5g-arrives-today/d/d-id/746457 (accessed October 2019).

[49] Alex Lawson, "Verizon 5G Home Internet is Coming to Chicago," *Verizon*, October 21, 2019, https://www.verizon.com/about/news/verizon-5g-home-internet-coming-chicago (accessed October 2019).

[50] Joan Engebretson, "Analysts Question Financial Viability of Verizon Home 5G Fixed Wireless Service," *Telecompetitor*, March 20, 2019, https://www.telecompetitor.com/analysts-question-financial-viability-of-verizon-home-5g-fixed-wireless-service/ (accessed October 2019).

to generate a negative net present value of $16 billion, with a 10- year internal rate of return of -34 percent. This leads the researchers to doubt that Verizon will roll out its fixed-wireless offering as aggressively as it has suggested.[51]

Although Verizon remains bullish on the fixed-wireless opportunity, company leadership has walked back its initial build out target of providing 300 Mbps service to 30 million households. Executives have stated that in less competitive markets, their fixed-wireless service may only provide speeds up to 100 Mbps.[52]

Wall Street analysts are similarly skeptical of T-Mobile's fixed-wireless plans. As part of its campaign to win regulatory approval for the T-Mobile-Sprint merger, T-Mobile has stated that Sprint's spectrum assets will allow new T-Mobile to compete with cable and other wired ISPs.[53] However, home broadband subscribers consume far more data than mobile data subscribers,[54] and mobile carriers will only be able to accommodate fixed-wireless customers in markets where they have significant excess network capacity.

AT&T began using its existing LTE network to provide fixed wireless service to rural customers in 2017 in order to meet its federally mandated FCC Connect America Fund commitments. More recently, it's launched an LTE-based fixed wireless service aimed at serving small business customers. fixed-wireless customers will be able to migrate to AT&T's 5G network as it becomes available.[55] The company has said it will reach 880,000 locations with its fixed-wireless service by the end of this year, and 1.1 million locations in 18 states by the end of 2020. While

[51] Bernie Arnason, "Analyst: Verizon 5G Fixed Wireless Threat Modest at Best," *Telecompetitor,* https://www.telecompetitor.com/analyst-verizon-5g-fixed-wireless-competitive-threat-modest-best/ (accessed October 2019).

[52] Mike Dano, "Verizon's 5G Details, 30 Mobile 5G Markets in 1H19, MEC Launching this Year," *Light Reading*, https://www.lightreading.com/mobile/5g/verizons-5g-details-30-mobile-5g-markets-in-1h19-mec-launching-this-year/d/d-id/749611 (accessed October 2019).

[53] John Legere, "New T-Mobile: Creating a True Alternative to Fixed Broadband," *T-Mobile*, March 7, 2019, https://www.t-mobile.com/news/new-t-mobile-fixed-broadband-alternative (accessed October 2019).

[54] A recent Preseem report found that the average fixed-wireless customer uses 196GB per month, up from 167GB/month a year ago: Joan Engebretson, "Fixed Wireless Usage Report: 4Mbps, 196GB per month" *Telecompetitor,* https://www.telecompetitor.com/fixed-wireless-usage-report-4-mbps-average-speed-196-gb-per-month/ (accessed October 2019);

Video content moving online could cause the average home data consumption to skyrocket in the next few years. New Street Research predicts that by 2023, the average American household will consume 800 GB/month: Mike Dano, "How Mobile 5G Could Affect In-Home Broadband," *Light Reading,* July 29, 2019, https://www.lightreading.com/mobile/5g/how-mobile-5g-could-affect-in-home-broadband/a/d-id/753029 (accessed October 2019).

[55] Mike Dano, "AT&T, Verizon Expand Fixed Wireless (Both LTE and 5G) to Small Biz Market, *Light Reading*, https://www.lightreading.com/mobile/5g/atandt-verizon-expand-fixed-wireless-(both-lte-and-5g)-to-small-biz-market/d/d-id/749722 (accessed October 2019).

the company has announced a "nationwide" roll out of 5G in early 2020, it will be using sub-6 GHz spectrum, which will likely provide only a marginal increase in speeds compared with LTE.[56]

All three companies are still testing the market at this time but insist that they will be able to use their mobile networks to provide a large segment of the country with a fixed-wireless service that competes with wired broadband service in the next few years. Still, building out 5G infrastructure is incredibly capital intensive, and at least in the near term, investment is likely to be concentrated in those areas that offer the greatest return on investment.

8.2 Our predictive analysis indicates that 5G will not solve the County's rural broadband gaps

Our concerns regarding the likely deployment patterns for 5G are reinforced by an exercise we undertook to predict the deployment of 5G small cells through machine learning techniques. Our predictive model we developed with a goal of predicting which census block groups—the smallest geographical unit for which the U.S. Census Bureau maintains detailed datasets—would see dense deployments of small cells. (Because small cells typically are located in clusters, we established a definition of dense deployment as being 10 or more small cells per square mile.) These dense deployments represent areas where wireless carriers are likely to deploy 5G coverage in the future.

Based on our model, we estimate that only 182 of the County's 1,422 census block groups will receive dense small cell deployments over the next three years. As the maps below illustrate, those census block groups are generally densely populated areas—meaning that 5G deployments will not fill the County's broadband service gaps.

8.2.1 Data analyzed

We base our estimates on analysis of the following publicly available datasets:

- Parcel data (including unit density, heights, and building height variances—an indicator of "downtown" districts where network users might congregate)
- Demographic data (including population density and many other datapoints from the U.S. Census Bureau)
- Social media data (number of geotagged tweets)
- Major corridor data (miles of major roadways)

[56] Mike Dano, "AT&T's New Nationwide, Mobile 5G Timeline," *Light Reading*, January 10, 2019, https://www.lightreading.com/mobile/5g/atandts-new-nationwide-mobile-5g-timeline/d/d-id/748721 (accessed October 2019).

8.2.1.1 Parcel data

To analyze the County's data, we calculated building heights and the number of buildings in census block groups using the data provided by the King County GIS team. Figure 43 shows the residential unit density per square mile, with the higher-density block groups indicating built-up areas; Figure 44 shows building height variance, with darker areas illustrating the highest variance within each block (i.e., town centers and non-residential areas).

Figure 43: Residential Unit Density per Square Mile in the County

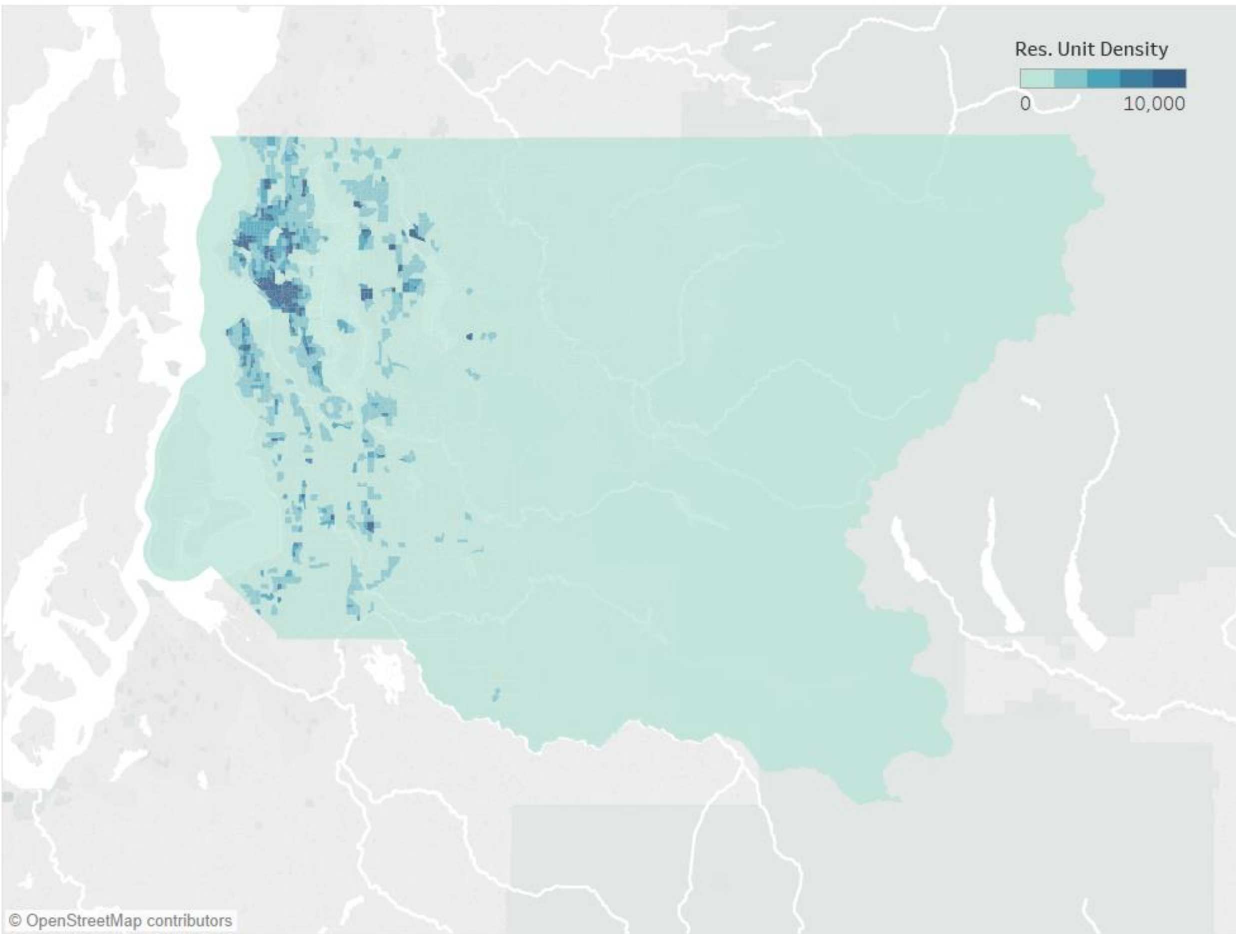
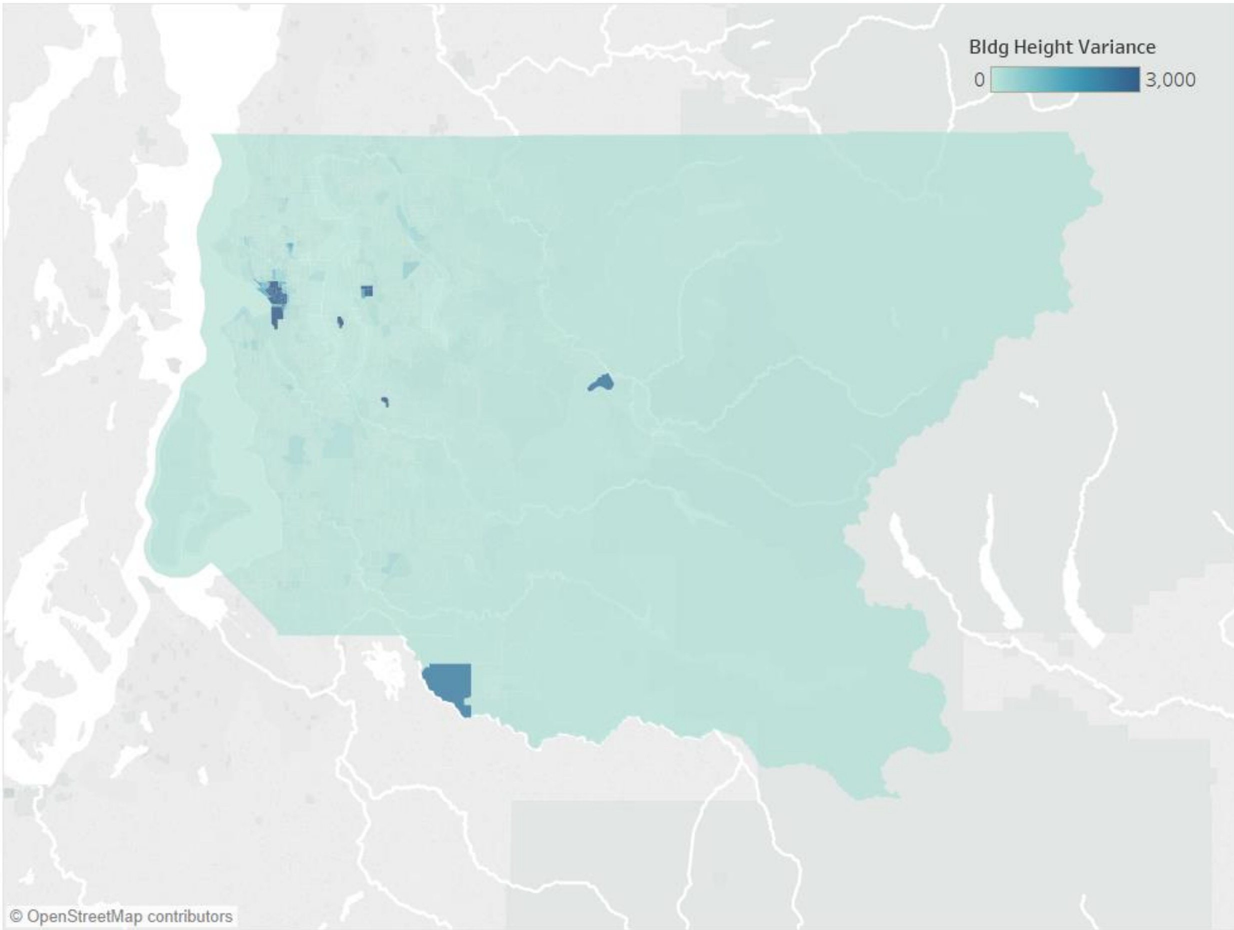


Figure 44: Building Height Variance in the County



8.2.1.2 Demographic data

We collected demographic data from the U.S. Census Bureau. The dataset, from the 2010 census, contains hundreds of types of demographic data for each of the County's census block groups.[57]

8.2.1.3 Social media data

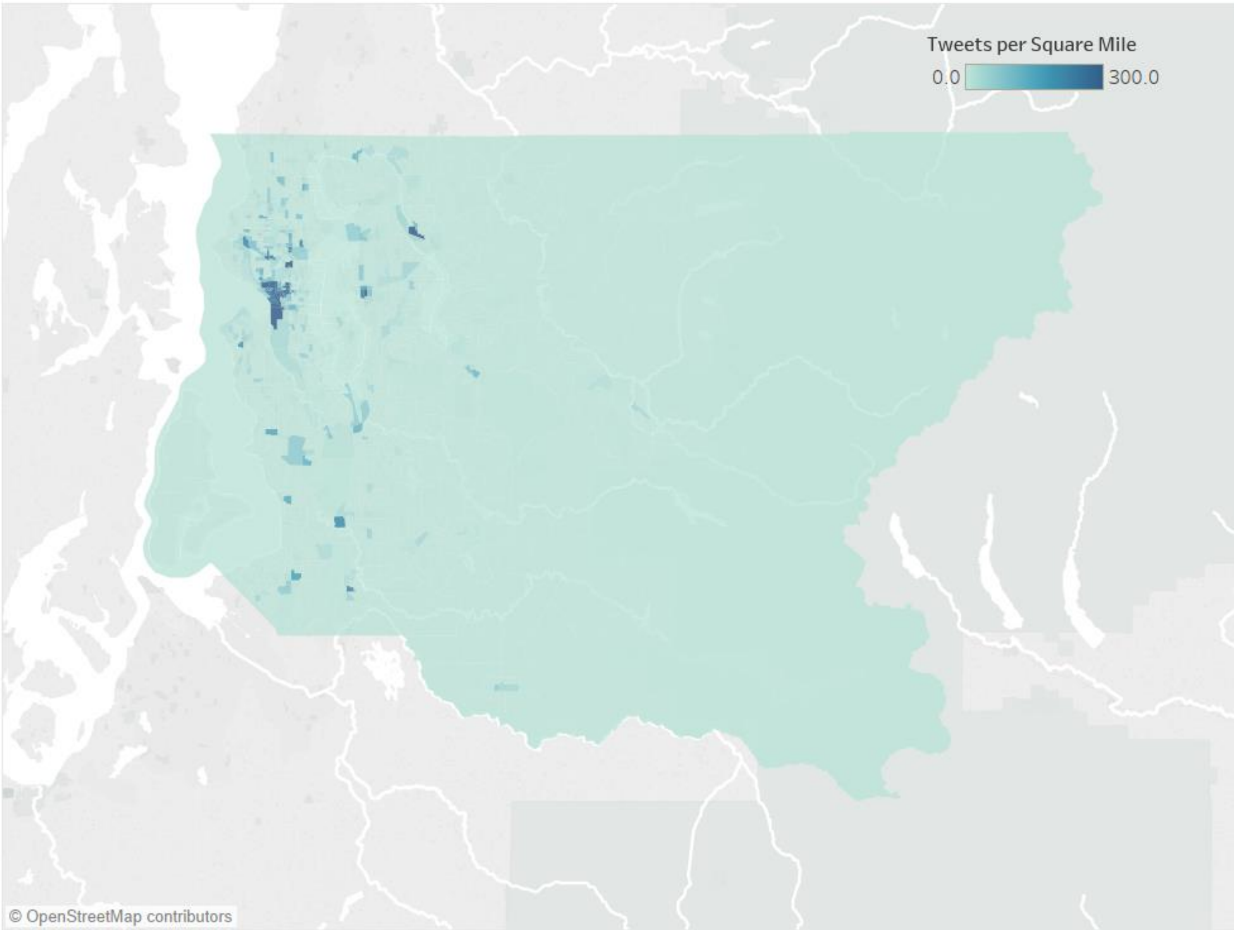
The third dataset consists of details about tweets that originated in the County. While few people "geotag" their tweets, most tweets are made from mobile devices. Therefore, most geotagged tweets will indicate where the mobile network is being used, regardless of carrier.

CTC's analysis captured about 2,000 tweets made within King County between October 1, 2019, and October 8, 2019. After taking certain preparatory steps with the data, we then calculated

[57] A description of the data fields can be found at: https://www2.census.gov/geo/docs/maps-data/data/tiger/prejoined/ACSMetadata2011.txt

the number of tweets that were made within each census block group. This became a new variable we called “Tweet Count” (Figure 45).

Figure 45: Tweet Count Density by County Census Block Group (Oct 1, 2019 - Oct 8, 2019)



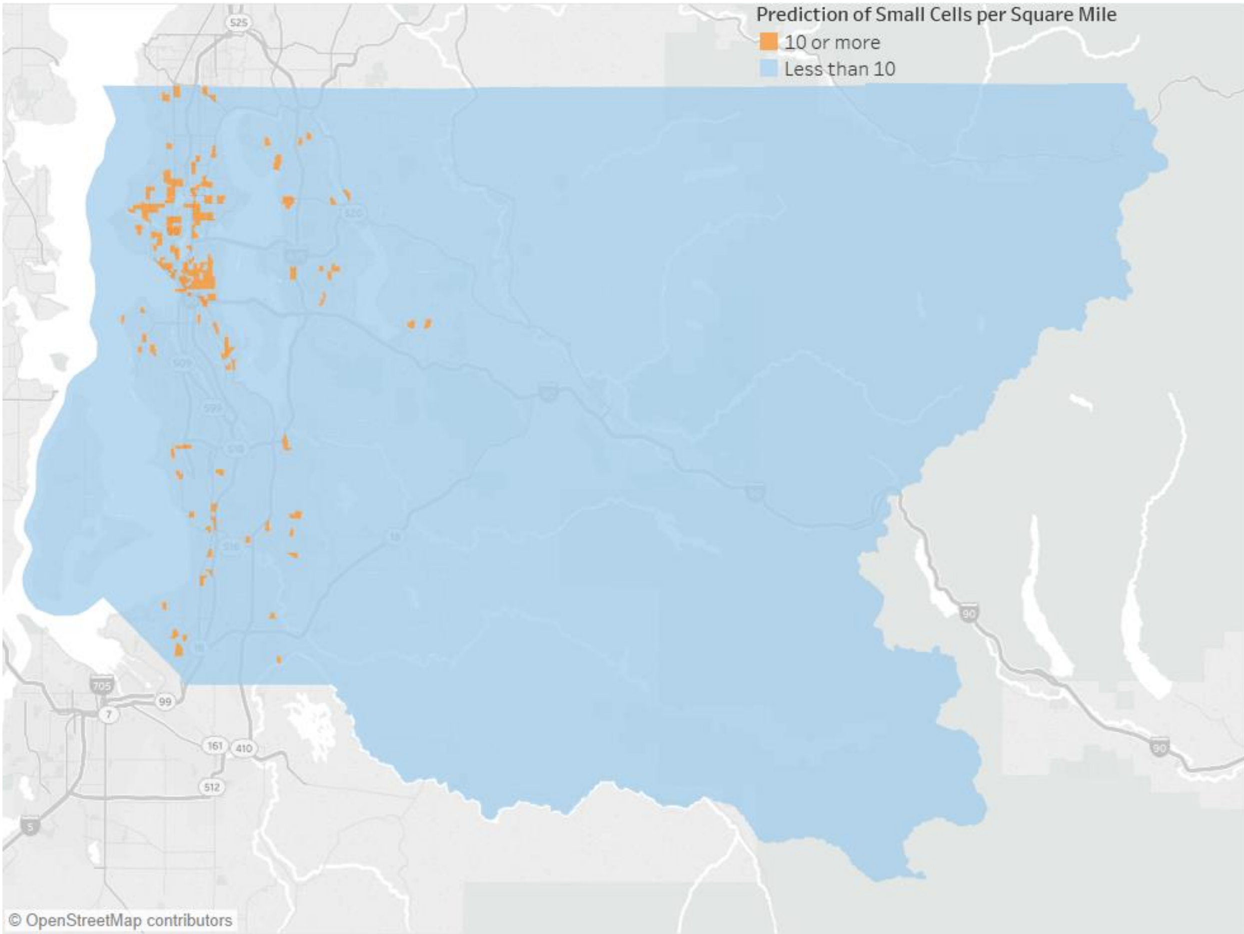
8.2.1.4 Major corridor data

King County’s major roadway corridor miles were calculated from data obtained from King County’s GIS team. We made several calculations to arrive at major corridor miles.

8.2.2 Predictive model findings for King County

We applied the model to King County’s census block group data to predict which of the County’s census block groups can expect dense small cell deployments. Figure 46 shows areas that are expected to have dense deployments of small cells—none of which are in the County’s identified unserved rural areas.

Figure 46: Expected Small Cell Deployments in King County, by Census Block



9 Federal and State Grants and Loans Offer New Opportunities to Address the Needs of Unserved King County

Federal and state funding sources are often an important element of large-scale broadband deployments. At present, most funding opportunities are limited to new solutions for unserved areas. Additional smaller opportunities may emerge in any given year—examples of the always-changing broadband funding and financing landscape.

It is important to note that the majority of federal funding programs are designed for communities that are significantly more economically distressed than the County. Demographic criteria including population density, average household income, and the existence of providers offering at least 10 Mbps download and 1 Mbps upload speeds (10/1 Mbps) preclude the majority of the populated areas of the County from receiving assistance from most federal programs.

As a complement to this overview of funding sources, we present in Appendix C a brief discussion of some of the common types of bonds that public entities typically rely on for capital projects.

9.1 USDA's ReConnect program represents a new, unique rural funding opportunity

The ReConnect program represents the most significant congressional appropriation of broadband funding since the Recovery Act in 2009. The program awards loans, grants, or a combination of the two for last-mile connections in rural areas. It is overseen by the Rural Utilities Service (RUS).

We recommend that the County plan for applications to ReConnect, regardless of whether there is sufficient time to prepare for the upcoming round of grant applications that will likely be due in early 2020. In the sections below, we first present detailed information about the grant program—then present our findings on ReConnect-eligible portions of the County. (See Section 10.2 for details on our recommended ReConnect approach.)

9.1.1 With bipartisan support, ReConnect will likely have annual appropriations

We expect continued appropriations for ReConnect and for other RUS broadband loan and grant programs, as these programs enjoy strong bipartisan support. For fiscal year 2020, new rural broadband funding of $690 million is included in a Senate appropriations bill and $605 million is included in a House bill. Depending on the outcome of the final legislation, this funding would likely become available in calendar year 2021, which would represent the third year of ReConnect.

The program currently comprises three separate funding categories: 100 percent grants (covering up to 75 percent of eligible project costs, with a 25 percent match), 50 percent grants with a 50 percent loan or other form of match, and 100 percent loans. Each category has different requirements in terms of existing services allowed in the proposed funded service area (PFSA):

1. For awards with loan components (i.e., 50 percent or 100 percent loans), funds will go to rural areas where 90 percent or more of the households lack access to broadband (defined as speeds of at least 10 Mbps download and 1 Mbps upload).

2. For 100 percent grant awards, 100 percent of the households in the PFSA must lack access to 10/1 Mbps broadband.

Applicants must propose networks capable of providing access to every premises in the PFSA at minimum speeds of 25 Mbps downstream and 3 Mbps upstream.

Matching funds are another point of distinction. Applicants for 100 percent grant awards will need to provide matching funds equivalent to 25 percent of the project's cost for the project—and that matching contribution must be expended first, followed by grant funds. For 50 percent grants with a 50 percent loan or other form of match, applicants can propose a cash alternative to the loan at the time of application. (For an awarded project in this scenario, all cash proposed must be expended first, followed by loan funds and then by grant funds.)

Generally, we anticipate that USDA will prioritize private-sector applications and public-private partnerships, so it will be important for local governments to build a public-private partnership strategy for this program. RUS will consider public networks that lack extensive experience to be startups and may disfavor their applications. Therefore, public entities without extensive experience as an internet service provider (ISP) should consider partnering with an experienced public or private ISP to compete for these funds. And any experienced ISP, whether public or private, will require the strong collaboration and support of its local (and state) government to present a compelling case for funding.

We anticipate RUS will make grant/loan combinations in the $3 million to $10 million range. This is quite a bit more than RUS's Community Connect grants—and, because the program's funding is considerably larger in total dollars, we anticipate that ReConnect will make more awards. Further, ReConnect does not have the low-income requirements of Community Connect, making it a more flexible program.

Applications to this program will require a detailed business plan and pro forma. It will be critical to provide documentary evidence of the fact that the PFSA is unserved under the statutory definition (i.e., no 10/1 service available). As such, business planning and engineering will be essential. The PFSA must be defined with a count of the number of rural premises to be connected, including homes, farms, schools, libraries, healthcare facilities, and businesses (which are important because they confer additional points in the application). The engineering methodology used to demonstrate that the PFSA lacks service must also be documented.

Furthermore, applicants must verify that the PFSA contains no Connect America Fund II award census blocks and that the PFSA does not overlap a Protected Broadband Borrower Service Area (i.e., the service area of a borrower that has an RUS broadband loan).

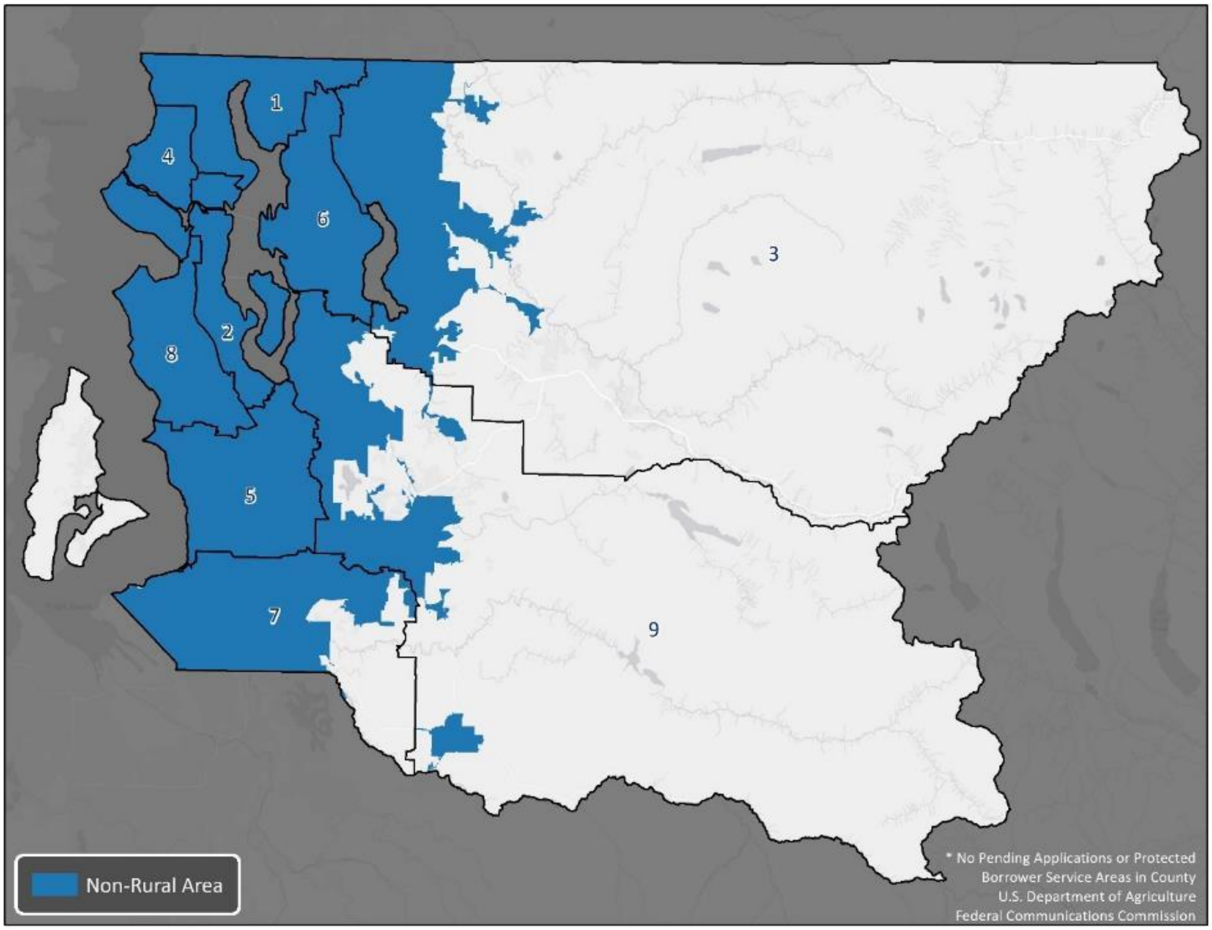
RUS will grant application review points based on many factors. The rurality of the PFSA can earn almost 25 points alone. RUS will also award points to applications proposing to build networks capable of at least 100/100 Mbps. Additional points can be scored if the proposed area includes a healthcare center, education facility, or critical community facility. Furthermore, points will be awarded for projects in states with an updated broadband plan in the past five years.

9.1.2 Our analysis establishes that parts of King County are eligible—a critical element of ReConnect applications

The ReConnect program defines "underserved" similarly to the definition in existing federal programs, dictating that projects will be funded only if 90 percent of the households in the project area have less than 10 Mbps/1 Mbps (download/upload) service.[58] Pockets of eastern King County will qualify for this program.

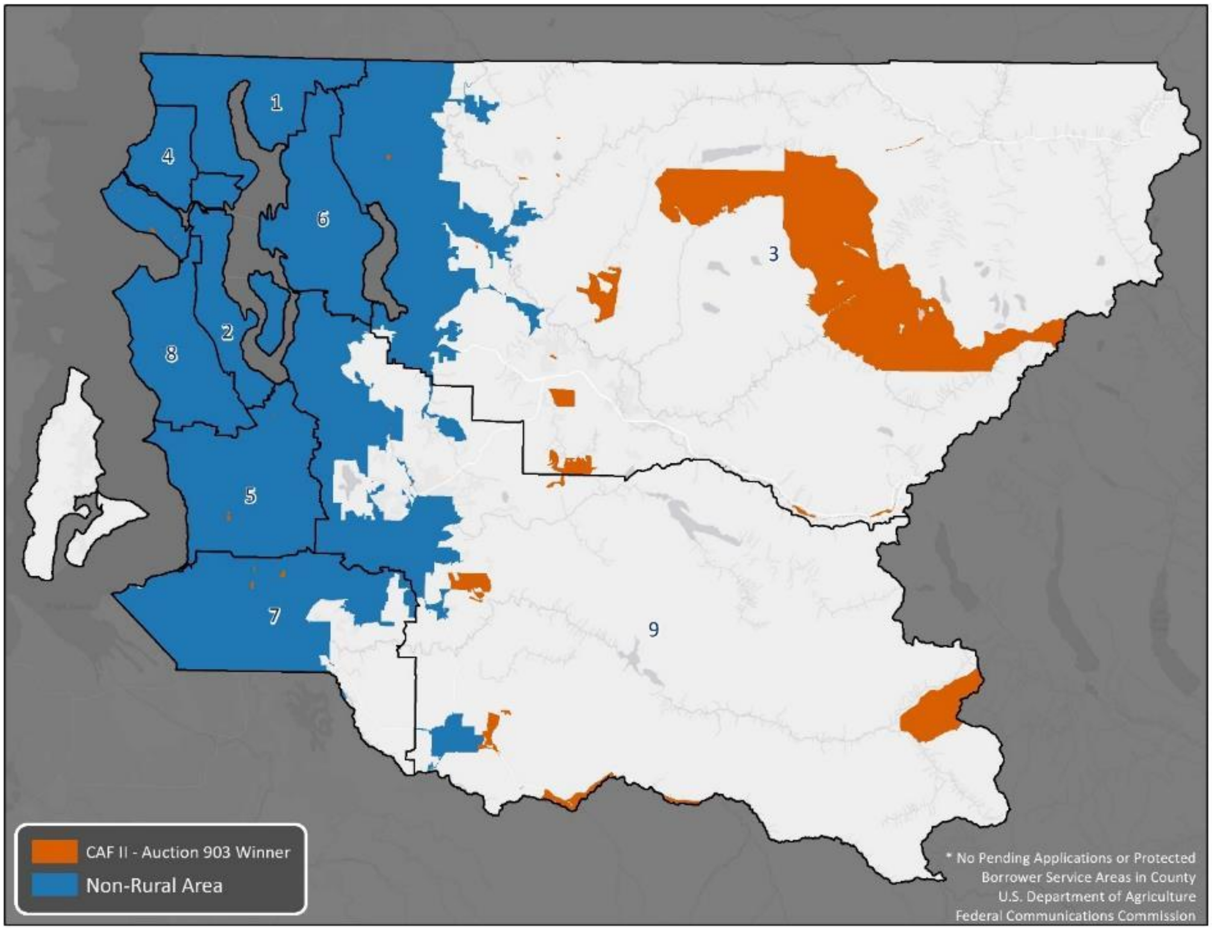
The map below identifies King County's rural areas, which would nominally be eligible for ReConnect funding. (Non-rural areas, identified in blue, would not be eligible.)

Figure 47: ReConnect-Eligible Areas (Baseline Rural)



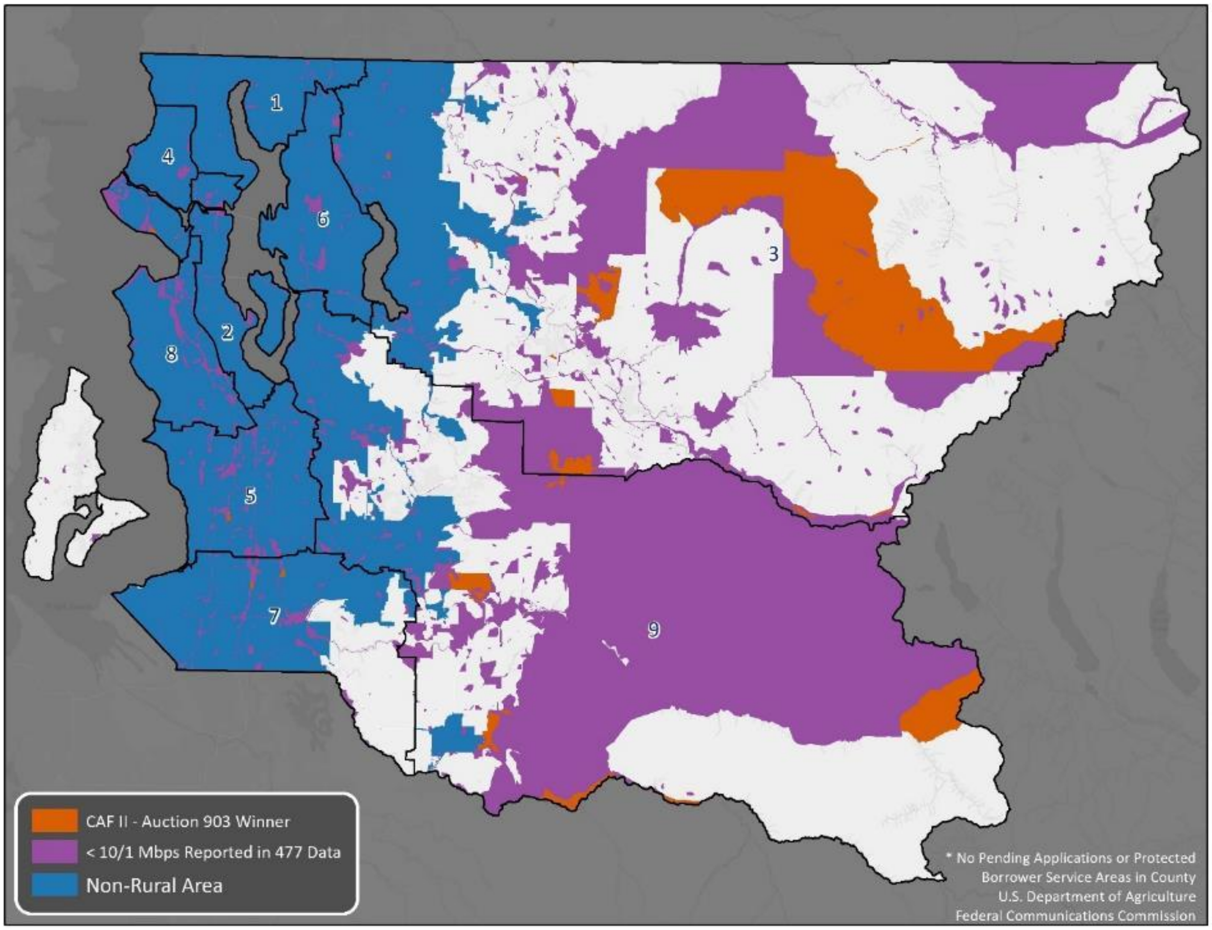
In the next map, the protected areas in orange are also excluded; USDA cannot make grants or loans under ReConnect to geographies where there are CAF II recipients. For the 10 years of that program's operating support, no one can bid on ReConnect funding. (Unfortunately, the CAF II awardees do not have to show progress for five years, and they do not need to deliver robust services.) We note that USDA is looking at fixed service only; the existence of mobile service does not preclude eligibility for ReConnect.

Figure 48: ReConnect-Eligible Areas: Baseline Rural & Non-CAF II Auction Winners



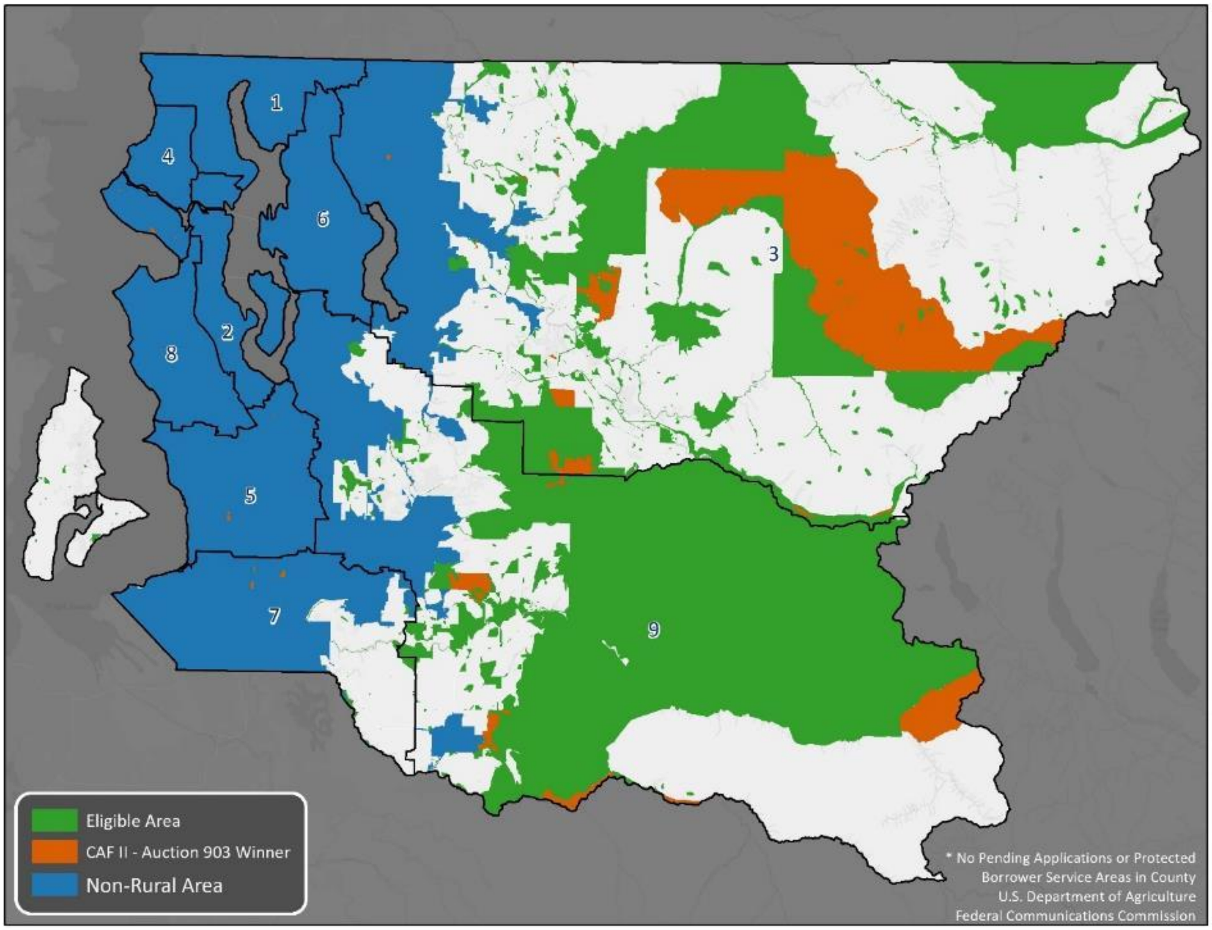
The next map overlays FCC Form 477 data, identifying unserved areas in the County as defined by those data. The Form 477 is not the final word; there could still be an application for a project so long as it demonstrates that Form 477 data are wrong, and that the area actually is unserved. (There is a mechanism in the ReConnect program for showing this.)

Figure 49: ReConnect-Eligible Areas: Baseline Rural, Non-CAF II Auction Winners & Unserved (Form 477)



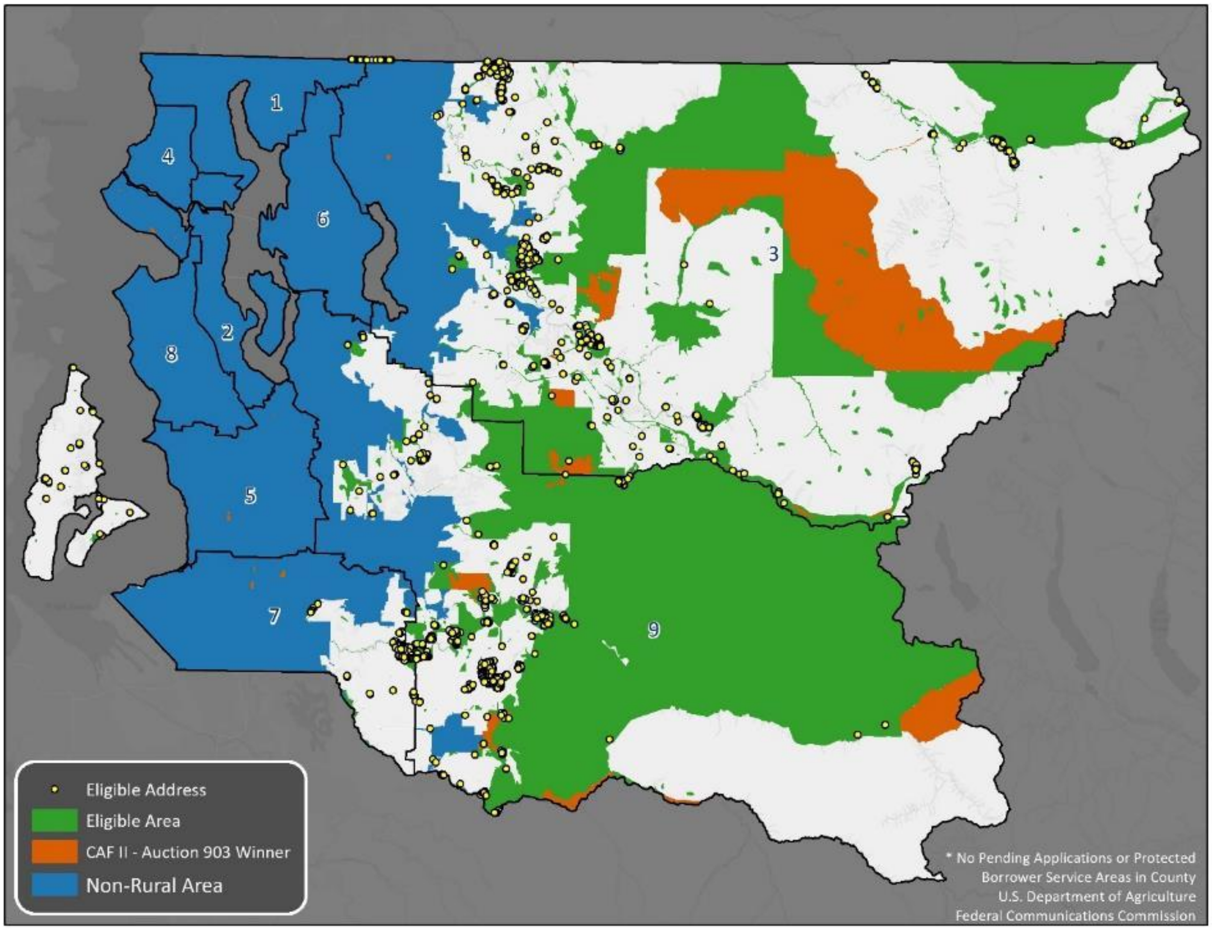
The next map illustrates the County's eligible areas.

Figure 50: ReConnect-Eligible Areas



We then applied data showing populations based on County's address data. The yellow dots illustrate areas for potential grant applications. We note there are also opportunities on Vashon Island, even if they are not showing up on Form 477.

Figure 51: ReConnect-Eligible Addresses



9.2 USDA's Community Connect program represents another, more modest opportunity

Community Connect is another program to which the County could apply with a partner (e.g., for deployment along U.S. 2).

The USDA administers this modestly sized grant program for local and tribal governments; it targets broadband deployment to unserved (defined as speeds less than 10 Mbps download and 1 Mbps upload), low-income rural communities with fewer than 20,000 residents. Grantees must ultimately offer service at the broadband grant speed (defined as 25 Mbps download plus 3 Mbps upload) to *all* households and community institutions in the Proposed Funded Service Area (PFSA), with free service for at least two years to a community center.

The application process is rigorous and competitive (i.e., only about 10 percent of applicants receive an award) and once awarded, program requirements can be demanding (e.g., requiring last-mile service be available for all households in the service area). The program has been funded consistently since it was introduced in 2002 and represents an important opportunity for qualifying communities.

Eligible applicants include incorporated organizations, Indian tribes or tribal organizations, state or local units of government, or cooperatives, private corporations, and limited-liability companies organized on a for-profit or not-for-profit basis. Individuals or partnerships are not eligible. Any public or private applicant must have the legal capacity and authority to own and operate the proposed broadband facilities, to enter into contracts, and to otherwise comply with applicable federal statutes and regulations. Thus, awards cannot be granted to a local government entity that does not want to own or operate the broadband service.

The Community Connect program targets communities where broadband service is not available[59] and where low population densities and poverty make deployment costs high, and build-out of infrastructure unlikely. Funding is limited to contiguous areas with populations less than 20,000 and without Broadband Transmission Service (defined as 10 Mbps download and 1 Mbps upload speeds). Service areas need not be in the same state, so long as the areas are contiguous.

Once awarded, projects must offer last-mile service at the broadband grant speeds (25 Mbps download and 3 Mbps upload) to *all* businesses, residents, and community facilities in the PFSA, with free service provided to all critical facilities,[60] and at least one community center (with weekend hours and two to 10 public computer access points) for at least two years from the grant award. Grants can be used to offset the cost of providing such service and to lease spectrum, towers, and buildings as part of the project design.[61] The lesser of 10 percent of the grant or $150,000 can be used to construct, acquire, or expand an existing community center.[62]

In summary, Community Connect awards must:

- Offer last-mile service of at least 25 Mbps download and 3 Mbps upload to an entire PFSA[63] that did not previously have service;

[59] Applicants should check all available sources to confirm that service is not available. These include but are not limited to service provider websites, the NTIA and FCC National Broadband Map (http://broadbandmap.gov/ and/or https://www.fcc.gov/reports-research/maps/), and the grant awardee database.
[60] Critical community facilities include public schools, public libraries, public medical clinics, public hospitals, community colleges, public universities, law enforcement, and fire and ambulance stations.
[61] Leasing costs can only be covered for three years.
[62] Note that additional funds can be used to provide the computer access points and their connection to the network. Applicants may use their own resources to cover costs exceeding this limit. The program historically required provision of at least 10 computer access points in a public community center; however, now requires only two such access points—with a *maximum* of 10 computers.
[63] The minimum requirements increased from FY 2017 to FY 2018 and may change again before FY 2019. The NOSA will announce any changes. The requirements provided reflect the most recent numbers from the FY 2018 cycle.

- Benefit rural areas (with fewer than 20,000 residents *and* not adjacent to cities with more than 50,000 residents); and
- Provide complimentary service for at least two years to all critical facilities and a community center that meets the grant requirements.

To prepare the most competitive Community Connect grant application possible, we would recommend that an applicant acquire or create a utility chart of an area within its unserved footprint, then target the lowest-income portions of that area. Community Connect is a competitive program with approximately 10 percent of the roughly 150 applicants receiving funding.

9.3 Department of Commerce economic development grants assist distressed communities

The Department of Commerce's Economic Development Administration (EDA) oversees the Economic Development Assistance program, which has provided economic assistance to distressed communities for many years. Public broadband projects in economically distressed communities are eligible for funding under the Public Works and Economic Adjustment Assistance programs.

The program also now coordinates with a $587 million grant program[64] also under the oversight of the Department of Commerce. This opportunity attempts to remedy disaster-stricken areas of the economic burdens that such disasters impose. Disasters are defined per the President's declaration. If the County were to qualify, this opportunity would provide a less competitive, but similar application process to the broader, non-disaster Economic Development Assistance grants.

As an initial matter, the Notice of Funds Available (NOFA) repeatedly emphasizes the importance of consulting with the appropriate regional EDA contacts. Regional staff is available to review project proposals, assess proposed cost shares, and preview all application materials. Though optional, we believe that such consultation will ultimately be beneficial.[65]

EDA's materials on Public Works funding explicitly mentions broadband:

> Public Works investments help facilitate the transition of communities from being distressed to becoming competitive in the worldwide economy by developing key public infrastructure, such as technology-based facilities that utilize distance learning

[64] See https://www.grants.gov/view-opportunity.html?oppId=302953, accessed November 2019.
[65] EDA regional contacts available online at: https://www.eda.gov/contact/, accessed November 2019.

> networks, smart rooms, and smart buildings; multitenant manufacturing and other facilities; business and industrial parks with fiber optic cable; and telecommunications and development facilities.[66]

This language appears to have been added into the program description in 2009. Despite this, it does not appear that broadband funding has been a significant part of the funding portfolio. In fact, the online annual reports (2007–2017) include only eight references to relevant projects:[67]

1. In October 2017, the EDA awarded $760,025 to the Telluride Foundation in Telluride, CO, to support business growth by providing broadband connectivity to the communities of Nula, Naturita, Redvale, Norwood, Ilium, Telluride, Mountain Village and Ophir.[68]

2. The EDA awarded $144,000 to the Confederated Tribes of the Umatilla Indian Reservation, in Pendleton, OR, in 2017. The award will support the development of a broadband fiber optics network near Pendleton to be located on the Umatilla Reservation. This investment will improve the information systems technology infrastructure to facilitate the formation and expansion of regional business enterprise, which will increase business capacity and create new, higher paying job opportunities for the region's workforce.[69]

3. In 2014, the EDA awarded $714,861 in Public Works funds to OneCommunity, Case Western Reserve University, Ideastream, and the City of Cleveland, OH, to support construction of three miles of an ultra-high-speed, 100 gigabit network through Cleveland's Health-Tech Corridor. This investment is part of a $1,021,230 project that the grantees estimate will create 115 jobs and leverage $35 million in private investment.[70]

4. In 2014, EDA awarded a grant in the amount of $300,000 to the town of Estes Park, CO, "to conduct a regional economic diversification and industry cluster job retention and

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[66] EDA, Public Works Program Pager, https://www.eda.gov/pdf/about/Public-Works-Program-1-Pager.pdf, accessed November 2019.
[67] EDA annual reports available online at: https://www.eda.gov/annual-reports/, accessed November 2019.
[68] "Telluride Foundation Receives $760,025 Grant for Regional Broadband Expansion," *Telluride Foundation,* October 17, 2017, https://telluridefoundation.org/telluride-foundation-receives-760025-grant-for-regional-broadband-expansion-foundation-one-of-35-projects-nation-wide-to-receive-economic-development-administration-funding/, accessed November 2019.
[69] "Latest EDA Grants," *EDA*, https://www.eda.gov/grants/, accessed November 2019.
[70] "EDA $700K Grant to City of Cleveland/OneCommunity Lays Groundwork for First Commercially Available 100 Gigabit Fiber Network," *EDA,* November 21, 2014, https://www.eda.gov/archives/2016/news/press-releases/2014/11/21/one-community.htm, accessed November 2019.

recovery strategy" after the town suffered heavy damage from a 2012 wildfire and 2013 flood, which significantly affected the crucial tourist industry. Part of the grant project was to find new ways to utilize Estes Park's existing fiber optic ring to improve broadband services to the town and region.[71]

5. EDA awarded $1.2 million to the town of Vidalia, LA, in 2014 to build a Technology Center and extend fiber optics into the city, to promote entrepreneurship and business development. Additionally, the new fiber is intended to contribute to the operations of public safety systems and to aid in future disaster recovery efforts.[72]

6. EDA awarded a grant in 2013 to the Vermont Digital Economy Project, a partnership between EDA and the Council on Rural Development, which "will help small rural communities affected by flood events to create new job opportunities, strengthen downtowns, and enhance municipal communications systems to support both businesses and emergency services. The project seeks to improve online access within twenty-five core communities and other targeted locations, strengthen online communications within the state, and enhance community and non-profit economic development functions." Vermont received a total of six grants together worth $6.5 million in 2013.[73]

7. During FY 2012, EDA awarded 10 grants in the State of Georgia totaling $5.6 million.[74] These included six Public Works projects for critical infrastructure—road improvements and rail spurs, increased sewer capacity, and installation of fiber optic cable—that are helping communities across the state to support business expansion and the attraction of new industry. It is unclear what share of the states' awards were directed to fiber.

8. In FY 2012, the Tulalip Tribes in Washington "coordinated to create Tulalip Broadband and Tulalip Data Services, which offer technology services to Tribal members and businesses looking to locate near tribal lands. All of these businesses have brought jobs and income both to tribal members and the surrounding community and serve as a strong example of how long-term, coordinated economic development planning can lead to increased prosperity." Note that support for this effort was a modest $48,000.[75]

[71] CO FY2014 Annual Report, *EDA*, https://www.eda.gov/annual-reports/fy2014/states/co.htm, accessed November 2019.
[72] LA FY2014 Annual Report, *EDA*, https://www.eda.gov/annual-reports/fy2014/states/la.htm, accessed November 2019.
[73] EDA, FY2013 Annual Report, at 83, https://www.eda.gov/files/annual-reports/fy2013/EDA-FY2013-Annual-Report-full.pdf, accessed November 2019.
[74] EDA, FY2012 Annual Report, at 28, https://www.eda.gov/files/annual-reports/fy2012/EDA_FY_2012_Annual_Report_full.pdf, accessed November 2019.
[75] *Id.* at 70.

While broadband funding to date through the EDA appears to be modest, both construction and technical assistance are clearly eligible. Moreover, applicants can apply existing federal funds toward the cost-share, which allows them to leverage available resources. Given this, we highly recommend contacting Regional EDA representatives to explore this opportunity. Regional agency contact information is available on the EDA website.

9.4 The FCC's Rural Digital Opportunities Fund is an emerging opportunity

The Rural Digital Opportunity Fund represents the latest iteration of the FCC's Universal Service Fund's (USF) high cost program. Since 1996, the FCC has used the high cost program to subsidize telecommunications services in rural and remote areas, where the return on investment would otherwise be too low to prompt companies to invest in telecommunications infrastructure.

While the program initially provided subsidized telephone service on an ongoing basis, in 2011 the FCC began reorganizing and modernizing the high cost program, creating the Connect America Fund (CAF) with the goal of accelerating the buildout of broadband-capable infrastructure to unserved and underserved areas. Instead of providing an ongoing subsidy in exchange for serving eligible areas, the CAF program provides an annual subsidy for a fixed period of time to help cover the initial cost of building out broadband-capable infrastructure in rural and remote areas.

The CAF program uses a cost model to estimate the appropriate subsidy for each eligible census block, and first made these funds available to incumbent price-cap carriers in exchange for a commitment to serve every household and business with service with speeds of at least 10 Mbps download and 1 Mbps upload. For those areas where the price-cap carrier declined CAF support, the FCC made funds available to any qualifying service provider through a multi-round, reverse, descending clock auction, with added weight given to those bids that committed to offering faster and lower latency broadband services.

The CAF Phase II auction took place in 2018 and was widely viewed as a success. The auction awarded just under $1.5 billion in support in exchange for a commitment to serve 713,176 homes and small businesses in 45 states, a total of 73 percent of eligible areas. Thanks to the weighting system that favored service providers willing to offer higher tiers of service, 99.75 percent of locations will have speeds of at least 25/3Mbps, 53 percent will have at least 100/20 Mbps and 19 percent will have 1 Gbps/500 Mbps. The 103 winning bidders will receive an annual sum each year for 10 years, provided they meet build-out requirements. Winners must offer service to 40 percent of homes and businesses by year 3 and continue to increase by 20 percent each year until year 6 when 100 percent of eligible homes and businesses must be served.[76] The total amount of support awarded was 70 percent less than the Connect America Cost Model (CACM) estimated would be needed.[77] Although the reverse auction process was complex, it secured higher quality service for consumers at a significantly lower cost to the Universal Service Fund than previous methods of allocating subsidies.

The Rural Digital Opportunity Fund (RDOF) builds on the success of the CAF Phase II auction, with a proposal to allocate an additional $20.4 billion over the next decade in order to support the build out of high-speed broadband networks in unserved and underserved areas of the country. While it is still in the rule-making phase, the FCC has proposed using a reverse auction mechanism almost identical to the one used in the CAF Phase II auction, though this time incumbent price-cap carriers will not have the right of first refusal. The FCC proposes awarding funds through two phases, the first focused on those areas wholly unserved by broadband at speeds of 25/3 Mbps, and the second on partially-served areas. As in the CAF Phase II auction, the FCC will use the CACM to establish the maximum subsidy available for each eligible area, and bidders compete for available subsidies with preference given to those bidders willing to commit to offering faster speeds and lower latency service. The bidder willing to commit to providing an area with the best quality service at the lowest subsidy amount wins the available support.[78]

The biggest change the FCC proposes is raising the service availability threshold to 25/3 Mbps, making even those areas where a provider received CAF funding for 10/1 Mbps service potentially eligible for support. The commission is also considering a number of other minor adjustments, such as changing the minimum bidding areas from census blocks to census block tracts or counties, as well as adding a subscribership benchmark which would make some percentage of funds contingent on a winning bidder gaining sufficient market share.[79]

While the Republican commissioners appear ready to move forward with the RDOF, the Democratic commissioners argue that the FCC first needs to fix issues with its mapping data in order to more accurately state which areas are unserved and underserved.[80] Although there are still many details to work out, some version of RDOF will become a reality in the near future

[76] "Connect America Fund Auction to Expand Broadband to Over 700,000 Rural Homes and Businesses," *FCC*, August 28, 2018, https://docs.fcc.gov/public/attachments/DOC-353840A1.pdf (accessed November 2019).
[77] Joseph Gillan, Lessons from the CAF II Auction and the Implications for Rural Broadband Deployment and the IP Transition, *National Regulatory Research Institute,* https://pubs.naruc.org/pub/9F958420-E885-F843-1AEC-4D290DC9A28E (accessed November 2019).
[78] Federal Communication Commission, "Rural Digital Opportunity Fund, Connect America Fund," 84 FR 43543, August 21, 2019, https://www.federalregister.gov/documents/2019/08/21/2019-17783/rural-digital-opportunity-fund-connect-america-fund (accessed November 2019).
[79] Ibid.
[80] Marguerite Reardon, "FCC Greenlights $20 billion rural broadband subsidy auction," *CNET*, August 1, 2019, https://www.cnet.com/news/fcc-greenlights-20-billion-rural-broadband-subsidy-auction/ (accessed November 2019).

thanks to the broad, bipartisan consensus in Washington that rural areas need better broadband.

9.5 Washington's Public Works Board broadband grants could dovetail with federal funding

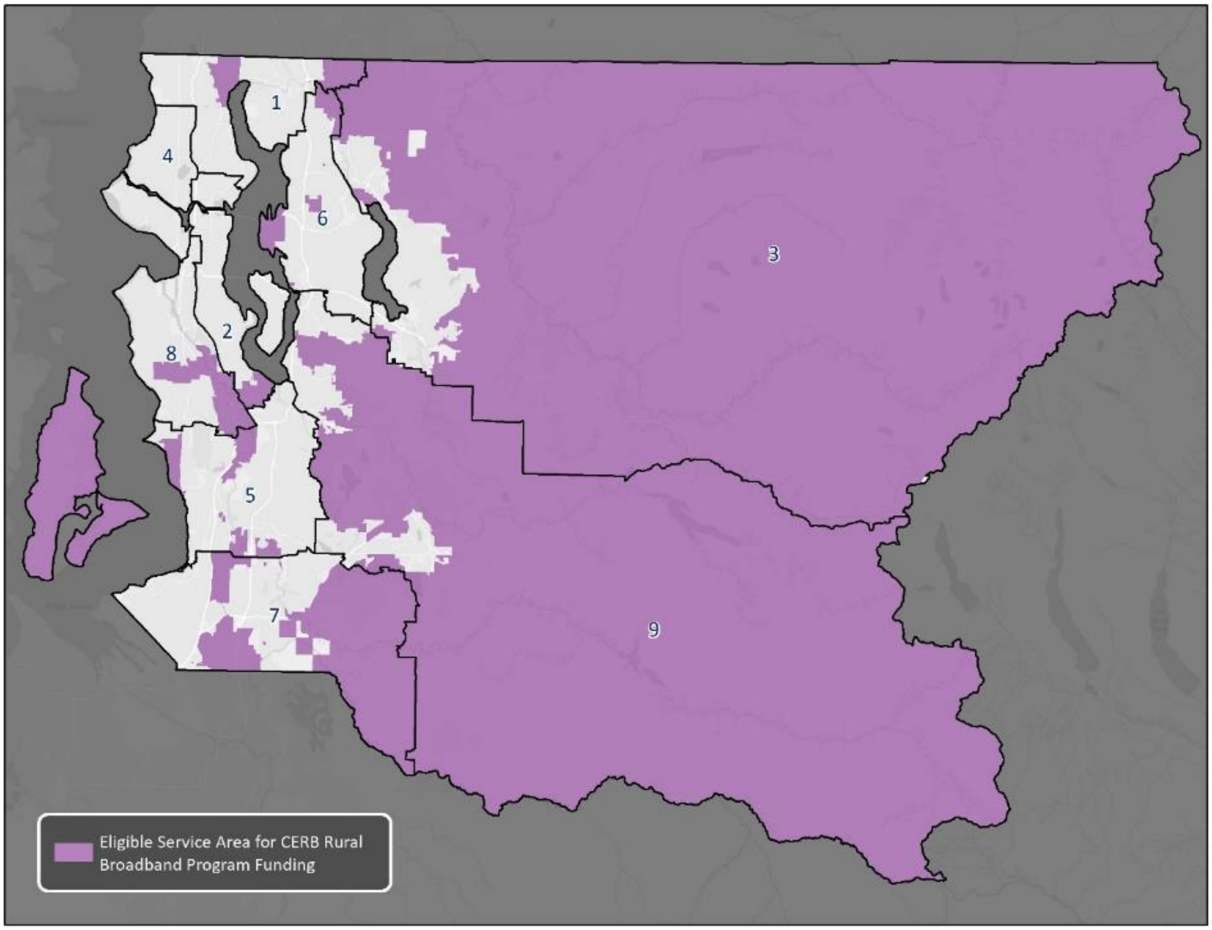
In the past year the State of Washington has created a broadband office and released a report. There will now be planning at a State level that has not happened in the years since the State's earlier broadband efforts came to end, and King County should coordinate with the new State office. Given the potential for new coordination of State efforts, as well as the emergence of new grant opportunities at the State level, the County's efforts could unlock new State funding for unserved King County. In addition to the existing CERB program, in 2019, the State legislature authorized $18 million in funding through the Public Works Board Broadband Program for grants aimed at expanding broadband access in unserved areas throughout the State.[81] This program is still being designed, with the expectation that guidelines will be issued in early 2020. The County should track this program to see if this funding could be utilized to support broadband deployment in rural King County, which we expect is highly likely.

9.6 Washington's CERB broadband grants represent an important funding opportunity

The State of Washington Department of Commerce's (DOC) Community Economic Revitalization Board provides low-interest loans and grants to qualified local governments and federally recognized Indian tribes within the State[82] for "financing the cost to build infrastructure to provide high-speed, open-access broadband service, to rural underserved communities, for the purpose of community economic development."[83] Funding can be used for the infrastructure to the point of service and applicants must partner with an internet service provider to be eligible. The program also provides limited support options related to rural broadband planning.

[81] "Public Works Board – Broadband Financing," Department of Commerce, State of Washington, https://www.commerce.wa.gov/building-infrastructure/pwb-broadband/ (accessed November 2019).
[82] Generally, applicants must have jurisdictional authority over the property included in the proposed project. This removes Economic Development Councils on their own from being an applicant. Additionally, colleges and universities are not eligible for funding.
[83] See https://www.commerce.wa.gov/building-infrastructure/community-economic-revitalization-board/rural-broadband/, accessed September 2019.

Figure 52: CERB-Eligible Areas in King County



Based on the basic eligibility requirements, the majority of land area in the County is eligible for CERB Rural Broadband Program funding; the DOC has issued a list of eligible entities/areas by county and tribe.[84] However, funding limits may make this program a less desirable option for large projects. In particular, the State had set aside $10 million in funding through June 2019.[85] Currently, available funding is approximately $3.45 million for the current biennium (July 2019 to June 2021), making this a relatively small and highly competitive program. The State anticipates that all funding will be awarded by March 2020.[86] There are no application

[84] See https://deptofcommerce.app.box.com/v/cerbruralcountiescommunities, accessed September 26, 2019.
[85] See https://deptofcommerce.app.box.com/v/cerbrbworkshoppresentation, "Available Funding," Slide 2, accessed September 26, 2019.
[86] Phone call with Janea Delk, Program Director & Tribal Liaison for the Community Economic Revitalization Board, October 30, 2019.

deadlines, but the CERB reviews project proposals every two months[87] and makes awards on a first-come, first-served basis.[88]

Funding amounts include a maximum of $2 million in low-interest loans per project (there is no option for loan forgiveness) and up to 50 percent of the total project award in grants, determined after an underwriting process that identifies a debt service coverage ratio (DSCR). Grant applicants are required to provide a cash match of 25 percent of the total project cost (not to be confused with the grant award) and must demonstrate overall project feasibility by providing a supporting study.[89]

Any application should aim to satisfy the CERB's general priorities and should document the overall value of the project to the community with demonstrated support from businesses and government in the project area; the ways in which the proposed project will meet stated goals in published planning documents (such as local economic development plans, comprehensive plans, capital facilities plans, and any applicable State planning requirements); the availability of matching dollars; local participation in the project; and the overall readiness of the project to proceed.[90]

As these funds are meant to aid in economic development generally, any proposed project must demonstrate an intention to "encourage, foster, develop, and improve broadband within the state,"[91] with an emphasis on:

- Job creation, innovation, and expansion of markets for local businesses
- Serving the needs of local education systems, health care systems, public safety systems, industries and businesses, governmental operations, and citizens
- Improving accessibility for underserved communities and populations[92]

The CERB Rural Broadband Program goes beyond the basic eligible infrastructure and minimum speed requirements of familiar federal-level grants (e.g., FCC, USDA). Those programs generally

[87] Applicants are required to attend the meeting at which their proposal is reviewed, and generally come prepared with a presentation not exceeding 20 minutes.
[88] See http://www.commerce.wa.gov/wp-content/uploads/2019/06/cerb-2019-21-rural-broadband-program-policies-06172019-2019.pdf. Program Overview, page 4. Accessed October 4, 2019.
[89] This report might qualify for these purposes.
[90] See https://deptofcommerce.app.box.com/v/cerbrbworkshoppresentation, "Project Prioritization," Side 5. Accessed October 30, 2019. Shovel-ready projects are defined as satisfying four important criteria: 1) a committed partner ISP; 2) documented and executed partnership agreements; 3) a technical plan; and 4) a detailed business plan.
[91] See https://www.commerce.wa.gov/building-infrastructure/community-economic-revitalization-board/rural-broadband/ accessed September 26, 2019.
[92] See https://www.commerce.wa.gov/building-infrastructure/community-economic-revitalization-board/rural-broadband/ accessed September 26, 2019.

require proposed infrastructure to deliver no less than 25 Mbps/3 Mbps regardless of proposed broadband infrastructure type; in contrast, the CERB program is specific about speed requirements for each medium of proposed broadband infrastructure. The following table summarizes the required speeds for various technologies under the CERB program.

Table 26: CERB Speed Requirements

Proposed Broadband Infrastructure	Required Minimum Speeds (Down/Up)
Cable Modem	100 Mbps / 20 Mbps
Fiber	1 Gbps / 1 Gbps
Wireless (Fixed Wireless, Wi-Fi)	50 Mbps / 10 Mbps
4G Mobile Wireless	25 Mbps / 5 Mbps
Broadband over Powerline (BPL)	100 Mbps / 100 Mbps
Microwave	100 Mbps / 20 Mbps

The CERB Program also has several notable eligibility restrictions. The program will not support any project that intends to foster eventual retail developments or gambling. Further, if a project is designed to attract businesses away from another jurisdiction in the State, it will be disqualified. Finally, the proposed project cannot provide equipment to a public entity that would then provide “retail telecommunications services” or any services that are not allowed by State statute, and there is an absolute disqualification for a publicly-owned backbone designed and implemented for the sole purpose of being competitive with incumbents currently in the area.

Additionally, applicants must provide proof that they have contacted incumbent service providers in the proposed project area to inquire whether those companies have any plans to upgrade services. Those letters are also an opportunity to seek interest from ISPs in partnering on the proposed project.

Once an award has been made, successful applicants are required to meet defined pre-contract requirements within six months of award. The Department of Archaeology and Historic Preservation (DAHP) must be contacted and a formal consultation initiated to review any potentially historically significant points of interest or concern in the project area. A tribal consultation may also be required if the project encompasses areas of concern for federally recognized Indian tribes.

Awardees will also be required to file quarterly progress reports with the CERB through the life of the project. CERB will seek project outcome information—including data regarding ISPs serving the area and number of passings and speeds of services for homes, businesses, and anchor institutions—for five years following project completion. Any facilities constructed with CERB support must be used for their original purpose for a minimum of 10 years.

Overall, this program boasts a relatively small allocation and the application process requires significant effort, including establishing a partnership with an incumbent provider in order to apply. As such, this program is likely to be highly competitive around smaller projects and not a good fit for larger projects with significant funding needs. Notably, applicants who qualify for CERB grants would generally be eligible for two other federal programs, as well: the USDA ReConnect program, which has $550 million available in the upcoming funding round, and the USDA Community Connect grants and loans. While the USDA programs are competitive, and the application processes are significant, these programs are somewhat less arduous—and have potentially greater funding for strong applications. Additionally, the County might consider looking at the federal Department of Commerce Economic Development Administration grants. EDA funding is designed to help support and accelerate economic development throughout the country. In particular, the Public Works and Economic Adjustment Assistance Programs will support broadband projects that can demonstrate job growth/savings and economic development due to the completion and implementation of broadband infrastructure.

10 Recommendations to Expand Access to Broadband in Unserved Areas

These strategies involve deployment of new infrastructure capabilities to unserved areas of King County. They reflect the strong desire among many unserved residents for broadband-speed internet access. For example, 71 percent of PMR survey respondents in the unserved Skykomish area reported that their slow connection speeds are a barrier to usage. And among all unserved residents, 40 percent cited "faster speeds" as the thing they would most want to improve in their internet service (as compared to 22 percent of all respondents, served and unserved).

In addition to the strategies described below, we also recommend that the County support ISPs in applying for federal ReConnect grants (see Section 9.1).

10.1 Recommendation: Work with Comcast and Wave to identify unserved areas with enough population density to create a business opportunity

The County deserves credit for the Comcast and Wave buildouts in unincorporated areas. This service availability did not just happen—it is based on 30 years of franchise negotiations that led to requirements for the cable companies to build to ever-increasing percentages of the community (based on certain population densities). The County anticipated its growth and where its infrastructure needs would be. We have seen that phone companies with no franchise obligations are upgrading by neighborhood (like CenturyLink in Seattle); Comcast is upgrading everywhere because it is required to do so by the franchise agreement.

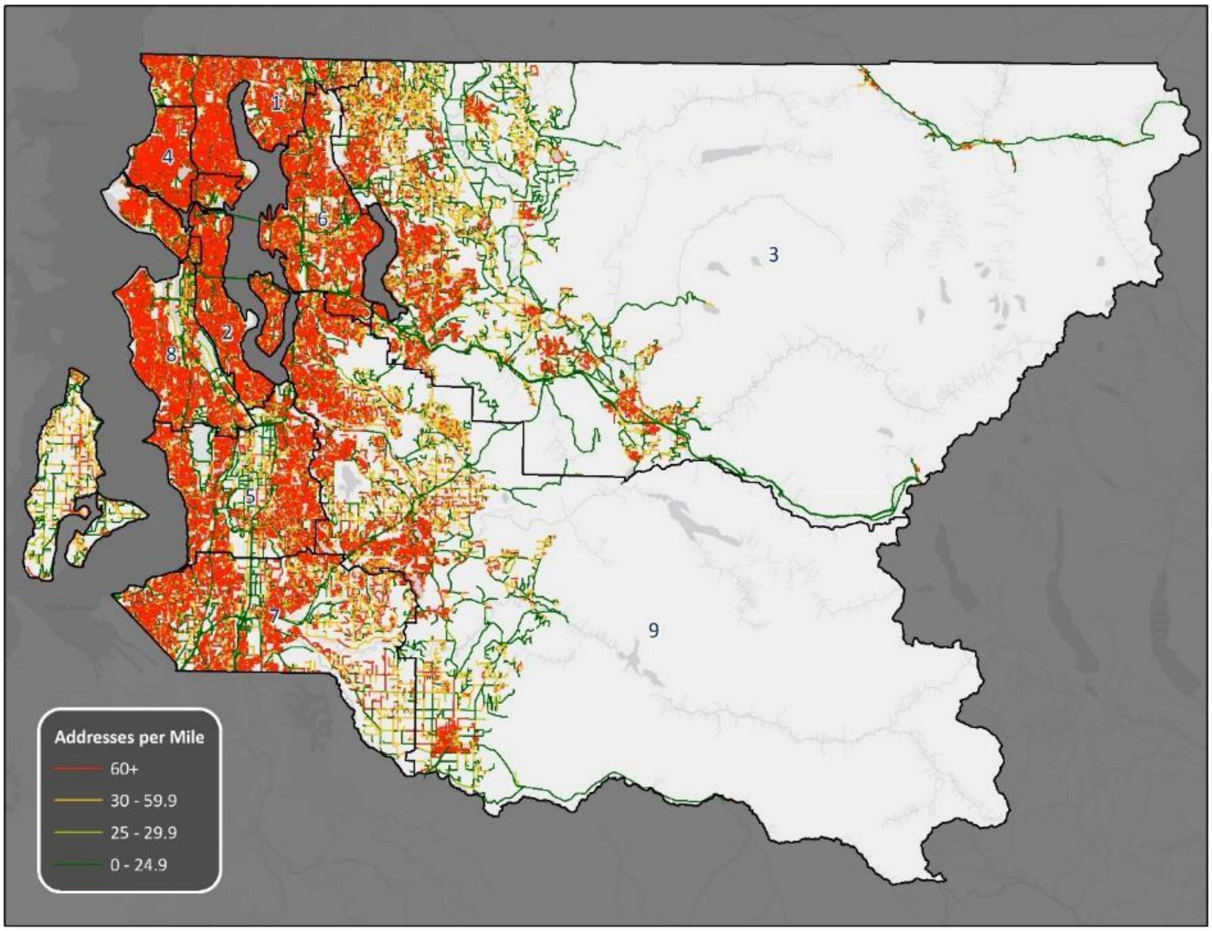
This means that the County's population centers are served, thanks to the County's efforts over time. Where there is population that meets density requirements, Comcast has plant. That does not mean it is affordable or that everyone will choose to buy it or use it—but there is at least one service provider with a network capable of delivering broadband speeds as defined by the federal government.

We performed an analysis to identify population pockets outside of the current franchisee service footprints that might meet density requirements of the franchise agreement—thus requiring Comcast or Wave to provide service. These areas might be business opportunities for Comcast or Wave if they are made aware of the residential density.

(We note that Comcast appears to be making decisions at a local level. In western Massachusetts, Comcast has been willing to work with the state on two types of projects: Areas where there is no service, and towns in rural communities where there is service in population centers but no service in more remote areas. In both cases, Comcast has accepted state funds to expand its service. In contrast, the company is not engaged in the same way in Maryland or Virginia.)

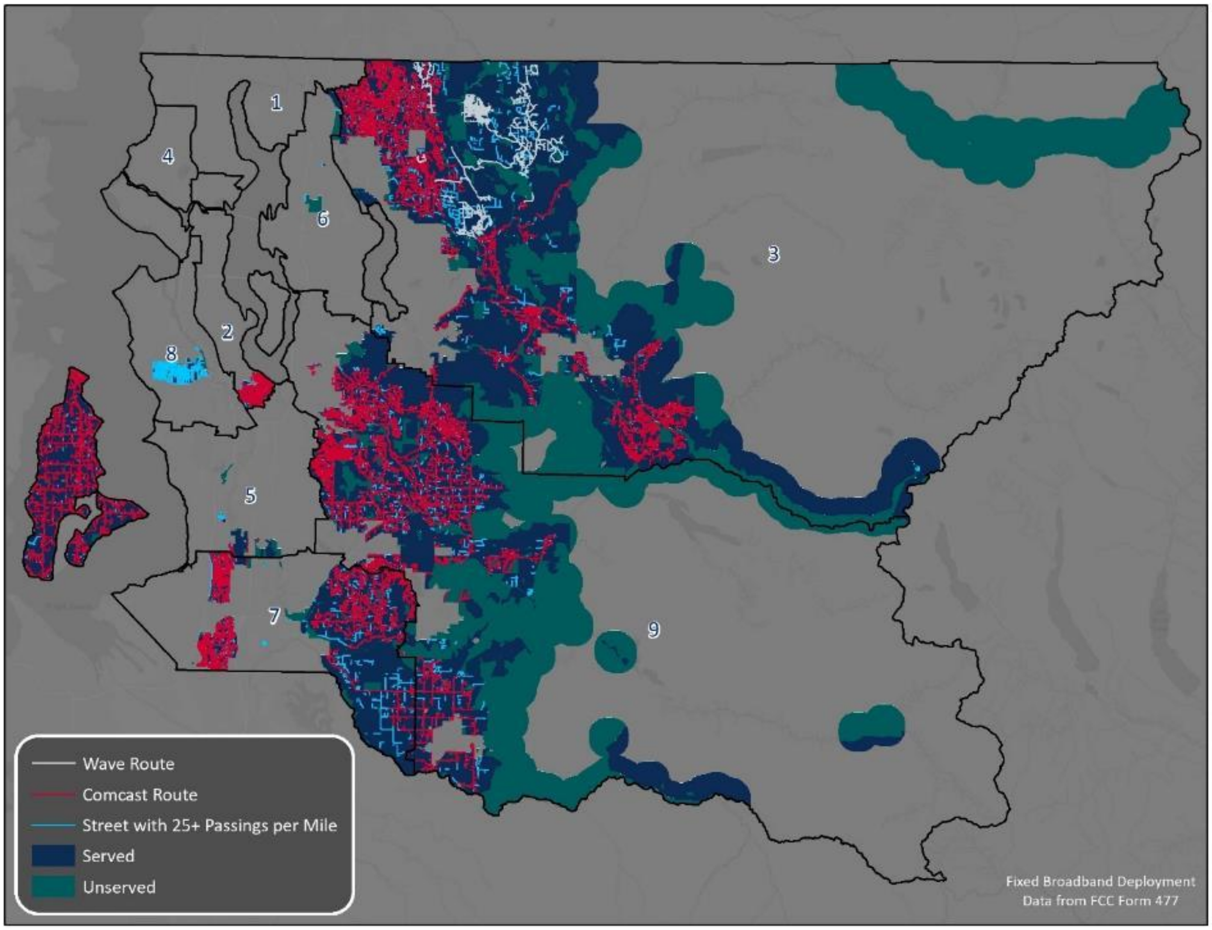
In the figure below, which illustrates the County's population density in terms of addresses per street mile, the dark green lines are streets with fewer than 25 homes per linear mile—the density that tends to be the trigger for franchise obligations.

Figure 53: Addresses per Mile as Illustration of Franchise Agreement Buildout Requirement



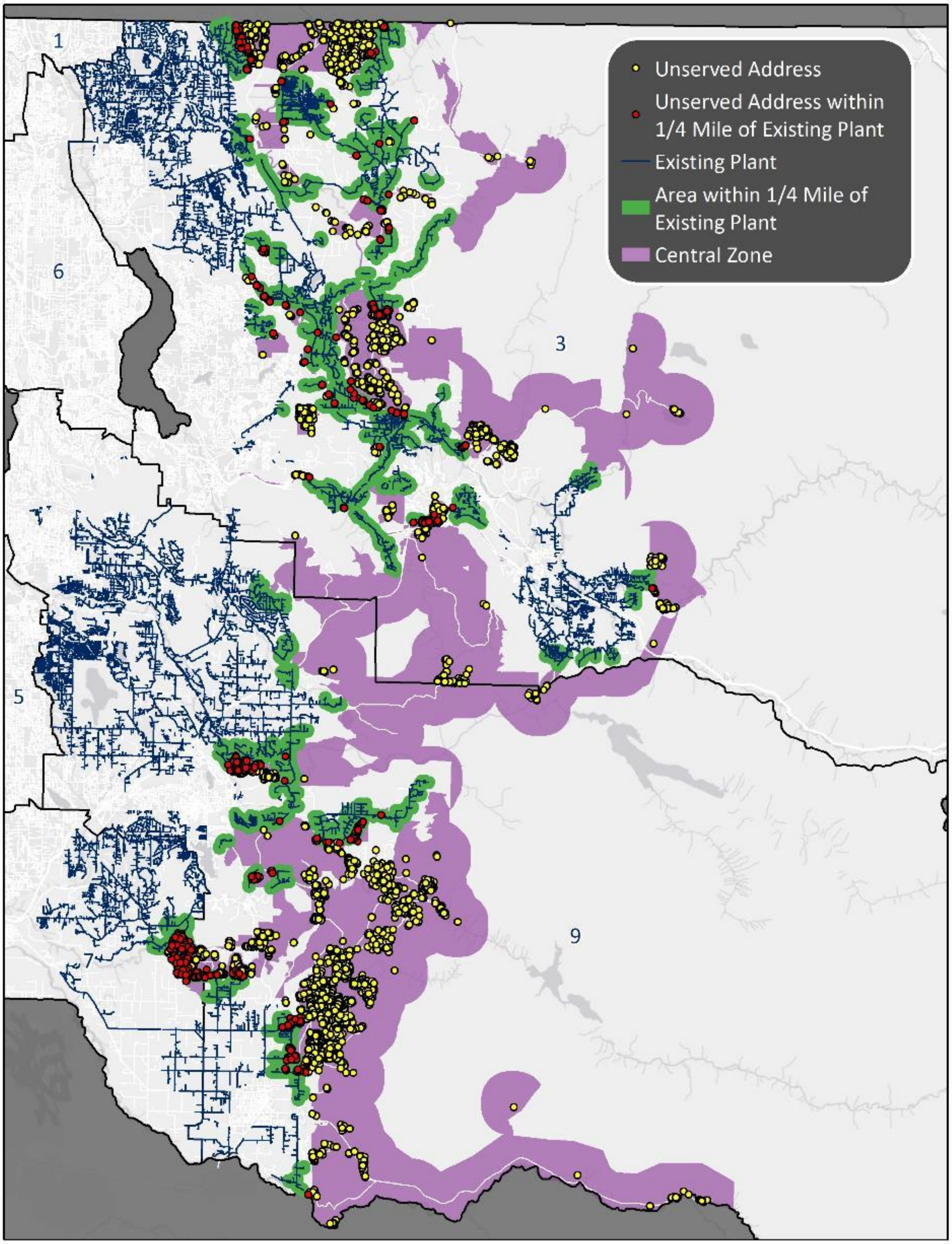
The map below illustrates population density in comparison to our target study areas and outside of the existing Comcast/Wave plant. The areas in white are streets with sufficient population density to merit consideration of (or, potentially, require) cable infrastructure buildout under the County's franchise agreements.

Figure 54: Street Density Outside of Comcast/Wave Franchise Footprint



As we discussed in our fiber infrastructure solution (Section 5.5), our analysis also indicates that a network expansion from the current cable company service areas to one-quarter mile into the unserved areas (Figure 55) would require just 34 miles of network construction. The extensions would provide service to approximately 750 unserved homes and businesses, which is 14 percent of the unserved population of the County. Since the providers have no conduit or aerial strand in the unserved areas, the unit cost would, like the FTTP estimate, be approximately \$100,000 per mile. Based on these assumptions, the total cost of network expansion would be \$3.4 million, or \$4,500 per passing. The costs do not include network electronics or drop installation, which would be required for each new subscriber—but the costs may be lower than what a new FTTP network would cost because the existing providers already have core systems in place.

Figure 55: Unserved Areas Within Close Proximity to Existing Cable Plant



10.2 Recommendation: Support ISPs in applying for federal ReConnect grants

We recommend the County develop a grant collaboration and funding strategy to support private sector ISPs with grant applications for the second round of the USDA RUS's ReConnect program. (See Section 9.1 for more details on the program and eligible portions of the County.)

The County could apply on its own—it is eligible—but we believe that RUS is dubious about any entity that it would consider a start-up, which includes King County, because the County is not in the business of service provision. For that reason, among others, we recommend the County seek to partner with a private sector entity.

Because this program is aimed at rural communities, it is likely that many of the providers that are funded through it will be WISPs. Given this, the County can start now to identify WISPs that it may want to encourage, and even begin the process of outreach.

One significant benefit of this approach is that the federal government will bear the cost and the effort of evaluating grant and loan applications, and then administering and enforcing their requirements. Our recommendation is that the County leverage that federal effort in two ways.

First, we recommend that the County commit funds to provide the matching amount necessary to enable ISPs to apply for the ReConnect program. For example, the grant program will require a 25 percent match to unlock a 75 percent federal award. The County can encourage and incent providers to apply for these grants by committing to pay some or all of the 25 percent match for successful grantees. This commitment will make the grant applications more competitive and viable—and will likely increase the number of applications filed for the County's unserved areas.

Committing to fund the match on any successful application will also enable the County to avoid having to pick and choose among ISPs, as it would effectively be committing to fund all ISPs in the event the ISPs' applications are successful. Given that the federal government will only fund a single project in any given geography—and will very carefully vet those geographies to ensure that the area is indeed unserved—the County has a built-in set of protections against the risk of having to fund too many projects, or projects that are not focused on unserved areas.

The second way we recommend the County leverage the federal effort is to help private ISPs prepare grant and loan applications. As we have learned in our interviews of smaller competitive ISPs in other jurisdictions, they tend not to compete for federal funds because the cost and burden of preparing an application is very high for smaller companies.

Our recommendation is that the County support these ISPs with GIS data, engineering support, business planning help, and other tasks that will be part of preparing a competitive grant application. There is cost to the County associated with this approach, but the payoff could be considerable in terms of leveraging the investment to bring federal funds to the County. Engaging with ISPs in this way will also enable the County to exert leverage to prevent cherry-picking of wealthy residents and the exclusion of lower-income households.

10.3 Recommendation: Develop public-private partnerships for rural infrastructure development

In this model, the County would seek to competitively procure one or more public-private partnerships to address gaps by funding infrastructure in unserved areas that would be owned by the County (for at least some period of time) but deployed and operated by a private partner. This model would enable the County to maintain control and ownership while creating private sector opportunity. This model could also be paired with rural middle-mile fiber and related strategies.[93]

10.4 Recommendation: Develop dig-once policies

At the core of the broadband challenge is the high capital cost of network construction.

"Dig-once" strategies enable local communities to expand their own fiber and conduit assets, as well as those of private providers. Such policies open rights-of-way to fiber/conduit construction when other projects are underway, thus realizing efficiencies in network construction. Such policies also protect roads and sidewalks from life-shortening cuts and minimize disruption from construction. Even if private entities do not take advantage of the opportunity, the locality can use dig-once opportunities to install its own conduit and fiber at a reduced cost compared to standalone construction—which can be leased to private providers in the future.

At the same time, Dig Once is rarely inexpensive—even though it is more cost-effective than standalone construction—and each opportunity must be carefully weighed to determine if it provides sufficient cost savings and is likely to meet some future need.

For these reasons, we recommend that the County adopt an approach to dig-once targeting the following objectives:

- Protecting newly and recently paved roads and sidewalks
- Enhancing the uniformity of construction
- Ensuring efficient, non-duplicative placement of infrastructure in the public right-of-way (PROW)

[93] A sample of current public-private partnerships in the Puget Sound area is included in Appendix D. While all of these are innovative and important, they are different to what we recommend here.

- Reducing overall costs of all underground work in the PROW, both utility- and telecommunications-related, for public and private parties
- Facilitating private communications network deployment by reducing construction costs
- Leveraging construction by third-party entities for the deployment of a public communications network, or deployment of conduit that can be made available to other entities

CTC has surveyed approaches adopted or proposed by other jurisdictions across the country, and we have interviewed representatives of local governments that have adopted dig-once or joint trenching policies to gather information about their outcomes and best practices. We then reviewed the treatment of costs in dig-once scenarios. In many cases, the incremental costs of construction are borne by the jurisdiction. Many policies also provide exceptions or forego the excess conduit construction if the cost-benefit analysis is not reasonable.

Based on our survey and our experience with best practices, we identified three general approaches to dig-once policies.

In the first approach, some local governments require an excavator applying for a permit in the PROW to notify utilities and other relevant entities about the project and invite their participation.

In the second approach, localities with a "shadow conduit" installation policy require the excavator to install excess conduit for future use; depending on the policy, the excavator or the jurisdiction may then lease that excess capacity.

Finally, in the third approach, other localities undertake a longer-term process, coordinating multi-year plans with excavators.

In considering these and other strategies, we recommend that the County take the following steps toward identifying the appropriate dig-once strategy:

- Analyze and prioritize known County projects suitable for additional construction based on a scoring mechanism that weighs estimated costs and potential benefits

- Develop a high-level estimate of the incremental costs for likely dig-once scenarios

- Survey potential dig-once partners to share the County's dig-once objectives and high-level cost models; identify likely geographic areas for future buildout requirements; refine technical specifications for dig-once infrastructure under varying buildout scenarios; and determine suitable parameters for a dig-once process that will encourage private investment in broadband infrastructure.

The primary goal of this planning effort is to ensure that a dig-once strategy can be crafted that is attractive to private service providers—a strategy that results in processes that do not unduly burden construction timelines and that provides infrastructure meeting the technical and operational requirements of the commercial providers. Once the strategic framework is determined, the County can undertake more detailed planning efforts necessary to implement the strategy, including:

- Develop a standard engineering specification for dig-once conduit
- Refine dig-once cost estimates and cost sharing models
- Develop a procedure to systematically track and manage the construction and to create a repository of existing infrastructure

10.4.1 The case for dig-once policies

The construction of fiber optic communications cables is a costly, complex, and time-consuming process. The high cost of construction creates a barrier to entry for potential broadband communications providers.

While aerial construction methods requiring attachments to utility poles is generally less expensive that underground construction, aerial installation has significant drawbacks—including a limit to the quantity of cables and attachments that can be placed on existing utility poles in more crowded areas, and greater exposure to outside conditions.

Underground construction using protective conduit generally provides scalable, flexible, and durable long-term communications infrastructure, but is also typically more expensive than aerial construction. Further, from the City's perspective, cutting roads and sidewalks substantially reduces the lifetime and performance of those surfaces. And each excavation diminishes the space available for future infrastructure.

Accordingly, encouraging or requiring simultaneous underground construction and co-location of broadband infrastructure in the PROW creates benefits for both the City and private sector communications providers.

Dig-once policies reduce the long-term cost of building communications facilities by capitalizing on significant economies of scale through:

1. Coordination of fiber and conduit construction with utility construction and other disruptive activities in the PROW.

2. Construction of spare conduit capacity where multiple service providers or entities may require infrastructure.

These economies exist primarily because fiber optic cables and conduit are relatively inexpensive, often contributing to less than one-quarter of the total cost of new construction. While material costs typically fall well below $40,000 per mile (even for large cables containing hundreds of fiber strands), labor, permitting, and engineering costs commonly drive the total price toward $200,000 per mile if conducted as a standalone project.

To put the cost savings in perspective, consider two examples. If fiber construction is coordinated with a major road or utility project that is already disrupting the PROW in a rural area, the cost of constructing the fiber, communications conduit, and other materials can be as low as $10,000 per mile. However, if fiber construction is completed as part of a separate standalone project, the cost of constructing fiber and communications conduit typically range from $95,000 to $200,000 per mile, and even higher in complex urban environments.

Another motivation for coordinating construction is to take the opportunity to build multiple conduit in a closely packed bank. Banks of conduit constructed simultaneously allow a single excavation to place several conduit in the physical space usually used by one or two. Conversely, multiple conduit installed at different times must be physically spaced, often by several feet, to prevent damage to one while installing the next. Once the PROW becomes crowded, the choices of construction methods are reduced, leaving only less desirable methods and more-costly locations for construction of additional infrastructure.

The key benefits achieved through coordinated construction efforts include reduced:

- Labor and material costs, through reduced crew mobilization expenses and larger bulk material purchases
- Trenching or boring costs when coordination enables lower-cost methods (e.g., trenching as opposed to boring) or allows multiple entities to share a common trench or bore for their independent purposes
- Traffic control and safety personnel costs, particularly when constructing along roadways that require lane closures
- Engineering and survey costs associated with locating existing utilities and specifying the placement of new facilities
- Engineering and survey costs associated with environmental impact studies and approvals
- Lease fees for access to private easements, such as those owned by electric utilities
- Railroad crossing permit fees and engineering

- Restoration to the PROW or roadway, particularly in conjunction with roadway improvements
- Bridge crossing permit fees and engineering

10.4.2 Dig-once policies across the country

A number of cities and counties across the country have developed and implemented dig-once policies. The primary motivation for municipalities has been to preserve the ROW and improve the telecommunications competition in the market. Within King County, the City of Bellevue does not have a formal dig-once requirement but does condition development projects on the excavator providing the city with conduit through the length of the frontage and also possible street lighting and/or signal upgrades. Every transportation project that constructs on the sidewalk is required to install conduit.

The following table summarizes dig-once policies adopted by communities around the country.

Table 27: Sample Dig-Once Policies

Locality	Summary	Costs
Boston	• Shadow conduit installation • Conduit system not standardized • Expensive for potential users of conduit	One time cost: present value of construction + $5/foot/year
Berkeley	• Excess capacity required to be made available for leasing	Determined by lessor of excess capacity
Bellevue	• Additional conduit during some capital improvement and development projects • Transportation projects required to install conduit	Funded from city budget
Gonzales, CA	• Shadow conduit installation • Standards developed for conduit • Decision to install conduit only if the cost-benefit analysis is favorable	Public Works budget
Santa Cruz, CA	• Joint build based on costs • Optional bids for extra ducts	Joint build costs and/or county budget

Locality	Summary	Costs
	• City opted not to build conduit because of high incremental conduit cost in the first project attempted under the policy	
San Francisco	• Shadow conduit installation and conduit available for leasing • Project prioritization based on scoring mechanism	Incremental costs paid by city, priced at $20.07 per foot (shared trench) and $29.14 per foot (offset trench)
San Benito County, CA	• Conduit to be constructed as part of county road projects • Coordination with county fiber build	County capital program funds
Arlington County, VA	• Obtained conduit and fiber as part of an agreement for an electric grid upgrade project in the PROW by investor-owned electric utility • County developed specifications and inspected installation	County funds, $392,082 for 21,700 feet

10.4.3 Recommendations for enacting a dig-once policy

Given the strong business case for dig-once, we recommend that the County consider candidate opportunities and solicit input from private providers. While considering enacting a dig-once policy, we recommend that the County identify and prioritize known County projects as the basis for further analysis of dig-once opportunities; develop high-level cost estimates and standard specifications for dig-once construction, and survey potential dig-once partners to develop requirements for dig-once processes and further refine technical specifications.

The following is a recommended process for evaluating dig-once, based on best practices established around the country and internationally.

<u>First, analyze and prioritize County construction projects</u>. The cost of installing conduit is drastically reduced when a trench is already dug. However, the cost is still significant, and the County will need to prioritize projects that achieve the most value for the money spent, and maximize the likelihood of the conduit being used. Because of the cost of conduit installation, even in a dig-once opportunity, it is necessary to prioritize construction to ensure that 1)

County priorities are identified when dig-once opportunities emerge, and 2) resources are not wasted in building conduit that is unlikely to be used.

Second, estimate incremental costs. To solicit feedback from candidate dig-once participants, the County should estimate incremental dig-once planning and construction costs for varying scenarios aligned with its priority projects.

For cost estimation purposes, the incremental cost is the cost of additional materials (conduit, vaults, location tape, building materials) and labor (incremental engineering, incremental design, placement and assembly of incremental conduit, placement of incremental vaults, interconnection, testing, and documentation).

The cost does not have to include roadway or sidewalk restoration or paving (which we assume to be part of the original project) beyond that which is specifically required for the placement of vaults for County communications conduit within paved or concrete surfaces outside of the original project boundaries.

Where trenches are joint, the cost does not include trenching or backfilling. Where the dig-once trench is separate from the original trench, the incremental cost includes trenching and backfill, but does not include repaving or restoring the road surface (again, assumed to be part of the original project).

Average costs may be derived based on an ensemble of contractor pricing schedules. As the County gains experience by participating in projects, it will develop a more accurate sense of cost.

Third, solicit provider input on specifications and procedures. We recommend that the County survey potential dig-once partners to share the County's dig-once objectives and high-level cost models, and to solicit input related to the technical and procedural aspects of a dig-once program. Input from private providers required to develop a successful program is likely to include:

- Identification of priority buildout areas / routes for near-term and long-term expansion plans;

- Technical parameters required by each provider, such as required size of conduits and spacing of conduit access points (vaults, handholes, etc.); and

- Operational parameters acceptable to each provider, such as requirements for shared versus dedicated infrastructure (vaults, conduit, fiber strands, etc.); timeframes for accessing shared infrastructure under various scenarios (routine maintenance and service activations versus emergency repairs); ability to forecast and willingness to share construction plans at various planning stages; and timeframes for County review of dig-once construction opportunities

Fourth, develop a standard specification and refine cost estimates. Based on the provider input, the County can then create a set of standard specifications and refined cost estimates for dig-once opportunities. The following factors may be considered in developing a conduit specification:

1. Capacity—sufficient conduit needs to be installed, and that conduit needs to have sufficient internal diameter, to accommodate future users' cables and to be segmented to enable conduit to be shared or cables added at a future date
2. Segmentation—users need to have the appropriate level of separation from each other for commercial, security, or operational reasons
3. Access—vaults and handholes need to be placed to provide access to conduit and the ability to pull fiber. Vaults need to be spaced to minimize the cost of extending conduit to buildings and other facilities that may be served by fiber
4. Costs—materials beyond those that are likely to be needed will add cost, as will the incremental labor to construct them. Beyond a certain point, trenches need to be widened or deepened to accommodate conduit
5. Robustness—the materials, construction standards, and placement need to reasonably protect the users' fiber, and not unduly complicate maintenance and repairs
6. Architecture—sweeps, bend radius, and vault sizes need to be appropriate for all potential sizes of fiber

Cost estimates should be refined based on final standard specifications.

Fifth, develop a procedure to track and manage infrastructure. As part of this effort, the County will need a systematic way to track the planned, ongoing, and completed construction in a timely way (potentially using the County's asset management system) and prioritizing and selecting projects for County participation. The County will also need a way to quickly notify potentially interested parties and to coordinate participation with excavators. The impact on the excavator can be minimized through the use of a well-thought-out process that minimizes delays.

11 Recommendations for Strategies to Expand Broadband Access to Underserved Populations

11.1 Recommendation: Connect County fiber to public housing and deliver free broadband service to residents

Based on the high concentration of underserved persons living in public housing facilities, we explored the feasibility of the County, in collaboration with the King County Housing Authority (KCHA), providing broadband internet service to residents in some or all KCHA buildings using cost-effective Wi-Fi technology.

PMR's survey data illustrate the opportunity to meet the needs of underserved residents who live in KCHA buildings. Almost one-fourth of residents living in public housing lack internet access where they live—as compared to only 4 percent of respondents for the County as a whole. Of those with internet access, only 55 percent of residents living in public housing reported their access as being "completely/mostly" adequate—as compared to 76 percent of County residents as a whole. And in terms of broadband, only 64 percent of residents living in public housing have a broadband subscription, as compared to 92 percent of County residents as a whole.

Our engineering team developed a model for in-building provision of free, best-effort Wi-Fi at KCHA locations. In addition, we developed engineering and cost estimates for two approaches to backhaul connectivity to the KCHA properties: 1) constructing new fiber, to include use of fiber to be constructed as part of the EasTrail rail corridor initiative, and2) using commercial managed services. Notably, County I-Net fiber is not available for these purposes given contractual restrictions on its use (i.e., I-Net fiber can only be used by government, non-profits, and educational organizations).

We developed unit costs for the indoor wiring and network electronics necessary to serve the KCHA locations. For the sake of comparison, installation at a two-story building with eight housing units would cost $15,000, or $3,000 per unit—whereas a larger building with six floors and 80 units would cost $58,500, or $731 per unit. The larger the building, the lower the costs of installation are per housing unit.

We estimate the capital cost of the fiber construction approach to be $49 million, corresponding to approximately $7,400 per unit. Over a period of 10 years the fiber construction and operations would cost approximately $67 million, while managed services would cost approximately $29 million.

11.1.1 Understanding the opportunity

As PMR's analysis has established, the County has a critical need and challenges around broadband affordability and access. The high concentration of lower-income members of the community living in KCHA's approximately 563 buildings (comprising about 6,600 housing units) means that the County's investment would have a significant impact on addressing underserved residents' needs.

Indeed, the population density of some KCHA buildings represents an opportunity to leverage County communications infrastructure to deliver fixed broadband to some of the County's most vulnerable residents with much less investment per home than would be required in less densely populated areas of the community.

We anticipate that KCHA would be a willing partner in any initiative the County spearheads to bring more cost-effective broadband options to its residents. Because KCHA owns these properties, the deployment complexity and costs would likely be reduced in relation to access to critical infrastructure required in any broadband deployment scenario, such as existing underground conduit, building rooftops, and private easements.

This recommendation is not just about seizing an opportunity to deliver cost-effective service—it is a policy-driven approach to ensuring that low-income, underserved residents have access to fixed broadband in their homes, either as their only service or to complement their smartphones. (It is also an important complement to the recommendation in Section 11.1 that the County develop a mobile service offering for those residents.)

The Pew Research Center concluded that 26 percent of U.S. households earning less than $30,000 are "smartphone-dependent" internet users[94] who own a smartphone but do not have a home broadband connection. PMR survey results indicate that 53 percent of King County residents with annual income less than $25,000 use a smartphone as their primary device to access the internet. These citizens must use smartphones for tasks that typically are completed more easily with larger screens (like completing homework or applying for a job). It is no surprise, then, that Americans who can afford to purchase both fixed and mobile broadband service tend to buy both.

In the sections below, we first present an engineering approach for a scenario by which the County or its contactors—in partnership with KCHA—would deliver broadband service. We then compare that approach to the estimated cost of purchasing managed services to connect

[94] Monica Anderson and Madhumitha Kumar, "Digital divide persists even as lower-income Americans make gains in tech adoption," May 7, 2019, https://www.pewresearch.org/fact-tank/2019/05/07/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/ (accessed May 2019). Note, too, that the number of people who are "smartphone dependent" has increased by 14 percent since 2013.

the properties. The fiber construction approach is just one potential way to address these unserved residents' needs—but from an infrastructure standpoint, in terms of having an impact on the challenges around the County's underserved populations, this is the most direct and efficient means of those we considered and that have been tested elsewhere.

11.1.2 The County's existing and planned fiber will support the technical approach to serving public housing buildings

CTC worked with the County staff to identify any County-owned fiber that could be leveraged to support a buildout to public housing locations. The County did not feel confident in the usability of its existing fiber due to the use restrictions placed on those assets by the cable television franchise agreements and similar arrangements under which access to the fiber was acquired. However, the County is working on a sperate initiative to place 28 miles of new fiber along the EasTrail corridor from Renton to the Snohomish County border. The fiber placed along this route is specifically intended to have no restrictions on use and plenty of capacity for County use, allowing the County to leverage the asset for just this sort of innovative application.[95]

Figure 56 and Figure 57 illustrate the locations of KCHA's properties by city[96] and Council District—and their proximity to the planned EasTrail fiber.

[95] The initiative would leverage County-owned fiber infrastructure to the extent possible, but would be logically separate from all internal County services. Similarly, the wireless systems supporting residents would also be physically separate from all internal County Wi-Fi systems.

[96] During our discussions with the City of Bellevue, we learned that the City is already working on a public housing initiative to bring internet access to residents. Therefore we did not include the KCHA sites in Bellevue in this plan.

Figure 56: KCHA Properties by City

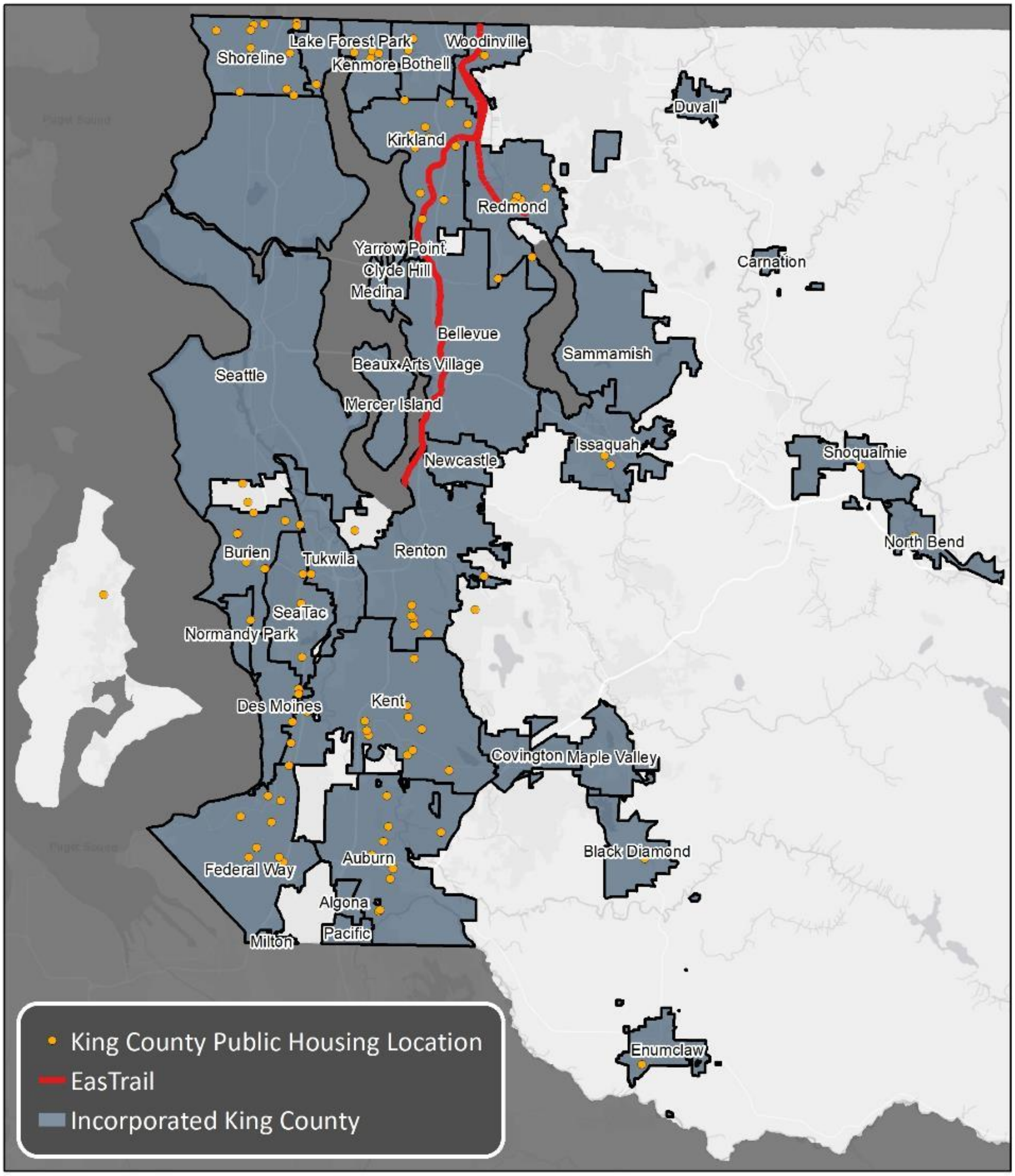
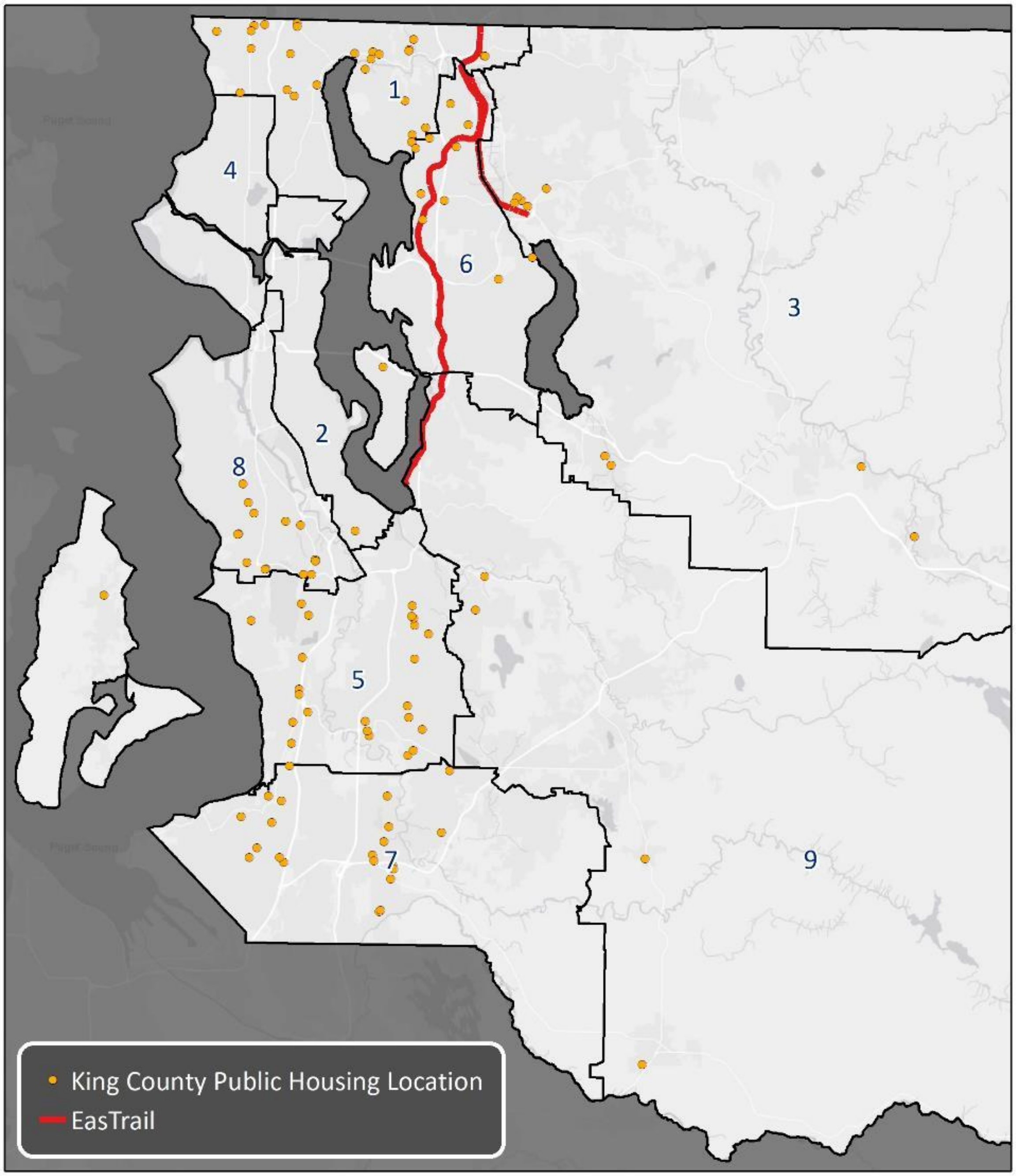


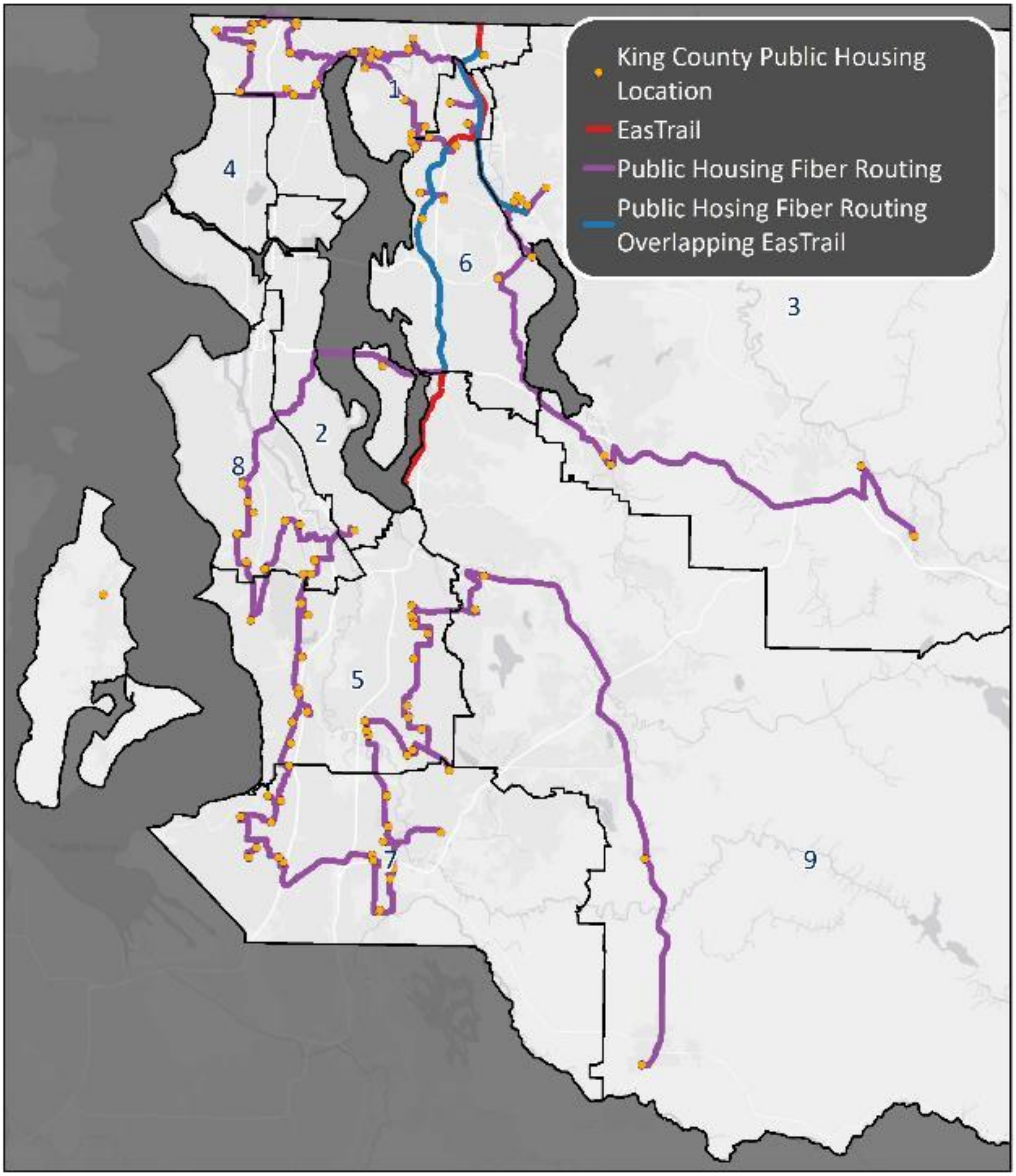
Figure 57: KCHA Properties by District



11.1.3 Connecting KCHA's properties would require 187 miles of new fiber

We estimate a total of 187 miles of new fiber would be required to construct fiber lateral connections from the County's existing and planned fiber to reach the 563 buildings identified by KCHA for this analysis. (The buildings in the City of Bellevue have been removed because the City is working on its own public housing broadband initiative.) Candidate fiber routes based on the shortest, most likely routes and currently available County fiber maps are shown in Figure 58.

Figure 58: Candidate Fiber Laterals for Public Housing Connectivity

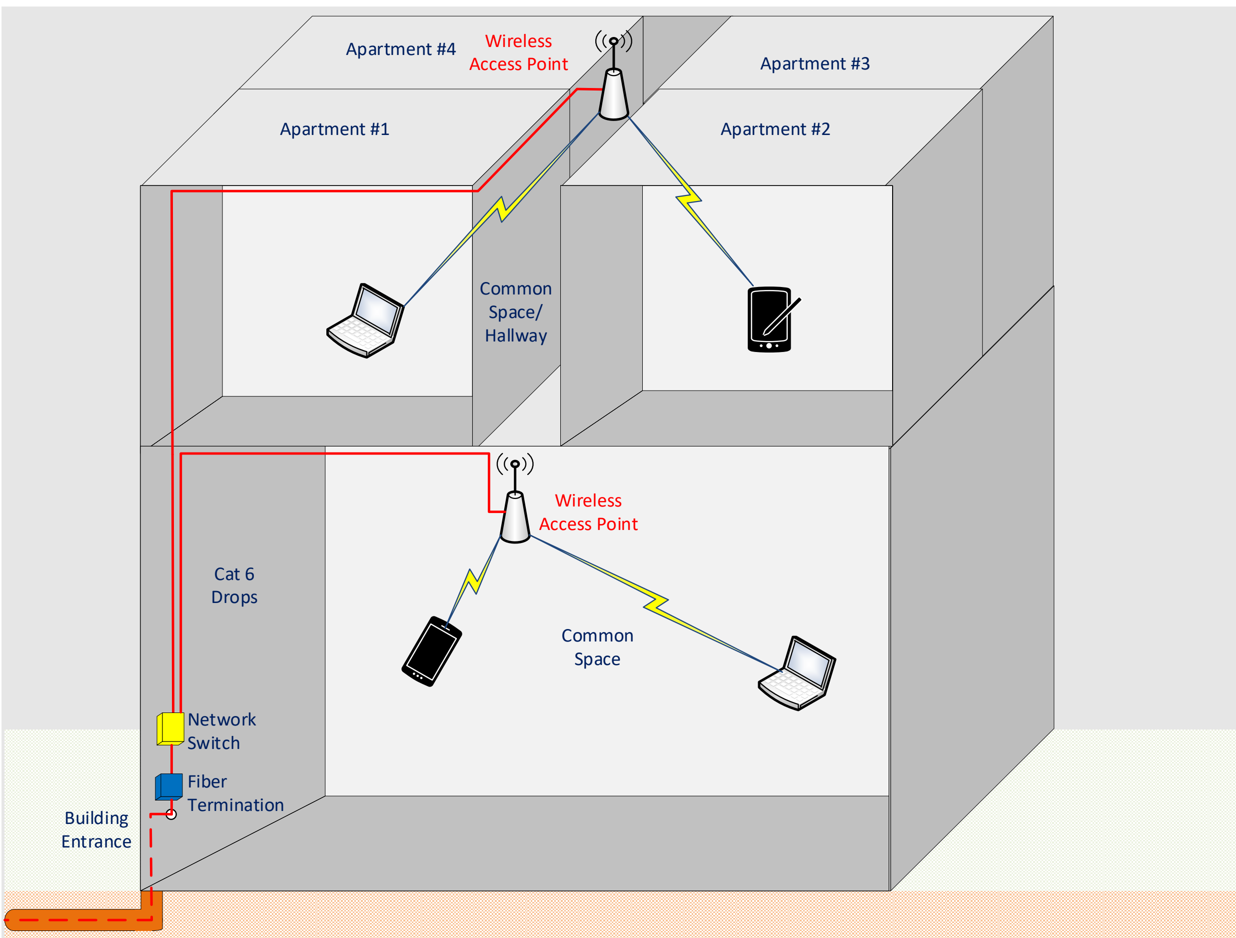


The candidate fiber network connects all the public housing sites except one on Vashon Island, where an alternative approach to network connectivity would be required due to the high cost and limitations of constructing fiber to the island.

Note that many of the public housing facilities are clustered together with several buildings located on the same block or parcel of land. The clustering of public housing buildings decreases the amount of fiber construction needed.

Additional infrastructure costs would be incurred for local wireless and wireline distribution of connectivity throughout these public housing buildings. Wired connections would be required to wireless access points (WAP) from common demarcation points in each building. WAPs would be installed in common spaces (such as wiring closets, hallways, and community rooms) on each floor of each building. We estimate approximately one WAP would be required per four residential units, on average (Figure 59).

Figure 59: Public Housing Wi-Fi Access Layer Concept



Our candidate design includes routers for terminating internet connectivity from internet service providers. We anticipate that a free service would be provided on a “best effort” basis, without particular service level guarantees, but the program would still necessitate certain operations support to deliver a reliable service and ensure the overall technical success of the initiative. This includes central monitoring of the network to track network performance and to receive notifications of hardware failures. Numerous options exist, from commercial service providers offering cloud-based monitoring and hardware support, to the addition of internal County technical support staffing and the deployment of on-premises management systems.

The scale of the deployment will determine the optimal operating model. As the network scale grows, the opportunity to augment internal staff with technical support capabilities becomes more cost-effective, and may offer the added benefit of providing additional capacity to support internal County services.

11.1.4 The County's costs will include construction and ongoing operations

Providing free service to public housing residents requires three primary capital cost components:

1. Constructing outside fiber optics to the public housing facilities from the existing County fiber, where available, to a termination point in each building
2. Constructing indoor wiring to create a network path from the fiber termination to WAPs
3. Network electronics, including WAPs and network switches

To reach the 563 buildings, we estimate a total capital cost of $37 million for 185 miles of new fiber construction to connect the complexes to existing County fiber at a cost of $200,000 per mile. This does not include costs for local distribution cabling infrastructure and equipment within each of the public housing complexes or for the core network electronics. Table 28 and Table 29 itemize the estimated costs for fiber construction by city and council district.

Table 28: Fiber Construction Costs per City

City	Buildings	Miles of Fiber Construction	Fiber Construction Costs
Auburn	53	14.8	$2,960,000
Black Diamond	1	2.7	$540,000
Bothell	3	4.3	$860,000
Burien	6	9.8	$1,960,000
Des Moines	7	2.8	$560,000
Enumclaw	2	2.7	$540,000
Federal Way	84	12.6	$2,520,000
Issaquah	2	6.8	$1,360,000
Kenmore	7	5.7	$1,140,000
Kent	108	15.9	$3,180,000
Kirkland	90	8.6	$1,720,000
Lake Forest Park	6	3.8	$760,000

City	Buildings	Miles of Fiber Construction	Fiber Construction Costs
Mercer Island	1	3.1	$620,000
North Bend	1	1.5	$300,000
Redmond	23	6.4	$1,280,000
Renton	36	6.7	$1,340,000
SeaTac	6	5.9	$1,180,000
Shoreline	65	13.5	$2,700,000
Snoqualmie	8	2.3	$460,000
Tukwila	12	5.3	$1,060,000
Woodinville	13	1.4	$280,000
Other Areas of King County	30	48.5	$9,700,000
Total	**563**	**385**	**$37 million**

Table 29: Fiber Construction Costs per District

Council District	Buildings	Fiber Construction Miles	Fiber Construction Costs
1	121	30.6	$6,120,000
2	22	4.8	$960,000
3	33	25.6	$5,120,000
5	157	32.2	$6,440,000
6	63	19.0	$3,800,000
7	138	27.7	$5,540,000
8	21	18.1	$3,620,000
9	8	27.3	$5,460,000
Total	**563**	**185**	**$37 million**

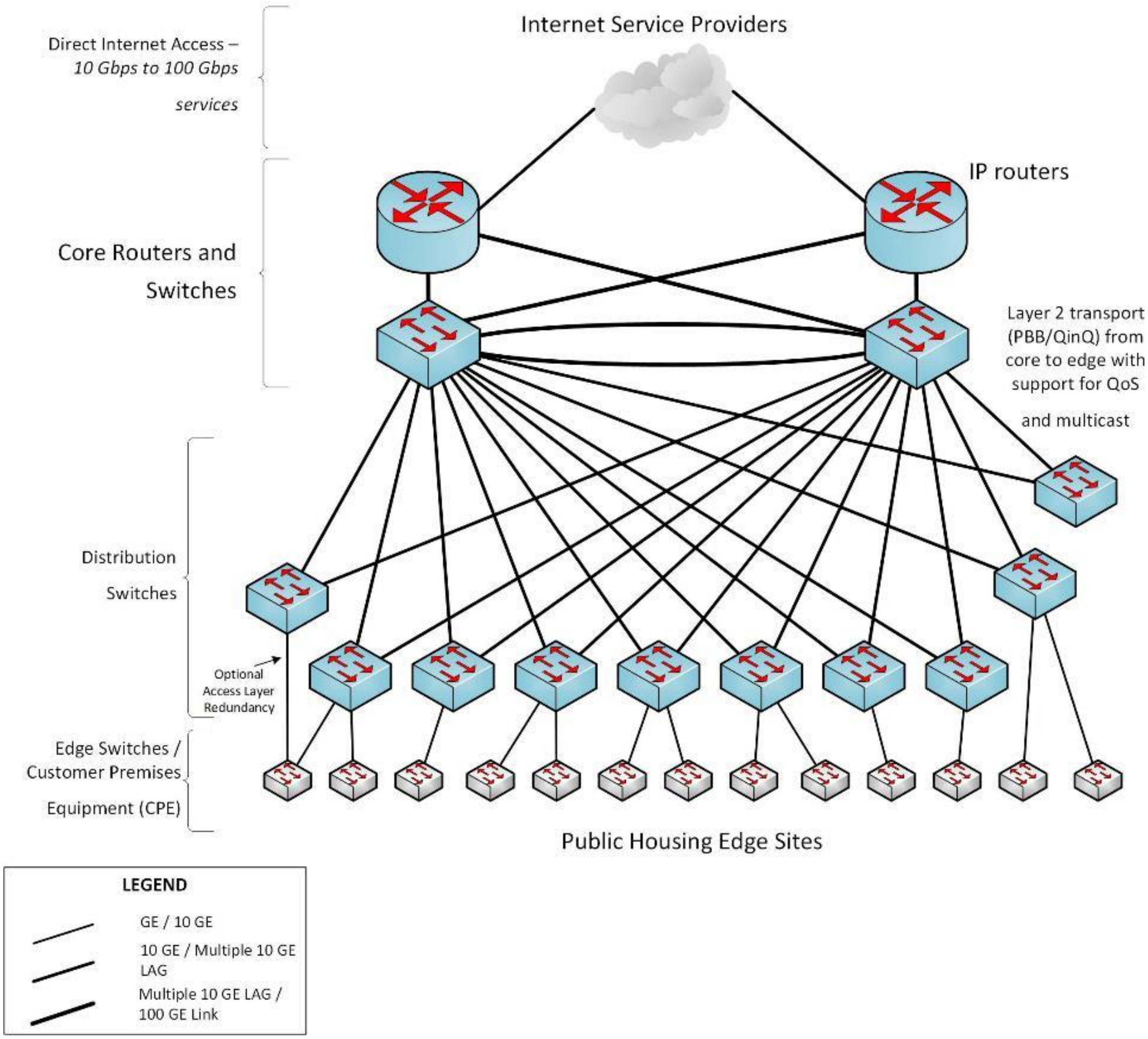
We estimate that the cost of maintaining the fiber would be 1 percent annually of the total construction costs or $370,000. This would include any required fiber adds, moves, and changes.

For network electronics we envision using the fiber optics to create a robust network core capable of serving the internet access needs of the public housing community as well as other public broadband initiatives that the County pursues. We envision a dual core network with redundant routers at both locations. The core location should be connected in a redundant ring for network reliability. Each core should have a multi-gigabit connection to the internet.

To increase redundancy and reduce the fiber counts needed, we recommend that the network have aggregation hubs that connect back to both core sites. The hubs will house distribution switches that aggregate the connections from the public housing facilities back to the core. Redundant core connections will allow the network to self-heal in the event of a core outage. We estimate a network of this size would have approximately 10 hubs distributed throughout the County.

The network should utilize carrier-grade Layer 2 transport technologies (e.g., PBB, Q-in-Q, VPLS, etc.) to securely segment traffic between customers so that each can configure its own routing, IP addressing, and VLANs independently and without coordination from KCIT. The network should not alter or remove any Layer 2 or Layer 3 data carried between public housing edge sites and the internet. Furthermore, the network should enforce Committed Information Rates (CIR) of any level up to the full provisioned capacity for all traffic, or more granularly for specific applications marked by VLAN tag or physical port at the customer edge. Figure 60 is a diagram of a conceptual broadband network to support the public housing facilities.

Figure 60: Public Housing Conceptual Network



For the core network electronics and installation, we estimate a cost of $2,350,000. We estimate that hardware maintenance contracts on the network electronics to be 10 percent of the total network electronics costs annually, or $235,000.

For indoor wiring and network electronics we developed unit costs to be applied to the proposed Wi-Fi deployments (Table 30).

Table 30: Unit Costs for Public Housing Wi-Fi Service

Item	Description	Unit Cost	Unit
Building Entrance	Conduit and fiber into the building, internal wiring to telecommunication closet, fiber splicing, and fiber termination and testing.	$5,000	Per Building
Fiber Network Edge Switch	Edge switch to connect to the fiber optic network and backbone electronics such as the Ciena 3928 switch. Includes installation and configuration.	$3,000	Per Building
Fiber Network Aggregation Switch	Aggregates connections from the various floors and switches to the fiber network edge switch. Required where there are more than four switches. Such as the Meraki MS410-16. Includes SFPs, installation, and configuration.	$10,000	Each
Riser Cables	Pull fiber through existing conduit between telecommunications closets on each floor. Includes fiber optic splicing, termination, and testing.	$1,000	Per Floor
Switch	8-port POE layer 2 switch such as the Cisco C3560CX-8PC. Includes SFPs.	$1,750	Each
Wireless Access Point	802.11ac-compatible WAP using 4x4 MU-MIMO antennas at 5 GHz and 2x2 MIMO at 2.4 GHz. POE-powered. Including mounting hardware. Such as the Ubiquiti UAP-nanoHD.	$250	Per Four Units
Wireless Installation	Includes Cat 6 wiring to the access point with cabling raceways. Access point mounting, configuration, and integration with the network monitoring system.	$1,000	Per Access Point

For example a two-story building with eight housing units would cost $15,000, or $3,000 per unit—whereas a larger building with six floors and 80 units would cost $58,500, or $731 per unit. The larger the building, the lower the costs of installation are per housing unit. Table 31 and Table 32 itemize the estimated costs by city and Council District.

Table 31: Inside Wiring and Electronics Costs by City

City	Buildings	Units	Inside Wiring and Electronics Costs
Auburn	53	454	$820,000
Black Diamond	1	31	$20,000
Bothell	3	138	$90,000
Burien	6	539	$300,000
Des Moines	7	45	$130,000
Enumclaw	2	84	$50,000
Federal Way	84	754	$1,300,000
Issaquah	2	165	$100,000
Kenmore	7	71	$110,000
Kent	108	742	$1,500,000
Kirkland	90	555	$1,330,000
Lake Forest Park	6	107	$110,000
Mercer Island	1	30	$30,000
North Bend	1	20	$20,000
Redmond	23	174	$360,000
Renton	36	239	$490,000
SeaTac	6	386	$360,000
Shoreline	65	1,491	$1,300,000
Snoqualmie	8	31	$140,000
Tukwila	12	258	$260,000
Woodinville	13	61	$190,000
Unincorporated King County	30	292	$480,000
Total	**563**	**6,667**	**$9.4 million**

Table 32: Inside Wiring and Electronics Costs by District

Council District	Buildings	Units	Inside Wiring and Electronics Costs
1	121	1734	$2,250,000
2	22	88	$300,000
3	33	348	$580,000
5	157	1735	$2,450,000
6	63	434	$950,000
7	138	1306	$2,140,000
8	21	718	$560,000
9	8	304	$210,000
Total	**563**	**6,667**	**$9.4 million**

We estimate the complete capital costs for a deployment to the 563 public housing buildings to be $49 million, or an average cost of $7,400 per unit. This includes all indoor cabling infrastructure and Wi-Fi equipment to serve the approximately 6,600 housing units. Table 33 summarizes the total capital costs for providing wireless access at the public housing facilities.

Table 33: Total Costs for Providing Wireless at Public Housing Facilities

Description	Subtotal
Core Network Costs	$2,350,000
Outside Plant Construction to Housing Sites	$37,400,000
Inside Wiring and Edge Electronics	$9,450,000
Total	**$49,200,000**
Units	6,660
Cost per Unit	**$7,400**

We estimate operating expenses (comprising hardware maintenance, internet capacity, and network monitoring) at a total monthly cost of approximately $2.50 per residential unit, or approximately $200,000 annually. This is applicable to both the fiber model and managed service model discussed below. It does not include maintenance of core network electronics, as these were addressed separately as part of the core network electronics operations.

We also estimate it will take the equivalent of two full-time employees to manage the public housing broadband network. The personnel would oversee the network, manage the contractors, review network performance, and handle issues relating to the service from customers.

Alternatively, if the County chose not to construct fiber to each public housing facility, the County could lease commercial services to provide internet access to the public housing units. We estimated that buildings having 10 or fewer units (a total of 457 buildings) could be served with a cable modem service costing $50 per month. An area of risk would be if Comcast and Wave would not allow the cable modem service to be used for providing public housing wireless broadband and for any services the County partners with such as an MVNO. More expensive internet access services would be required.

Buildings with more than 10 units (a total of 106 buildings) would require a fiber optic service with an estimated cost of $750 per month. Using these costs, we estimate that the cost of leasing services would be approximately $61,000 per month.

A leased circuit architecture would connect the inside wiring and networks electronics to a leased service device at each facility that would provide direct internet access to the customers. This architecture would eliminate the need for fiber construction or core electronics as they would be included in the leased circuits. The leased circuit network would be managed by a cloud-based Wi-Fi management system. The cloud-based service would monitor the devices and the network traffic in the public housing facilities.

If we compare the technical costs of the two models over a period of 10 years we can get a sense of the total cost of the two networking options. Table 34 outlines the two technical costs over 10 years.

Table 34: 10-Year Technical Cost Comparison

Costs	Fiber Construction Model	Leased Circuit Model
Core Network Electronics *(Including Hardware Maintenance)*	$4,700,000	NA
Fiber Construction	$37,400,000	NA
Leased Circuit Costs	NA	$7,368,000
Inside Wiring and Network Electronics	$15,526,000	$15,526,000
Wireless Maintenance and Customer Support	$2,000,000	$2,000,000
Fiber Maintenance	$3,740,000	NA
Network Staffing (2 FTE at $200,000)	$4,000,000	$4,000,000
Total 10-Year Cost	$67,366,000	$28,894,000
Total 10-Year Cost per Unit	$10,100	$4,300

While the leased-circuit model is far less expensive than the fiber network, it does not provide the capacity, visibility, and scalability of the fiber optic network. The capacity of the leased network is limited to supporting just the wireless broadband initiatives. Other initiatives (such as the County contracting with an MVNO or KCHA implementing advanced building access control or video surveillance) may not be supported by these leased circuits at their intended capacities.

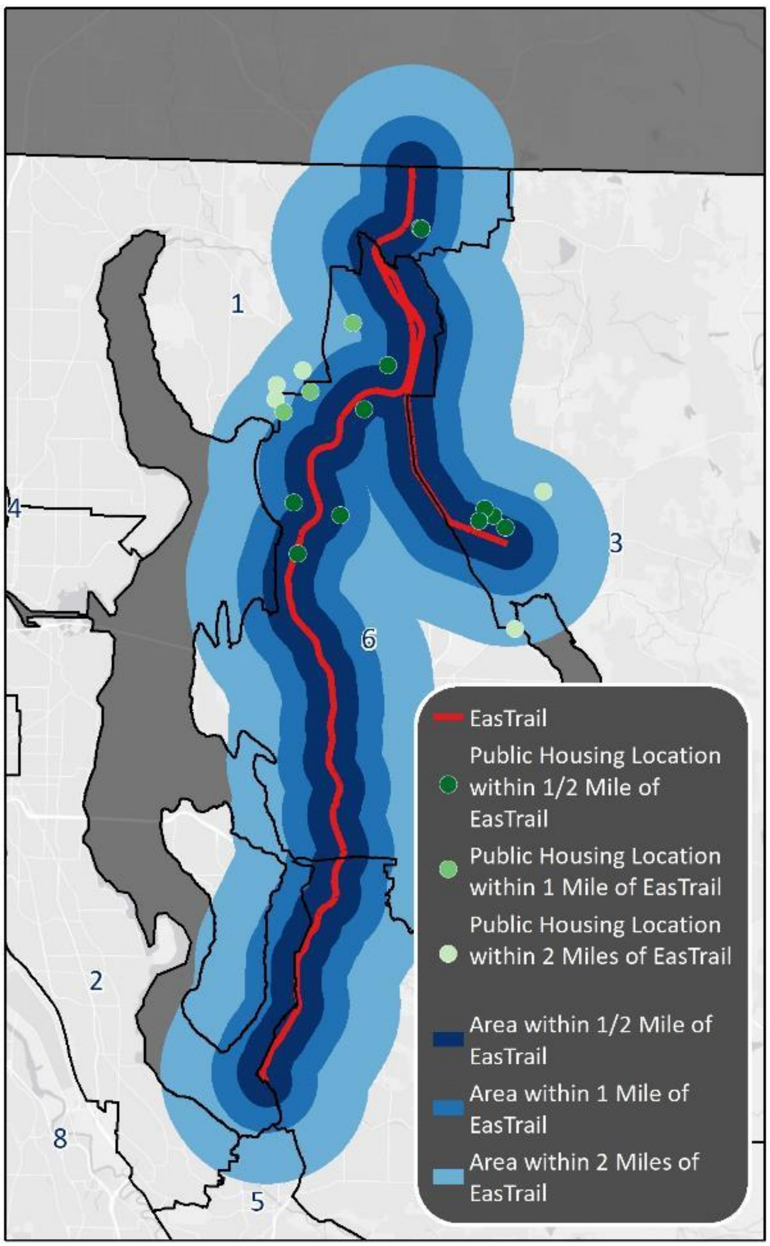
The leased circuits also do not provide any visibility into the transport of network traffic over the network. The County would be unaware of network issues happening on the transport network that may be affecting the user's broadband experience. There is also no visibility into single points of failure along that transport that could impact broadband services in the event of a failure.

As the wireless broadband demand grows, the County will need to purchase higher-speed and higher-cost leased services, whereas a fiber optic network is built to support demand many years into the future. (And with fiber, if certain sites required more bandwidth, the speed of the link to any public housing facility could be upgraded by merely changing the network optics on each end of the fiber optic link at a relatively low cost.)

11.1.5 KCHA properties in close proximity to EasTrail fiber could be connected at much lower cost per unit

To limit capital expenditures of fiber construction and the time it takes to construct fiber, the County could leverage the EasTrail fiber to connect nearby facilities quickly and inexpensively. We first identified the public housing facilities within one-half mile, 1 mile, and 2 miles. Figure 61 shows the facilities.

Figure 61: Public Housing Facilities in Close Proximity to the EasTrail Fiber



We then looked at each building and property site to determine the cost of extending fiber to each facility. Once we had the fiber construction costs, we could look at the total cost per unit for each facility by including the costs of internal wiring and electronics. Our goal of optimization was to reduce the cost per unit to less than half of the $7,400 per-unit cost for the total build. This meant that some smaller facilities close to the EasTrail may not have been selected as part of the value-engineered initial phase. It also meant that larger facilities with lower per unit inside wiring and electronics costs could "afford" longer fiber construction drops to the EasTrail fiber and still stay below the threshold.

Using the average $3,700 total cost per unit threshold we identified 38 facilities comprising 311 units that would be ideal for an initial connection to the EasTrail fiber (Figure 62).

Figure 62:Value-Engineered Public Housing Sites Near the EasTrail Fiber

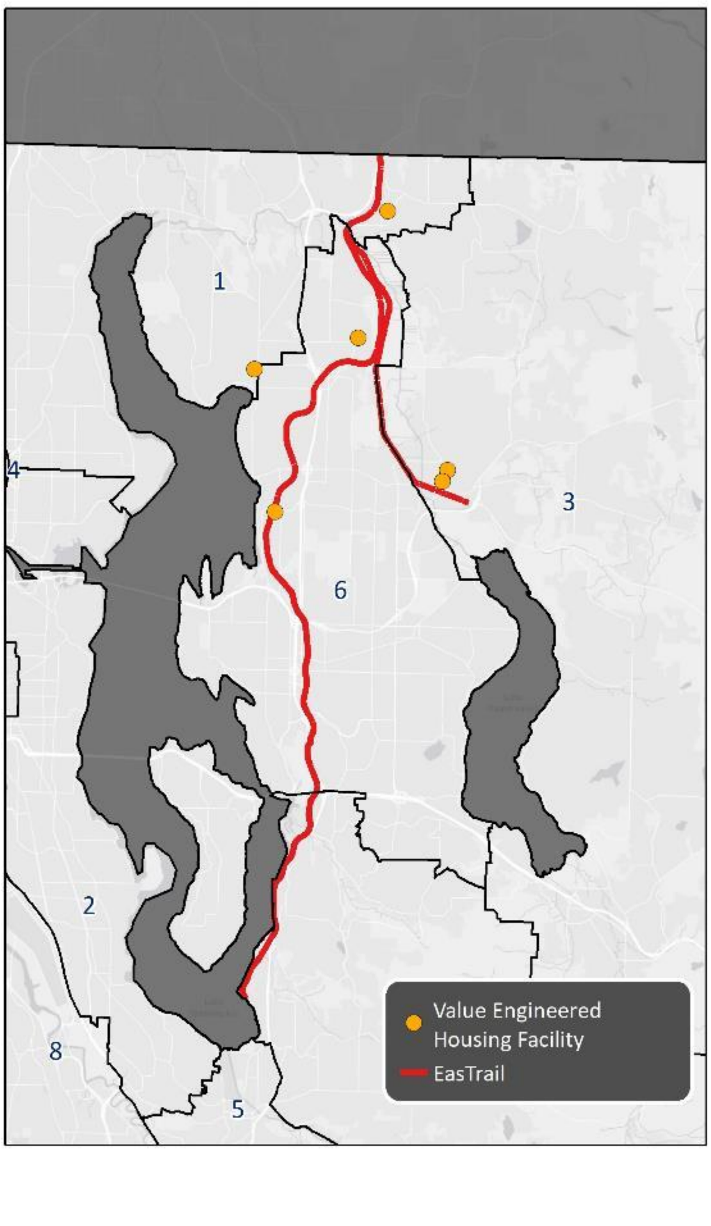


Table 35 outlines the total capital costs to connect the 39 facilities.

Table 35:Total Costs For Providing Wireless at Public Housing Facilities

Description	Subtotal
Core Network Costs	$110,000
Outside Plant Construction to Housing Sites	$460,000
Inside Wiring and Edge Electronics	$380,000
Total	**$950,000**
Passings	311
Cost Per Unit	**$3,054**

Core network costs include a small router at one core location to provide Internet access to the facilities. We recommend purchasing modular network equipment that can be expanded as the fiber network is built out and reaches more public housing facilities. We estimate a total cost of $110,000 for network electronics and implementation.

We estimate it will require 1.9 miles of construction from the EasTrail fiber to reach all of these public housing facilities as they are clustered together on the same property. At a cost of $200,000 per mile, we estimate $460,000 in fiber optic construction.

The largest capital cost will be the inside wiring and wireless equipment needed at the public housing facilities. To serve 38 facilities and 311 units the total estimated cost is $950,000.

11.2 Recommendation: Supplement County fiber service to public housing buildings by partnering to offer private sector mobile service to residents

Achieving parity in broadband service for the low-income residents of affordable housing will not be achieved only through the fixed service recommended in the previous section. Mobile service is also necessary for low-income residents. Indeed, national survey data indicate that most low-income Americans will choose a mobile connection over a fixed broadband service if they do not have sufficient income to buy both. Mobile connections are more flexible and are a lifeline service in a way that fixed services are not; those benefits outweigh mobile services' shortcomings as compared to fixed services (e.g., lower speeds, bandwidth caps). As a result, however, low-income families may be dependent on mobile connections and may not have extensive experience using a fixed connection because it has not been available to them.

Understanding this key issue—and capitalizing on the state-of-the-art in wireless technologies—we recommend that the County consider developing a mobile service for low-income residents. The goal would not be for these community members to switch from mobile to fixed, but that they would have access to both—which is the norm among most Americans who can afford it.

Importantly, the approach we outline here would make this scenario feasible without the County going into the mobile business. This would be a mobile product paired with the fixed product recommended in the section above, all based on the County leveraging its capabilities and assets to achieve a first-of-its-kind outcome for low-income residents.

A key element of this approach is a type of mobile product offered by mobile virtual network operators (MVNO), which resell capacity from the mobile network operators that own nationwide infrastructure (like Verizon or AT&T). We recommend that the County utilize a competitive process to secure best possible pricing from an MVNO; based on our knowledge of the industry and discussions with MVNOs, we believe there would be a robust response to a competitive procurement opportunity of this sort. The County's mobile service would be cost-effective because the County would purchase mobile service in bulk, and it would offload as much network traffic as possible to Wi-Fi within the residents' buildings. (As with most contemporary mobile phones, pre-loaded configurations would automatically switch to Wi-Fi whenever possible.)

In other words, the fixed product in residents' homes would become a platform for a very low-cost MVNO mobile product that would be usable in the home and elsewhere. The County would focus on its assets and strengths (e.g., conduit and fiber; connecting public housing buildings; in-building service) to provide fixed connectivity. The MVNO—which is virtual, not facilities-based—would be responsible solely for the mobile service.

We have spoken with potential private partners that specialize in low-cost mobile service. They are confident that the County's costs could be quite low, given the significant amount of Wi-Fi offload in this scenario—but also the low cost for bulk bandwidth purchase by the County. If the County buys in bulk for all residents of public housing, rather than those residents buying individual services, then the MVNO has one customer, one bill, and no collections or other typical costs of doing business—which would lower its costs and enable lower pass-through pricing. Depending on the scale of the County's deployment, we tentatively conclude that the service could be $10 per month per resident.

If this approach were to work, from a technical and financial standpoint, it would be exceptionally meaningful for low-income residents. Unlike purchasing low-cost cable modem service for all public housing units (a pitch made by the cable industry), the County would be addressing mobility, which is the service that the data show is of most interest to low-income consumers. A successful pilot project in public housing buildings (where the County controls and has access to the physical infrastructure) could be extended to other low-income communities over time.

11.3 Recommendation: Explore 5G partnerships for digital inclusion

Collaborative negotiations with wireless carriers and infrastructure companies can result in win-win outcomes for both the County and the companies. The recommendations below are intended to enable the County to further its goals in both the digital divide and 5G arenas, while providing a powerful demonstration to the industry, residents, and the economic development ecosystem that the County continues to use technology to create value.

The advanced wireless technologies known as 5G hold promise and opportunity for new, faster wireless services. For the moment, 5G is primarily a marketing term and an evolving set of formal standards—not a widely-deployed technology.[97] And widespread 5G deployment cannot occur until a range of necessary events occur: spectrum must be allocated, equipment must be developed, and the wireless industry (and investors) must commit to a massive infrastructure investment. These developments may take years to emerge.

Recognizing the County's dual commitment to bridging the digital divide and enabling and supporting the development of next-generation wireless services, we recommend the County seek to develop collaborative agreements with the wireless industry on future 5G deployment.

We recommend developing public-private partnerships between the County and wireless network operators (such as Verizon and AT&T) and wireless infrastructure companies such as Crown Castle. In our experience, there is no better way to address the broadband needs of a community while creating opportunity and value for a private investor than through local collaboration and negotiation.

As the 5G era approaches and, even before the advent of 5G as wireless carriers densify their 4G networks with small cells, County-owned assets such as light poles and traffic poles are an important and efficient means by which the companies can meet their deployment and service goals. And though the companies have aggressively sought preemption of local authority in Washington, D.C., and have seen some success at the Federal Communications Commission (in the form of an Order that is currently being challenged by local governments in the U.S. Court of Appeals for the Ninth Circuit[98]), the companies are still willing in some cases at the local level to negotiate mutually beneficial agreements. Examples of some of the leading agreements of this sort negotiated by the City of San Jose, California, are discussed below.

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[97] The blanket marketing term 5G refers to two groupings of technologies—one of which is the mobile technology developed by participants in the 3GPP standards development process, which is part of the next generation of cellular mobile technology for smartphones. The other is a group of fixed technologies, which will represent a wireless (but not mobile) mechanism for reaching homes and businesses. One fixed technology is being pursued by a separate development group, the Verizon-driven 5G Technical Forum (5GTF; http://www.5gtf.org/).

[98] Chris D. Linebaugh, "Overview of Legal Challenges to the FCC's 5G Order on Small Cell Siting," Congressional Research Service, February 25, 2019, https://fas.org/sgp/crs/misc/LSB10265.pdf (accessed October 2019).

On the assumption that the highly problematic, counterproductive FCC Order preempting local government authority with respect to placement of small cells and fee will not survive court challenge, we recommend that the County continue its strategy of signaling openness to the wireless industry to negotiate contracts that offer strong terms and conditions for access to public assets in return for public goods that are of high policy value to the County, such as equitable deployment in low-income neighborhoods and funding of programs to support digital inclusion initiatives.

Indeed, the County's light poles and traffic poles represent County-owned assets, built and maintained by the taxpayers of the County. These are assets that, for purposes of fairness and better broadband outcomes, the County should have complete authority to determine how to use to attract and shape private investment in broadband. In our experience, allowing that kind of local creativity is the most effective way to meet local broadband needs and to meet the needs of the industry in equitable ways that reflect the fact that these are publicly owned and maintained assets. These are among the reasons we have opposed preemption and the FCC's Order.[99]

11.3.1 Model: Agreements between the City of San Jose and wireless companies

The City of San Jose, California's 2018 agreements for deployment of small cells by Verizon, AT&T, and Mobilitie[100] represent a model for the type of negotiated collaboration that the County might develop.

When it announced the agreements, San Jose noted that they represented the largest planned small cell deployment in any major U.S. city.[101] The three companies plan to use the city's 4,000 light poles and install related infrastructure, such as fiber, that collectively will represent $500 million in private sector investment.[102]

[99] ""Closing the Digital Divide: Broadband Infrastructure Solutions," Testimony of Joanne Hovis before the U.S. House of Representatives Committee on Energy and Commerce, Subcommittee on Communications and Technology, Jan. 30, 2018, http://www.ctcnet.us/wp-content/uploads/2019/02/HHRG-115-IF16-Bio-HovisJ-20180130-U5002-1.pdf (accessed June 2019).

[100] San Jose, "City of San Jose Announces Major Agreements with Verizon, AT&T & Mobilitie to Significantly Enhance Broadband Infrastructure in San Jose," June 15, 2018, http://www.sanjoseca.gov/DocumentCenter/View/78342 (accessed June 2019).

[101] "City of San Jose Announces Major Agreements with Verizon, AT&T & Mobilitie to Significantly Enhance Broadband Infrastructure in San Jose."

[102] City of San Jose Announces Major Agreements with Verizon, AT&T & Mobilitie to Significantly Enhance Broadband Infrastructure in San Jose."

Additionally, these agreements will generate an estimated $24 million in fees over the next 10 years for San Jose's Digital Inclusion Fund[103]—which was created to close the digital divide for the 95,000 residents of San Jose who lack access to a broadband internet connection.[104]

The individual agreements outline the terms of each company's small cell deployment plans with the city. All three documents state that the agreements are designed to improve quality of service in the city, generate revenue for the Digital Inclusion Fund, incent private-sector investment, and spur market competition.

Each company also has business-specific terms within each agreement, which vary among the three agreements. Verizon's agreement, for example, will last for either 10 or 15 years, depending on a five-year option in the final five years of the 15-year agreement. The company plans to deploy "between 1,500 and 2,500 small cell sites."[105] Verizon will pay $750 per small cell site per year, which includes a $175 attachment fee. These fees will provide the city with about $11.4 million in revenue to be allocated to the Digital Inclusion Fund. The Verizon agreement also includes about $2.3 million for the city to "scale Verizon Connect and pilot other Verizon smart city solutions" such as Traffic Data Services, Intersection Safety Analytics, and Parking Optimization. Verizon will make an initial $850,000 permit fee payment.

AT&T's agreement will also last for either 10 or 15 years.[106] Per this agreement, AT&T will replace its prior agreement (170 small cell sites for a usage fee of $1,500 per site per year) with an agreement to build 2,000 small cells for a usage fee of $750 per site per year. This fee includes the $175 attachment fee. The agreement will provide an estimated $10 million in small cell usage fee revenue to be allocated to the Digital Inclusion Fund and an additional $2 million to pilot AT&T Smart City solutions, including smart lighting controllers, lighting as a connectivity platform, street light-based sensors, and community Wi-Fi.

Mobilitie's agreement will last 15 years and is for about 140 small cells to be built on behalf of its customer, Sprint.[107] The company will pay a $1,500 usage fee per site per year for the first five years, with an annual inflation escalator of 3 percent beginning in year six. Mobilitie will make a $700,000 up-front permit fee payment as well as a $1 million permit process improvement payment as permits are approved. In addition, the Mobilitie agreement will contribute approximately $2.5 million to the Digital Mobility Fund through usage fee revenues.

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[103] City of San Jose Announces Major Agreements with Verizon, AT&T & Mobilitie to Significantly Enhance Broadband Infrastructure in San Jose."

[104] City of San Jose, "San José Launches Digital Inclusion Fund to Close the Digital Divide," February 12, 2019, http://www.sanjoseca.gov/DocumentCenter/View/82743 (accessed June 2019).

[105] City of San Jose, "Verizon Agreement – File 18-922, Item 3.5," June 15, 2018.

[106] City of San Jose, "AT&T Agreement – File 18-921, Item 3.4," June 14, 2018.

[107] City of San Jose, "Mobilitie Agreement – File 18-920, Item 3.3," June 15, 2018.

11.3.2 Potential elements of a County/industry wireless collaboration

The following is a discussion of the key issues related to the County reaching agreement with a wireless provider on a collaborative, win-win process for large-scale 5G deployment. We suggest a range of strategies here from a business and technical standpoint; we cannot opine on any legal issues related to the strategies.

Reaching an agreement would, as in the case of the City of San Jose, likely produce significant positive visibility for the County. Though many of the benefits of 5G technology are still speculative, and it is not yet clear when, how quickly, where, or on what scale this deployment may happen, there is definitely a buzz around the technology among the public and among business and political leaders.

However, to the extent possible, the agreement should not create a net cost or significant new detriments to the County or its residents. Any agreement should also be enforceable, so that the County has recourse if a provider violates the terms—such as by causing damage and not repairing it, by creating traffic problems during construction, or by violating aesthetic or safety standards.

A permitting approach designed to accommodate a large-scale deployment should take into account the County's unique environment, such as to what extent the County can use existing poles, the processes involved in installing conduit from existing conduit to poles, the availability of County staff, and the ability of the County to contract for additional staff and capabilities. Based on our work across the country, we know that no two localities are identical; with respect to permitting, facilitating, and overseeing wireless expansion, the County would have different strengths and challenges than San Jose.

Thinking more broadly than just the steps in the permitting process itself, the County should be prepared for the public response to widespread placement of devices in the right-of-way—including not just concerns about aesthetics and property values, but also oft-heard questions regarding the health effects of RF emission and new questions about the millimeter-wave spectrum that will be part of many 5G deployments.

Any potential agreement should require wireless providers to be in compliance with the FCC's RF standards; the County is an important part of rigorous and transparent oversight of that compliance. Looking more broadly, a potential agreement should also continue to require compliance with the County's aesthetics standards.

11.3.3 Potential benefits to the County

An agreement may provide benefits to the County beyond the advancement of wireless and broadband technology and increased performance and capacity. As in San Jose, a digital inclusion fund beyond what is necessary to cover the County's costs can help bring the advantages of the technology to a broader group of residents—for example, by enabling the County to execute some of the access strategies proposed in this document, or to subsidize devices and digital inclusion instruction for residents who need that help.

Beyond covering the County's costs and providing funding for related services, the County should consider in-kind benefits. The best in-kind benefits are those that have the lowest incremental cost to the provider and the largest benefit to the public. Examples include infrastructure that a provider can add to its project at a low material cost and with little or no additional staff time. For example, a company installing wireless attachments could leverage its construction and restoration costs to install additional fiber or conduit capacity or an enhanced replacement pole at relatively low incremental cost.

Historically, fiber and conduit are among the most useful in-kind benefits, mostly requiring only incremental materials (e.g., larger fiber count, additional materials) and limited incremental labor, while significantly reducing the County's communications and construction costs and reducing future impacts on the rights-of-way. The fiber and conduit may be limited to County use or potentially made available for lease to providers building to support the County's economic development goals.

There are further in-kind benefits that are specific to wireless technology. There exists a logical synergy between a range of County technology initiatives and a new wireless provider agreement. For example, rather than replacing a streetlight pole with a standard-design pole to support the small cell, the provider could install a smart pole that complies with the County's specifications and has sensors, cameras, a Wi-Fi access point, and other features.

The County could also provide an incentive for placing small cells in underserved areas—offering access to those areas at reduced costs (as is done in New York City) or requiring deployment of small cells in underserved areas.

Similar to that would be an incentive to place the small cells or indoor wireless technology (such as a distributed antenna system) in areas that have been separately identified by the County as needing improved service.

11.3.4 Considerations related to benefits

In order for the benefits to be optimal or useful for the County, the County (including representatives of potential user departments) should have a process to evaluate the benefits.

For example, although it may seem useful to obtain mobile broadband accounts, devices, or service, these devices and services should be consistent with what the County needs or wants. Obtaining a handful of accounts and devices from a provider not otherwise used by the County (especially one with poorer coverage) might not be useful and might disrupt the standardization and architecture already in place.

The same considerations apply to other potential benefits that may be more trouble than they are worth, or that may simply go unused.

While wireless providers may be offering or piloting Smart City services, the County's leadership should review the offering to determine if it is useful to add another pilot approach, for example, or if it would be better to get the benefit as part of digital inclusion funds that can be used to purchase Smart City infrastructure of the County's own choosing. In addition, the County should look critically on any solution offered by a wireless provider that appears low-cost or cost-free but actually locks the County into proprietary technologies that may have high costs in the long run.

Some wireless service operators provide hardware and software solutions related to emergency command centers, 9-1-1, and dispatching. Again, the County's various departments—including public safety, Public Works, and Transportation—may find these solutions to be useful—or may already have a suitable solution that is not compatible with that of the wireless carrier. Again, digital inclusion funding might be the better approach, providing a more useful solution, as well as one that can be a more consistent request among all wireless carriers, if the County is seeking an agreement that can apply uniformly to all carriers.

11.3.5 Considerations regarding process

If the number of small cells installed in the County will indeed increase greatly, the total fees collected will be large, even if per-site fees need to be reduced and processes need to be accelerated. This increase will provide latitude for the County to increase its staff and obtain better economies of scale.

The wireless provider will have a reciprocal responsibility to submit applications and perform work that is consistently high-quality. Elements of improved processes for the applicant should include:

- Choosing among highly standardized designs—using one or a small handful of options for antennas, radios, and pole placement
- Working in advance with County departments to fine-tune and pre-approve the highly standardized, aesthetically appropriate, and technically acceptable designs
- Agreeing that most, if not all, sites will conform exactly with County -sanctioned locations (e.g., pole density, placement with respect to buildings and structures, aesthetics)

Changes on the County side may include establishing a coordinating entity to serve as the clear single point of contact and leader for the County; creating the ability to have full, real-time electronic visibility into each application in entire process; and for the coordinating entity to have the ability and authority to take action to make changes in individual process steps (such as inspection, review, and public input).

It may also be necessary for the County to procure qualified contractors to perform more of the work and its mid-level oversight—which would require a mechanism to search broadly to get the necessary quality of work at the right price, and to hire it quickly.

11.3.6 The criticality of reciprocal obligations

Some wireless industry players have lobbied for communities to commit to granting access to publicly owned assets and reducing attachment pricing without requiring wireless companies (i.e., the beneficiaries of those valuable County commitments) to make reciprocal commitments. Any agreement the County makes to change its processes or pricing to benefit the wireless industry should require wireless providers to agree to responsibilities that benefit the County and its residents. Further, the agreement should have enforcement mechanisms that give the County leverage in the event a partner does not consistently meet its obligations.

Crafting an agreement that equitably addresses the County’s broadband needs and a wireless carrier’s needs is feasible if the County and its negotiating partner can develop a shared understanding of the County’s strategic and tactical broadband goals—and can identify investments or service obligations to which the wireless carrier can commit.

The goal in developing these reciprocal obligations is to create a real, two-way partnership. The wireless carrier should feel it will receive value in return for investing in infrastructure or service that will meet its business requirements while also helping the County advance its efforts to improve the broadband environment (such as by expanding service in low-income neighborhoods that might otherwise be passed over for antenna densification).

11.4 Recommendation: Encourage low-income residents to consider Comcast’s Internet Essentials program

Because Comcast recently expanded its Internet Essentials program’s eligibility requirements to encompass many families that previously would not have qualified, the easiest way for the County to enable low-income residents to access the internet would be to educate the community about the availability of the program, and encourage currently unserved households to apply if they are eligible.

The program, which delivers low-cost wired internet connections ($9.95 per month) to low-income customers, represents an imperfect solution because of its limited performance—

download speeds are *up to* 15 Mbps, which is lower than the FCC's current definition of broadband (25 Mbps download)—but it is low-cost and is available to customers throughout Comcast's service area in the County.

Internet Essentials also includes added benefits; customers can purchase a refurbished computer for $149.99,[108] and they have 40 hours of access per month to out-of-home Wi-Fi on Comcast's Wi-Fi hotspots across the country. When the program started, Comcast only allowed families with children that qualified for the National School Lunch Program (NSLP) to apply. The company later expanded the program to four qualifying groups:

- Families that have at least one child who qualifies for the NSLP
- Families that receive HUD housing assistance
- Low-income veterans who receive federal or state public assistance
- Seniors (62 years of age or older) who receive public or state assistance[109]

In August 2019, Comcast announced an expansion of its eligibility requirements—adding categories that will enable more low-income residents in Jackson to acquire the service:

- Families that qualify for Medicaid
- Families approved for Supplemental Nutrition Assistance Program (SNAP) benefits
- Families that are eligible for Temporary Assistance for Needy Families (TANF)
- Families that are eligible for the Low Income Home Energy Assistance Program (LIHEAP)
- Families that are eligible for the Women, Infants, and Children (WIC) program
- Families that are eligible for tribal assistance
- Families who have a family member who qualifies for Supplemental Security Income

While these expanded eligibility requirements are a welcome improvement to the program, Comcast stipulates that a customer of the Internet Essentials program must not have received service from Comcast within the past 90 days.[110] This makes it difficult for people who were paying for service to switch to the more affordable Internet Essentials plan. Other documented problems include a difficult application process and challenges with customer service.[111,112]

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[108] Comcast, "Internet Essentials Programs," 2019, https://www.internetessentials.com/ (accessed Sept. 2019)
[109] This specific program was offered on a trial basis in limited areas.
[110] Comcast, "FAQs," 2019, https://www.internetessentials.com/get-help (accessed June 2019).
[111] Jon Brodkin, "Comcast expands $10 low-income Internet plan," June 15, 2016, https://arstechnica.com/information-technology/2016/07/comcast-expands-10-low-income-internet-plan/ (accessed September 2019).
[112] Nicole Thelin, "Get Low Cost Internet from Comcast!," February 27, 2017, https://lowincomerelief.com/get-low-cost-internet-comcast/ (accessed September 2019).

12 Recommendation: Develop a Broadband-Focused Coordinating Entity for the Region's Public Entities—and a Broadband Office to Execute and Coordinate Strategies

CTC recommends that in order to effectively and efficiently execute the recommendations in this study, as well as to leverage broadband opportunities as they arise, the County establish a dedicated King County Broadband Office (Broadband Office).

Given KCIT's current operation of the County's I-Net fiber and services to County agencies, we recommend that the Broadband Office be housed within KCIT and be directed by the County's Chief Information Officer, or a director-level leader who would be in a position to coordinate with the leadership of other stakeholder agencies within the County.[113]

The Broadband Office will require resources and authority to operate effectively and serve its multi-part mission.

Preliminary recommendations regarding the purpose, goals, proposed structure, and resources requirements of the office are described in further detail below.

12.1 The County should facilitate a regional broadband-focused coordinating entity

We recommend that the County consider spearheading the creation of a broadband-focused coordinating entity to facilitate conversations and collaboration among all of the public entities within the County that are concerned with the broadband needs of unserved and underserved members of the community. This entity would have an important and singular role, given that other collaborative entities in the region are focused on other missions. (For example, C3's mission has to do with internal government communications opportunities as opposed to public-facing broadband.) This would be a coordinating entity for developing strategy and coordinating efforts with respect to public-facing broadband. It could include the Port of Seattle, the County's towns and cities, the County itself, and other public entities like Seattle City Light and the public school districts. Even statewide and larger entities like the K-20 Network and the Pacific Northwest Gigapop might be interested

Not all of these entities would be interested in participating, but the County stands to benefit by beginning the conversations. In our experience, ongoing shared collaboration and idea

[113] Of note, the next opportunities to negotiate use of the I-Net for broadband will be 2023 for Wave Broadband and 2024 for Comcast. However, it is not likely that either company will lift its restrictions on the use of the fiber to allow King County to provide services directly to consumers. We have not observed any other community in the United States where either of these companies was willing to change the terms of an I-Net agreement to allow use of I-Net fiber to provide services to the public.

generation of this type has long-term benefit, even if it does not have immediate concrete outcomes.

12.2 A New King County Broadband Office should manage the County's fiber and connectivity and execute public-facing strategies

The Broadband Office would represent a new entity within KCIT, dedicated to achieving the County's public-facing broadband goals and executing strategy designed to serve the unserved and underserved—those whose needs are not met by private sector broadband services.

The Broadband Office would be charged with developing ongoing mutual efforts and coordination mechanisms, particularly with other agencies of King County government that have significant stakes and assets associated with broadband (such as the County Department of Transportation), as well as tools for tight integration among agencies so as to be responsive to policy direction from County leadership.

The Broadband Office would be charged with ensuring that no silos exist among the County agencies with responsibilities and authority related to broadband planning—or the assets and infrastructure that enable it. Absent this kind of coordinated multi-agency effort, national experience suggests that silos inevitably arise or are perpetuated, and that opportunities to efficiently plan across agencies and between the public and private sectors will be lost.

The Broadband Office would also serve as a clearinghouse and execution mechanism for taking advantage of new community-focused broadband opportunities, as well as State and federal broadband grant opportunities, as they arise. In addition, the Broadband Office would be charged with developing and refining solutions for underserved members of the community based on factors such as adoption, pricing, and household income.

We recommend that the Broadband Office be housed within KCIT in light of KCIT's subject matter expertise and its management of the County's existing communications assets and cable franchises.

Appendix A: Summary of Data Sources Used to Develop Definitions of Unserved and Underserved

The sources consulted to develop these definitions include the following:

1. **Congressional Research Service:**[114]

"One way broadband can be defined is by setting a minimum threshold speed for what constitutes 'broadband service.' Section 706 of the Telecommunications Act of 1996 requires the Federal Communications Commission (FCC) to regularly initiate an inquiry concerning the availability of broadband to all Americans and to determine whether broadband is 'being deployed to all Americans in a reasonable and timely fashion…. In 2015 the FCC, citing changing broadband usage patterns and multiple devices using broadband within single households, raised its minimum fixed broadband benchmark speed from 4 Mbps (download)/1 Mbps (upload) to 25 Mbps/3 Mbps."

2. **Federal Communications Commission:**[115]

"The FCC retains the existing speed benchmark of 25 Mbps download/3 Mbps upload (25 Mbps/3 Mbps) for fixed services…"

"Consequently, we rely upon [Form 477] data to identify areas with access to services with maximum advertised speeds meeting our 25 Mbps/3 Mbps speed benchmark for fixed advanced telecommunications capability, as well as identifying areas with LTE coverage at minimum advertised (or in the case of SBI data, maximum advertised) or expected speeds of 5 Mbps/1 Mbps. We note that the Form 477 and SBI data only report service at the census block level, and not the household level. A whole census block is classified as served if the Form 477 or SBI data indicate that service is being provided anywhere in the block. Therefore, it is not necessarily the case that every person will have access to a service in a block that this Report indicates is served."

"Certain mobile services provide 'high-speed, switched, broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics and video telecommunications using any technology.' In this Report, we evaluate mobile deployment holistically and use various data points to assess the extent to which American consumers have access to advanced telecommunications capability under section 706. While we acknowledge the potential benefits of a single speed benchmark for mobile service, we find—as was the case in the last report—that adoption of a single mobile benchmark is

[114] Lennard G. Kruger, "Defining Broadband: Minimum Threshold Speeds and Broadband Policy," Report, Congressional Research Service, Dec. 4, 2017, https://fas.org/sgp/crs/misc/R45039.pdf (accessed May 17, 2019).
[115] "2018 Broadband Deployment Report," Federal Communications Commission, Feb. 2, 2108, https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report (accessed May 17, 2019).

currently unworkable given the inherent variability of actual mobile speeds and our available data. Instead, we will use 4G LTE as our starting point and will present LTE coverage data based on the Form 477 minimum advertised speeds of 5 Mbps/1 Mbps. However we are not asserting that 5 Mbps/1 Mbps is a mobile advanced telecommunications capability benchmark. "

3. U.S. Code Authorizing RUS Rural Broadband Access Loan and Loan Guarantee Program[116]

"The term 'broadband service' means any technology identified by the Secretary as having the capacity to transmit data to enable a subscriber to the service to originate and receive high-quality voice, data, graphics, and video."

4. U.S. Code Defining "Substantially Underserved Trust Area"[117]

"*Underserved* means an area or community lacking an adequate level or quality of service in an eligible program, including areas of duplication of service provided by an existing provider where such provider has not provided or will not provide adequate level or quality of service."

5. USDA RUS ReConnect Program[118]

"*Sufficient access to broadband* means any rural area that has fixed, terrestrial broadband service delivering at least 10 Mbps downstream and 1 Mbps upstream."

6. Broadband Technology Opportunities Program (BTOP)[119]

"Broadband means providing two-way data transmission with advertised speeds of at least 768 kilobits per second (kbps) downstream and at least 200 kbps upstream to end users, or providing sufficient capacity in a Middle Mile project to support the provision of broadband service to end users."

"*Underserved area* means a Last Mile or Middle Mile service area, where at least one of the following factors is met: (i) No more than 50 percent of the households in the Last Mile or Middle Mile service area have **access** to facilities-based, terrestrial broadband service at greater than the minimum broadband transmission speed (set forth in the definition of broadband above); (ii) no fixed or mobile terrestrial broadband service provider advertises to residential

[116] 7 USC 950bb(b)(1), https://www.law.cornell.edu/uscode/text/7/950bb (accessed May 17, 2019).
[117] 7 USC 1700.101, https://www.law.cornell.edu/cfr/text/7/1700.101 (accessed May 14, 2019).
[118] "Broadband Pilot Program Funding Opportunity Announcement (FOA) and solicitation of applications," Rural Utilities Service, U.S. Department of Agriculture, Federal Register, Dec. 14, 2018, https://www.federalregister.gov/documents/2018/12/14/2018-27038/broadband-pilot-program (accessed May 17, 2019).
[119] "Broadband Technology Opportunities Program Notice of Funds Availability (NOFA) and solicitation of applications," U.S. Department of Commerce, National Telecommunications and Information Administration Second, Jan. 22, 2010, https://www.ntia.doc.gov/files/ntia/publications/fr_btopnofa_100115_0.pdf (accessed May 17, 2019).

end users broadband transmission speeds of at least three megabits per second (''Mbps'') downstream in the Last Mile or Middle Mile service area; or (iii) the rate of terrestrial broadband subscribership for the Last Mile or Middle Mile service area is 40 percent of households or less. An underserved area may include individual Census block groups or tracts that on their own would not be considered underserved. The availability of or subscribership rates for satellite broadband service is not considered for the purpose of determining whether an area is underserved.

"*Unserved area* means a Last Mile or Middle Mile service area where at least 90 percent of the households lack access to facilities-based, terrestrial broadband service, either fixed or mobile, at the minimum broadband transmission speed (set forth in the definition of broadband above). An unserved area may include individual Census block groups or tracts that on their own would not be considered unserved. A household has access to broadband service if the household readily can subscribe to that service upon request. The availability of or subscribership rates for satellite broadband service is not considered for the purpose of determining whether an area is unserved."

7. Washington State Legislature[120]

"'Broadband' or 'broadband service' means any service providing advanced telecommunications capability and internet access with transmission speeds that, at a minimum, provide twenty-five megabits per second download and three megabits per second upload."

"'Unserved areas' means areas of Washington in which households and businesses lack access to broadband service, as defined by the office, except that the State's definition for broadband service may not be actual speeds less than twenty-five megabits per second download and three megabits per second upload."

8. Pew Center on Internet and Society[121]

Pew's research depends on self-reporting (i.e., Pew asks survey respondents if they have "broadband"). Pew also collects data on adoption patterns and notes that "as is true of internet adoption more broadly, home broadband adoption varies across demographic groups. Racial minorities, older adults, rural residents, and those with lower levels of education and income are less likely to have broadband service at home."

[120] "Broadband Technology Opportunities Program Notice of Funds Availability (NOFA) and solicitation of applications," U.S. Department of Commerce, National Telecommunications and Information Administration, Jan. 22, 2010, https://www.ntia.doc.gov/files/ntia/publications/fr_btopnofa_100115_0.pdf (accessed May 17, 2019).
[121] Kathryn Zickhur, "How Pew Research calculates broadband adoption," Pew Research Center, Aug. 29, 2013, https://www.pewresearch.org/fact-tank/2013/08/29/how-pew-research-calculates-broadband-adoption/ (accessed May 17, 2019); "Internet Fact Sheet," Pew Research Center, Feb. 5, 2018, https://www.pewinternet.org/fact-sheet/internet-broadband/ (accessed May 15, 2019).

Appendix B: Inventory of Usable and Available Broadband Infrastructure in King County

The following table summarizes usable and available infrastructure in the County that can be leveraged to support broadband deployment. Further description of each asset can be found in the sections below.

Table 36: King County Broadband Infrastructure List

Item #	Broadband Infrastructure Asset
1	**Existing Fiber & Cable Infrastructure**
1.1	County-owned fiber routes (non-restricted)
1.2	Municipal-owned fiber routes (non-restricted)
1.3	Cable franchisee service footprint
1.4	Third-party provider fiber routes
2	**Existing Wireless Infrastructure**
2.1	Communications Towers
3	**Assets to Facilitate Broadband Access**
3.1	Public Rights-of-Way (PROW)
3.2	Utility Poles
3.3	County-owned Property
3.4	Light Poles and Traffic Signals
3.5	Water and Sewer Pipes

Existing fiber and cable infrastructure

The County should consider leveraging existing telecommunications infrastructure as a starting point for expanding broadband access to its residents. In most cases, the purpose of telecommunications infrastructure is to provide broadband services and should require minimal effort to repurpose for the County's needs, providing a cost-effective starting point. Legal or technical restrictions may inhibit the usefulness of some existing fiber infrastructure, the County should prioritize fiber and cable that is usable for residential service and meets the capacity requirements of the broadband definitions outlined in this report document. Identified assets include the following:

1.1 County-owned fiber routes (non-restricted)

Data Source:

King County GIS Department

Detail:

Though limited, the County does own fiber optic assets. When considering County-owned fiber it is important to classify it into two categories; fiber with use restrictions and fiber without use restrictions. Much of the County's fiber is either I-Net, public safety, or purpose driven such as the Department of Transportation Rapid Ride Fiber. In each of these cases the fiber would not be usable for residential service as restrictions are placed on each to limit the use to government purposes.

1.2 Municipal-owned fiber routes (non-restricted)

Data Source:

Multiple Sources (39 incorporated municipalities *within King County)*

Detail:

Similar to King County, a number of the incorporated municipalities will have their own fiber assets which could be leveraged for broadband expansion. The County should consider collaboration options including possible resource sharing with the municipalities as a way to reduce the need for new construction. As a member of C3, the County already has a vehicle for collaboration with various public entities around Lake Washington and along the I-5 corridor. The C3 does not include all 39 incorporated municipalities, an additional consortium may need to be established to facilitate County-wide collaboration. The same "use restriction" requirements should be considered when exploring what usable assets each municipality has to offer.

1.3 Cable franchisee service footprint

Data Source:

https://www.kingcounty.gov/depts/it/services/cable-communications/cable-tv-route-map.aspx

Detail:

Both Comcast and Wave have franchise agreements to provide cable and internet services to residents throughout King County. As part of this agreement they are required to report all of their service footprint in unincorporated King County, which is then published on the County's website. While the County will not be able to use this infrastructure to serve residents directly, it can leverage the resource in several ways. If the County engages in a public–private partnership with either entity, whether for a federal grant application or another initiative, it would most likely involve the extension of the partner's footprint to serve additional residents. Additionally, the franchisees report where their infrastructure is aerial or underground. This information can be used by the County to determine areas where utility poles exist, which can help identify more cost-effective routes if new construction is required, based on the fact that aerial construction may be more cost effective then underground construction.

1.4 Third-party provider fiber routes

Data Source:

Directly from the Commercial Providers or Online Commercial Fiber Identifier Tool (FiberLocator, etc.)

Detail:

Within King County, there are several commercial providers that offer dark fiber and lit services. While these providers are mostly focused around Lake Washington and along the I-5 Corridor, there are fiber routes that extend east via I-90, U.S. 2, and a high-voltage transmission line easement south of I-90. The County could potentially lease dark fiber or lit services from a commercial provider as an alternative to building backhaul fiber to some of the unserved areas in the County, greatly reducing the capital cost required to reach these remote areas.

Existing wireless infrastructure

The County should consider leveraging existing wireless communications infrastructure as a cost-effective option for expanding broadband access to its more rural residents. Identified assets include the following:

2.1 Communications towers

Data Source:

Public Safety Radio Towers: Directly for the PSERN Group

Commercially-owned Communications Towers: Directly from each provider directly or from their respective online locator tool
(Example: https://www.t-mobiletowers.com/TowerSearch.aspx)

State-owned Communications Towers: Directly from the State's online locator tool
https://www.dnr.wa.gov/publications/psl_comm_sites_by_counties.pdf?mlr3fp

Detail:

Communications towers can be leveraged to provide a fixed wireless solution in low-density rural areas where building wired networks is cost prohibitive. Utilizing existing towers would eliminate the cost of the County having to building a new structure to provide the wireless service. In addition, using a County or State-owned tower may provide an option to avoid high ongoing operational expenses to lease space on a commercial tower. In any scenario, there is potentially a high initial capital cost for the backhaul, wireless antennas, and additional equipment needed to provide a broadband service. Another consideration to account for with leasing tower space is the application process which can take an extended amount of time to complete.

Assets to facilitate broadband access

There are a variety of assets the County could leverage to support the expansion of broadband service. While these assets do not exist solely for telecommunications use, they can be used, modified, and repurposed to support broadband and reduce cost of deployment. Identified assets include the following:

3.1 PROW (Public Right-Of-Way) in King County

Data Source:

https://gisdata.kingcounty.gov/arcgis/rest/services/OpenDataPortal/property__row_area/MapServer/436

Detail:

Public Rights-Of-Way are key for the deployment of any utility, including telecommunications. New broadband plant can be placed along most rights-of-way after and usually just require the completion of a permit application and fee, while placement outside of the PROW usually requires an easement or some type of legal agreement. PROW typically runs along roadways and are owned by municipalities, the County, or the State. Understanding where the PROW exists will help determine where infrastructure could reliably be constructed to expand broadband service.

3.2 Utility poles

Data Source:

County-owned: Obtained directly from the King County Road Services Department
Seattle-City Light: Obtained directly from Seattle-City Light
Puget Sound Energy: Obtained directly from Puget Sound Energy

Detail:

Typically located in the PROW, utility poles are used to support overhead power lines and various other public utilities, such as fiber optic cable, coax cable, and even wireless antennas. The benefit of constructing fiber on utility poles is the cost can be significantly less than constructing underground. Utility poles have space designated for the placement of non-electrical utilities often referred to as the telecommunications space. When this designated space becomes overcrowded, additional work is required to make space available for new attachments. This is called make-ready. Make-ready typically involves moving the existing utilities in the telecommunications space or even replacing the utility pole with a large size to accommodate more utilities, both of which increase the cost of aerial construction. In some rare cases aerial construction could even cost more than underground if enough make-ready is warranted.

The County owns a few poles, but the major utility pole owners are the power companies: Seattle City Light (SCL) located in the Western part of King County centered in Seattle and extending just beyond the City boundaries to the north and south and Puget Sound Energy (PSE) located in rest of the County including the eastern areas where broadband needs are the greatest. Each company has their own permitting process for pole attachments and will provide details on their infrastructure for discrete sections of their plant at a time, but do not typically provide detailed information of their entire network.

3.3 County-owned property

Data Source:

https://gisdata.kingcounty.gov/arcgis/rest/services/OpenDataPortal/property___realprop_area/MapServer/1289

Detail:

County-owned property, encompassing both facilities and land can be used to for a variety of purposes that support broadband deployment. County-owned property could be used to house network hubs, telecommunications huts, towers, and other infrastructure that may not fit easily in the PROW. County property could also be leveraged for fiber deployment where PROW is limited or non-existent along a potential route.

3.4 County-owned light poles and traffic signal poles

Data Source:

Traffic Signals:
https://gisdata.kingcounty.gov/arcgis/rest/services/OpenDataPortal/transportation___base/MapServer/1470

Light Poles: Obtained directly from the King County Road Services Department

Detail:

Both traffic signals and light poles may provide a targeted use for fixed broadband deployment but should not be considered as a primary asset for countywide deployment. Antennas could be attached to both traffic signal and light poles to provide fixed wireless service but will have limited range due to the height limitations of these assets. Both light poles and traffic signals will have electrical infrastructure built to them and traffic signals may be connected to fiber as well. It is unlikely that there will be enough capacity in the infrastructure connecting these assets to support a residential deployment service, but there may be targeted cases where these assets provide value.

3.5 County-owned water and sewer pipes

Data Source:

Sewer Lines: https://gis-kingcounty.opendata.arcgis.com/datasets/wastewater-conveyance-of-king-county-sewer-line

Water Lines: Obtained directly from the King County Natural Resources and Parks

Detail:

In some very rare instances, other types of utilities can be leveraged to reduce the cost of fiber deployment. There have been cases where fiber cable is placed in abandoned water and sewer pipes to avoid expensive new construction work in urban environments. In Washington State there has even been instances of placing fiber in active water lines to provide middle mile service (Anacortes Fiber Project). While this type of deployment approach can provide cost savings under the right scenario in middle-mile fiber deployments, the savings are diminished greatly in a residential buildout as water pipes to don't provide the same level of access as purpose-built fiber infrastructure. The effort required to obtain access to the water pipes tends to offset the savings provided by using the asset in the first place.

Appendix C: Traditional Bonding Options

With or without outside funding (see Section 9), a key consideration for any broadband network deployment is how to finance upfront capital construction costs. These costs represent a large expenditure that is generally slow to yield a return; the lack of a quick return on investment (ROI) sheds some light on why the private sector is not clamoring to upgrade existing legacy networks with fiber infrastructure, or to build new networks, in many parts of the country.

The County can seek bonding, or borrow funds, to cover construction costs both to construct a network and in consideration of likely operations and maintenance (O&M) costs. Public bonds may also factor into a public–private partnership; that is because, even with a partner, the County will likely be required to finance some portion of a fiber network, and especially if it opts to retain ownership and control of the network. Public entities that have good credit ratings and a low cost for bond financing are at an advantage and are attractive to potential partners.

While not every partnership will require the County to pursue bonding, all potential private partners will likely request some contribution from the community. One partnership structure that may be particularly desirable to the County entails the public sector owning and operating the infrastructure while a private partner either lights the fiber and offers retail services over it or leases dark fiber to support a targeted wireless deployment. In this scenario, the County would likely need to bond to fund construction of the network.

We discuss here some of the common types of bonds that public entities typically rely on for capital projects, and the advantages and disadvantages of each. Please note that the following is a summary, does not include every financing mechanism available, and does not offer any legal or tax advice.

General obligation bonds

General obligation bonds are directly tied to the public entity's credit rating and ability to tax its citizens. This type of bond is not tied to revenue from any specific project but is connected instead to communitywide taxes and revenues that can be used to repay this debt. County leadership is likely very familiar with this type of bonding, as general obligation bonds are commonly sought by local governments to fund capital improvement projects.

General obligation bonds can be politically challenging because they generally require a public approval process. These bonds are usually issued for projects that will clearly serve the needs of the entire community, such as roadway improvements. While it is our opinion that a fiber enterprise serving the public clearly meets this condition, incumbent opposition is likely. If seeking this type of financing, the County will need to develop a clear vision for its messaging to convey to the community that it intends for the fiber network to enhance the lives of all residents, and to serve all citizens' needs. A model that opens access to the fiber to multiple providers may support general obligation bonding because it would enable new and existing providers to offer new services and give consumers a choice and alternatives.

It may be especially helpful if the County can work within existing initiatives and with other public, quasi-public, and private institutions to demonstrate how the fiber network can effectively benefit the entire community. For example, the County may want to consider tapping into the knowledge and resources of a local Community Development and Economic Development entity to show a fiber network's role in economic development.

Revenue bonds

Revenue bonds are directly tied to a specific revenue source to secure the bond and guarantee repayment of the debt. For example, the revenue stream from a public entity's electric, natural gas, or water utility may be used to secure a revenue bond.

Theoretically, any service that generates some sort of revenue that could be used to repay debt might potentially be used to secure a revenue bond; publicly owned transportation services or hospitals are two examples. But while the revenues generated from owning a fiber optic network and leasing it to providers could ostensibly be used to guarantee a revenue bond, this is typically not an accepted practice within the bonding community. Municipal broadband projects without a proven revenue stream are usually viewed as high-risk in the bonding community, and the projected revenues from the network will likely be viewed as too uncertain to support repayment of the loan. Given this, revenue bonds are not a strong candidate for financing a broadband network.

Appendix D: Representative Sample of Partnerships Between Public Entities and Private Broadband Providers in the Puget Sound Region

The following are a representative sample of existing broadband-related public–private partnerships in the Puget Sound region:

1. Tacoma Public Utilities recently concluded negotiation of a long-term partnership for its Click! Network with Rainier Connect
2. Bellevue School District worked with AssistX Education to make the app aParent Online available for free to parents of children who have been lent tablets by the school district[122]
3. Northshore School District[123] and Central Kitsap School District[124] provide digital libraries to students/staff with the help of OverDrive
4. In 2015, Google began working with the King County Library System to provide free Wi-Fi hotspots to library users[125]
5. Auburn School District works with SIS to provide a parent portal called Family Access[126]
6. In 2013, Federal Way Public Schools was chosen to participate in A Global Partnership, an initiative of Microsoft, Promethean, Intel, and The Gates Foundation, that focuses on using technology to collaborate, think critically, and solve real-world issues[127]
7. In 2008, Federal Way Public Schools founded a 6th-12th grade STEM-based school in partnership with Technology Access Foundation[128]

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[122] "One-to-One Computing." *Bellevue School District*, http://bsd405.org/departments/district-technology/1to1/. Accessed 23 July 2019.
[123] "Northshore School District Digital Library." *Northshore School District*, http://northshoresdwa.libraryreserve.com/10/45/en/SignIn.htm?url=Default.htm. Accessed 23 July 2019.
[124] "Central Kitsap School District Digital Library." *Central Kitsap School District*, http://centralkitsapwa.libraryreserve.com/10/45/en/SignIn.htm?url=Default.htm. Accessed 23 July 2019.
[125] Markovich, Matt. "Google, Seattle Library Team up to Offer Free Wi-Fi Hotspots." *Komo News*, 18 May 2015, http://komonews.com/news/local/google-seattle-library-team-up-to-offer-free-wi-fi-hotspots. Accessed 23 July 2019.
[126] Quattrocchi, Christina. "Technology with a Cause: Spotlight on Eight Seattle Districts." *EdSurge*, 15 Oct. 2014, http://www.edsurge.com/news/2014-10-15-technology-with-a-cause-spotlight-on-eight-seattle-districts. Accessed 24 July 2019.
[127] Quattrocchi, Christina. "Technology with a Cause: Spotlight on Eight Seattle Districts." *EdSurge*, 15 Oct. 2014, http://www.edsurge.com/news/2014-10-15-technology-with-a-cause-spotlight-on-eight-seattle-districts. Accessed 24 July 2019.
[128] Quattrocchi, Christina. "Technology with a Cause: Spotlight on Eight Seattle Districts." *EdSurge*, 15 Oct. 2014, www.edsurge.com/news/2014-10-15-technology-with-a-cause-spotlight-on-eight-seattle-districts. Accessed 24 July 2019.

8. Highline Public Schools participated in a blended learning initiative called BlendEd, which was led by the Puget Sound Educational Service District and Pacific Lutheran University, and funded by the Gates Foundation[129]

9. As part of an effort to close the digital divide, Kent School District has distributed over 5,000 refurbished computers since 2003, all with a free Microsoft Digital Literacy suite included[130]

10. Seattle Public Schools works with Microsoft through the Teals Program, in which Microsoft programmers come to schools and teach computer science classes[131]

11. Comcast provides free Wi-Fi and tech training classes to El Centro de la Raza, a community center for people of all races[132]

12. Comcast provided free technology resources, digital literacy classes and internet connectivity to Mary's Place emergency family shelters[133]

[129] Quattrocchi, Christina. "Technology with a Cause: Spotlight on Eight Seattle Districts." *EdSurge*, 15 Oct. 2014, www.edsurge.com/news/2014-10-15-technology-with-a-cause-spotlight-on-eight-seattle-districts. Accessed 24 July 2019.
[130] Quattrocchi, Christina. "Technology with a Cause: Spotlight on Eight Seattle Districts." *EdSurge*, 15 Oct. 2014, www.edsurge.com/news/2014-10-15-technology-with-a-cause-spotlight-on-eight-seattle-districts. Accessed 24 July 2019.
[131] Quattrocchi, Christina. "Technology with a Cause: Spotlight on Eight Seattle Districts." *EdSurge*, 15 Oct. 2014, www.edsurge.com/news/2014-10-15-technology-with-a-cause-spotlight-on-eight-seattle-districts. Accessed 24 July 2019.
[132] "Comcast Invests Nearly $6 Million in Washington State Nonprofits in 2018." *AP News*, 20 Dec. 2018, www.apnews.com/4a670b478c814aae897e2fffe49daa1b. Accessed 24 July 2019.
[133] "Comcast Invests Nearly $6 Million in Washington State Nonprofits in 2018." *AP News*, 20 Dec. 2018, www.apnews.com/4a670b478c814aae897e2fffe49daa1b. Accessed 24 July 2019.

Appendix E: Estimated Fixed Wireless Deployment Costs

The tables below illustrate the full costs of the fixed wireless deployment scenarios described in Section 6.

Table 37: Cost Estimate for Using Existing Towers to Cover Unserved Areas with Fixed Wireless

Network Core										
Description	**Unit**	**Unit Price**							**Qty**	**Extended Cost**
Core network, security, and provisioning equipment	EA	$100,000							1	$100,000
Network equipment at NOC	EA	$100,000							1	$100,000
									Installation of network core:	***$200,000***

Distribution Sites										
Description	**Unit**	**Unit Price**	**Central Qty**	**Central Cost**	**I-90 Qty.**	**I-90 Cost**	**Rt2 Qty.**	**Rt2 Cost**	**Qty**	**Extended Cost**
Existing Towers	EA	$0	53.00	$0	4.00	$0	7.00	$0	64	
TVWS APs	EA	$3,750	40	$150,000	3	$11,250	6	$22,500	49	$183,750
CBRS APs	EA	$3,750	159	$596,250	12	$45,000	21	$78,750	192	$720,000
5 GHz APs	EA	$3,750	40	$150,000	3	$11,250	6	$22,500	49	$183,750
11 GHz Backhaul	EA	$15,000	59	$885,000	5	$75,000	8	$120,000	72	$1,080,000
Engineering and Design	EA	$30,000	59	$1,770,000	5	$150,000	8	$240,000	72	$2,160,000
Installation of 11 GHz and APs	EA	$30,000	59	$1,770,000	5	$150,000	8	$240,000	72	$2,160,000
Site Acquisition	EA	$100,000	59	$5,900,000	5	$500,000	8	$800,000	72	$7,200,000
Installation of distribution sites:				***$11,221,250***		***$942,500***		***$1,523,750***		***$13,687,500***

Premises Units										
Description	**Unit**	**Unit Price**	**Central Qty**	**Central Cost**	**I-90 Qty.**	**I-90 Cost**	**Rt2 Qty.**	**Rt2 Cost**	**Qty**	**Extended Cost**
Installation of Subscriber Radios	EA	$800	3215	$2,572,000	65	$52,000	789	$631,200	4069	$3,255,200
Subscriber Units		$1,000	3215	$3,215,000	65	$65,000	789	$789,000	4069	$4,069,000
Installation of Subscriber Radios				***$5,787,000***		***$117,000***		***$1,420,200***		***$7,324,200***

Total Cost (Distribution Only)	$13,887,500
Total Cost (35% penetration)	$16,450,970.00
Total Cost (60% penetration)	$18,282,020.00
Per Address (Distribution Only)	$3,413.00
Incremental Cost Per Customer (CPE & Installation)	$1,800
Cost Per Address Plus Incremental Cost Per Customer	$5,213
Average Network Cost Per Tower (Distribution Only)	$ 216,992.19
Per Customer (35% penetration)	$11,551.43
Per Customer (60% penetration)	$7,488.33

Table 38: Cost Estimate for Building Additional Towers to Cover Unserved Areas with Fixed Wireless

New Towers										
Description	**Unit**	**Unit Price**	**Central Qty**	**Central Cost**	**I-90 Qty.**	**I-90 Cost**	**Rt2 Qty.**	**Rt2 Cost**	**Total Qty**	**Extended Cost**
Build new tower in select locations	EA	$150,000	5	$750,000	0	$0	1	$150,000	6	$900,000
									Installation of network core:	***$900,000***

Distribution Sites										
Description	**Unit**	**Unit Price**	**Central Qty**	**Central Cost**	**I-90 Qty.**	**I-90 Cost**	**Rt2 Qty.**	**Rt2 Cost**	**Qty**	**Extended Cost**
TVWS APs	EA	$3,750	4	$15,000	0	$0	1	$3,750	5	$18,750
CBRS APs	EA	$3,750	15	$56,250	0	$0	3	$11,250	18	$67,500
5 GHz Aps	EA	$3,750	4	$15,000	0	$0	1	$3,750	5	$18,750
11 GHz Backhaul	EA	$15,000	6	$90,000	0	$0	2	$30,000	8	$120,000
Installation of 11 GHz and APs	EA	$30,000	6	$180,000	0	$0	2	$60,000	8	$240,000
Engineering and Design	EA	$30,000	6	$180,000	0	$0	2	$60,000	8	$240,000
Site Acquisition	EA	$100,000	6	$600,000	0	$0	2	$200,000	8	$800,000
									Installation of distribution sites:	***$1,505,000***

Premises Units										
Description	**Unit**	**Unit Price**	**Central Qty**	**Central Cost**	**I-90 Qty.**	**I-90 Cost**	**Rt2 Qty.**	**Rt2 Cost**	**Qty**	**Extended Cost**
Installation of Subscriber Radios	EA	$800	121	$96,800	0	$0	23	$18,400	144	$115,200
Subscriber Units		$1,000	121	$121,000	0	$0	23	$23,000	144	$144,000
									Installation of Subscriber Radios	***$259,200***

Total incremental cost (distribution only)	***$2,405,000***
Total incremental cost (35% penetration)	***$2,495,720***
Total incremental cost (60% penetration)	***$2,560,520***
Cost per incremental passing (distribution only)	***$16,701***
Cost per incremental installed customer (CPE plus installation))	***$1,800***
Cost per incremental passing plus customer installation	***$18,501***
Incremental cost per tower (distribution only)	***$ 400,833.33***

Appendix F: King County Technology Access and Use Study – Full Countywide Results – December 20, 2019 (Pacific Market Research)