Infrastructure Essentials BEAD Toolkit

Broadband Grant Opportunity Analysis

Introduction / User's Guide

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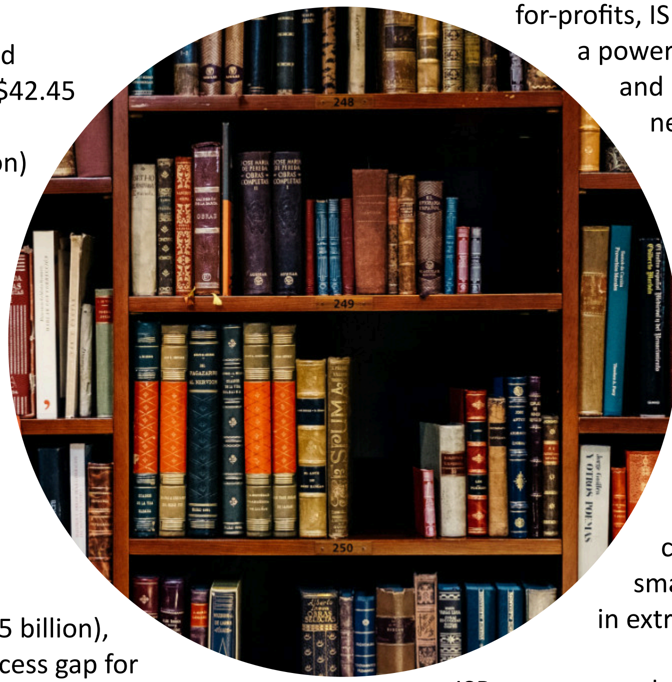
Introduction

On November 15th 2021 the Infrastructure Investment and Jobs Act (IIJA), sometimes called the bi-partisan infrastructure bill, was signed into law. It authorized $1.2 trillion in infrastructure spending, including $65 billion for broadband. The broadband initiatives will be administered by the NTIA, the FCC, the USDA, and by state and local governments. The provisions include:

- NTIA: Broadband Equity, Access, and Deployment Program, a.k.a. BEAD ($42.45 billion)
- NTIA: Digital Equity Act ($2.75 billion)
- NTIA: Tribal Connectivity Technical Amendments ($2.00 billion)
- NTIA: Enabling Middle Mile & Broadband Infrastructure ($ 1.00 billion)
- FCC: Affordable Connectivity Program ($14.2 billion)
- USDA: Rural Utility Service ($2.00 billion)
- State / Local: Private Activity Bonds ($0.60 billion)



The largest allocation of funds, BEAD ($42.45 billion), goes to states and territories to close the access gap for unserved and underserved geographies. Every participating state or territory will develop a 5-year plan and put in place a process to select subgrantees to build the required infrastructure.

On May 13th, 2022 the NTIA released a 98-page BEAD Notice of Funding Opportunity (NOFO), laying out the details of the grant program and inviting eligible entities (states and territories) to participate.

There are other funding opportunities outside of BEAD / IIJA, but they are modest in comparison.

This geospatial toolkit, which visualizes a large collection of high quality data sets, provides all BEAD stakeholders (governments, not-for-profits, ISPs, grant-writers, and engineering firms) with a powerful resource for identifying eligible unserved and underserved areas and for prioritizing the needs of one geographic area over another.

The FCC Fabric

The Broadband Deployment Accuracy and Technology Availability (DATA) Act was signed into law in early 2020. It commissioned the FCC to embark on an ambitious new effort to precisely map broadband availability. The DATA Act uses a "fabric" of building locations, rather than census blocks. While many census blocks are small - the size of a city block - a few, especially in extremely rural areas, are large.

ISPs were recently required to submit coverage data relative to a set of fabric locations. On November 18th, 2022 the FCC released a preliminary set of results. This initial release starts a "challenge" process where individuals / organizations, ISPs, and state and county governments can challenge the results. The fabric is important in part because it will serve as the basis for allocating BEAD funds among states and territories. Version 1.2 of the *Infrastructure Essential BEAD Toolkit* visualizes data from this first "fabric" release.

Version 1.2 of the Toolkit also enables an ISP or state to visualize the set of locations they may have received from the FCC. The locations appear as a point layer within the Toolkit and can be juxtaposed with other data layers.

The FCC press release focuses on a newly released online map that allows the user to zoom in to a particular location to see a small cluster of buildings and to see how well those locations are served. Even more compelling than the consumer-oriented map - at least in the eyes of journalists and policymakers - are the tens of GBs of data that can be downloaded. These files tell a rich and nuanced story.

Version 1.2 of the *Toolkit* visualizes Fabric results at the County level and the Place level for a variety of performance thresholds. Each visualization is color coded with optional overlaid text. The visualization shows the percentage of fixed locations for which the specified performance threshold is achieved . In the previous "Form 477 paradigm" a census block was covered or not (a binary choice) at a particular threshold. In the new fabric-oriented paradigm a geographic area is covered at 0% of locations or 100% of locations or anything in-between. A nearly continuous color scale is therefore appropriate. Showing performance by "Place" is also new. Places are towns or other geographical areas with recognizable names. There are often large physical gaps between "places". A map showing all known places is therefore not contiguous. Even so, it offers a high level of detail. Finally, it is possible to parse the data in the most detailed files and project it onto census blocks (similar to 477 data). It is also possible to do detailed "cluster of points" visualizations. Which of these deep dive analyses is most compelling is an excellent future discussion.

Figure 1 shows several possible visualizations using Fabric data. Version 1.2 of the Toolkit retains its many layers of 477 data, as well, since these represent a familiar perspective to many users.

The Opportunity

The magnitude of investment associated with BEAD ($42.45 billion) makes it a once-in-a-generation opportunity. It follows a large number of previous programs (CAF, CAF II, RDOF, ReConnect, etc.) using grants, loans, reverse auctions and other tools to fund infrastructure deployment in challenging high cost areas.

Equally important, BEAD ups the ante by defining "qualifying broadband" as reliable service offering 100 Mbps down / 20 Mbps up, with no more than 100 msecs of latency. It further defines "underserved" as greater than or equal to 25 Mbps / 3 Mbps but less than 100 Mbps / 20 Mbps and "unserved" as less than 25 Mbps / 3 Mbps.

The map of the United States changes with these new definitions of broadband. 40.8% of all 2010 census blocks (based on Form 477 filings as of 12-31-2020) are now unserved or underserved. With these new definitions one does not need to look far to find geographies that lack qualified broadband.

This Toolkit presents a very different set of images than the previous *Infrastructure Essentials Toolkit*, because of the much more aggressive definition of qualifying broadband under BEAD.

Figure 1: FCC “Fabric” Data Visualizations. Top: % of locations, 100-20, Bottom Left: % 100-20 Places, Bottom Right: Rooftop Points

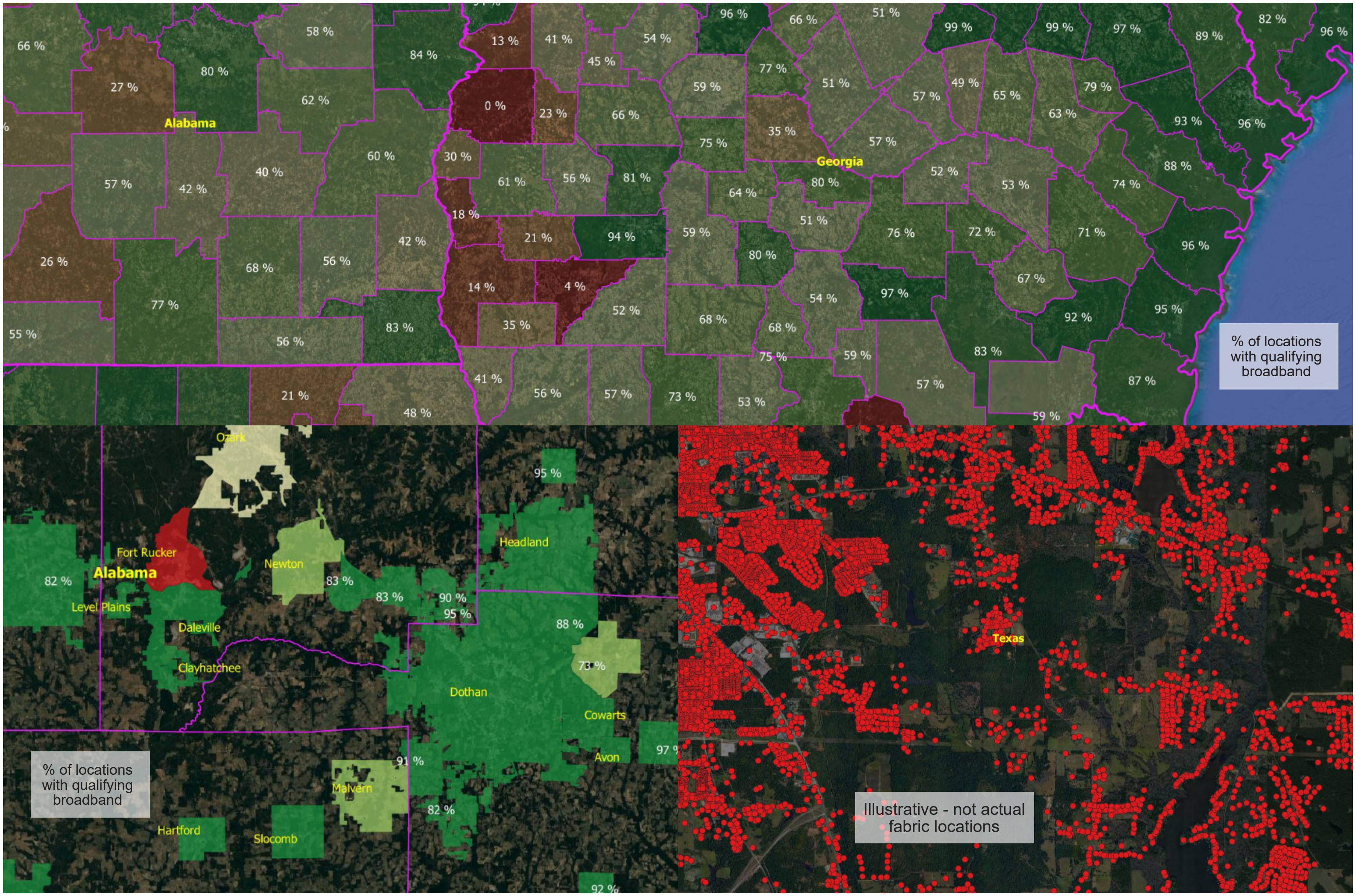


Figure 2: Unserved (Mustard, < 25-3 Mbps) and Underserved (Salmon, >= 25-3 Mbps, <= 100-20 Mbps) Census Blocks

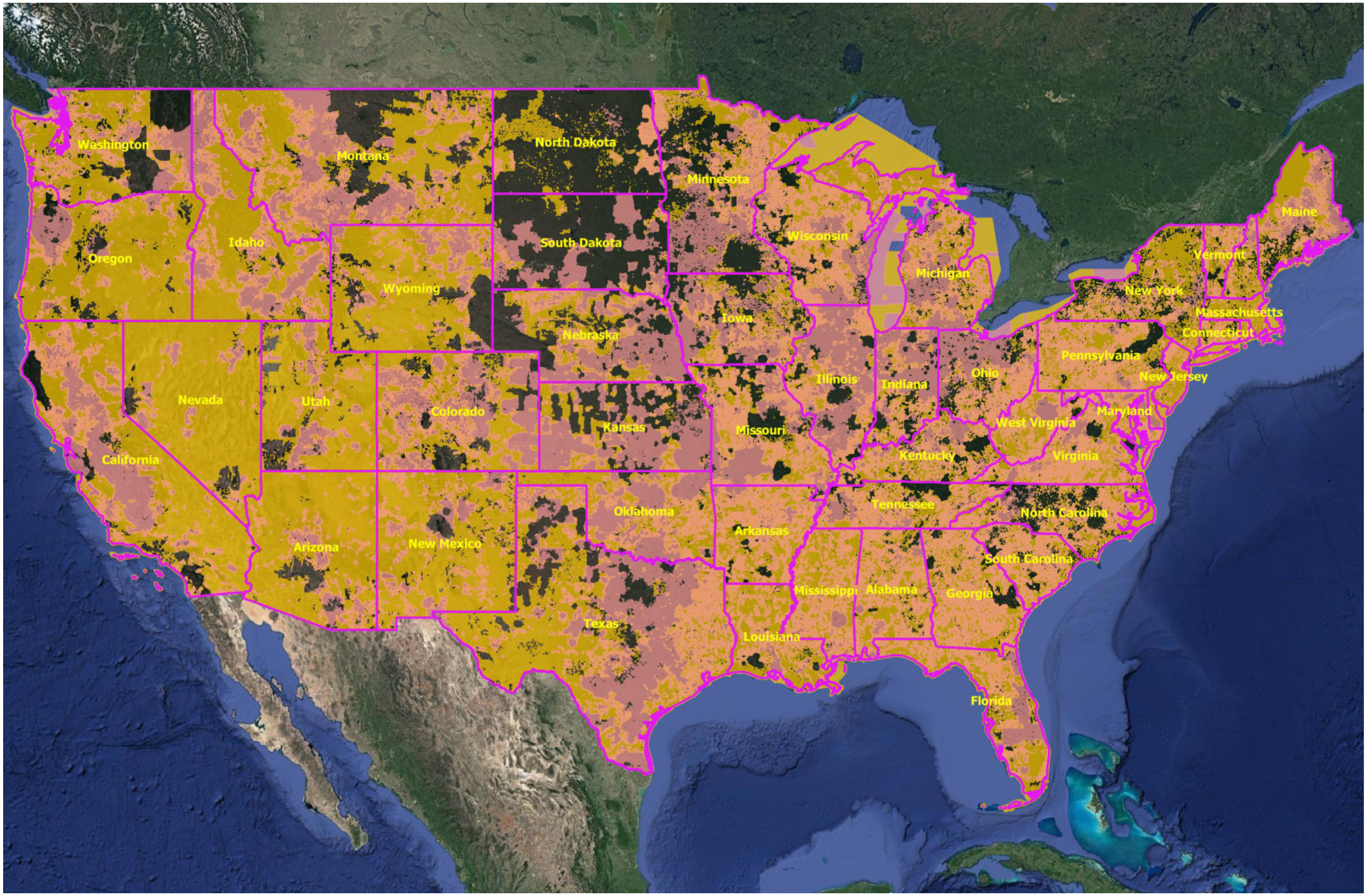


Figure 3: Qualifying / Served (100-20 Mbps) Census Blocks, based on FCC Form 477

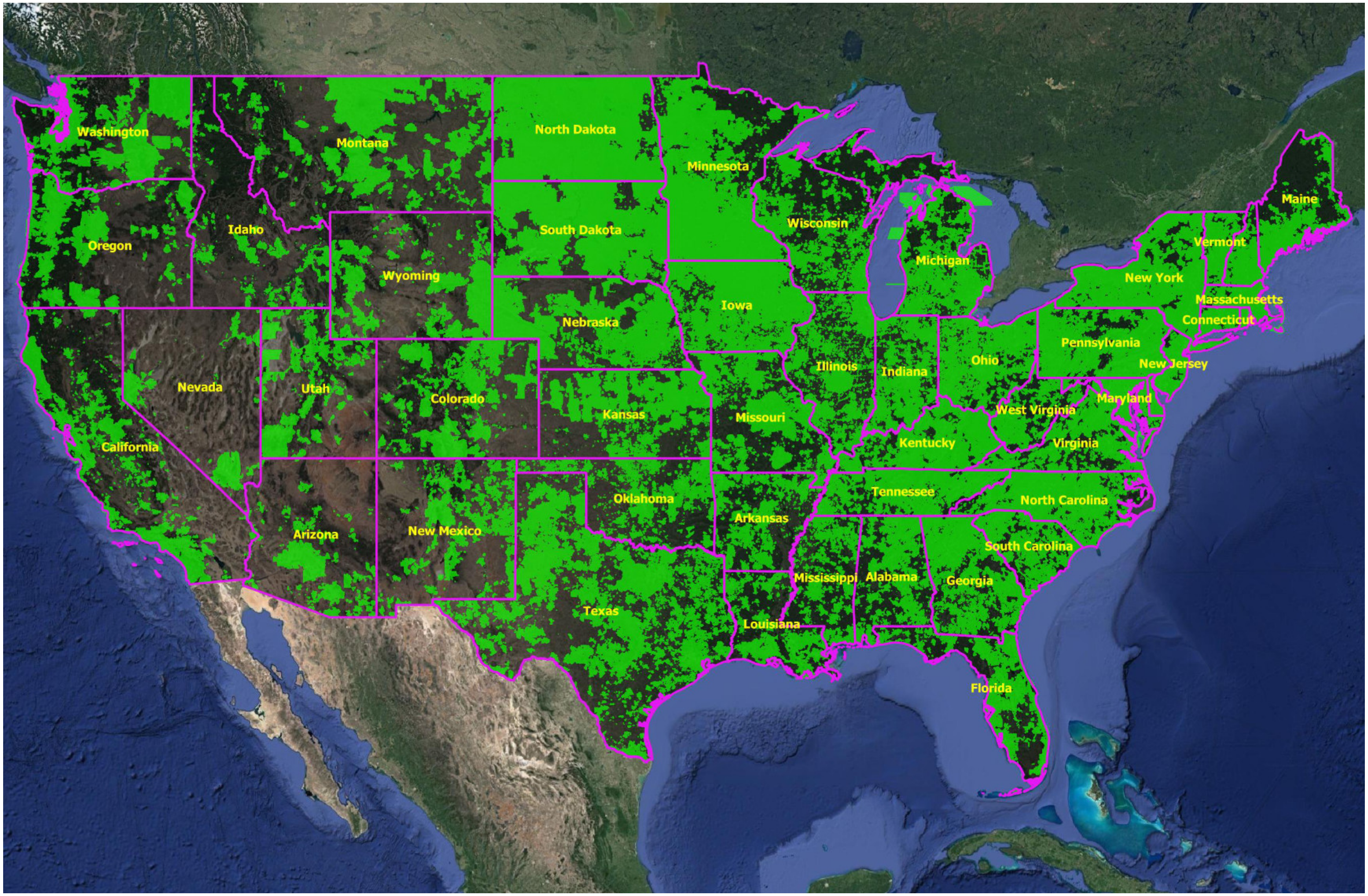


Figure 4: Every Census Block Is either Unserved (Mustard), Underserved (Salmon), or Served (Bright Green) based on FCC data

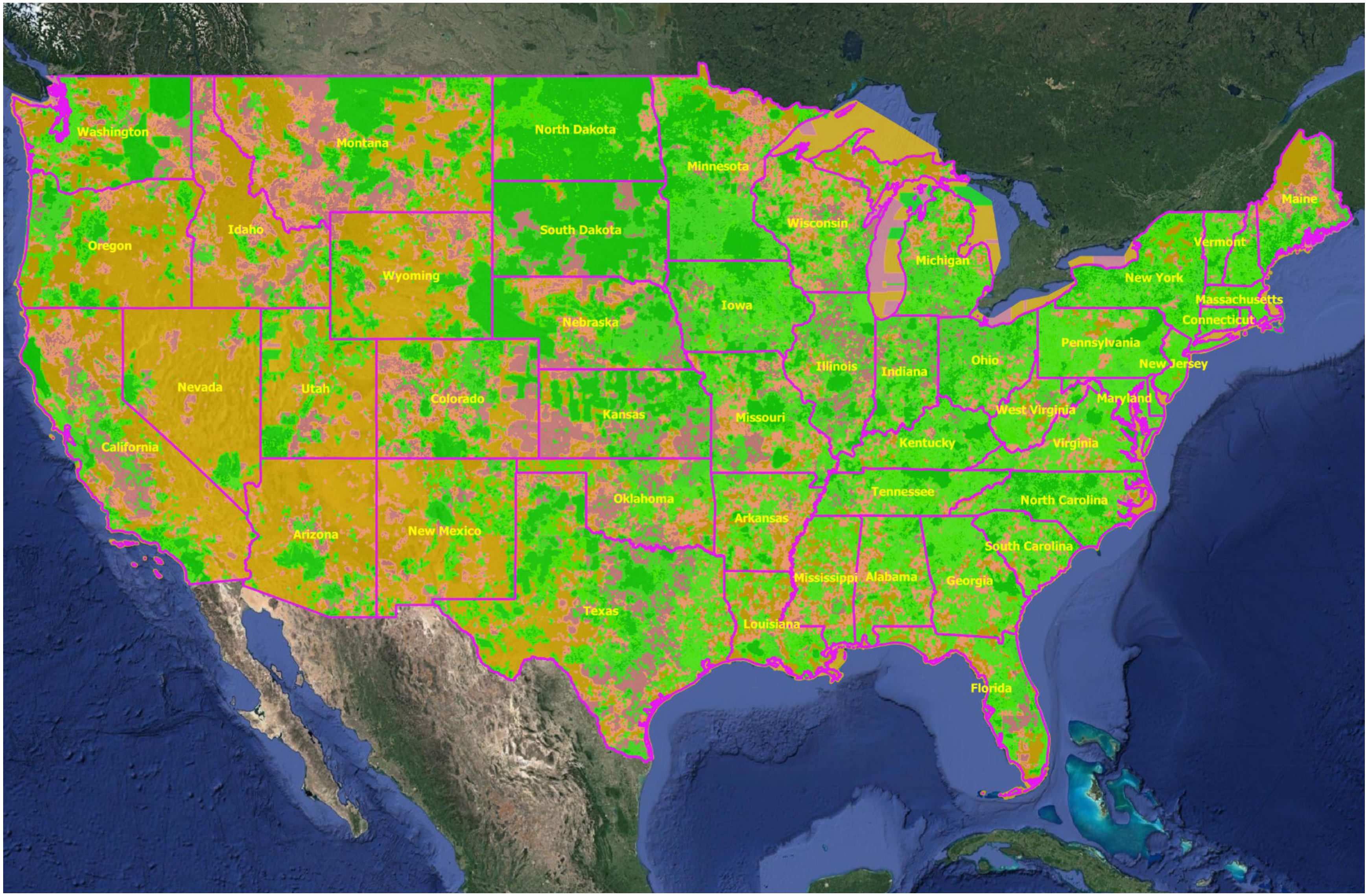


Figure 5: Incremental Broadband Coverage as a Result of CAF II, RDOF, and USDA Programs

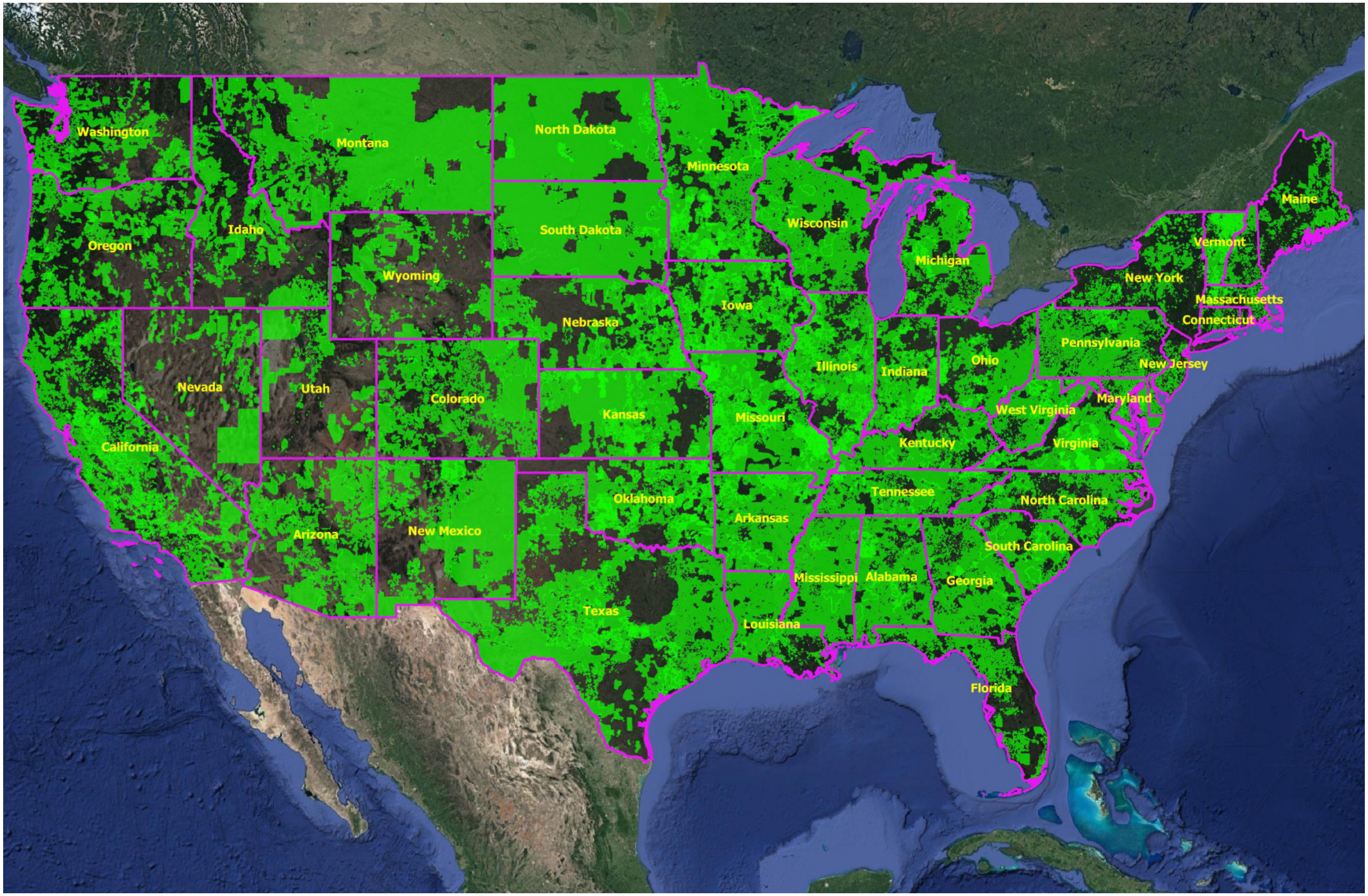


Figure 6: Kansas, Unserved (Mustard), Underserved (Salmon), and Qualifying / Served (Green), based on FCC Form 477

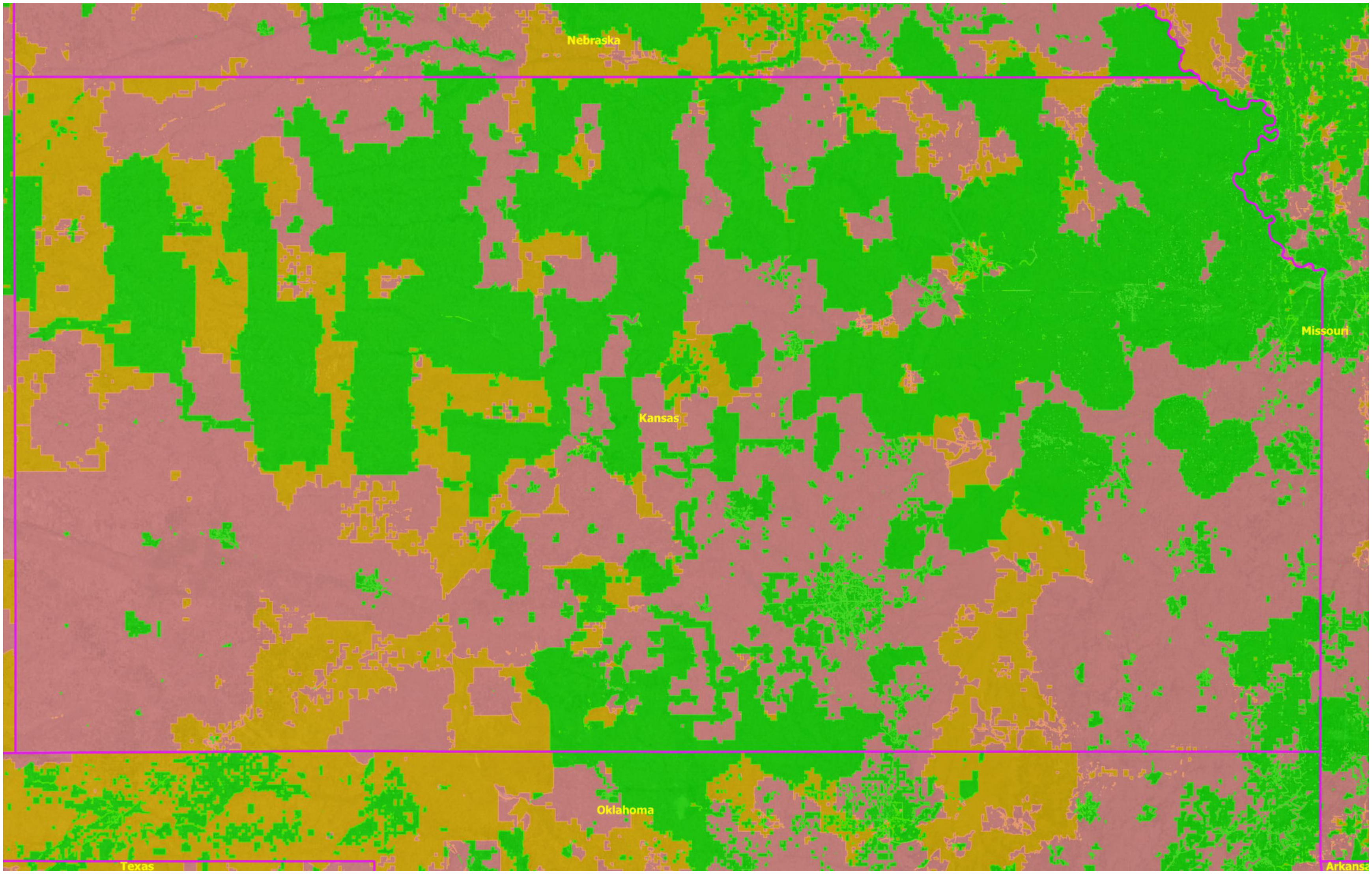


Figure 7: Kansas, Unserved (Mustard), Underserved (Salmon), both based on Form 477, and Ookla Measured Speeds (Green if >= 100-20)

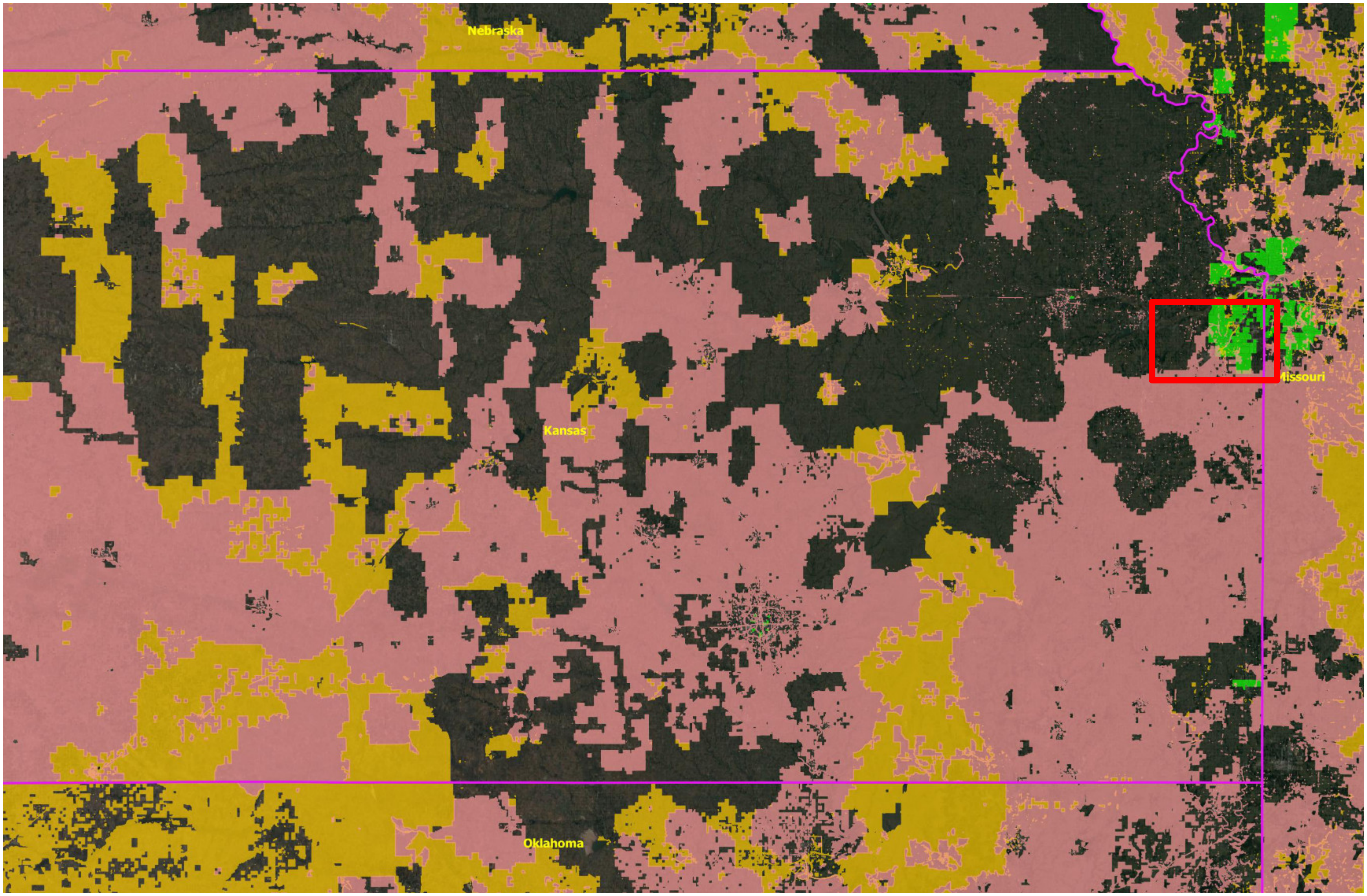


Figure 8: Housing Units by Block Group and Ookla Measured Speeds (Green is >= 100-20) by Tract

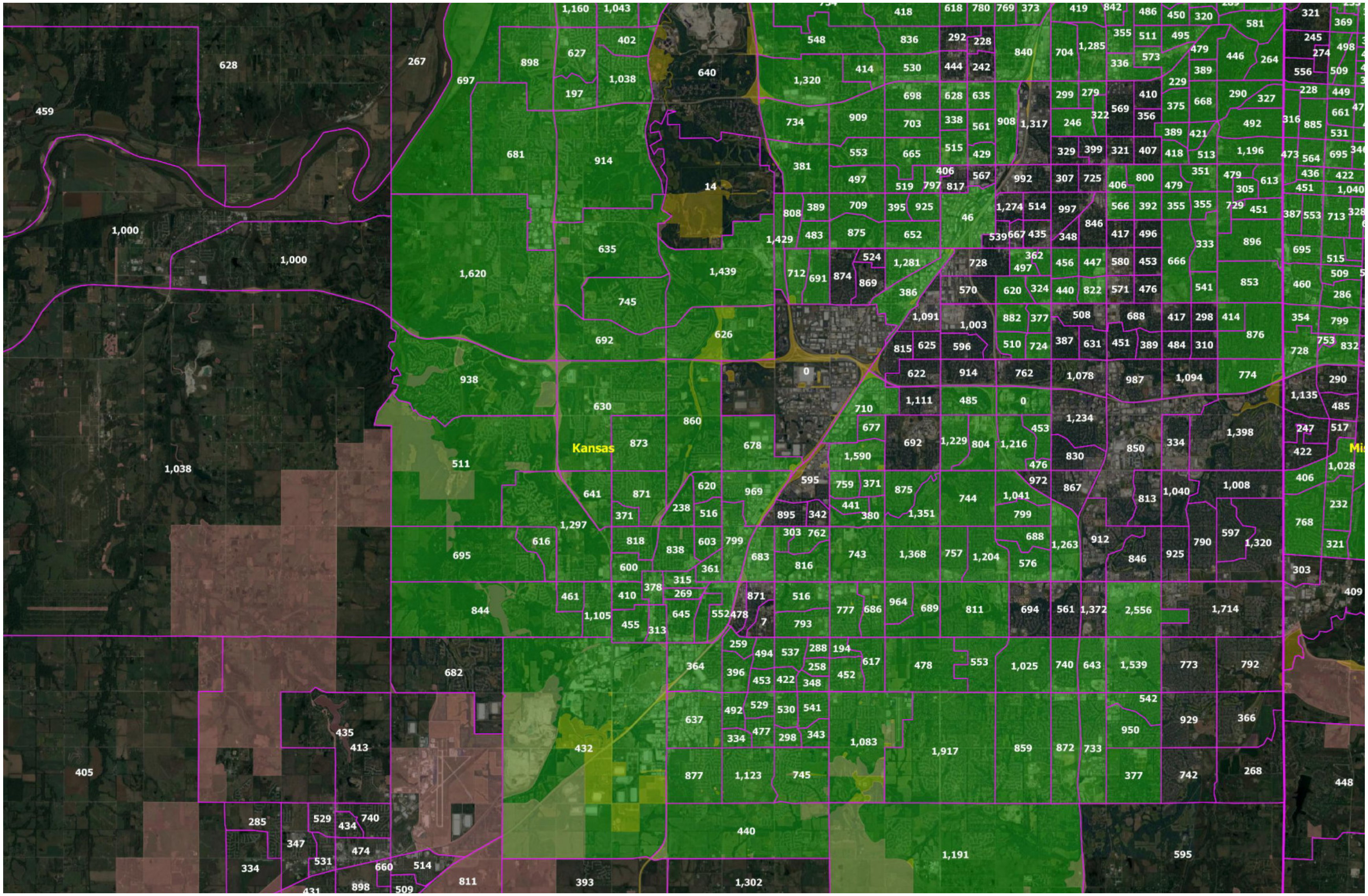


Figure 9: Median Speeds (Down-Up, Ookla) by Census Tract

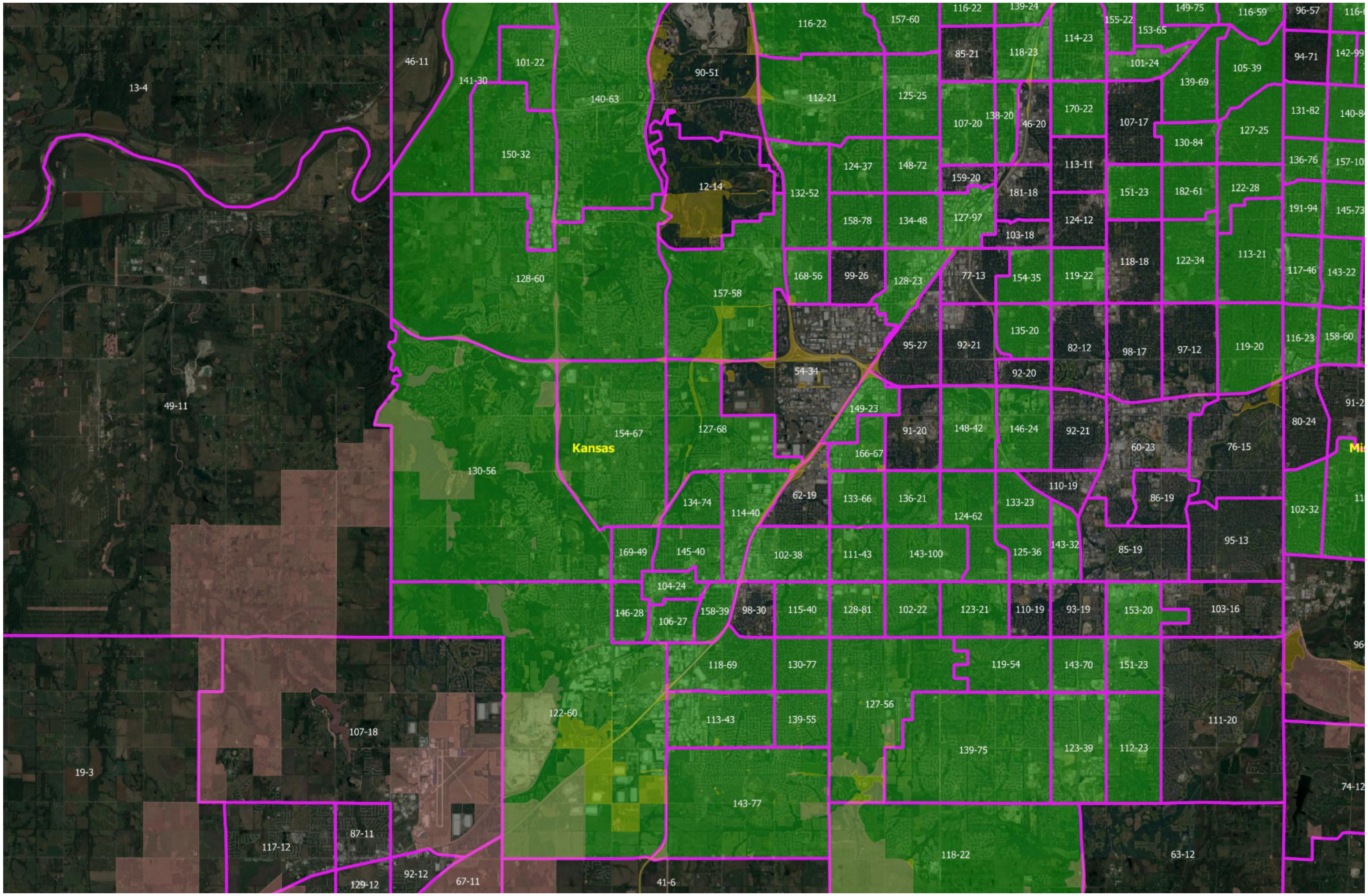


Figure 10: Moving from Block-Group-Level to Block-Level Data

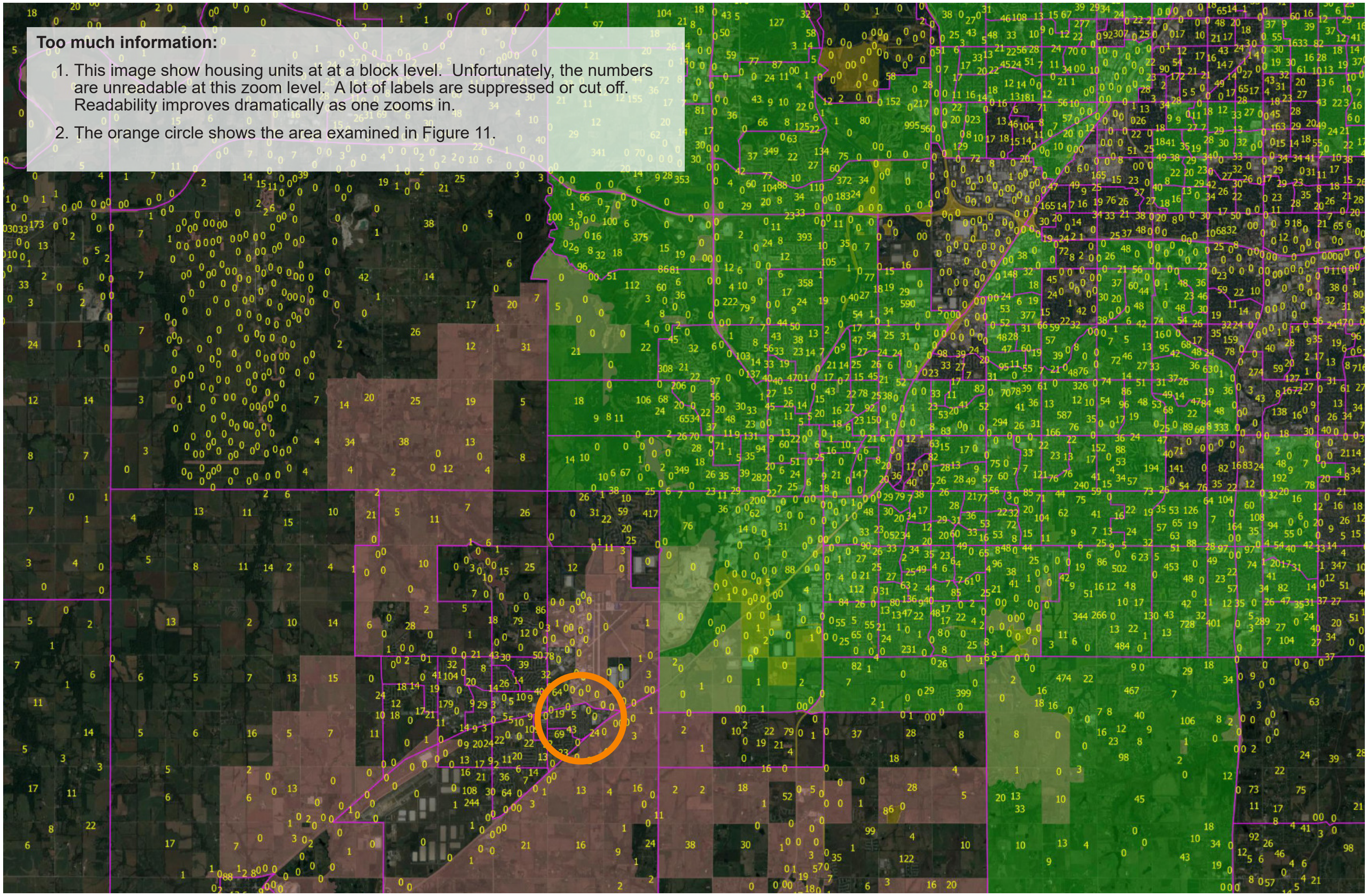
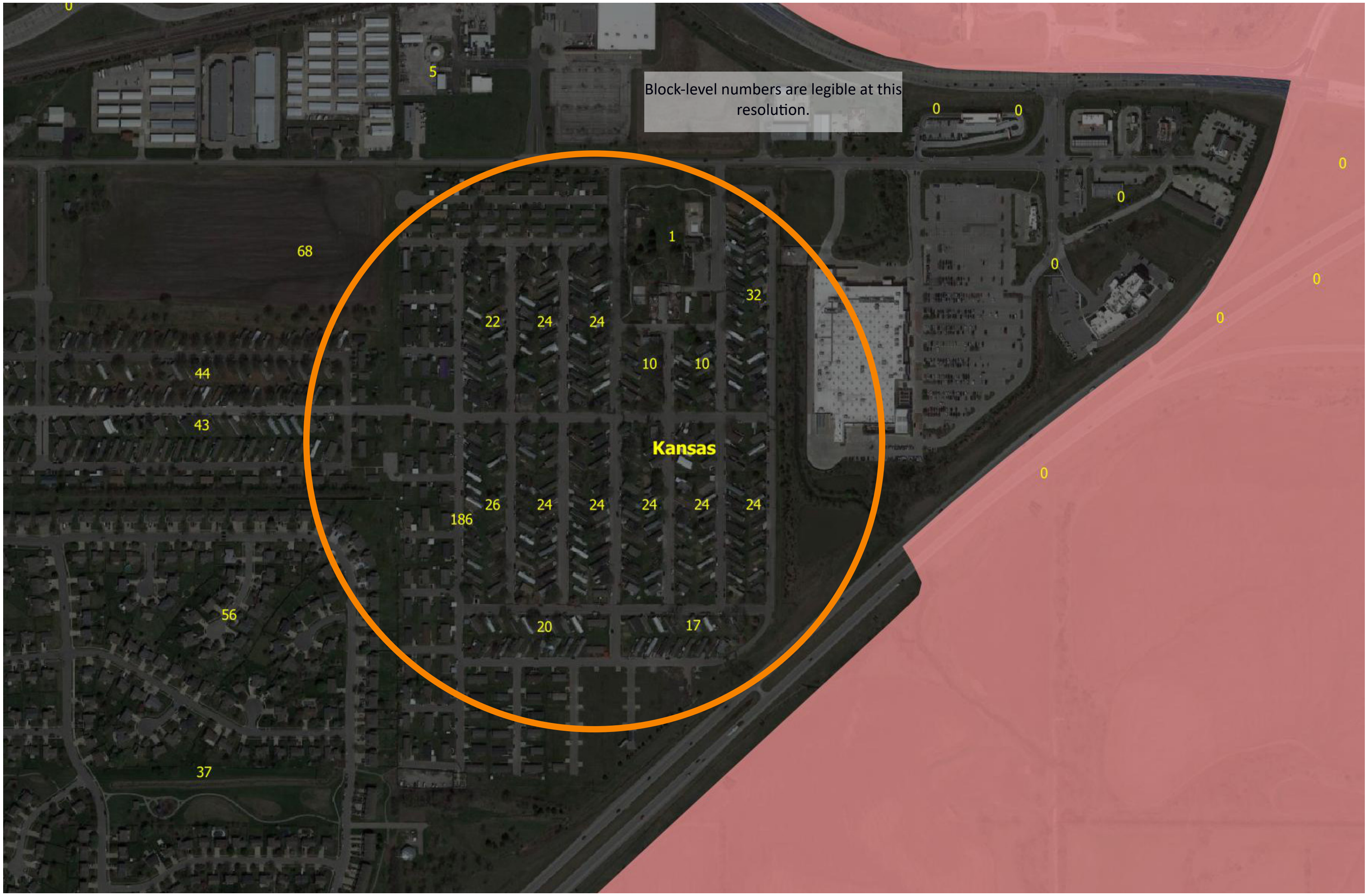


Figure 11: A Single Community, 300 - 400 Homes Passed



Nation at a Glance

Figures 2, 3, 4, and 5 give a quick view of the geography of the United States that is unserved (< 25-3 Mbps), underserved (>= 25-3 Mbps and < 100-20 Mbps) speeds, and fully served at qualifying speeds (100-20 Mbps), at least according to the FCC's for 477 data (more on that to come).

It is important to note that the FCC definition of qualifying broadband also stipulates low latency (< 100 msecs 95% of the time), however there is no explicit measurement of latency in FCC Form 477 data. Generally, terrestrial solutions are low latency. LEO satellite solutions are also - by design - low latency. GEO satellite solutions, in general are not low latency.

Figure 5 shows the result of the most impactful federal subsidy programs: RDOF, CAF II, and the USDA initiatives (most importantly ReConnect). In this case only qualifying (100-20 Mbps and low latency) RDOF and CAF II areas are visualized in green.

A likely response to the national coverage map (showing over 11 million blocks at once) it is that it is hard to see what is happening. In the next section we will take a deep dive into some local geography. That exploration will highlight the many tools and data sets in the Toolkit and demonstrate how insights emerge when examining small regions with detailed local data.

Discovering Uncovered Geography

Governments, investors, and ISPs are eager to identify unserved and underserved areas that have enough density to serve cost-effectively.

Figures 6, 7, 8, 9, 10, and 11 illustrate that process:

- Figure 6 shows the state of Kansas using form 477 data. It's a sea of pastel. Every census block is characterized as unserved, underserved, or served.

- Figure 7 shows the same unserved and underserved areas. Tracts with a median speed of 100-20 or greater based on Ookla data (vs FCC 477 data) are now colored green. We discover that a large portion of the geography previously characterized as served based on FCC 477 data is not served at the required 100-20 Mbps, based on a stricter metric. The metric in this image has been changed from "maximum advertised speed" (FCC 477 data) to "median measured speed" (Ookla data). Figure 6 shows a rectangle enclosing an area on the southwest side of Kansas City. We will look at that area in the next figure.

- Figure 9 is a close-up of the area highlighted in Figure 6. The image shows the number of housing units by block group for an area southwest of Kansas City.

- Figure 9 is identical to Figure 8 except that it shows measured data rates per tract instead of housing units per block group.

- Figure 10 displays the most detailed level of demographic data. It shows the number of housing units per block. A this zoom level the numbers are essentially unreadable. Figure 10 fixes this.

- Figure 11 is a close-up view of the orange circle of Figure 10. As one zooms in additional block labels appear that were previously suppressed by QGIS as a result of a congestion of

Figure 12: Fiber (Technology) Coverage by Neighborhood at a Block Level

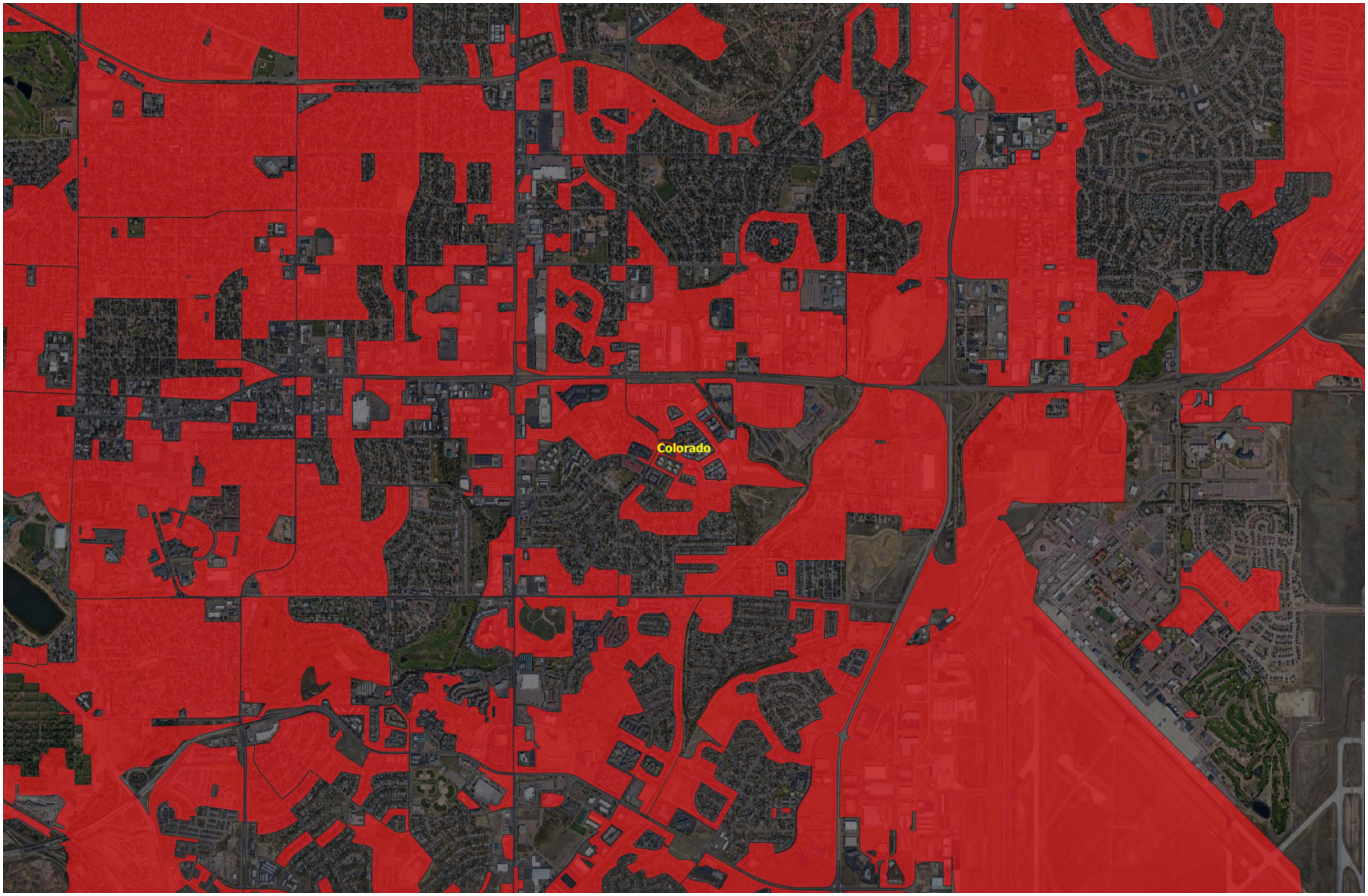


Figure 13: Charter (Specific Competitor) Tract Level Coverage in Green and Cable (Technology) Block-Level Coverage in Yellow

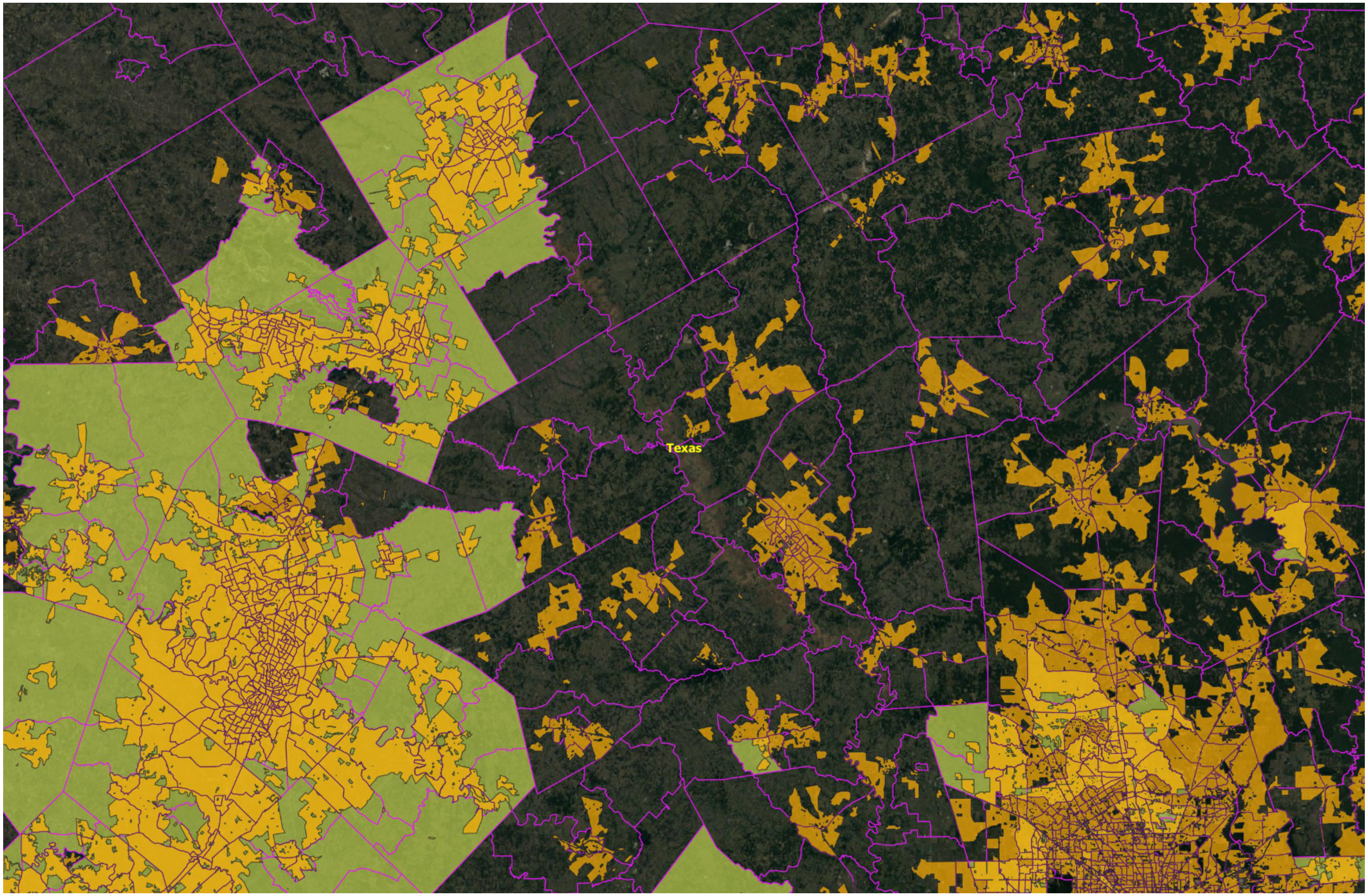


Figure 14: National Fixed Broadband Competitors (by Tract)

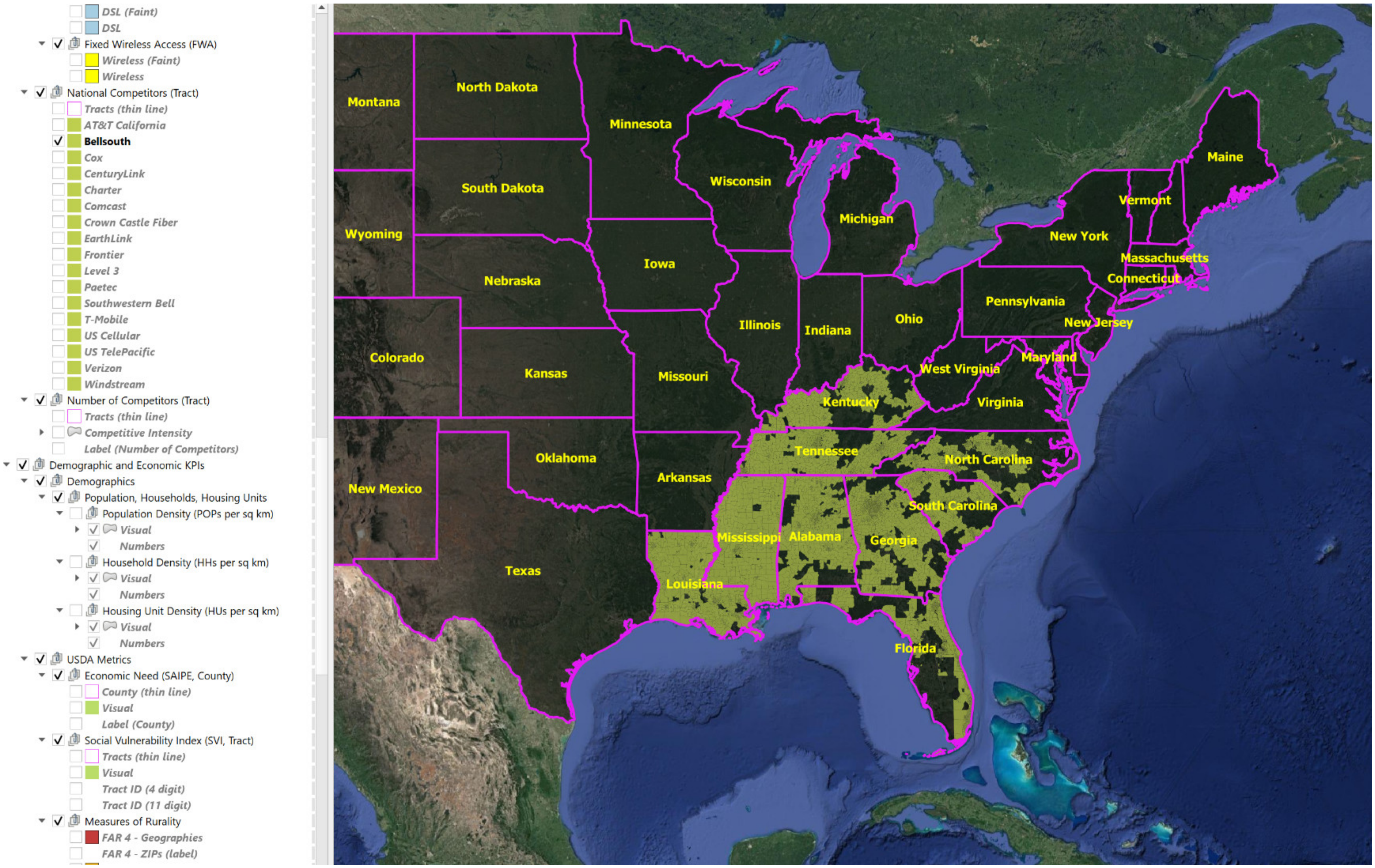
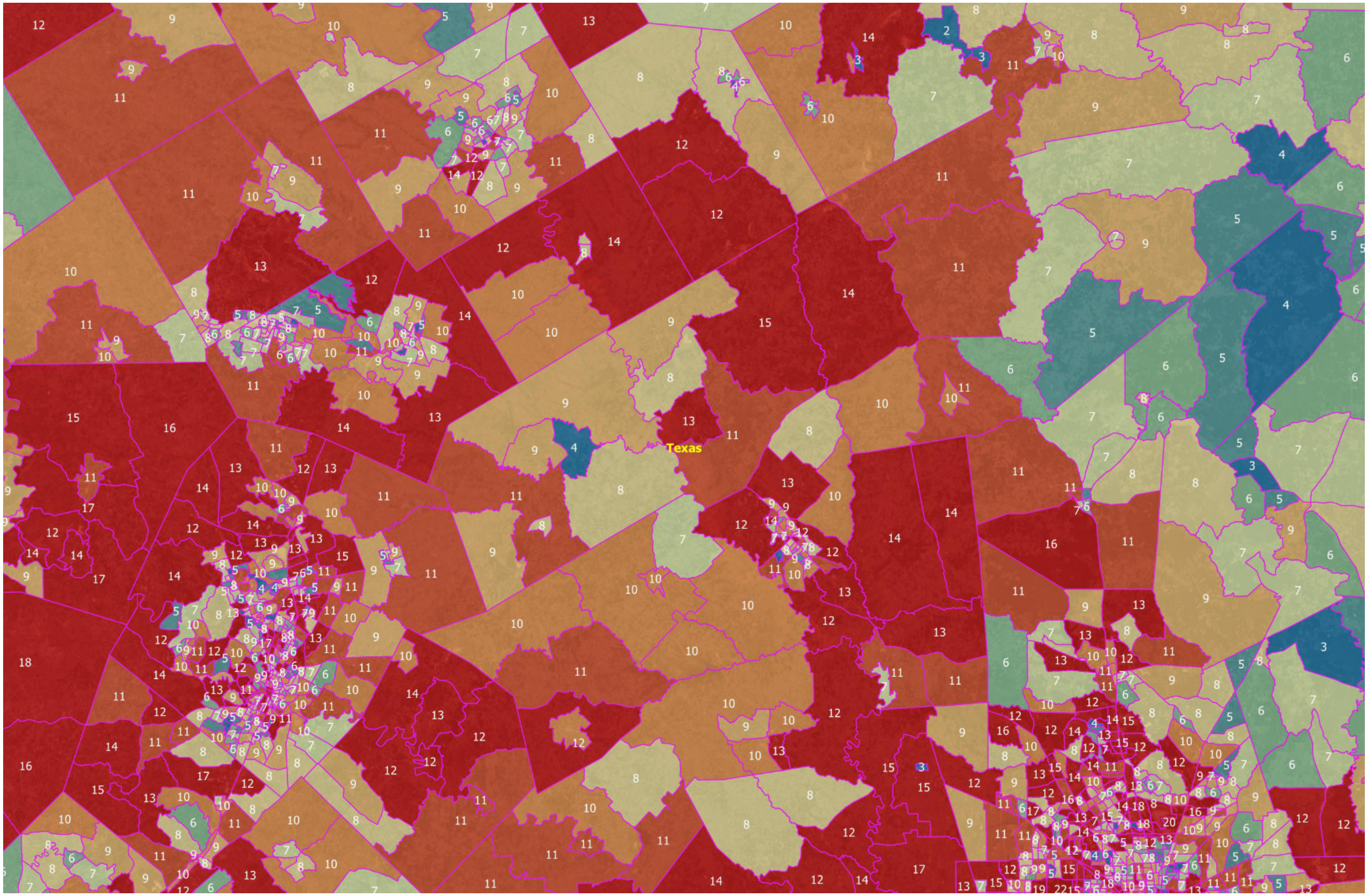


Figure 15: Number of Competitors (Competitive Intensity) by Tract. Same view as Figure 12.



labels. An area with 300 - 400 homes appears. One can easily see where the homes are located.

Figures 12, 13, 14, and 15 show data from the *Technology and Competition Module* (a product, sold separately, that augments the Infrastructure Essentials BEAD Toolkit):

- Figure 12 shows coverage at a block level by a specific technology (Fiber). In this example one neighborhood is covered by fiber and the next is not. One could simultaneously see the presence of other technologies by turning on other technology layers.

- Figure 13 shows how competitive information and technology information can be juxtaposed. In this image the competitive footprint of Charter, at a tract level, is shown in green. At the same time the technology footprint of cable (DOCSIS) is shown in yellow. One can see large areas of cable plant almost certainly owned by Charter. One can also see large areas of cable plant owned and operated by other cable operators. We know that these networks belong to someone else because Charter does not have a reported presence in any of these tracts.

- Figure 14 shows a list of national competitors whose footprints can be displayed.

- Figure 15 shows competitive intensity at a tract level. The colors and the numbers indicate how many fixed broadband providers are offering service within each Census Tract. Interestingly, the areas with the greatest number of competitors are often areas that are not well covered (e.g. not dominated by a single fiber provider or a well-financed cable provider) but are also not extremely remote (and therefore uneconomic to cover).

Figures 16, 17, and 18 show socio-economic metrics:

- Figure 16 shows median household income per block group. Economic metrics are helpful in demonstrating need.

- Figure 17 shows the percentage of households receiving SNAP (a.k.a. food stamp) benefits. A SNAP recipient qualifies for a monthly subsidy under the Affordable Connectivity Program (ACP).

- Figure 18 shows the lowest priced broadband subscription by Zip Code. It is helpful in that it highlights the relationship between availability and competition and affordability.

Figures 19 and 20 show other useful data sets:

- Figure 19 shows community anchor institutions. These as red dot in this figure. There are seven different categories. They can be displayed in aggregate or by category with or without labels.

- Figure 20 shows the juxtaposition of several different data sets in an urban area. The image shows housing units per block in yellow and housing units per block group in white. The block group is enclosed in a magenta boundary. Every block with one or more group homes (college dormitories, nursing homes, prisons - basically any facility with people who are not living in households) has a large yellow dot. Such venues often represent an opportunity to provide a larger broadband pipe.

Figure 16: Median Household Income by Block Group

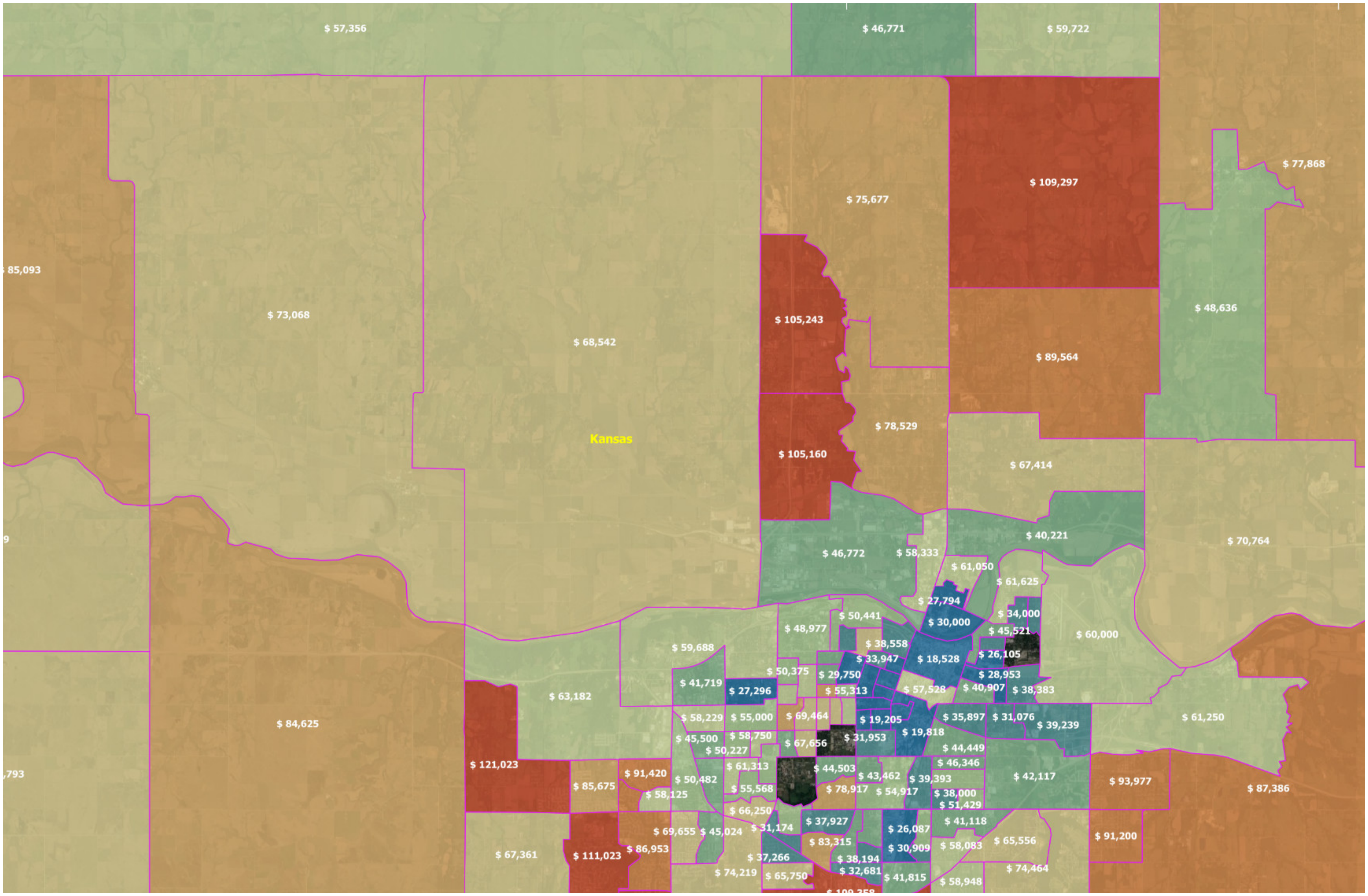
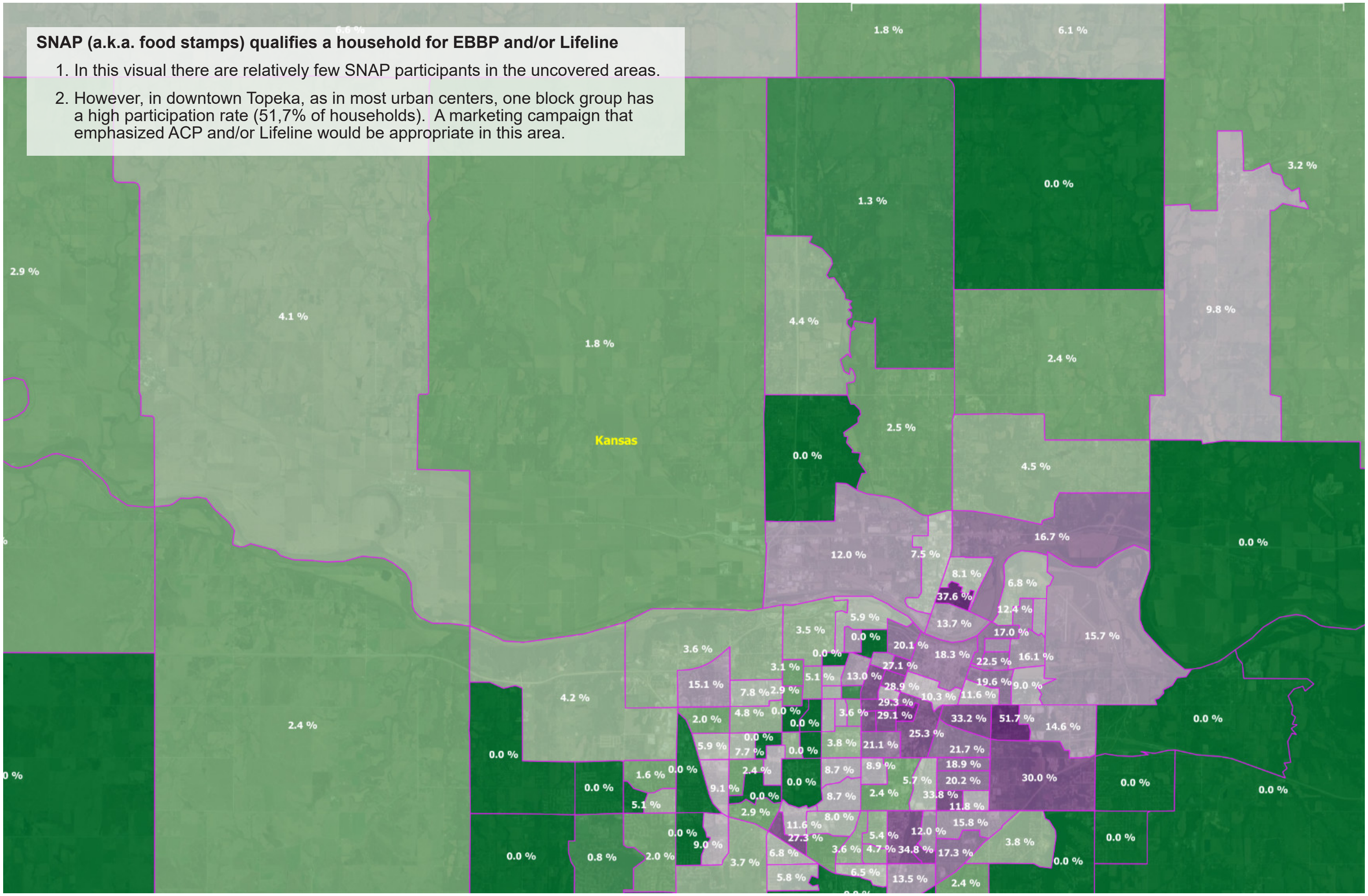


Figure 17: Food Stamp Participate Rate (% of Households) by Block Group



Measuring Performance

There are a number of factors that greatly influence performance and contribute to the significant differences in reported speeds. These include:

- *Advertised vs. Measured*. When an ISP reports its performance to the FCC on Form 477 it is asked to describe the "maximum advertised speed". This number of often greater than the average (mean or median) speed delivered. In some cases an ISP may advertise a speed that it can only deliver to some subscribers. In addition, most ISPs offer a range of plans and many subscribers do not purchase the most expensive plan. Thus, there is a difference (often a large difference), between the maximum advertised speed and the speed delivered to the average subscriber.

- *A Partially Covered Census Block*. When an ISP reports its performance to the FCC on Form 477 it identifies each census block it serves in whole or in part. If it has a single subscriber then that census block is categorized as served. The resulting coverage map – in the eyes of most consumers – overstates coverage. The FCC fabric seeks to address this.

- *Mean vs. Median*. The "average" speed can be measured many different ways. In most networks performance statistics are skewed to the right. In other words there are likely to be a few subscribers with very high speeds and a large number of subscribers with very modest speeds. The median speed (the number above which half of the data points fall and below which half of the data points fall) is generally consider a more meaningful metric, just as median household income is a better measure of spending power than mean income. We find with performance data some sets of measurements that report mean speeds and others that report median speeds. Means speeds in most cases will be significantly higher than median speeds. Both measurements may be technically correct but the resulting numbers are different. Additionally, one could consider time-of-day differences or use a cumulative distribution function. A service level agreement that promises to deliver a certain speed 99.9% of the time is far more stringent than a promise to deliver the same speed "on average".

- *Geographic Area*. The size of the geographic area considered greatly influences the numerical result and how meaningful it might be. In a large geographic area (especially one that includes both urban or dense suburban geography and rural geography) the urbanized portion is likely to be better served than the rural portion. A single performance number is likely to overstate rural quality of service. Also, since household densities are higher in urban areas the distribution of measurements is likely to disproportionately reflect urban households. The solution is to characterize network performance in as small a geographic area as possible. Blocks are better than block groups which are better than tracts which are better than counties.

- *Modem Speed vs. Wi-Fi Speed*. If one measures performance at the modem the result is likely to be more favorably than the same measurement on a device connected via Wi-Fi. Wi-Fi networks, while convenient, are notoriously unreliable. Like any radio access technology they are subject to signal strength degradation (due to obstructions, distance, and reflective fading) and to interference (especially in an urban environment). Equally importantly many consumers don't

Figure 18: Minimum Monthly Cost of Broadband by Zip Code (BroadbandNow)

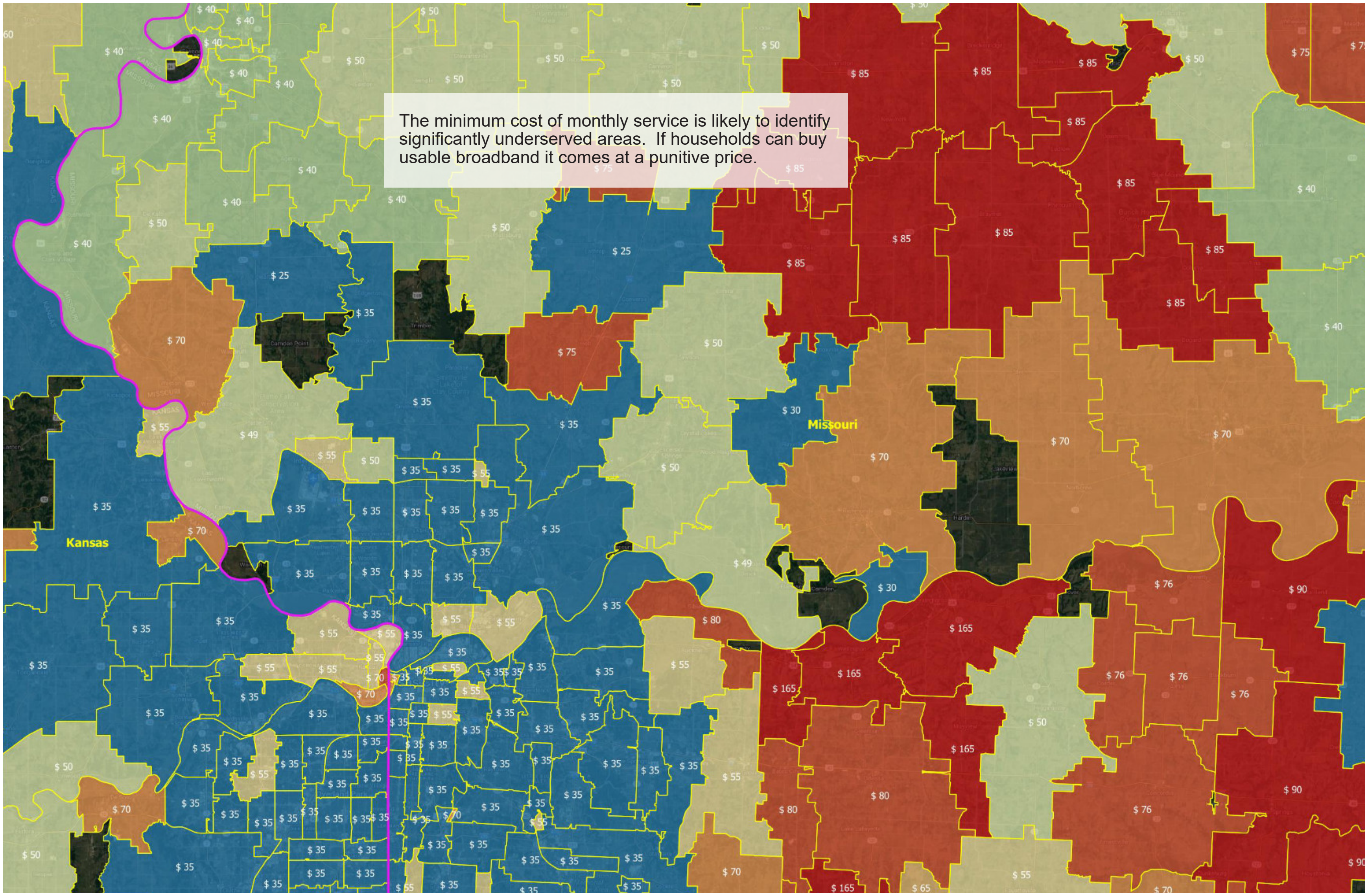
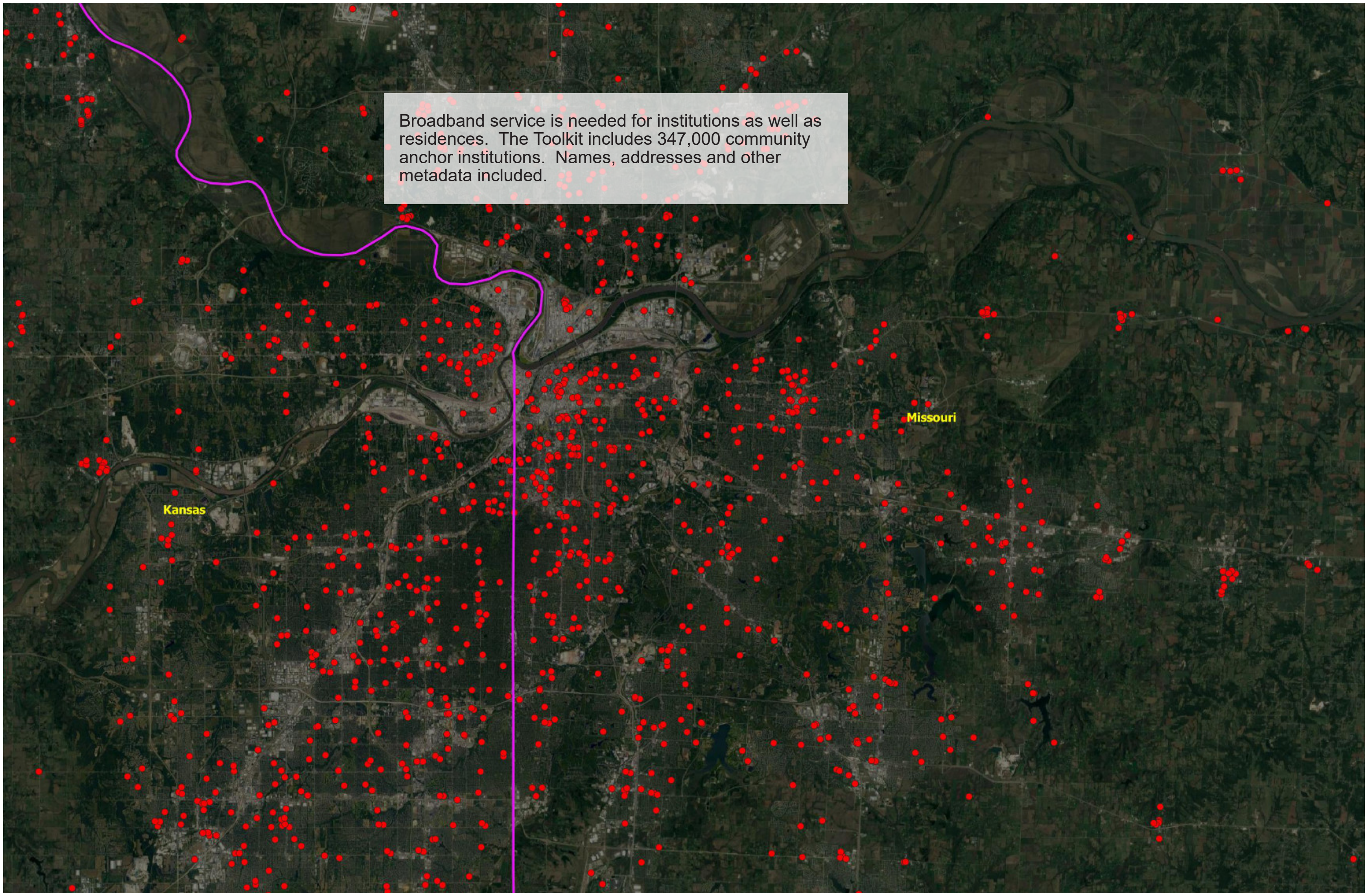


Figure 19: Community Anchor Institutions (7 selectable categories such as schools, libraries, medical facilities, etc.)



know how to set up a Wi-Fi network or how to optimize it for performance or how to measure performance. Many view Wi-Fi in binary terms, like electrical power that is either "on" or "off" (a black out). Wi-Fi networks are, of course, much more nuanced and can be a major factor limiting one's broadband experience. If a consumer has a poor experience because of a poorly configured Wi-Fi network it is unfair to blame the ISP.

- *Intentionality*. When someone runs a speed test it is likely that they believe they should have reasonable connectivity. In contrast, when machine-to-machine downloads are measured passively the consumer may be unaware that communication is taking place. A laptop user, for instance, might close his laptop and plug it in to charge in a room that has poor Wi-Fi coverage. A measurement of passive download speeds (e.g. operating system updates) may not represent the speeds the user experiences when deliberately connecting to the network.

- *Pricing of Service*. Most consumers do not purchase the most expensive broadband plan available. Consequently, a measurement of consumer speed is not necessarily an indicator of the capabilities of the associated outside plant.

FCC vs. Industry Data

With the above caveats, here are the included data sets:

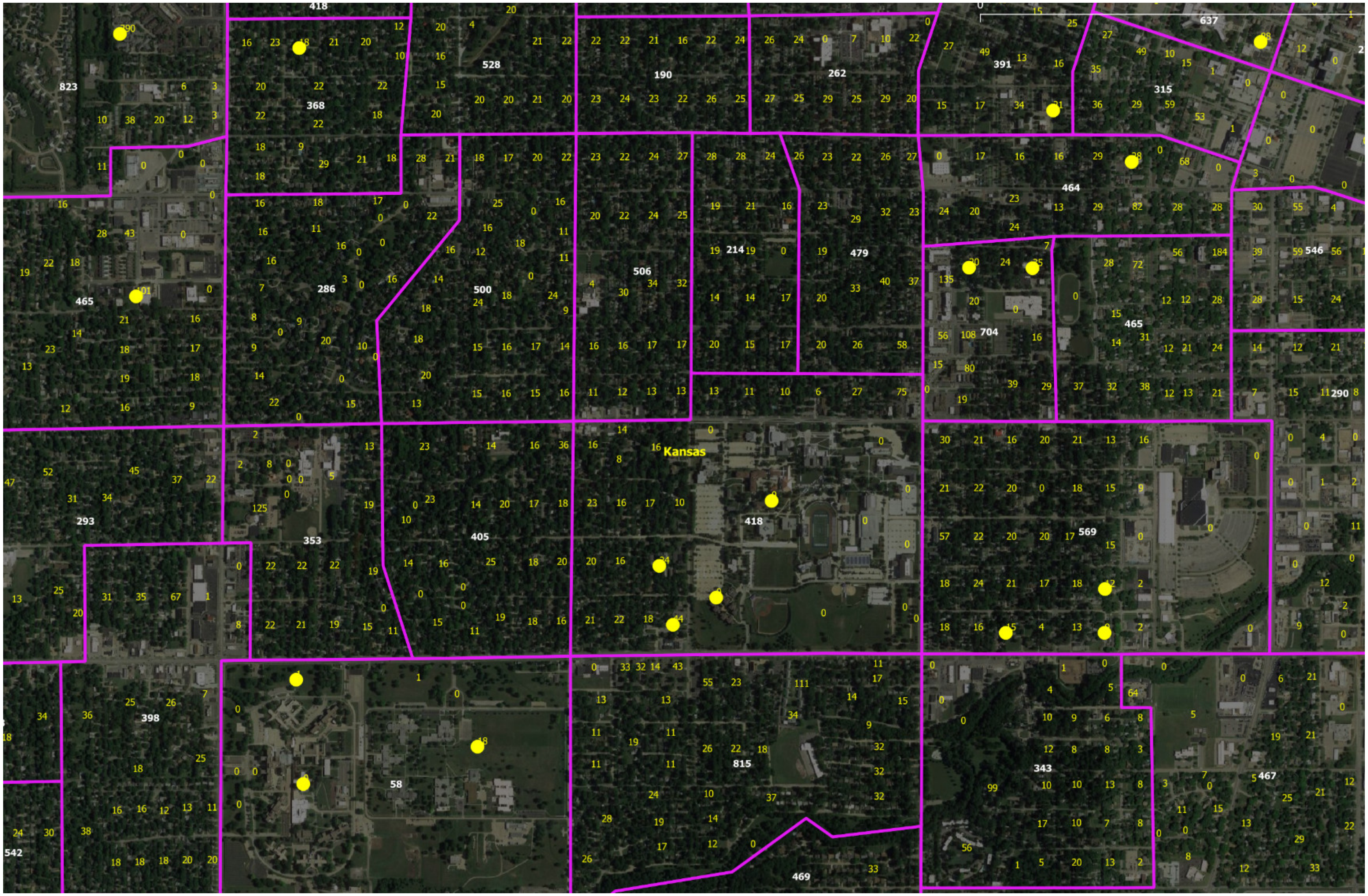
- FCC Form 477. The FCC requires ISPs to report service availability twice a year on Form 477. Despite its many limitations this data serves as a starting point to understand broadband availability by geography. The Toolkit includes three important layers (June 30th, 2021 networks, excluding satellite. The raw data was released by the FCC on July 29th, 2022). The *calculated* layers include:
  - Qualifying Broadband / fully served areas (census blocks with a minimum of 100 Mbps down and 20 Mbps up)
  - Underserved blocks (< 100-20 Mbps and >= 25-3 Mbps)
  - Unserved blocks (< 25-3 Mbps)

- Federal Commitments. The federal government (the FCC, the USDA, and others) as well as state governments have subsidized the deployment of broadband infrastructure. The Toolkit includes data from the three most impactful federal programs. NTIA grant programs general preclude infrastructure grants in these areas to avoid duplication. Various exceptions exist, including instances in which the funding commitment will not result in a network that meets the current definition of broadband. The Toolkit includes the following calculated layers:

  - RDOF. A map layer that shows all RDOF awards that fit the "low latency" category and deliver 100-20 Mbps.
  - CAF II. A map layer shows all CAF II awards that meet or exceed 100-20 Mbps and are "low latency".
  - USDA. Map layers (protected and pending) showing USDA commitments, most notably ReConnect, including both grant and loan programs.

- Measured Data. The NTIA, as part of their National Broadband Mapping Program, collected measured data from multiple commercial and non-profit entities and made that data available to the public. The contributors included Ookla, M-Lab, and Microsoft. Links to each of the source data sets, including additional descriptive information and, in some

Figure 20: Urban View. Housing Units by Block Group (White) and by Block (Yellow) and Group Homes by Block (Large Yellow Dot)



cases, public use licenses, are included in the "Web Site Links" folder of the Toolkit. The data is provided in multiple resolutions and with a wide variety of metrics. The Toolkit visualizes the most important metrics. Here is a quick summary of each data set:

- *Ookla*. Ookla, the owner of speedtest.net, reports gathering 37 billion speed tests worldwide. The data they provided to the NTIA was collected between January 1st and June 30th of 2020. It is aggregated by census tract and by county. It reports median download and upload speeds.

- *M-Lab*. M-Lab is "a consortium of research, industry and public-interest partners dedicated to: Providing an open, verifiable measurement platform for global network performance. " M-Lab similarly reports median download and upload speeds. The data they provided to the NTIA was similarly collected between January 1st and June 30th of 2020. The results are aggregated on a county basis.

- *Microsoft*. Microsoft reports the performance associated with passive machine-to machine downloads (operating system and other updates). The sample size is spectacular. The results (characterizing the percentage of downloads fulfilled over a 25 Mbps / 3 Mbps or better connection) are more pessimistic than others, possibly because of the passive nature of the communication and the possibility that many devices may be in poor Wi-Fi coverage. The results are aggregated on a county basis.

- BroadbandNow (also BroadbandNow Research) collects a range of metrics on a Zip Code basis. They were not included in the NTIA collection but represent another credible source of measured data. In terms of resolution a Zip Code is better than a county but not as good as a tract. The Toolkit shows BroadbandNow download speeds and the "The Lowest Regular Monthly Priced Terrestrial (Wired + Fixed Wireless) Residential Standalone-Internet Broadband (25 Mbps Download / 3 Mbps Upload) Plan available." Areas with poor internet connectivity often have high prices, as shown by this metric.

In its 2021 grant programs the NTIA strongly encouraged applicants to present their own data. This could be data they collect themselves or data acquired in collaboration with another entity.

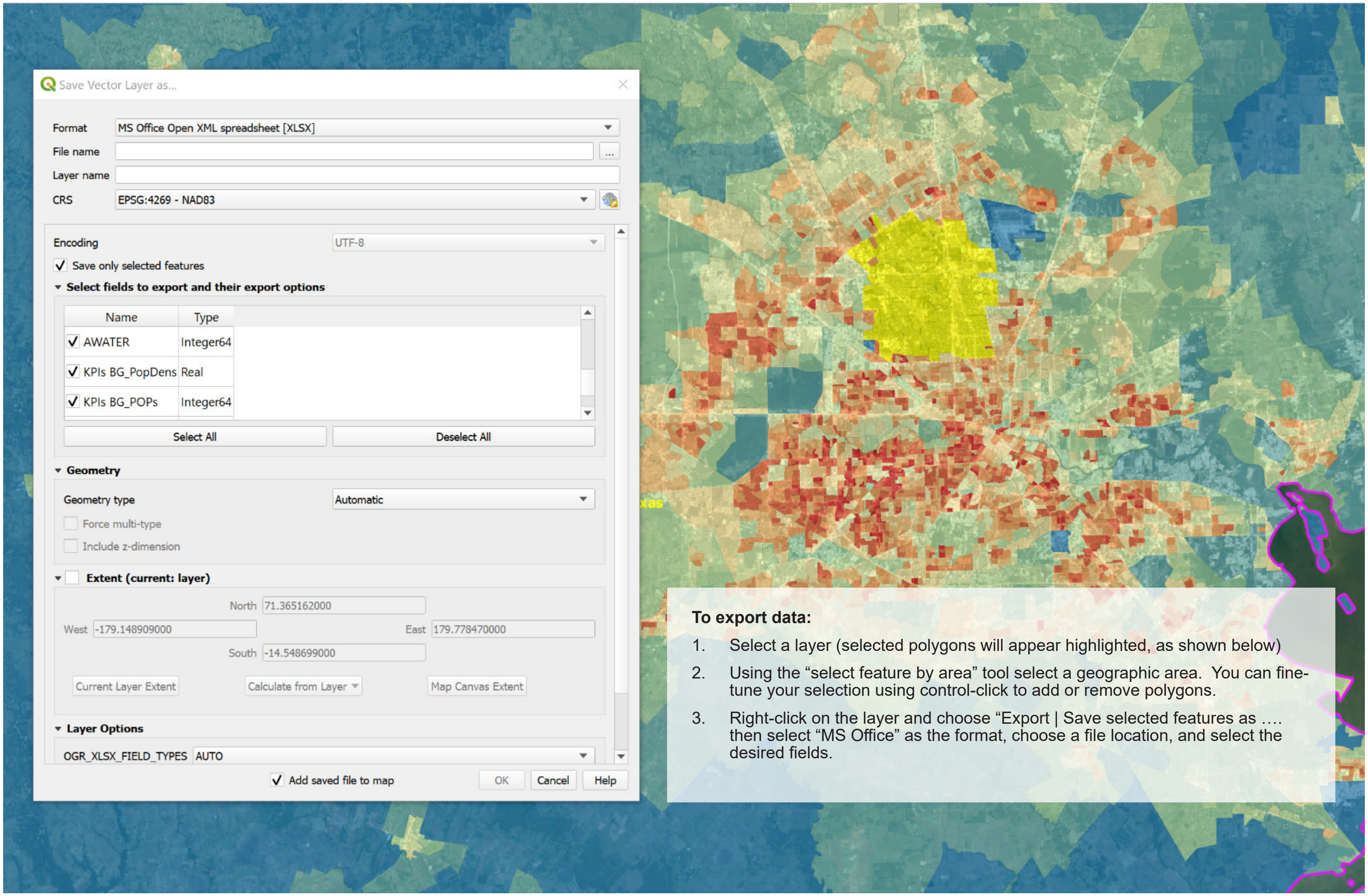
Custom data is helpful in making the case than an area, while theoretically covered based on Form 477 submissions, may not be covered to the required standard.

Layers of Visualization

- Inputs required to identify eligible geographies (tract and block group):
  - Household size
  - Median household income
  - Poverty threshold as a function of household size

- Key demographic inputs (block group):
  - Population density
  - Household density
  - Housing unit (physical structures, whether currently

Figure 21: How to Select and Export Data



occupied or not) density

- Key income inputs (block group):
  - Income per capita
  - Mean income per household
  - Median income per household
  - Average household size
  - Estimated poverty line
  - SNAP (a.k.a. food stamps) household participation rate

- Important contextual data:
  - A wide variety of streamable background maps (physical geography, roads, etc.) from leading map content providers, as well as solid backgrounds (for readability).
  - Geographic boundaries (block groups, tracts, zip code tabulation area, counties, states, and congressional districts) alone, or with associated numerical codes and/or names.
  - FCC license areas (BEAs, BTAs, CMAs, EAGs, MEAs, MTAs, PEAs, REAs, RPCs), relevant to those who may be providing wireless solutions.
  - Roads (primary and/or secondary, with or without labels).
  - Elevation data. The user may, optionally, view the underlying terrain in a color-coded format that reflects land elevation, hills, and valleys. Imposing natural boundaries often dictate services areas. The data is both visual and numerical.

- The data sets take several forms that can be used in any combination:
  - Visual data in a geographical information system tool (where layers can be enabled or disabled).
  - Color-coded layer information (enabling rapid assessment of large geographic areas)
  - Numerical text layers (enabling the user to see exact numbers)
  - Selectable data (enabling the user to select a geographic area and extract that specific data from a large database).
  - Excel spreadsheet data (enabling the user to view and manipulate all of the data that ships with the tool).

Many of these included resources are described in greater detail in the coming pages.

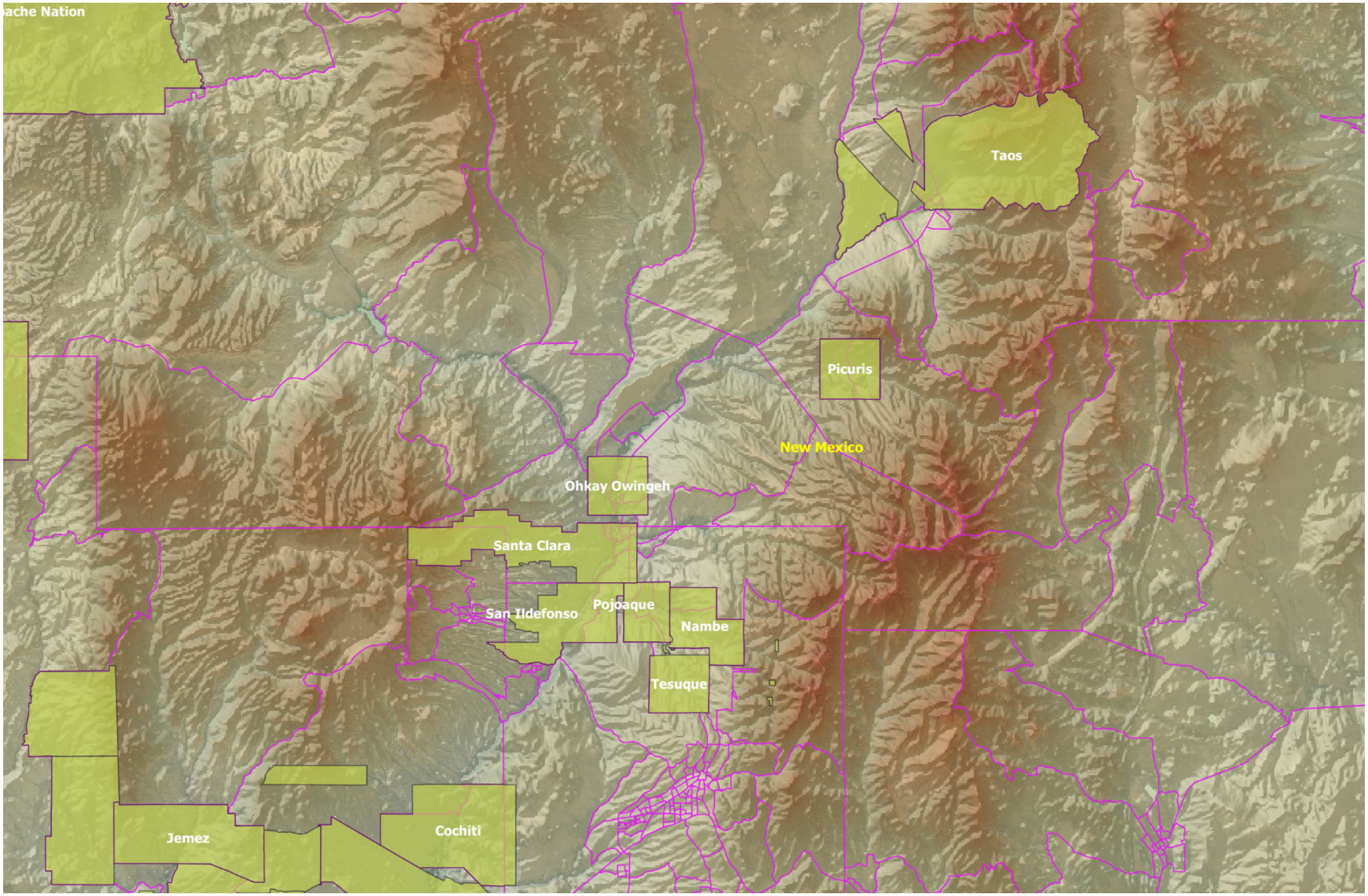
Demographic Data Sets

It is important to understand the significance of the various demographic data sets:

- *Housing Units* reflect the number of physical structures (single family homes, apartments, condominiums, mobile homes, etc.) in which a household could reside. The occupancy rate is the ratio of (rented HUs + owner-occupied HUs) / total HUs.

  In a city with 100% occupancy housing units could – conceptually – equal households, although such a situation rarely, if ever, exists.

Figure 22: Elevation Data



- *Households* are the number of groups of people (family and non-family) that live together. A household would generally have a single fixed internet connection to the home. We know the number of households and the population associated with the households for each census block.

- *Group Quarters* are larger groups who do not live in households. Group quarters include university dormitories, nursing homes, and prisons, as examples. The population in group quarters is distinct from the population living in households.

- *Population*. This is the total number of people living in an area, regardless of their housing situation. This total population includes those living in households (the vast majority, whether in family or non-family households) plus those living in group quarters.

Income-Related Data

The Toolkit provides a number of layers of data describing income and income-related programs:

- *Annual Income per Capita*. This is annual aggregate income divided by total population.

- *Mean Annual Household Income*. This is annual aggregate household income divided by total households. The portion of the population that lives in group quarters (college dormitories, nursing homes, and prisons, as examples) is excluded.

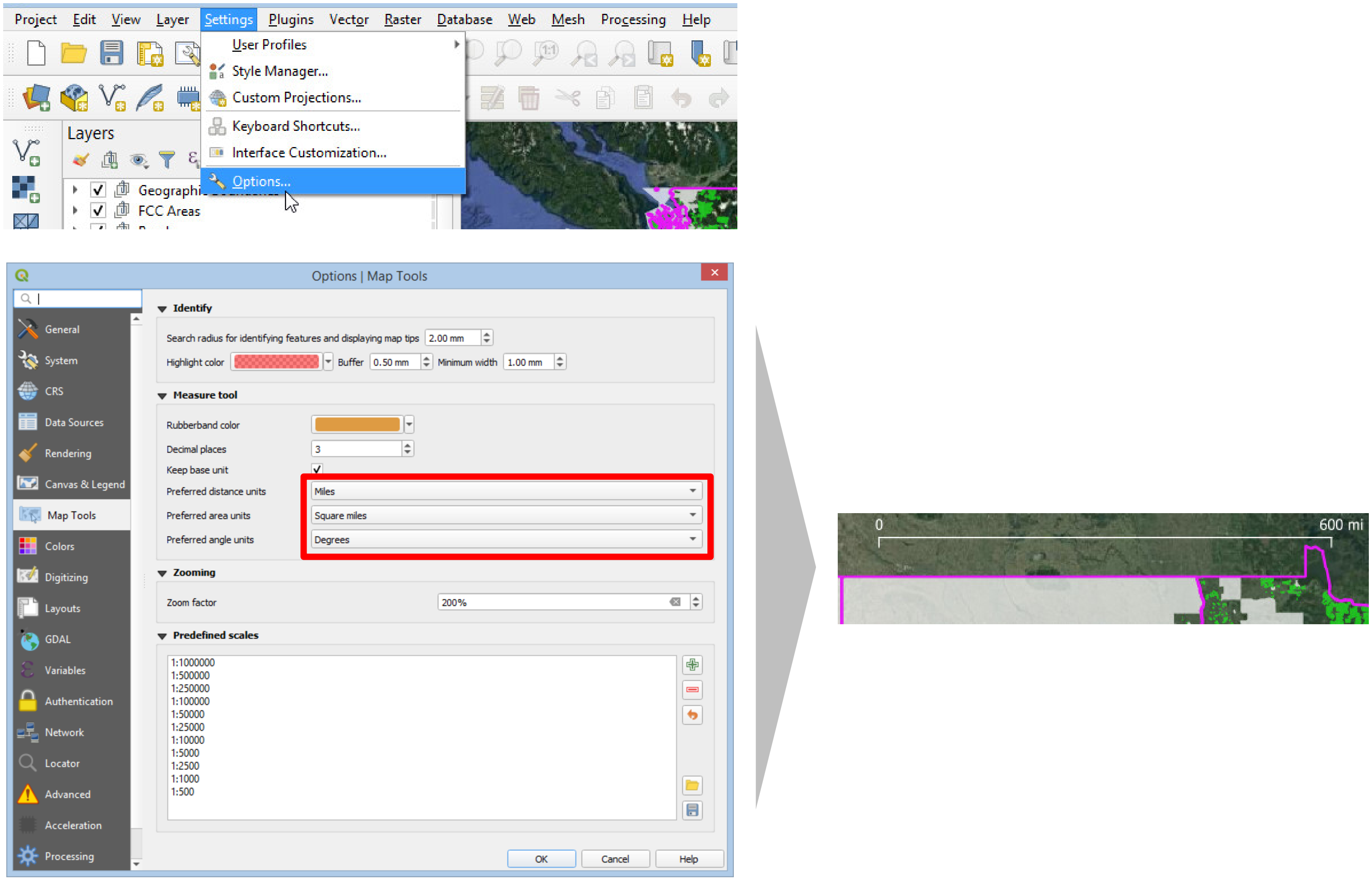
- *Median Annual Household Income*. The median annual household income is a number above which half the households earn more and below which half the households earn less. In most geographic areas median income is lower than mean income because a few larger earners pull the mean upward. Median income is considered the best indicator of household buying power for non-luxury goods.

- *Poverty Line*. The Act refers to the "poverty line". Both the US Census Bureau and the US Department of Health and Human Services (HHS) provide poverty metrics. The Census Bureau uses "Poverty Thresholds" for statistical purposes. It is a 48-cell matrix that includes family size, number of children, 1 and 2 person units, and whether or not an individual is elderly. There is no geographic dimension. In contrast, the Department of Health and Human Services uses a relatively simple "Poverty Guidelines". The latter can be calculated based on family size and geography (Alaska vs. Hawaii vs. the Contiguous 48 States). In its 2021 grant programs the NTIA decided to use a national average of the Census Bureau "Poverty Threshold". The way the NTIA used it, the calculation was dependent upon household size. The reader was instructed to round the average household size in a geographic area up to the next integer value then performed a lookup.

- *Household Size*. The household size is calculated for each block group using the total number of households and the total population in households (excluding the population in group quarters).

- *SNAP Participation Rate*. The Supplemental Nutrition Assistance Program (SNAP), a.k.a. food stamps, participate rate is shown as a percentage of households within each

Figure 23: Setting the Legend to Miles



block group. A household receiving SNAP benefits is eligible for ACP and Lifeline subsidies..

USDA Data Sets

The US Department of Agriculture (USDA) publishes a number of data sets that represent either evaluation criteria or eligibility criteria. They identify areas of economic need, area that meet certain definitions of "rurality", and areas that have received or are likely to receive USDA funding:

Measures of rurality:

Frontier and Remote Areas (FAR Level 4) that are:

- 15 minutes or more from an urban area of 2,500-9,999 people
- 30 minutes or more from an urban area of 10,000-24,999 people
- 45 minutes or more from an urban area of 25,000-49,999 people
- 60 minutes or more from an urban area of 50,000 or more people.

FAR is visualized as a set of ZIP Code areas. It is described in detail on the USDA Economic Research Service FAR web page.

Non-Rural Areas are represented as a set of polygons. They tend to coincide – as one might expect – with cities and other urban areas.

The 100-mile butter is, as its name suggests, a buffer around urban areas.

Economic Need:

Small Area Income and Poverty Estimates (SAIPE) are *counties* with a 20% or higher rate of poverty. It is described in detail on the Census Bureau SAIPE web page.

Socially Vulnerable Communities, identified by the Socially Vulnerable Index (SVI), are the most vulnerable census *tracts*, based on 15 measures of economic vulnerability.

Funded Geographies:

Protected. These are areas that have received USDA funds (ReConnect, Community Connect, Farm Bill Broadband, Telecommunications Infrastructure), either grants or loans, and are "protected" from duplicative funding.

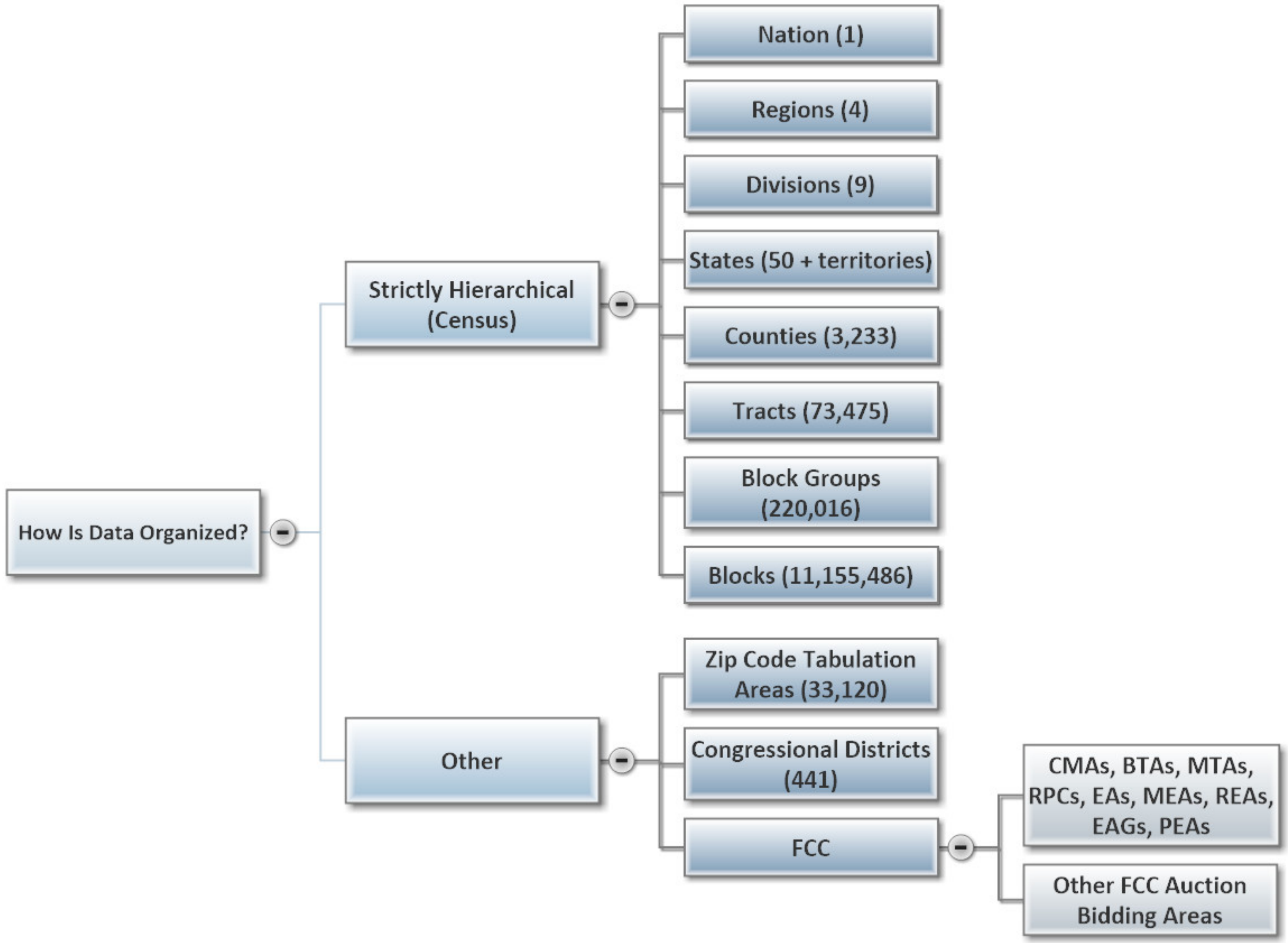
Pending Applications. These are areas with applications for USDA funding currently under consideration.

Technology and Competition

Three questions most ISPs ask before investing in are new geographic area are:

- What broadband technologies (fiber, cable, DSL, wireless) are present?
- Which competitors are present?
- How many competitors are present?

Figure 24: Hierarchy of Geographic Boundaries



The optional *Technology and Competition Module* provides this information. It visualizes technologies at a block level: fiber (technology 50), cable (technologies 40, 41, 42, and 43), DSL (technologies 10, 11, 12, and 20), and wireless (technology 70). If a technology is present it is shown, regardless of whether the operator provides a qualifying (100/20) level of service or not. Example: Figure 11.

The top 15 providers, based on geographic footprint, are visualized at a tract level. Example: Figure 12. This enables the user to quickly identify who is in the neighborhood. Companies that have filed with a large number of purely geographic FRNs (e.g. Verizon and Windstream) are shown as a single entity. Companies that have recently merged but are still listed under separate FRNs are shown separately. A spreadsheet in the *Technology and Competition Module* shows all terrestrial competitors on a tract by tract basis. Its tabs are presorted by location, company name, and technology.

Finally, one section shows competitive intensity (example: Figure 13). It is a color coded map with the number of competitors per tract. If an area is poorly served there might be few providers, or there might be many providers, each offering mediocre service.

These tools in combination help the user understand the competitive landscape.

Opportunity Zones

Opportunity Zones were created by the 2017 Tax Cuts and Jobs Act to spur economic development and job creation in distressed communities. Opportunity zones have been designated in all 50 states and in every inhabited US territory (American Samoa, Guam, Northern Mariana Island, Puerto Rico, and the US Virgin Islands). Investors benefit from deferral or exclusion of capital gains. The community benefits from financial investment. They are designed to encourage investment in areas with high socioeconomic needs. The statute excludes specific luxury investments (e.g. golf courses) and specific "sin industries", but is otherwise applicable to any business.

The Toolkit visualizes Opportunity Zones either as bright green polygons (if one wishes to find them on a map) or as clear tiles in an ocean of whited out space. Understanding the location of Opportunity Zones relative to other measurable metrics – particularly indications of need – is extremely powerful. It enables a business to deploy capital in locations that are likely to have a favorable social impact while offering investors unique tax incentives. Local governments (urban and rural) may wish to encourage outside investment based on the juxtaposition of Opportunity Zones with important needs identified by other layers of data.

Geocoded Data

The visual portion of the Toolkit includes a number of important features:

- *Scrollable / pannable user interface*. A user can easily zoom in for a closer view or zoom out for a more distant view using the mouse's wheel. Similarly, a user can grab the image and drag it in any direction. One can start in Florida, zoom out then fly to Hawaii or Alaska (with the national tool) then zoom in again for a detailed view. As the user manipulates the screen all of the underlying data scrolls and pans accordingly.

- *Many layers*. The Toolkit includes many layers of data that can be individually toggled on or off. The Toolkit is designed to show one graphical layer at a time. Each layer is translucent, so that the underlying map is visible.

- *Meaningful colors*. Numerical data is displayed using a range of colors. In most cases the scale runs from blue (low values) to red (high values). The color scheme provides a hint as to the type of data. In each case there are ten color thresholds that represent quantiles (an equal number of data points). There is no absolute meaning to "red" or "blue" across data elements, since the color scheme changes with each data element to reflect the underlying range of the data. The colors are designed to provide a visual cue to help the user see patterns and identify outlying values within any particular data set. Each data set has a legend that the user can see by clicking the "expand" triangular icon next to the "Visual" label for the data set. The legend displays the exact range of values associated with each color.

- *Numerical overlays*. Most of the data sets (all of demographic and economic data) display not only colors, but also numbers. With demographic and economic data it is desirable to turn on the numerical overlay to see the exact value of each underlying region, especially when zoomed in to a small geographic area. If the user zooms out it is generally desirable to turn off the numerical display and enjoy a rich mosaic of color. If numerical text continues to be displayed when zoomed out the text associated with adjacent regions starts to overlap and quickly becomes unreadable.

- *Geographic Boundaries*. The Toolkit includes a long list of boundaries that can be turned on or off. These include state lines, county lines, congressional districts, zip code (ZCTA) boundaries, census tracts, census block groups, and census blocks.

- *License Areas*. The FCC has licensed spectrum over the years using different geographic boundaries. Some users of the Toolkit may own spectrum. The toolkit therefore includes boundaries for the most widely used license areas. These include: Cellular Market Areas (CMAs), Basic Trading Areas (BTAs), Major Trading Areas (MTAs), Regional PCS Areas (RPCs), Economic Areas (EAs or BEAs), Major Economic Areas (MEAs), Regional Economic Areas (REAs), Economic Areas Groupings (EAGs), and Partial Economic Areas (PEAs).

- *Boundary names and other data*. In most cases the name of the boundary (e.g. the state or county) can be displayed. Alternatively a code may be displayed. The Census Bureau has a hierarchical numbering scheme called FIPS that begins at the state level (2 digits) then goes to the county level (2+3 = 5 digits) then to the tract level (2 + 3 + 6 = 11 digits) then to the block group level (2 + 3 + 6 + 1 = 12 digits) then to the block level (2+ 3+ 6 +1 +3 = 15 digits). If a user wishes to pull up spreadsheet data that corresponds to a visualize image it is helpful to turn on the numerical display for FIPS, take a screen shot, then look for the corresponding data set of spreadsheet data. Since everything is hierarchical one can select a county (the first 5 digits of the FIPS) by selecting all the block group data with the desired county code in the first 5 digits, as an example.

- *Roads*. The Toolkit includes primary and secondary roads, with or without name labels. Road layers may be turned on or off. Alternatively, one might choose an underlying map that includes road and place labels. Google, Bing, and OpenStreets, in the Maps folder, each include this option.

Choice of Units for Distance and Area Measurements. In the United States people discuss distances in miles and areas in square miles or perhaps acres. The scientific community tends to use kilometers and square kilometers. The FCC and the Census Bureau have increasingly adopted metric units in their publications.

1 km = 0.621371 statutory miles. Similarly 1 square kilometer = 0.386102 square miles. A square mile is equal to 640 acres or 258.999 hectors.

The Toolkit can display the map legend in either kilometers or miles. *Figure* 10 shows how to change from one set of units to another.

The internal databases of the Toolkit, including the spreadsheets, represent units in meters, square meters, kilometers, and square kilometers.

Graphical Versus Tabular

To build a business case one needs real data, not just a pretty picture. The Toolkit includes a comprehensive set of geocoded spreadsheet data that largely matches the demographic and economic data sets in the visual tool. Each data set includes:

- *Numerical Code*. A numerical identifier for the region (typically a FIPS code), either a block or block group or a fragment of a block.

- *Name of Region or Entity*. The name of the region (e.g. a state and county or tribal nation) or an entity (a college, university).

- *Calculated Metrics*. Examples include areas, percentages, prorated metrics, growth factors, median household income, etc.

- *Raw "Counter" Data*. Raw data. The most important elements are housing units (structures), households (people), population (people), and the population included in households. Census polygons are hierarchical. Each block group, for instance, sums all of the blocks within it.

- *Population Estimates / Forecast.* In addition, the Toolkit includes separate population estimates / forecasts for every county in the 50 United States plus for the District of Columbia and Puerto Rico, based on the most recent yearly data from the Census Bureau. Recent county-level growth rates are used to produce near-term forecasts through the date of the auction (July 1, 2020).

Optimizing Performance

Geographical Information Systems, such as the QGIS browser, are data crunching machines and miraculous pieces of software in that they seek to visualize overwhelmingly large amount of data elegantly. The Visual Toolkit, as an application, has been highly optimized for performance, using as few computer resources as possible to achieve its objectives. Even so, it is helpful for every user to be aware of factors that impact performance:

- *Computer Hardware*. Every GIS application demands significant hardware resources. Ideally, one would run the Toolkit on a computer with a 64-bit operating system, lots of RAM, reasonable processing power, and fast disk access (ideally SSD). The current version of QGIS and the current highly optimized version of the Toolkit will both run with modest resources.

- *Application Loading Time*. Expect any GIS application to take a few minutes to load. Think of it as an opportunity to get a fresh cup of coffee. During the load process it connects to all of the linked data sets and prepares to load the associated data on demand. It doesn't work like Microsoft Word, where one clicks on a document and, an instant later, the document appears. Once loaded, though, the application is designed to be responsive, with a few caveats.

- *First Time Loading a Layer*. The first time a user loads a visual layer after launching the application in QGIS the application may pause for a few seconds as it finds the desired data. Afterwards, one can select and deselect that data layer and expect the text and graphics to appear and disappear almost instantaneously, because it has been cached by the application. One can then sometimes zoom in and out and pan with minimal delay.

- *Streaming Maps*. In theory, streaming maps can cause the user interface to be slow because map data must be retrieved from a remote server. In practice, with the current version of QGIS and with a fast internet connection, the delay is negligible. Do be careful not to enable multiple maps at the same time. Doing so will multiply the volume of data that must be downloaded. Also, the user will see only one map at a time, so most of the effort will be wasted. If the user is in an airplane or has a slow internet connection or no connection at all then the user should disable the map by unchecking the map layer. If one is unsure about the impact of the map it is easy to disable it and to enable, instead, a solid color background (gray, black, white) to see if the application becomes visibly more responsive. Dark solid backgrounds, while not as pretty as a map, are wonderful for reading detailed overlaid data.

- *Text Overlays*. A text overlay can sometime slow the display. This is generally the case when text is enabled with a high resolution data set and the user is zoomed out. Imagine, for instance, looking at the continental United States, viewing data at the block group level, with text enabled. QGIS would attempt to write 200,000 numerical values on the screen, one number for each polygon visualized. The user interface would be slow and the resulting image would be a mess. It is best to turn off text overlays before you zoom out then decide what text is appropriate at the new zoom level. Up close, one might be interested in block group FIPS codes, but zoomed out one might be interested in state boundaries and state names, as an example. High resolution boundaries (e.g. block group boundaries) when zoomed out can also slow the user interface and flood the resulting image with a single color of ink (reflecting the color of the boundaries). The implications of most of these decisions will become obvious the first time one uses the application.

Curated Sources

The carefully curated data in the Toolkit comes from a number of exceptionally high quality government sources as well as other public and private sources already discussed:

- US Census Bureau (many different products)
- Federal Communications Commission (FCC)
- National Telecommunications Information Administration (NTIA)
- U.S. Geological Survey (USGS)
- U.S. Congress (legislative text)

Significant sources include:

- US Census Bureau, American Community Survey. The ACS surveys 3.5 million households + 185,000 persons in group quarters per year on subjects ranging from household income to demographics to physical space and amenities to devices and connectivity to monthly household expenditures. These are converted into single-year and 5-year estimates and other data products. The Toolkit uses the 2019 5-year estimates, which were published on December 10th, 2020.

- US Census Bureau, Population and Housing Estimates (PEP), The International Data Base, County Business Patterns, and a wide rage of geographic boundary products and definitions. Extremely important are well-documented processes, which give the numerical data important context and meaning.

- The Federal Communications Commission. The FCC collects fixed and mobile coverage by technology by operator, as well as other service metrics and publishes detailed auction results. This tool includes FCC Form 477 fixed data (as described above), reverse auction (CAF II and RDOF) funding commitments for geographies that meet or exceed the FCC's definition of broadband, as well as USDA (e.g. ReConnect) funding commitments. Visibility into funding commitments is important for infrastructure-oriented grants to prevent a duplication of funding.

Video Tutorials

Video tutorials exist to help new users get started, understand the sophisticated functionality, enable and disable options, and effectively use the various Toolkit products. Be sure to visit *https://www.youtube.com/channel/UCDgYo4d8RJfVfE294CbsbHQ*.

Next Steps

The New Initiatives page includes a complete set of information on the Infrastructure Essentials BEAD Toolkit. It includes the latest manuals and links to tutorial videos:

https://broadbandtoolkit.com/pages/bead

The Toolkit team will be happy to answer your questions / discuss your needs by phone or video conference.

You can reach us at **support@broadbandtoolkit.com**.