Eastern Shore of Virginia
Rural Broadband Communications

07 December 2022

Providing Internet Access Approaches for the Unserved and Overlooked Citizens of Accomac and Northampton Counties. A unique approach with self-service to achieve full Internet connectivity.

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1 Introduction and Findings

Providing broadband service to rural communities is more expensive per user due to lower population density, and greater expense can fall more heavily on those least able to afford it. We identified five unserved communities in Accomac and Northampton Counties and estimated the best way to extend broadband to connect them to the Internet. To help in adoption we investigated cost sharing models to help make it more affordable and encourage increased participation.

George Mason University Graduate Telecommunications Class 750 for Fall 2022 performed a follow-on analysis of rural broadband communication on the Virginia Eastern Shore as part of their course work. This follows the analyses performed by the Spring 2022, Spring 2021 and Fall 2020 TCOM 750 classes. The TCOM Graduate Students reviewed current legislative initiatives and incentives, existing providers, current coverage areas, developed an engineering process leveraging Geographic Information System (GIS) and Radio Frequency planning tools, reviewed emerging solutions and coverage options with an aim to empower unserved communities. George Mason University's analytic process followed a 6-step approach and is shown in **Figure 5 The George Mason University (GMU) Approach Followed a 6-Step Process to Acquire and Integrate data, Identify Unserved Areas, Plan the community service approaches/costs and write our report.**

George Mason University also explored cost models to determine if there were ways for unserved residents to band together and get service for their communities and equitable share the costs. For those looking for the quick answer you can review the following:

- Chapter 2 – Cost Sharing Models
- Chapter 3 - Analytic Approach
- Chapter 4 – 2022 Virginia Telecommunications Initiative (VATI) Coverage Areas
- Chapter 5 – Proposed Locations Identified by GMU
- Chapter 6 – Detailed Site Analyses of the Five Locations
- Chapter 6 – Newly Served Sites Not in the 2022 VATI Grant Application
- Chapter 7 – Recommendations

The Eastern Shore of Virginia was chosen due to its disadvantaged status for communications, the familiarity of it with several participants, and the existing body of work performed by previous TCOM 750 classes. Identified provider options, current and future, included:

1. Satellite Broadband
    - SpaceX STARLINK
    - Amazons' Project Kuiper (future)
    - OneWeb (future)
    - Hughes Network Systems (legacy Geosynchronous)
    - Dish Network (legacy Geosynchronous)
2. Fiber to the Home (FTTH) Providers
    - Eastern Shore Virginia Broadband Authority (ESVBA)
    - Eastern Shore Communications Corporation (ESCC)
3. Wireless Internet Service Providers (WISP)
    - Neubeam
    - Eastern Shore Communications Corporation (ESCC)
4. Cellular Internet/Fixed Wireless
    - T-Mobile/Sprint
    - Verizon

- AT&T
- Dish Network (future)

5. Cable Television Providers[1][2]
    - Charter/Spectrum[3]

Key findings, based on our previous studies were essentially unchanged and were as follows:

- Installed fiber is generally the more cost-effective approach over the other options as it provides consistent performance unaffected by the weather or contention between customers.
- The cost of providing service to rural isolated citizens features a low return on investment (ROI) and alternative approaches to providing services and/or cost-sharing in outlying areas need to be explored.
- Areas that do have broadband service coverage resemble a soccer game among 5-year-olds where they all run to the ball and do not work together as a team for the common benefit of all.
- Accomac and Northampton Counties chartered the Eastern Shore of Virginia Broadband Authority (ESVBA) as a non-profit, but it has only been able to develop coverage to reach approximately 50% of the population. We note the ESVBA has re-paid its initial loans to the counties and through subsequent Virginia Telecommunications Initiative (VATI) funding is on its way to providing much greater coverage, but this is not a comforting thought to citizens who still do not have service.
- Last Mile WISP providers, Eastern Shore Communications (ESCC) and Neubeam are wary of competition/cooperation with ESVBA and have stated they feel ESVBA will help them develop new markets but then encroach on those areas negating their investments.[4][5]
- Federal Communications Commission (FCC) efforts to stimulate broadband are essentially non-existent on the Eastern Shore and the development of a 4th nationwide wireless company with Dish Networks is unlikely to stimulate the existing three wireless providers (Verizon, AT&T, and T-Mobile) to significantly expand their service to make an impact even with their new Home Cellular offerings.

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[1] Article "Cable's evolutionary path leads to mobile, convergence" detailing cable companies new business approach, website https://www.lightreading.com/cablevideo/cables-evolutionary-path-leads-to-mobile-convergence/d/d-id/764609?, accessed 10 December 2020.

[2] Article "How rising broadband demands might reshape US telecom", website https://www.lightreading.com/opticalip/how-rising-broadband-demands-might-reshape-us-telecom/d/d-id/764382?, accessed 10 December 2020 describes how customers are flocking to fixed broadband providers like Comcast and Charter in unprecedented numbers.

[3] Article Comcast and Charter announced 5G coverage was expanding", website https://www.fiercewireless.com/operators/comcast-charter-add-nationwide-5g-iphone-12-to-line-ups, accessed 02 November 2020.

[4] Errata (https://www.easternshorepost.com/2019/01/24/internet-provider-says-broadband-authority-poses-unfair-competition/)

- ESVBA "directly competing with us" and causing an "imbalance" in local market, Eastern Shore Communications CEO Ronald Van Geijn said.
- ESVBA acted as a last-mile provider, supplying high-speed internet directly to government organizations and businesses starting in 2010 and homes beginning in 2016.
- "ESVBA is not a middle-mile provider," ESVBA Executive Director Robert Bridgham recently emphasized. A middle-mile provider typically offers wholesale pricing to companies that provide end-users with high-speed internet at retail prices.

[5] Article "Neubeam Lawsuit Against Broadband Authority Dismissed" website https://www.easternshorepost.com/2019/12/12/neubeam-lawsuit-against-broadband-authority-dismissed/, accessed 11 January 2021.

- Citizen frustration with the slow pace of coverage is clear and is not mitigated by efforts such as WiFi hotspots that are essentially in areas being served by broadband.[6][7][8]
- COVID-19 shutdowns highlighted the burden on public school students who do not have the means to perform adequate coursework remotely.
- Commonwealth of Virginia assistance in the form of VATI grants are having a direct measurable impact but more is needed.
- Alternatives, such as Starlink satellite broadband promise exceptional speed and low latency to a limited number of households, but cannot scale to make a difference to most citizens and their cost is substantially more than terrestrial broadband options. Recent experience in user growth has led to reduced speeds. [9]
- The local electric utility, Accomac and Northampton Electric Cooperative (ANEC) has excellent route engineering, but has not been engaged beyond allowing broadband service providers to use their installed telephone pole infrastructure.
- Cable and Cellular providers are beginning to provide home broadband, but in areas that may not be most beneficial to rural users[10] and most likely in competition with other providers. [11]
- Virginia has the 5th highest cost for broadband service in the United States[12] and for many on the Eastern Shore it is essentially unobtainable with no substantial changes in sight.
    - ESVBA's least expensive plan for residential customers is $39.99/month for 10/5 Mbps Download/Upload[13]
    - Local Wireless Providers are charged a discounted rate, but they must add to that rate to pay for their costs to make the service economically viable based on their business model.
    - Starlink Unlimited service is $110.00/month, but is limited in capacity to approximately 1.5 million customers across the entire continental United States.
    - Cellular Service Mobile Hotspot service such as T-Mobile's, where available, can be as low as $10.00/month under their military plan for 2GBits/month of data with additional data

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[6] Article "300 miles of broadband down for rural Va. Shore — 1,200 miles to go", website https://www.delmarvanow.com/story/news/local/virginia/2017/12/21/broadband-eastern-shore-virginia/972410001/, accessed 11 January 2021.

[7] Article "Inadequate Internet Service Rouses Ire of Captain's Cove Residents", website https://www.easternshorepost.com/2020/09/17/inadequate-internet-service-rouses-ire-of-captains-cove-residents/, accessed 11 January 2021.

[8] A key example of this in line with our 5-year-old soccer game scenario is the town of Bloxom that has broadband fiber, a WiFi Hot Spot, and two RF Point-to-Point Towers by Neubeam and ESCC all within 100 meters of each other.

[9] Article "Starlink Speeds Drop Significantly in the US Amid Congestion Woes", website https://www.pcmag.com/news/starlink-speeds-drop-significantly-in-the-us-amid-congestion-woes, accessed 30 November 2022.

[10] Article "Gov. Northam Returns Home for Event on Broadband Expansion for the Shore", website https://www.easternshorepost.com/2020/11/12/gov-northam-returns-home-for-event-on-eastern-shore-broadband-expansion/, accessed 11 January 2021.

[11] Article "T-Mobile in Home Internet", website https://www.theverge.com/2018/9/21/17886574/t-mobile-in-home-internet-sprint-5g-goals-charter-comcast, T-Mobile is planning to offer in-home internet based on 5G service, to be the 4th largest ISP in America by 2024. Its goal is to cover "52% of the zip codes across the county by 2024," "64% of Charter's territory and 68% of Comcast's territory."

[12] Article "Here's Where People Shell Out the Most and the Least for Internet Virginia is 5th highest in Cost.", website https://www.pcmag.com/news/heres-where-people-shell-out-the-most-and-the-least-for-internet, accessed 20 December 2020.

[13] ESVBA Website, https://esvba.com/residential/, accessed 21 January 2021.

for purchase but are subject to environmental conditions. But they are limited in coverage area and suffer many of the drawback that WISP's see.[14][15]

- Rural areas in Virginia's Eastern Shore suffer the tyranny of distance where it is too expensive to economically extend service to them without some type of subsidy. These trade-offs are shown in **Figure 1 Cellular Capacity vs Latency vs Coverage Area**.

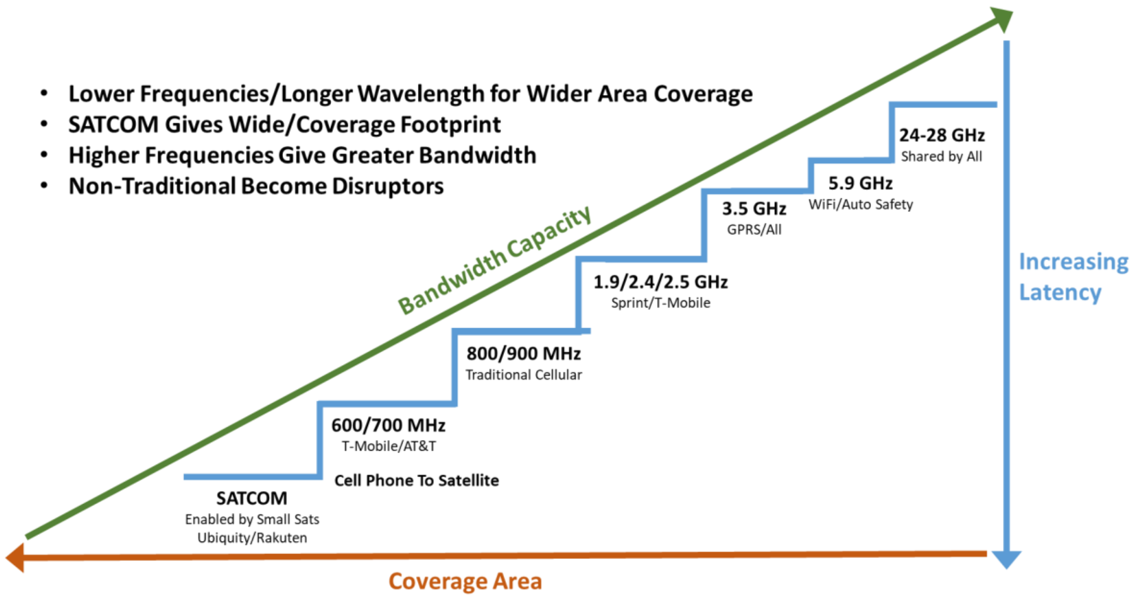

Figure 1 Cellular Capacity vs Latency vs Coverage Area[16]

[14] Article "T-Mobile begins putting 5G into its fixed wireless Internet service", website https://www.lightreading.com/opticalip/t-mobile-begins-putting-5g-into-its-fixed-wireless-internet-service-/d/d-id/766436, accessed 09 January 2021.

[15] Article "Inside T-Mobile's new 'Home Internet' business", website https://www.lightreading.com/mobile/5g/inside-t-mobiles-new-home-internet-business/a/d-id/754548, accessed 09 January 2021.

[16] Cell phone to satellite service has been announced between T-Mobile and Starlink for 2023, for the Apple iPhone and Globalstar and the other major cell phone carriers have reported to be developing technology and deals as well.

2 Cost Sharing Models[17][18]

The TCOM 750 class did a literature search and review of Cost Sharing Models as part of developing our cost model. An overview is provided in the following sections. We want to assure homeowners that options, including self-organizing, are possible and we want to help clarify those. We also note all of our files and collected data documenting our findings are in the Google Earth Pro and Cambium Networks Link Planner file formats and are in the public domain and available for all who want them.

BLUF[19] - To save some readers, this material in this section is exceptionally theoretical and the bottom line is while "Location Theory" sounds very complicated, the idea is simple in that you really just want to **minimize the amount of distance you have to cover to connect up as many passings (homes and businesses) as possible**.

1.1 Cost Sharing Models for Cooperative Homeowner Progress

The 2022 VATI grant to Accomac and Northampton Counties has had a positive impact on broadband availability on Virginia's Eastern Shore. In discussions with select citizens there is much anticipation and several noted they expected to receive service within the coming year. While we applaud the progress, we also acknowledge there are multiple homeowners/communities who still lack service. These unserved homeowners/communities will be much harder to service with a blanket grant and therefore we propose a model for cooperative sharing of the cost burden in the hope it is helpful. A lot of our work was influenced by Justo Puerto from the Universidad de Sevilla and his seminal paper on "Cost Sharing Models Required for Cooperative Homeowner Progress" which states:

"A location problem occurs whenever a set of users have to agree on the position of one or several facilities in order to provide some service for them. The goal is to minimize the overall service cost and depending on the framework space, nature of the service and the globalizing cost function many different models appear: median, center, ordered median, coverage, hub-location, and etcetera. Any of these problems has produced a large body of literature in order to find optimal or approximate solutions to their corresponding optimization problems. However, even knowing the exact solution of those problems there is another interesting problem that deserves the attention of researchers: ***How to share the cost of implementing such an optimal solution among the users of that system?*** *This chapter addresses this question for several well-known location problems that appears in location problems in the continuous setting."*

We also drew inspiration from the book "Location Theory: A Unified Approach" by Dr. Puerto and Professor Stefan Nickel that they published in 1995 with one key statement standing out:

"Infrastructure sharing in telecommunications refers to the joint utilization of assets and/or services necessary to provide telecommunication service in order to reduce the costs of building, operating, and maintaining network infrastructure. Sharing can happen in any of the interrelated internet networks and has the potential to re-shape the structure and function of the different telecommunication services markets."

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[17] FCC Broadband Assessment Model, https://transition.fcc.gov/national-broadband-plan/broadband-assessment-model-paper.pdf, March 2010, accessed 11 October 2022.

[18] "Sharing Costs in Some Distinguished Location Problems", website https://www.researchgate.net/publication/315847637_Sharing_Costs_in_Some_Distinguished_Location_Problems, accessed 04 October 2022.

[19] BLUF – Bottom Line Up Front

Other works we referenced include recent works from the World Bank focused on Africa[20], commercial providers, consultants attempting to find solutions[21][22], and others. Broadband access to rural households can be a difficult engineering feat requiring multiple technology solutions to develop optimal solution for all. The design challenges to serving rural markets due to environmental variation also manifest in a provider's business model. Low population density, terrain and foliage, lack of backbone backhaul connectivity, lack of accessible infrastructure, and limited-service provider resources are all items that a provider's business model must account for. Thus, current broadband business models that depend on scale (especially a consistent, repeatable approach) are inadequate for many businesses to tackle rural connectivity. If this is to change, new business models must address the obstacles of current business models to provide an easier entry into rural markets.[23]

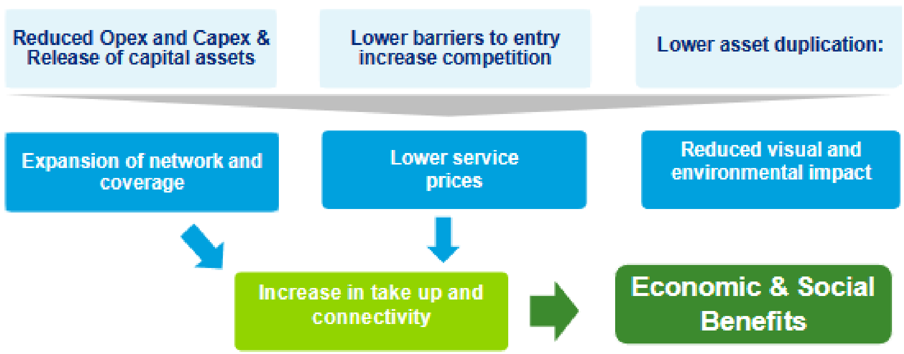

Figure 2 Major Benefits of Infrastructure Sharing[24]

One key aspect of the broadband business model is revenue and cost sharing and the benefits are shown in **Figure 2 Major Benefits of Infrastructure Sharing**. In the operator-only model, all revenue from the end customers is paid directly to the operator, which is then used to pay back any loans used for the build, for ongoing operations, and for business expansion. In urban markets, where large numbers of customers are more easily obtained, that market becomes self-sustaining relatively quickly. Urban areas also have enough business that construction, operations and maintenance can be focused in a single area. In rural areas, such as Virginia's Eastern Shore, there are many fewer customers to provide revenue. The result is a much lower revenue stream for that area, even with an optimistic 100% uptake of the total addressable

[20] "The economics and policy implications of infrastructure sharing and mutualisation in Africa", Jose Marino Garcia, josemarinog@gmail.com, Tim Kelly, tkelly@worldbank.org, November 2015, website https://pubdocs.worldbank.org/en/533261452529900341/WDR16-BP-Infrastructure-Mutualisation-Garcia.pdf, accessed 11 October 2022.

[21] "Unlocking broadband for All", Deloitte and Touche, APC, April 2015, https://www.apc.org/sites/default/files/Unlocking%20broadband%20for%20all%20Full%20report.pdf, accessed 111 October 2022.

[22] "5 Shared Services Pricing Approaches", Gartner, https://www.gartner.com/smarterwithgartner/5-shared-services-pricing-approaches, November 2019, accessed 11 October 2022.

[23] 3rd Party Enablement Business Models for Rural Broadband, A White Paper by the C Spire Rural Broadband Consortium, https://www.cspire.com/resources/docs/rural/CRBC_BusinessModels_WhitePaper_202012.pdf, accessed 11 October 2022.

[24] "Unlocking broadband for all", Deloitte and Touche, APC, April 2015, https://www.apc.org/sites/default/files/Unlocking%20broadband%20for%20all%20Full%20report.pdf, accessed 111 October 2022.

market (household and businesses alike). A key feature of broadband, especially in rural areas, is that it provides new opportunities for citizens that are hard to match.

1.2 Infrastructure Sharing

There are three models of infrastructure sharing. They are 1) infrastructure asset sharing, 2) infrastructure mutualization, and 3) infrastructure cooperation, and the bargaining power of involved agents.

- **Infrastructure asset sharing** - when two or more competing operators providing a telecommunication service share the assets required to provide the service. Examples of these include mast, ducts, antennas, transmitters, and also rights of use and spectrum licenses.
- **Infrastructure mutualization** - a particular type of infrastructure sharing that happens when a common network infrastructure is built, operated, and maintained by a third party (the ESVBA is one such example), an infrastructure provider, and jointly used by telecommunication service providers (example ESVBA, Neubeam, ESCC, Charter/Spectrum). Service providers lease a portion of the mutualized infrastructure and pay a wholesale price for it.
- **Infrastructure cooperation** - when telecommunication infrastructure is housed or jointly constructed with other linear infrastructures to exploit potential synergies in the construction, operation, and maintenance of several networks at the same time.

The last mile segment is the highest-priced component of a fixed access network. Last mile construction involves high sunk costs or Capital Expense (CAPEX), which lead to high and non-transitory barriers to entry, lack of infrastructure-based competition and high prices in the broadband retail market. An example of the trades involved are shown in **Figure 3 Different Build Details, Relative Costs and Categorization of the Expenses**.

	Description	Cost	One-time vs. on-going	CAPEX vs. OPEX
Market Selection	Market analysis tools	$	One time	CAPEX
Network Design	Access and backhaul design tools and services	$-$$	One time	CAPEX
Backhaul Construction	Equipment (network hardware and construction), software and licenses, labor, permitting, engineering, etc.	$-$$$$$	One time	CAPEX
Access Construction		$$-$$$$	One time	CAPEX
Core Construction		$-$$$$	One time	CAPEX
Customer Acquisition	Marketing + sales, retail operations	$	Both	CAPEX
Customer Installation and Provisioning	CPEs, software and services installation costs	$-$$$	On-going	Both
Billing	Software to manage customer bills, collection, rate plans, etc.	$	On-going	OPEX
Network Monitoring	Operations & customer care (monitoring software and hardware, personnel)	$-$$	On-going	OPEX
Network Maintenance	Equipment upgrades and replacements (network and customer)	$-$$$	On-going	OPEX
General Overhead	New rent/lease (space, tower), employee salaries, utilities, non-network maintenance & upgrades, etc.	$-$$$	On-going	OPEX

Figure 3 Different Build Details, Relative Costs and Categorization of the Expenses or Different Methods for Modeling a New Market Build[25]

Retail market competition is traditionally achieved through regulations that force incumbents to share last mile infrastructure. Incumbents are obliged to offer connectivity services in different interconnection points at regulated prices, for example, with local loop interconnection.

This model allows a certain degree of facility-based competition because the entrant is required to build the local loop network segment. A different option is bit-stream interconnection, which is the interconnection to the complete last mile network. In this case, only service-based competition occurs.

Connecting an entrant to the last mile link requires technical coordination among the incumbent and the entrant. As a result, there is a trade-off between increased competition and higher coordination complexity; closer interconnection points to customers require more complex incumbent-entrant technical coordination. Examples of incumbent would be the ESVBA, with entrants being ESCC, Neubeam and Charter Spectrum.

1.3 Location Theory[26]

The idea of having a facility placed at a location which is in average good for each client, led to the median objective function is also called the Weber or Fermat-Weber objective. Finding a location, which is even for the most remote client, as good as possible, brought up the idea of the center objective. The insight, that both points of view might be too extreme, led to the cent-dian or centdian approach. Researchers always distinguished between continuous, network and discrete location problems. Therefore, the main scope of researchers is seen as picking a problem from the table in **Figure 4 Example Table that illustrates**

[25] 3rd Party Enablement Business Models for Rural Broadband, A White Paper by the C Spire Rural Broadband Consortium, https://www.cspire.com/resources/docs/rural/CRBC_BusinessModels_WhitePaper_202012.pdf, accessed 11 October 2022.

[26] Location Theory – A Unified Approach, Dr. Stefan Nickel, Dr. Justo Puerto Albandoz, ISBN 3-540-24321-6, 2005.

a way to compare approaches (Median Objective Function, Center Objective and Cent-Dian) for an optimal solution by selecting a row and a column, maybe adding some additional constraints to it, and then finding good solution procedures.

		decision space		
		continuous	network	discrete
objective function	median			
	center			
	cent-dian			
	...			

Figure 4 Example Table that illustrates a way to compare approaches (Median Objective Function, Center Objective and Cent-Dian) for an optimal solution

In geometry, the Weber problem, named after Alfred Weber, is one of the most famous problems in location theory. It requires finding a point in the plane that minimizes the sum of the transportation costs from this point to n destination points, where different destination points are associated with different costs per unit distance.[27] <u>For our purposes this involves minimizing fiber runs or wireless equipment</u>.

The centdian problem seeks P points, such as passings, that minimize a convex combination of the median (average) and center (maximum) distance objectives. One approach to solve the problem is to assume facilities are located on network nodes (e.g., passings). First solve the P-center problem yielding the smallest maximum distance within which all demands can be served by P facilities. Then solve the P-median problem yielding the smallest average distance. The largest distance, Dc, for the P-median solution is then computed.[28] Then the largest distance, Dc, for the P-median solution is computed. A suitably large endogenously determined constant is added to all distances greater than or equal to Dc. The solution to a new P-median problem with the modified distance matrix utilizes new facility locations and has a maximum assigned distance strictly less than Dc, and a larger average distance. We then compute the maximum distance for the new solution and repeat the process until the maximum distance for the last solution found equals the objective function value for the P-center problem. The algorithm was tested on problems ranging in size from 49 nodes to 200 nodes and for values of P=5, 10, 15, 20.

While Location Theory sounds very complicated, the idea is simple in that you really just want to **<u>minimize the amount of distance you have to cover to connect up as many passings as possible</u>**. Since we have a rough cost model of $17,000[29] per mile to pull fiber and have a good understanding of where existing fiber is located, and we have identified likely customers, **one option we propose is a cost-sharing model to**

[27] "Weber problem", https://en.wikipedia.org/wiki/Weber_problem, accessed 19 October 2022.

[28] "The Centdian Problem: Solution Approach and Computational Results", website https://www.researchgate.net/publication/2529682_The_Centdian_Problem_Solution_Approach_and_Computational_Results, accessed 19 October 2022.

[29] Some other estimates are $18,000 to $22,000 per mile. Blog Post Blog Post "Starlink, Stasis and "Capacity Shortfall"", website https://www.platformonomics.com/2021/02/starlink-stasis-and-capacity-shortfall/, accessed 16 October 2022.

help all homeowners in a focused area acquire service. One possible approach would be to form a non-profit cooperative, acquire right of way and pull fiber.

1.4 Eastern Shore Technology Costs Based on Location and Infrastructure Sharing Theory

We reviewed the CAPEX and OPEX expense details from the previous section and applied it to the Eastern Shore using our understanding of operations. We also factored in the business case from Global Crossing where the University of California Los Angeles (UCLA) review that business and where we were struck by their categorization of how the process of adding additional customers to their sunk fiber resulted in little to no additional cost[30]. This is reflected in **Table 1 Adaption of Build Details, Relative Costs and Expense Categorization for New Market Build on the Eastern Shore**.

Table 1 Adaption of Build Details, Relative Costs and Expense Categorization for New Market Build on the Eastern Shore

	Description	Cost	Cost Basis Justification	CAPEX vs. OPEX
Market Selection	Market Analysis Tools	$0	Done by GMU TCOM 750 Students	CAPEX
Network Design	Access and Backhaul design tools and services	$0		CAPEX
Backhaul Construction	Equipment (network hardware and construction), software and licenses, labor, permitting, engineering, etc.	$17,000 /mile	Use of general figure that includes all	CAPEX
Access Construction			Included in backhaul construction costs	CAPEX
Core Construction				CAPEX
Customer Acquisition	Marketing and Sales, retail operations	$0	Marginal Cost to add customers to existing customer set	OPEX
Customer Installation and Provisioning	CPES, software and services installation costs	$0		Both
Billing	Software to manage customer bills	$0		OPEX
Network Monitoring	Operations and customer care (monitoring software and hardware, personnel)	$0		OPEX
Network Maintenance	Equipment upgrades and replacements (network and customer)	TBD	TBD	OPEX
General Overhead	New rent/lease (space, tower), employee salaries, utilities, non-network maintenance and upgrades, etc.	$0	Marginal Cost to add customers to existing customer set	OPEX

The costs to deploy (CAPEX) and operate (OPEX) broadband augmentation of the baseline wireline, cable and wireless networks are developed below. Additionally, the TCOM 750 students proffered numerous ideas on cost recovery that are also listed below.

- Capex - network required augmentation investments are determined for unserved areas based on
    - Broadband speed requirements defined by the user
    - Engineering rules for relevant technology (i.e., wireline wireless or cable)
    - Relevant Census Block characteristics (e.g., terrain, population, etc.)

[30] “Good Strategy Bad Strategy: The Difference and Why It Matters”, Richard P. Rumelt, Profile Books © 2011 Citation, ISBN 9780307886231, 0307886239.

    - User-selected options (e.g., number of competitors, National Purpose Site assumptions, etc.)
    - To consider for fiber deployment cost and driver of fiber construction cost (population density, terrain, labor, depth or height, equipment, etc.)[31]
- OPEX
    - Costs to operate augmentation networks developed through analysis of available operating cost information across related technologies (wireline, wireless and cable)
    - Related to and instructive of OPEX costs are Rumelt's[32] documentation of Global Crossing's business model by a 1999 UCLA Masters of Business Administration (MBA) class on the business case.
        - One STM-1 on a transatlantic cable as close to a perfect commodity as human mind has been able to create. ***Not good*.**
        - One operator's capacity essentially indistinguishable from another. ***Not good.***
        - Global Crossing introduced competition into business, three other private companies announced plans to enter. ***Not good*.**
        - Technology is not proprietary. ***Not good*.**
        - Technology making it ever cheaper to add huge chunks of new capacity: overcapacity a near certainty. ***Not good*.**
        - Capital costs of transatlantic cables literally "sunk." If prices don't cover capital costs, old cables continue to operate. ***Not good at all*.**
- Cost model options
    - ISP pays upfront cost to ESVBA to supply connectivity for a particular area
    - ISP rents from Broadband authority for ISP to use fiber
    - ISP pays fiber deployment charges upfront and recovers cost from customer
    - ISP pays upfront and charges $100 monthly fee above normal $75/month. 71 homes bring in $1775/month. Assuming no interest loan is paid back in 41 months.
    - ISP charge customers maintenance fees to recover ISP paid deployment cost
    - ISP offer customer services or discounts on fiber plans or credit as number of people hooked up to fiber increase
    - Competing service providers in the same area provide a challenge
        - ISP recover charges by providing rental services to customers, monthly maintenance, premium customer support fees, cancellation charges, activation charges, free self-installation, or technician charges for custom installation (smart-TV, security cameras, Alexa/Chromecast/fire stick)
        - Example: Verizon FIOS 1GBPS with Wi-Fi provider and premium services on 1Gbps plan but not cheaper plans so customers are forced to pay for 1GBPS plan to use all services and later charges after a certain period of time
    - ISP charges refundable security deposit when customer wants to end connection
    - ISP offers Internet services for trial period; customer required to sign up after a certain time period
    - For remote areas, cell phone coverage is a problem; have the ISP provide Voice over IP calling and/or family plans.

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[31] https://www.investopedia.com/terms/c/capitalexpenditure.asp

[32] "Good Strategy Bad Strategy: The Difference and Why It Matters", Richard P. Rumelt, Profile Books © 2011 Citation, ISBN 9780307886231, 0307886239.

  - Does Magic Jack do partner agreements with ISPs? Perhaps that could become a rental area. Magic Jack service is currently available for as little as $20 or $25 a year.
- If customer opts out of connection, have ISP require contract and a non-refundable security deposit and perhaps only refund after deducting that used up in installation and maintenance of the fiber connection - https://fiber.google.com/legal/schedule/ is how google charges for its fiber services.
- Provide referral bonus for new customers to reduce marketing costs.

1.5 Drivers of Fiber Construction Costs[33]

Fiber construction costs can vary significantly, depending on factors including labor, population density, depth or height of the fiber deployment, terrain, equipment, whether or not the provider has existing conduit, make ready costs, and permitting costs. We note our understanding is that given the ESVBA's long history in building out their fiber plan, we expect their cost model to be well defined and stable. Below are details on drivers of fiber construction costs:

- **Labor**: physical labor is the single largest cost component of fiber builds, often over 60% of total fiber construction costs
- **Population Density**: United States population density is about 93 people per square mile, relatively low on a global basis. For the Eastern Shore, Accomac County has a population density of 29.89 per square mile and Northampton County has a population density of 22.359 per square mile or 1/3 and 1/4 the population density of a typical US area respectively.[34] Fiber construction costs are lower for densely populated urban environments and meaningfully higher in sparsely populated rural areas with fewer opportunities to recover costs.
- **Depth or Height**: fiber optic networks are constructed through placement of underground and aerial fiber. Underground fiber optic cable in conduit is significantly more expensive than aerial fiber placed on poles like that used in Virginia's Eastern Shore.
- **Terrain**: fiber needs to be constructed across different types of land that can be more or less expensive to traverse. Fiber is often built around or through mountains and hills, valleys and plains, as well as natural elements like rivers, rocks, and soil types.
- **Equipment**: fiber optic transmission and other electronic equipment costs vary depending on the length of the fiber optic network being constructed.
- **Existing Conduit**: lower buried fiber construction costs benefit carriers that own existing copper conduits, which can be used to pull fiber optic cable through. For example, Frontier Communications, an incumbent local exchange carrier (ILEC), notes it has a ~$40 benefit per location passed by utilizing its existing conduit capacity
- Additional Drivers of Fiber Construction Costs
  - **Make Ready Costs**: expenses associated with securing rights of way, franchises, conduit leases, property leases, and pole attachments. Incumbent operators generally avoid these "make ready costs" if they own poles and/or conduit.

[33] https://dgtlinfra.com/fiber-optic-network-construction-process-costs/

[34] Virginia 2022 Population Review, website https://worldpopulationreview.com/states/virginia-population, accessed 17 November 2022.

- **Permitting Costs**: municipal and other governmental permits, licenses, and authorizations required to be obtained prior to commencement of construction.

To install fiber, costs differ greatly based on geographical area, with urban environments the most expensive, followed by suburban and rural areas being progressively cheaper. Rural areas have fewer obstructions, making pole attachments easier and more cost-effective.

3 Analytic Approach

The GMU analytic approach for the fall 2022 semester began by taking our existing catalog[35] of Eastern Shore Geographic Information System (GIS) infrastructure and updated that with new polygons showing the expected coverage areas from the VATI 2022 grant. We also reviewed and integrated census area[36][37][38] data and United States Postal Service ZIP Code areas. We identified the towns and areas in the two counties and acquired all of the known addresses in the two counties. The majority of this data was collected by the Fall 2021 and Spring 2022 TCOM 750 classes and we thank their efforts.

For the Fall 2022 effort, our effort had three foci, 1) Identify unserved communities, 2) Provide homeowners with a way to coordinate and bring broadband service to their communities in a cost effective and fair manner, and 3) to provide vetted data for the counties to use in planning for future VATI or other grants.

After reviewing the available data, we then scanned the areas not showing coverage and identified the five areas that deserve broadband service and are potentials for a future VATI 2023 application or via the communities banding together and contracting for services. We originally had eight areas identified but were able to eliminate three based on citizen feedback.

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[35] GMU Fall 2020 study acquired ESVBA GIS data supplemented with drive-by visual observations, Radio Frequency to Home (RFTH) towers utilized by Neubeam and ESCC and approximate coverage areas, Accomac County Open Data Portal (https://accomack-county-virginia-open-data-portal-accomack.hub.arcgis.com/datasets/accomack-county-addresses?showData=true) for county addresses, addresses from Northampton County GIS office (https://www.co.northampton.va.us/government/departments_elected_offices/planning_ permiting_enforcement/planning/gis_program), Accomack/Northampton VATI 2021 Grant Request data (https://www.dhcd.virginia.gov/sites/default/files/Docx/vati/2021/applications/accomack-county-application-VATI2021.pdf) and the 2022 VATI Grant Request data at the Virginia Open Data Portal at https://data.virginia.gov/Geographic-Information/VATI-2022-Application-Shapefiles-Accomack-Northamp/cuf8-xu5v, and finally FCC Form 477 applications at the FCC Open Data site (https://opendata.fcc.gov/Wireline/Fixed-Broadband-Deployment-Data-December-2019/whue-6pnt/data).

[36] Data.rgj.com, website https://data.rgj.com/american-community-survey/block-group-1-census-tract-901-accomack-county-virginia/population/total-population/yty/15000US510010901001/, accessed 21 April 2021.

[37] Data.gov Census Reporter, website https://censusreporter.org/profiles/15000US510010905001-block-group-1-accomack-va/, accessed 21 April 2021.

[38] US Census Cartographic Boundary Files, website https://www.census.gov/geographies/mapping-files/time-series/geo/cartographic-boundary.html, accessed 21 April 2021.

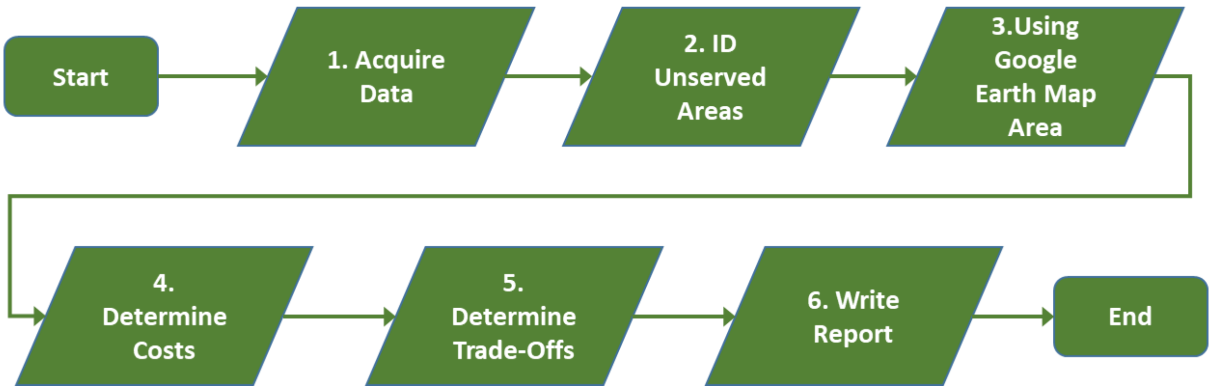

Figure 5 The George Mason University (GMU) Approach Followed a 6-Step Process to Acquire and Integrate data, Identify Unserved Areas, Plan the community service approaches/costs and write our report.

A more detailed review of our engineering steps is shown in the following steps.

3.1 Plan to reach unserved neighborhoods with engineering approach

1. Acquire and integrate data (GIS Files, Addresses, Locations of Interest).
2. Review GIS data and coverage areas; identify unserved areas.
3. Maps the areas in Google Earth; define service area and passings and estimate fiber run distance or wireless coverage.
4. Determine costs and trade-offs between the approaches (cost-benefit analysis)
    a. Determine fiber run costs
    b. Determine satellite costs
    c. Determine cable costs
    d. Determine cellular costs
    e. Determine wireless costs - Use Cambium Networks Link Planner to determine wireless costs (see LinkPlanner tutorial at https://www.cambiumnetworks.com/products/software/linkplanner/, https://youtu.be/X_dYxcVwyio)
5. Document Trade-Offs (different paths, cost comparisons)
6. Document findings
    a. Community Self-Help Approach (shared infrastructure plan to equitably distribute costs among customer and install a sense of fairness
        i. Plan for setting up a neighborhood ISP
            1. Community Charter
            2. Community Survey/Lay-out
            3. Community member agreement

4. Deal Framework with regional ISP (e.g., ESVBA, Neubeam, Charter Spectrum, ESCC)

b. County relationship/charter

c. VATI-ready documentation

d. Proposal to provider

4 2022 Virginia Telecommunications Initiative (VATI) Coverage Areas

Since the data submitted for the 2022 Accomac and Northampton VATI grant application is the most current data out there, we relied on the coverage areas to help us identify still unserved areas. **Figure 6 Montage of Accomac County Coverage Areas from the 2022 Accomac-Northampton VATI Grant Application** and **Figure 7 Montage of Northampton County Coverage Areas from the 2022 Accomac-Northampton VATI Grant Application** are provided for reference with their relative positions on the peninsula.

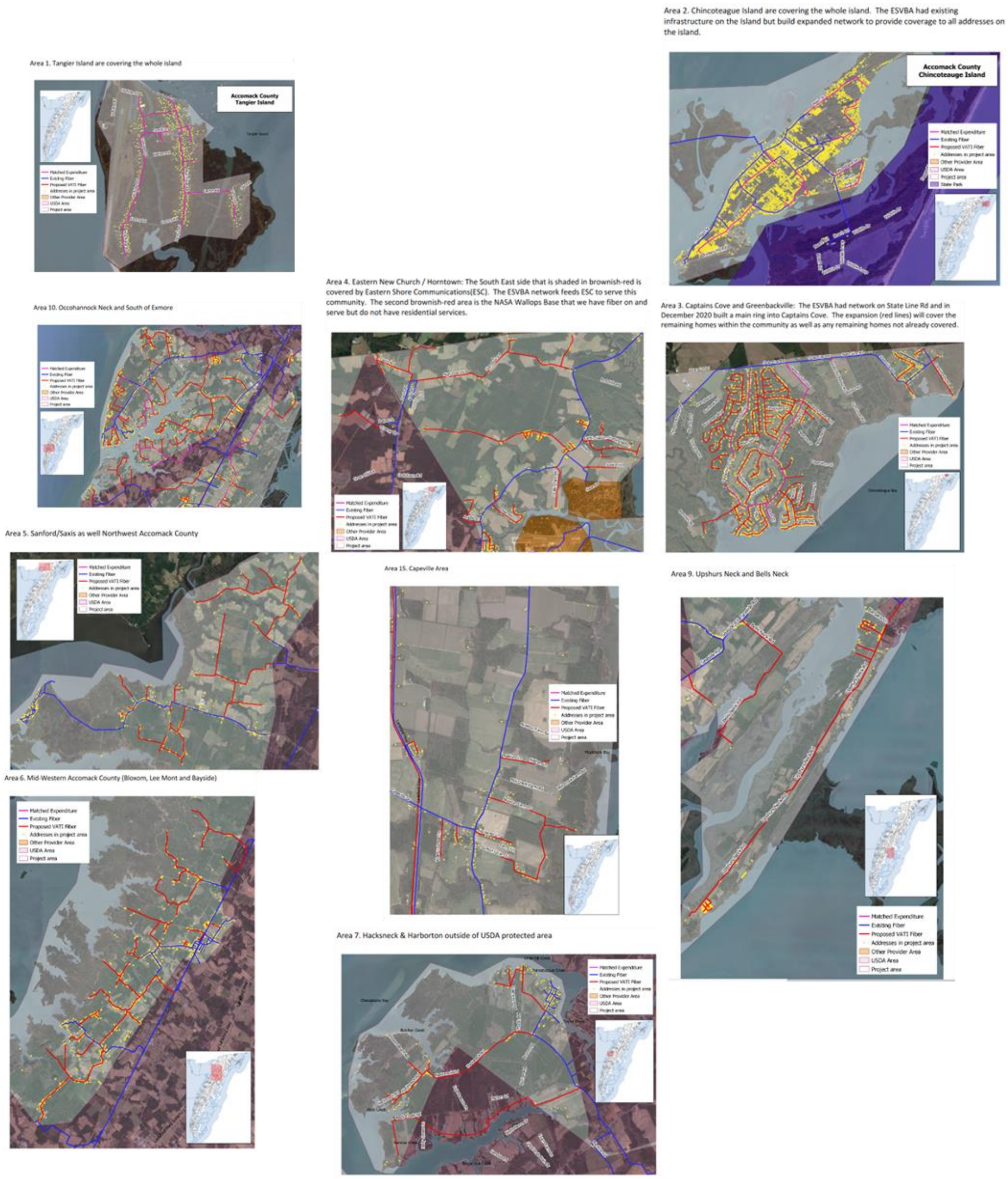

Figure 6 Montage of Accomac County Coverage Areas from the 2022 Accomac-Northampton VATI Grant Application

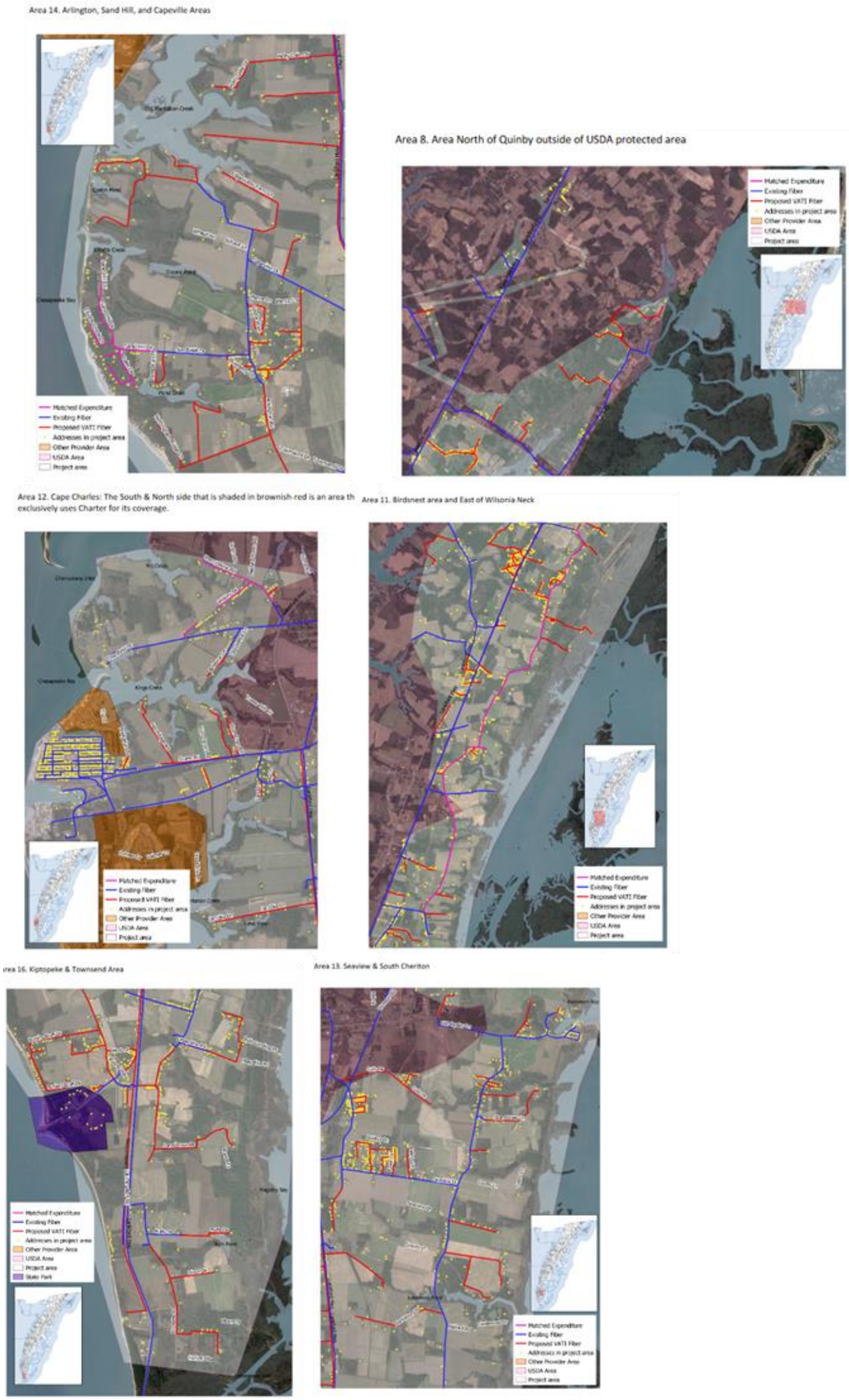

Figure 7 Montage of Northampton County Coverage Areas from the 2022 Accomac-Northampton VATI Grant Application

5 Proposed Locations Identified by GMU

Based on the research conducted in the Spring 2022 Semester at George Mason University in the TCOM 750 class, the Fall 2022 class proceeded to better research the identified locations and determine if there were alternative costing strategies that could be used to help these homeowners get broadband service. All but one of the locations are based in Accomac County and these are all close to Metompkin Road that is a major North-South secondary road on the Atlantic Ocean side of the peninsula that parallels Route 13. The locations are referred to as (in their order of occurring going from North to South):

1. Conquest Point
2. Persimmon Point
3. South Point
4. Parker Neck
5. Cheapside, the single Northampton County location

We originally included the areas of Society-Hogneck, Modest Town and Gargathy Neck but after several interviews and a site survey we determined that the ESVBA and Charter Spectrum were providing service to those areas and we were able to exclude them. We are actually pleased to see they now have service.

A major factor in our designation of these five sites is their exclusion from the coverage areas in the two counties 2022 Virginia Telecommunications Initiative (VATI) funding request and their relative concentration of passings that should make them more attractive for potential providers.

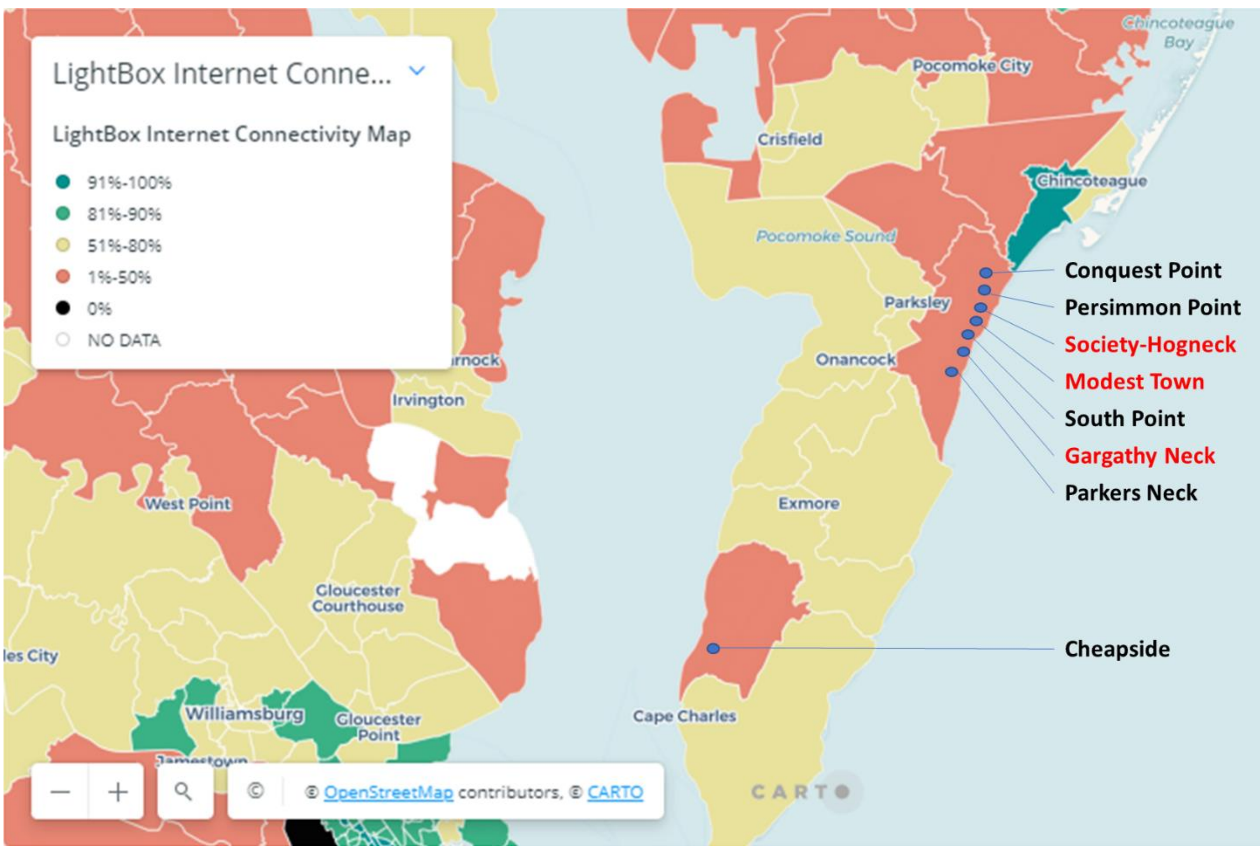

Figure 8 Lightbox Coverage Results showing the 8 selected locations - https://www.lightboxre.com/products/location-based-analytics/connectivity-map/

As of 21 November 2022, the Federal Communications Commission[39] released and updated nationwide fixed and wireless cellular coverage map. It shows many of the areas of the Eastern Shore have 100% fixed and mobile coverage at 25MBps. Our limited experience tells us this is not accurate and the real-world results are less than that. We note that foliage, rain, terrain and other factors can severely impact wireless coverage. Virginians are being encouraged by Virginia Senator Warner to go to the FCC site at https://outreach.senate.gov/iqextranet/iqClickTrk.aspx?&cid=SenWarner&crop=19432.1037563002174 5458.93414720&report_id=&redirect=https%3a%2f%2fbroadbandmap.fcc.gov%2fhome&redir_log=379 558296893231 to check their address and provide input to the FCC.

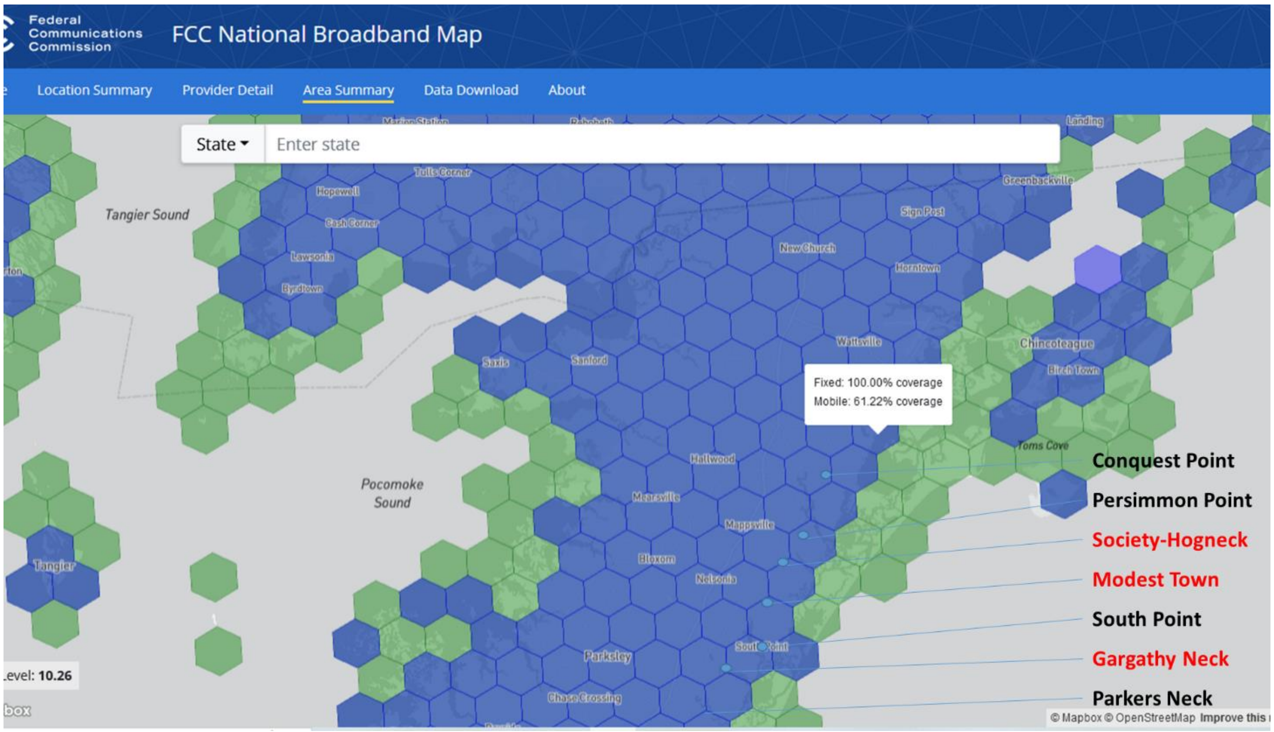

Figure 9 FCC Updated Fixed (Blue) and Mobile (Green) Cellular Coverage Map for Accomac County

[39] FCC National Broadband Map, website https://broadbandmap.fcc.gov/area-summary/combined?zoom=9.59&vlon=-75.857261&vlat=37.368587&fixed_br=r&fixed_speed=25_3&fixed_tech=1_2_3_4_5_6_7_8&fixed_pct_cvg=0&mobile_tech=tech_all&mobile_env=0&mobile_pct_cvg=0, accessed 21 November 2022.

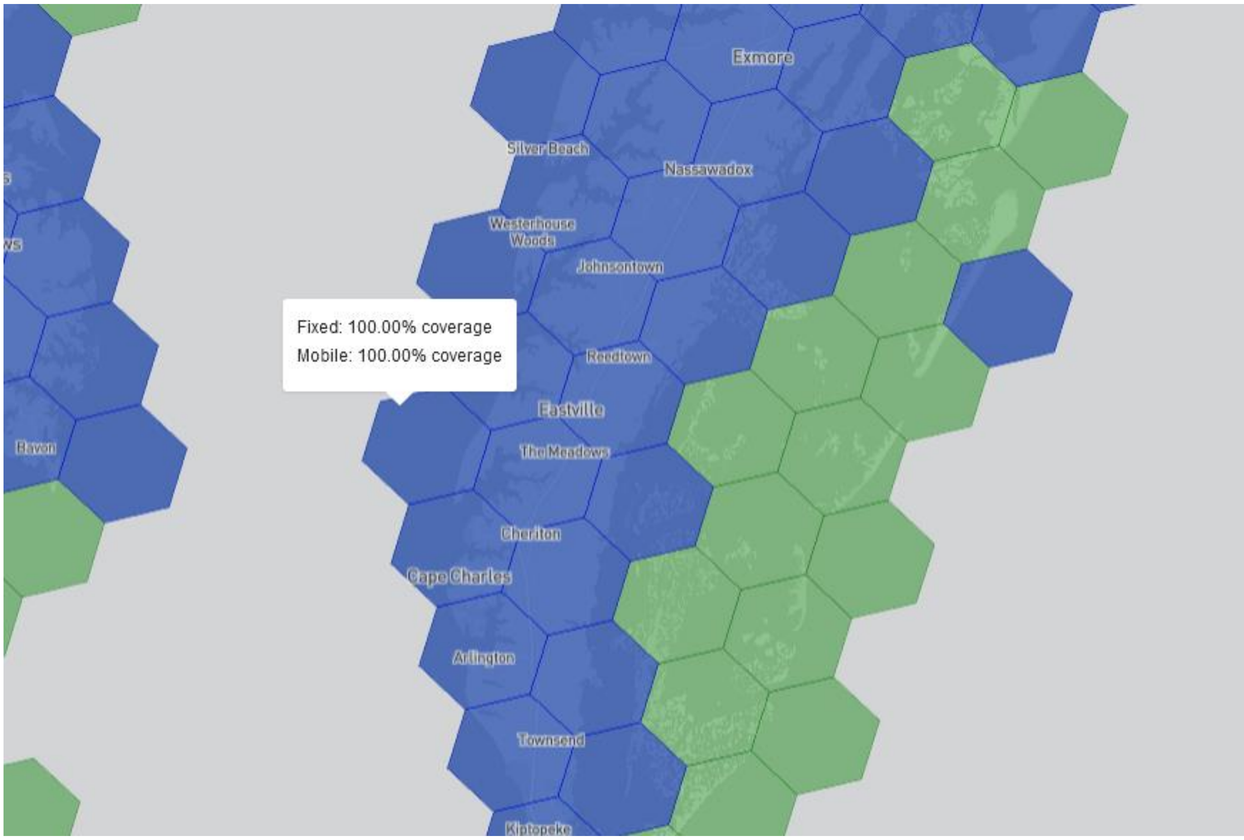

Figure 10 FCC Fixed and Mobile Cellular Coverage Map for Northampton County

We further support this coverage conclusion based on data from Lightbox, Starlink and BroadBandNow.com that also showed they were underserverved. We also note that while Starlink does show the areas as eligible for coverage (refer to **Figure 9 Accomac County Sites Starlink Availability Map - https://www.starlink.com/map**), Starlink coverage has capacity limitations[40][41][42][43][44][45] and the expense of initial equipment purchase and higher ongoing recurring costs over other alternatives available on the peninsula will likely be a significant financial hardship for many of the families in our proposed coverage areas. We included reported coverage areas from the three major cellular providers (T-Mobile, Verizon

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[40] Blog Post "Modeling Starlink capacity", website https://mikepuchol.com/modeling-starlink-capacity-843b2387f501, accessed 16 October 2022.

[41] Blog Post "Starlink's current problem is capacity", website https://www.jeffgeerling.com/blog/2022/starlinks-current-problem-capacity, accessed 16 October 2022.

[42] Blog Post "Starlink, Stasis and "Capacity Shortfall"", website https://www.platformonomics.com/2021/02/starlink-stasis-and-capacity-shortfall/, accessed 16 October 2022.

[43] Article "Starlink's Massive Growth Results in Congestion, Slow Speeds for Some Users", website https://www.pcmag.com/news/starlinks-massive-growth-results-in-congestion-slow-speeds-for-some-users, accessed 16 October 2022.

[44] Cartesian Press Release "Press release: New Research Highlights Concerns Whether Starlink™ Will Meet Federal Broadband Capacity Requirements", website https://www.cartesian.com/press-release-new-research-highlights-concerns-whether-starlink-will-meet-federal-broadband-capacity-requirements-2/, accessed 16 February 2022.

[45] Reddit discussion on Starlink. Website https://www.reddit.com/r/Starlink/search?q=flair_name%3A%22%F0%9F%92%AC%20Discussion%22&restrict_sr=1, accessed 16 October 2022.

and AT&T), but note real world experience as well as FCC findings are that their claimed coverage areas tend to be overstated and inaccurate.[46] That actual FCC maps can be found at https://fcc.maps.arcgis.com.

Figure 11 Accomac County Sites Starlink Availability Map - https://www.starlink.com/map

[46] Article “New FCC Report Shows that Wireless Carriers Exaggerate Coverage”, website https://voqal.org/new-fcc-report-shows-that-wireless-carriers-exaggerate-coverage/, accessed 21 October 2022.

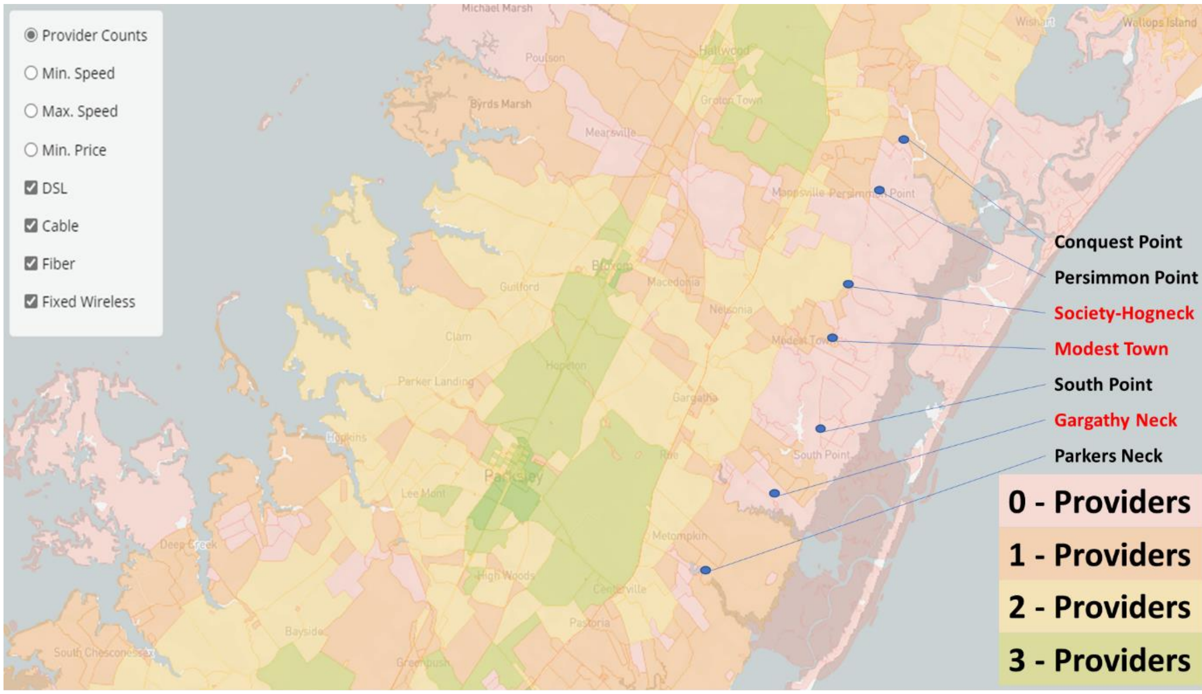

Figure 12 Broadband Now Coverage Survey - https://broadbandnow.com/national-broadband-map

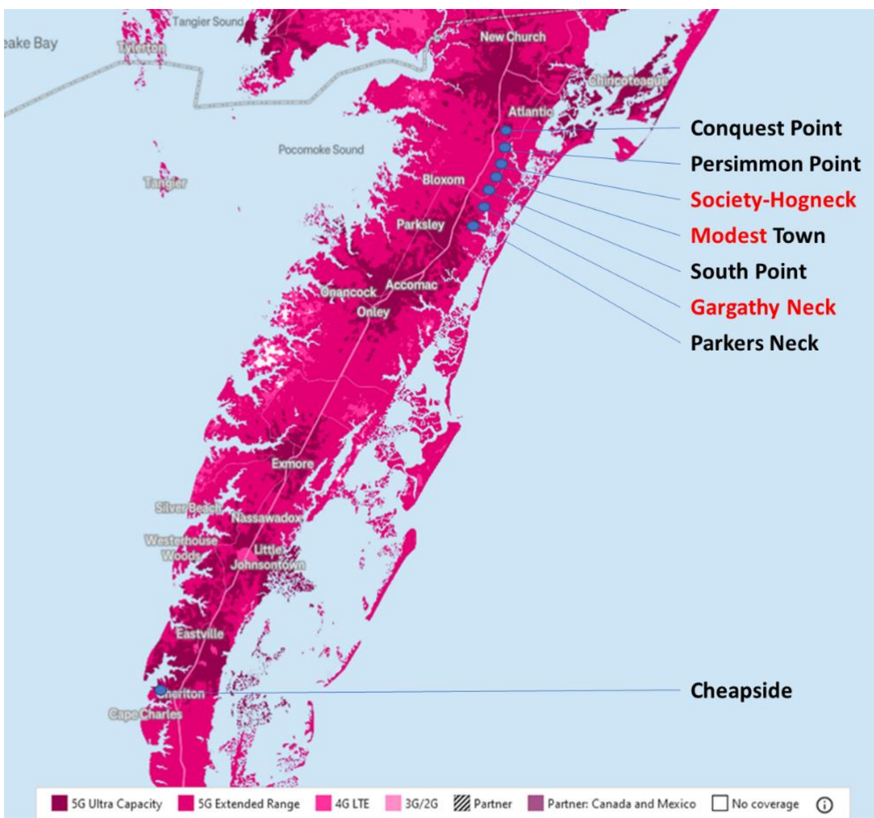

Figure 13 T-Mobile Wireless Coverage Map - https://www.t-mobile.com/coverage/coverage-map

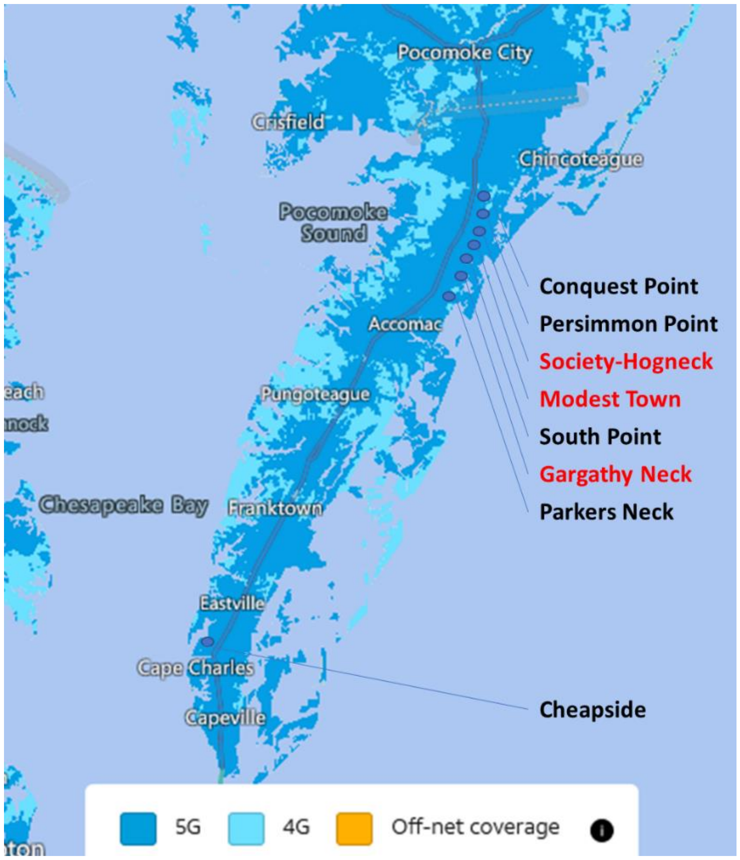

Figure 14 AT&T Wireless Coverage Map - https://www.att.com/maps/wireless-coverage.html

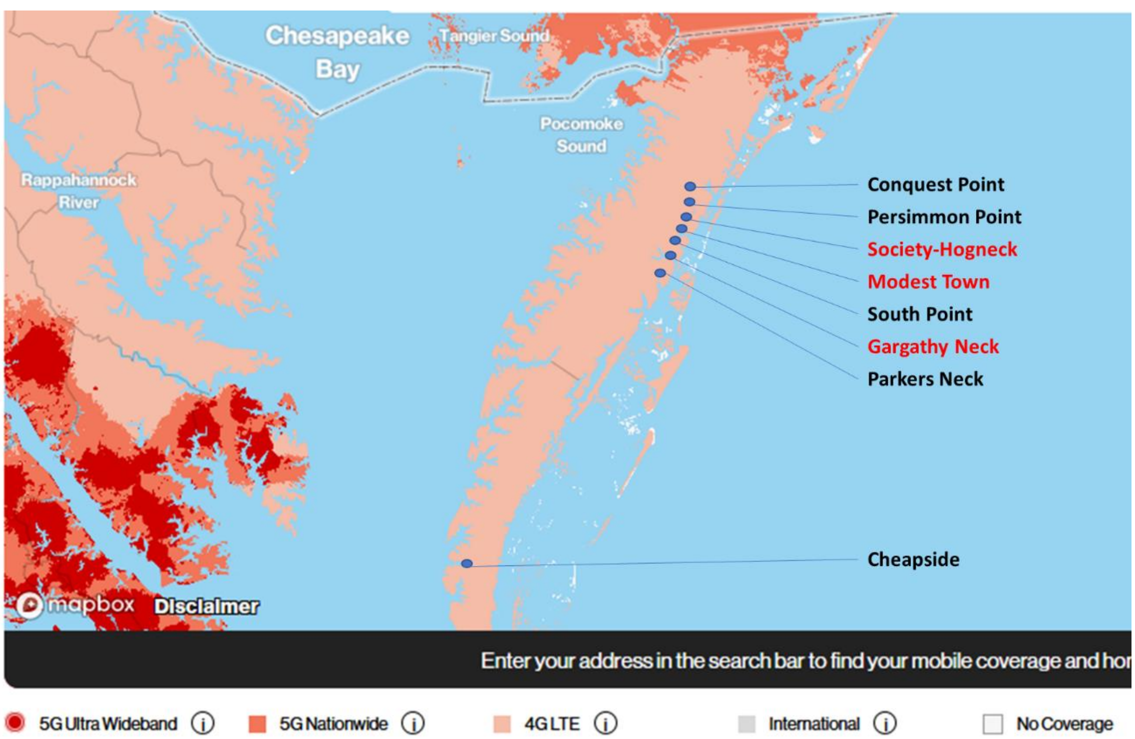

Figure 15 Verizon Mobile Coverage Map - https://www.verizon.com/coverage-map/

6 Detailed Site Analyses of the Five Locations

The locations that we feel are in need of broadband, and the primary subject of this report are referred to as (in their order of occurring going from North to South):

1. Conquest Point
2. Persimmon Point
3. South Point
4. Parker Neck
5. Cheapside (Northampton County)

6.1 Conquest Point

Conquest point is very perplexing to us as to why it does not have broadband service. In a drive by survey, we observed the fiber pulled up to the egress to the neighborhood, but no further. In fact, the fiber goes from the intersection of Metompkin Road and John Taylor Road toward Rt 13. There are existing power line poles that run down into the neighborhood. We admit the neighborhood is a bit of a hidden gem as, unless you know the homes are there, the view from the street does not indicate the neighborhood exists. Also, directly adjacent across the water feature is Arbuckle Neck Road which we assume does not have broadband. It would likely be a better candidate for Wireless Internet Service Provider Service or Satellite Internet via a service such as Starlink due to the housing density. For Conquest Point to confirm out thought we did cost out the difference between pulling fiber and deploying a WISP scheme and were surprised to see that fiber was not only superior in overall performance (considering weather and propagation factors), but was much more cost advantageous.

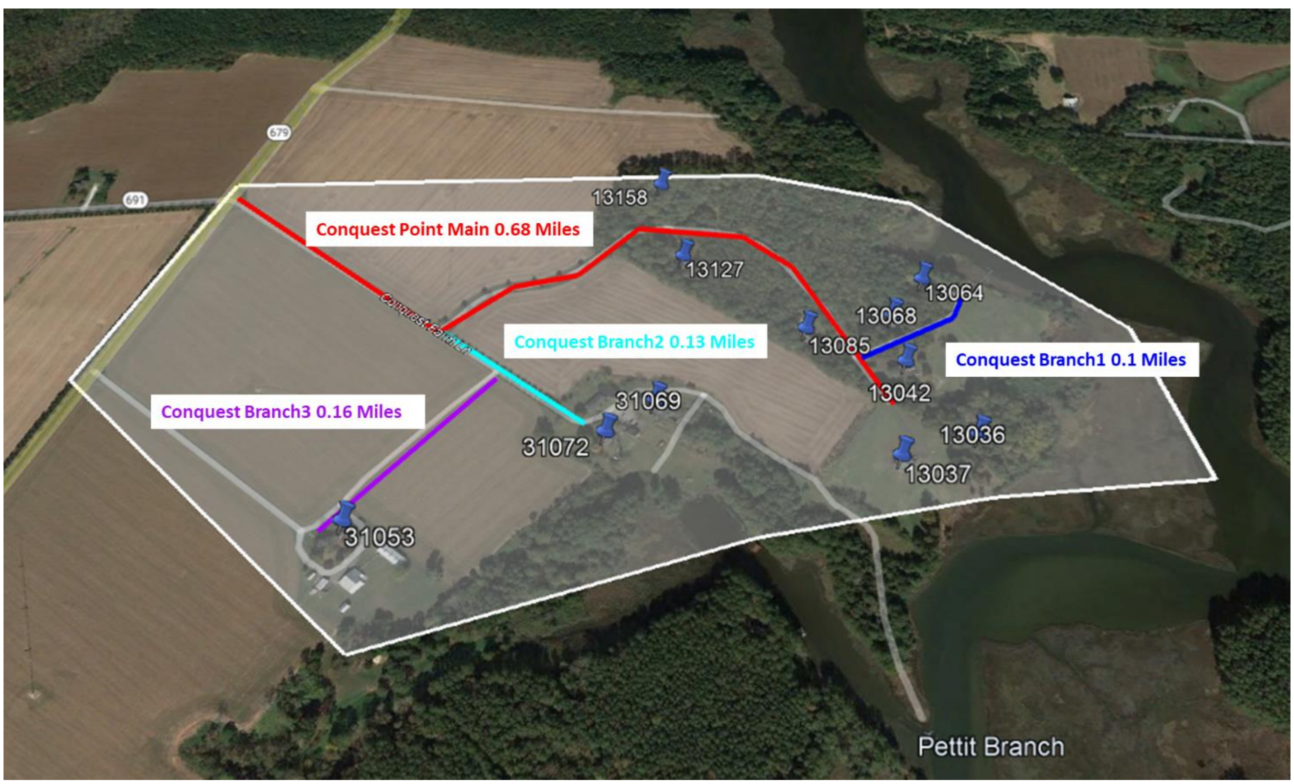

Figure 16 Conquest Point GIS Layout with Annotated Circuit Paths

Table 2 Conquest Point Fiber Segments and Cost Estimates

Circuit Designator		Length	Cost (Distance X Mile Cost)	Shared Cost Per Household
CP1	Conquest Main	0.68 miles	0.68 * $17,000/mile = $11,500	100% $1,650/household
CP2	Conquest Branch1	0.1 miles	0.1 * $17,000/mile = $1,700	
CP3	Conquest Branch2	0.13 miles	0.13*17,000/mile = $2,210	75% (9 households) $2,014/household
CP4	Conquest Branch3	0.16 miles	0.16*$17,000/mile = $2,720	
Totals		**1.07 miles**	**$18,130**	

Table 3 Conquest Point Locations and Details

	Full Address	Latitude	Longitude
1	31069 Conquest Farm Ln Assawoman 23302	37.85535517	-75.53473787
2	31072 Conquest Farm Ln Assawoman 23302	37.85495635	-75.5353304
3	31053 Conquest Farm Ln Assawoman 23302	37.8562593	-75.53637451
4	13127 Conquest Point Ln Assawoman 23302	37.857408	-75.53439518
5	13158 Conquest Point Ln Assawoman 23302	37.85858795	-75.53471083
6	13068 Conquest Point Ln Assawoman 23302	37.85651582	-75.53168702
7	13064 Conquest Point Ln Assawoman 23302	37.85705339	-75.53122363
8	13042 Conquest Point Ln Assawoman 23302	37.85587042	-75.53160036
9	13085 Conquest Point Ln Assawoman 23302	37.85632691	-75.53281663
10	13037 Conquest Point Ln Assawoman 23302	37.85467082	-75.53180998
11	13036 Conquest Point Ln Assawoman 23302	37.85492781	-75.53084979

Using Cambium Networks LinkPlanner we did map out a potential Point-to-Multipoint Network and the results are depicted below. While not as optimum as a direct fiber link it is an alternative for Conquest Point. One nice thing about LinkPlanner is it provides you with a bill of materials (BOM). We did a price check at https://www.ispsupplies.com and came up with a total of $39,224.80 for the materials. We did not estimate the man hours to install and calibrate the equipment. At nearly double our estimated cost to install FTTH, and given the need to recapitalize on a 5-year time span we do not think wireless is cost effective.

Figure 17 Conquest Point Hub to Subscriber Site 13037 Showing Acceptable Performance with the Hub Antenna mounted on a standard utility pole (15-meters) and a 10-meter height at the subscriber location.

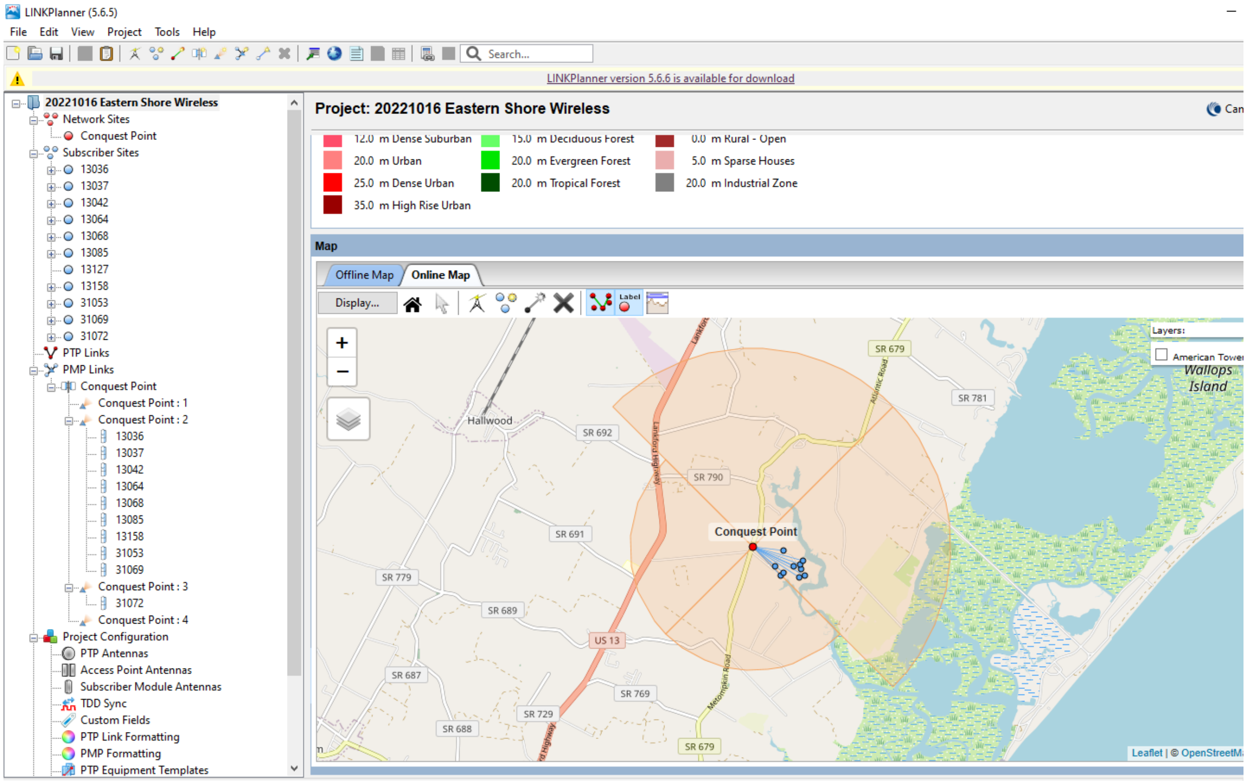

Figure 18 Map and Object View of a Conquest Point Implementation Using Cambium Point-to-Point Wireless Network

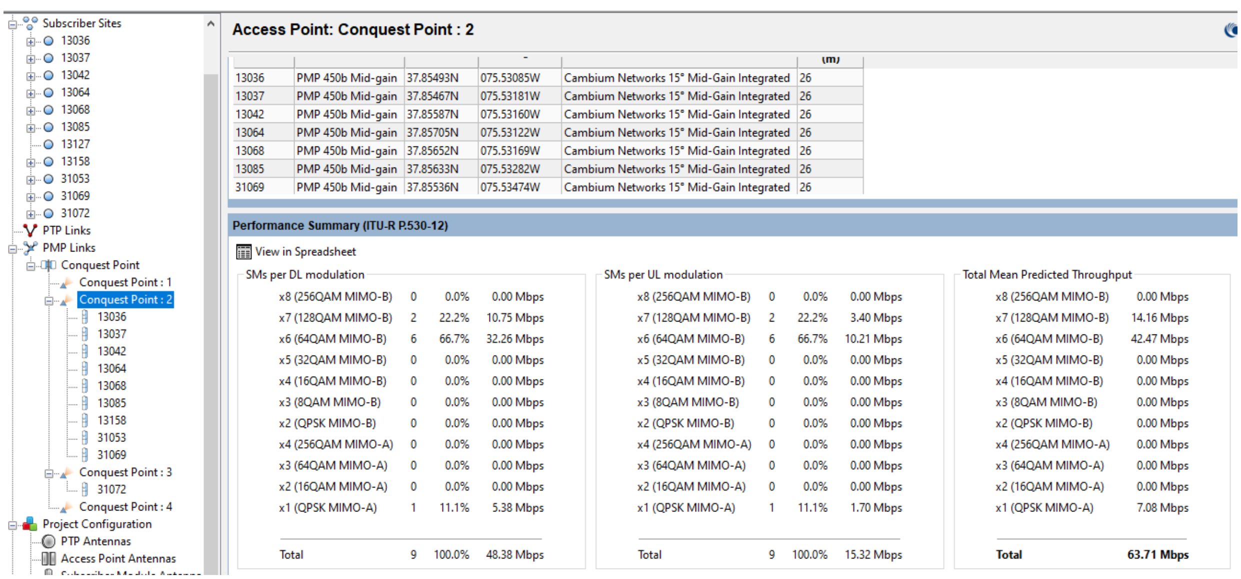

Figure 19 Performance Figures for Conquest Point with a Cambium Point-to-Point Wireless Network

Table 4 PMP Network BOM for 20221016 Eastern Shore Wireless[47]

Part Number	Description	Qty	Notes	Cost
01010419001	Coaxial Cable Grounding Kits for 1/4" and 3/8" Cable	8	$28.08 each	$224.64
C000000L066	cnPulse Sync Generator with CambiumSYNC	4	replaces UGPS (1096) $301.32 each	$1205.28
C000065L007	LPU and Grounding Kit (1 kit per ODU)	4	$432.00 each	$1728.00
C030045AL01	3 GHz PMP 450i Connectorized Access Point, LITE	4	3411.72 each	$13,646,88
C050045A005	5 GHz PMP 450i Integrated Access Point, 90 degrees (ROW)	3	Requires suffix "B" or newer; $3746.52 each	$11,239.56
C050045A006	5 GHz PMP 450i Integrated Access Point, 90 degrees (FCC)	1	Requires suffix "B" or newer; 3746.52 each	$3,746.52
EW-E2PM45AP-WW	PMP450/450i Access Point Extended Warranty, 2 Additional Years	4	$92.00 each	$368.00
N000000L034	PoE, 30.5W, 56V, GbE DC Injector, Indoor, Energy Level 6 Supply, accepts C5 connector	4	$28.62 each	$114.48
N000065L031	PTP 700 Pole Mount Bracket, Heavy Duty	4	$12.57 each	$50.28
N000900L031	AC line cord, US Type B, 720mm, C5 connector	4	replaces N000900L007; $6.00 each	$24.00
WB3176	328 ft (100 m) Reel Outdoor Copper Clad CAT5E (Recommended for PTP)	1	$534.60 each	$534.60
Total				**$32,882.28**

Table 5 PMP Subscribers BOM for 20221016 Eastern Shore Wireless[48]

Part Number	Description	Qty	Notes	Cost
C000000L065	Gigabit Surge Suppressor (30V)	10	$48.60 each	$486.00
C000000L066	cnPulse Sync Generator with CambiumSYNC	1	replaces UGPS (1096); $301.32 each	$301.32
C050045B031	5 GHz 450b - Mid-Gain - ROW	1	$344.52 each	$344.52
C050045B032	5 GHz 450b - Mid-Gain - FCC	9	$344.52 each	$3100.68
EW-E2PT450B-WW	PTP 450b Extended Warranty, 2 additional years (per END)	10	$187.00 each	$1870.00
N000900L001	PoE Gigabit DC Injector, 15W Output at 30V, Energy Level 6 Supply	10	$18.00 each	$180.00
N000900L031	AC line cord, US Type B, 720mm, C5 connector	10	replaces N000900L007; $6.00 each	$60.00
Total				**$6,342.52**

6.2 Persimmon Point

For Persimmon Point, a primary consideration was getting fiber to the neighborhood. We considered using a wireless Point-to-Point (PTP) link which could then feed a Point-to-Multi-Point (PMP) connection, but the expense for this approach becomes very uneconomical. To gain the necessary height for a clear Fresnel Zone in the PTP link, requires 80-foot utility poles. As these are $7,000 each and we would require two, as well as the additional transmit and receive equipment, we have likely exceeded our $17,000/mile

[47] Prices derived from https://www.ispsupplies.com, accessed 09 November 2022.

[48] Prices derived from https://www.ispsupplies.com, accessed 09 November 2022.

cost for installed fiber. And all of this would be before we factor in OPEX of replacing the electronics in a few years as well as the concern that weather could impact operations on a regular basis.

We do note there are no power poles from Metompkin Road up Pettit Road. It appears for the few houses there, the utilities are underground. On the eastern portion of Pettit Road there are power poles and it appears the power feed comes from Pierce Taylor Road.

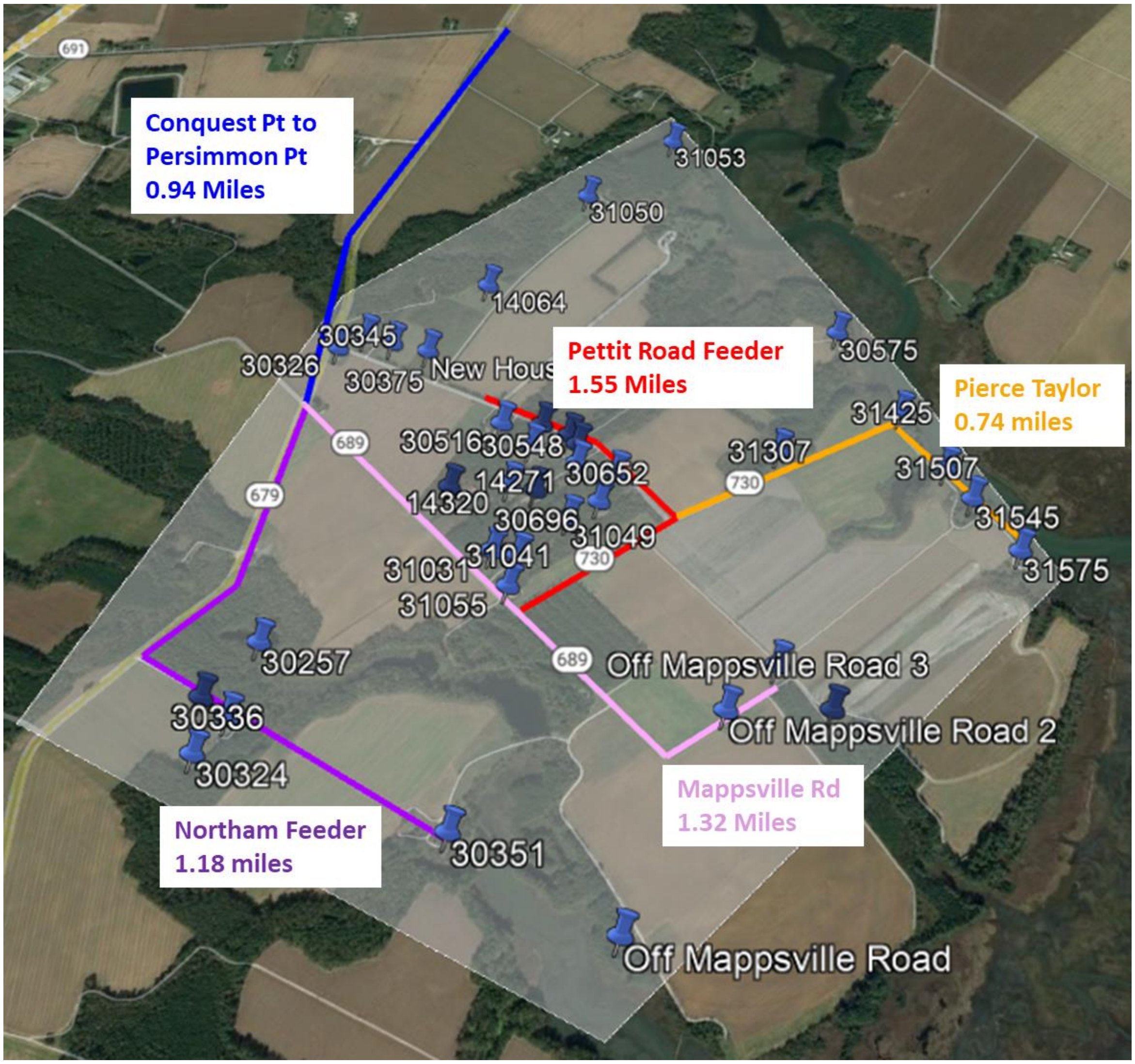

Figure 20 Persimmon Point GIS Layout with Annotated Circuit Paths

Table 6 Conquest Point Fiber Segments and Cost Estimates

Circuit Designator		Length	Cost (Distance X Mile Cost)	Shared Cost Per Household
PP1	Conquest Pt to Persimmon Pt	0.94 miles	0.94 * $17,000/mile = $15,980	100% (45 households) $2,164/household
PP2	Pettit Road Feeder	1.55 miles	1.55 * $17,000/mile = $26,350	

Circuit Designator		Length	Cost (Distance X Mile Cost)	Shared Cost Per Household
PP3	Mappsville Road	1.32 miles	1.32 * 17,000/mile = $22,440	75% (34 households) $2,865/household
PP4	Northam Feeder	1.18 miles	1.18 * $17,000/mile = $20,060	
PP5	Pierce Taylor	0.74 miles	0.74 * $17,000/mile = $12,580	
Totals		**5.73 miles**	**$97,410**	

Table 7 Persimmon Point Locations and Details

	Full Address	Latitude	Longitude
1	14064 Liberty Dr Hallwood 23359	37.8472	-75.53961294
2	14271 Deer Path Hallwood 23359	37.8411	-75.53592532
3	14319 Deer Path Hallwood 23359	37.8403	-75.53713203
4	14320 Deer Path Hallwood 23359	37.8404	-75.53796898
5	29371 Mappsville Rd Hallwood 23359	37.8456	-75.56154892
6	29397 Mappsville Rd Hallwood 23359	37.846	-75.56045037
7	29411 Mappsville Rd Hallwood 23359	37.8459	-75.56011774
8	29421 Mappsville Rd Hallwood 23359	37.8459	-75.55974093
9	29431 Mappsville Rd Hallwood 23359	37.8458	-75.55935717
10	29441 Mappsville Rd Hallwood 23359	37.8458	-75.55901784
11	29451 Mappsville Rd Hallwood 23359	37.8458	-75.55867501
12	29461 Mappsville Rd Hallwood 23359	37.8457	-75.55836071
13	29471 Mappsville Rd Hallwood 23359	37.8457	-75.55801016
14	29475 Mappsville Rd Hallwood 23359	37.846	-75.5578189
15	29477 Mappsville Rd Hallwood 23359	37.8457	-75.55750888
16	29485 Mappsville Rd Hallwood 23359	37.8496	-75.55102076
17	30257 Northam Ln Bloxom 23308	37.8359	-75.54464765
18	30306 Northam Ln Bloxom 23308	37.8344	-75.54594009
19	30324 Northam Ln Bloxom 23308	37.833	-75.54579214
20	30326 Pettit Rd Hallwood 23359	37.8449	-75.54427605
21	30336 Northam Ln Bloxom 23308	37.8339	-75.54505805
22	30345 Pettit Rd Hallwood 23359	37.8454	-75.54344752
23	30351 Northam Ln Bloxom 23308	37.8312	-75.53835522
24	30375 Pettit Rd Hallwood 23359	37.8451	-75.54250475
25	30516 Pettit Rd Hallwood 23359	37.8424	-75.53847507
26	30543 Mappsville Rd Hallwood 23359	37.8404	-75.5398208
27	30546 Pettit Rd Hallwood 23359	37.8423	-75.53717419
28	30548 Pettit Rd Hallwood 23359	37.8416	-75.53744024

	Full Address	Latitude	Longitude
29	30575 Pettit Rd Hallwood 23359	37.8454	-75.52764239
30	30596 Pettit Rd Hallwood 23359	37.842	-75.5362699
31	30602 Pettit Rd Hallwood 23359	37.8417	-75.53596998
32	30652 Pettit Rd Hallwood 23359	37.8408	-75.53466574
33	30696 Pettit Rd Hallwood 23359	37.8399	-75.53511017
34	31031 Mappsville Rd Hallwood 23359	37.8384	-75.53821916
35	31041 Mappsville Rd Hallwood 23359	37.8383	-75.53741208
36	31049 Mappsville Rd Hallwood 23359	37.8394	-75.53600731
37	31050 Liberty Ct Hallwood 23359	37.8506	-75.53654243
38	31053 Liberty Ct Hallwood 23359	37.8529	-75.53363671
39	31055 Mappsville Rd Hallwood 23359	37.8374	-75.53759419
40	31172 Pierce Taylor Rd Bloxom 23308	37.8341	-75.5279161
41	31307 Pierce Taylor Rd Hallwood 23359	37.8415	-75.52955167
42	31425 Pierce Taylor Rd Hallwood 23359	37.8427	-75.52563918
43	31507 Point Breeze Ln Bloxom 23308	37.8409	-75.52427905
44	31545 Point Breeze Ln Bloxom 23308	37.84	-75.52350936
45	31575 Point Breeze Ln Bloxom 23308	37.8384	-75.522168

6.3 South Point

South Point is nestled between Modest Town and Gargathy Neck. Two locations, 18286 and 29522, are approximately one-tenth to two-tenths of a mile from Gargathy Neck homes that have broadband fiber. They are separated by water and marsh land of approximately one-tenth of a mile. It is a case of so close, yet so far. At the intersection of Kegotank Road and Metompkin Road there is exiting fiber that services Modest Town. As of this time, that fiber was installed approximately six months ago or mid-2022. This is an ideal location for broadband connectivity as the power lines run directly down the road and there is only one circuit required as detailed in **Table 8 South Point Fiber Segment and Cost Estimate**.

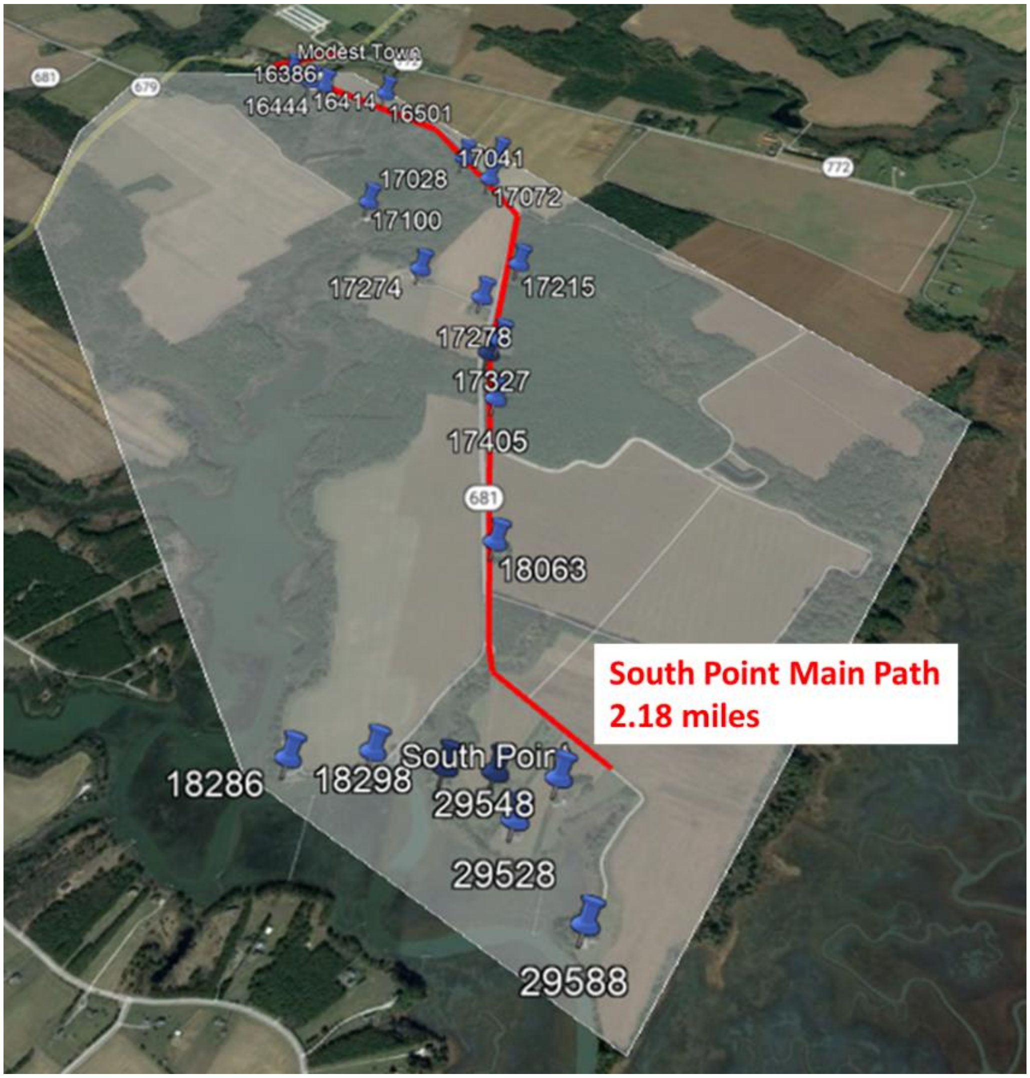

Figure 21 South Point GIS Layout with Annotated Circuit Path

Table 8 South Point Fiber Segment and Cost Estimate

Circuit Designator		**Length**	**Cost** (Distance X Mile Cost)	**Shared Cost Per Household**
SP1	South Point Main Path	2.18 miles	2.18 * $17,000/mile = $37,060	100% (21 households) $1,764/household
				75% (16 households) $2,316/household
Totals		**2.18 miles**	**$37,060**	

Table 9 South Point Locations and Details

	Full Address	Latitude	Longitude
1	18063 Kegotank Rd Bloxom 23308	37.7924177	-75.55949351
2	18286 Kegotank Rd Bloxom 23308	37.78683475	-75.56428043
3	17215 Kegotank Rd Bloxom 23308	37.80206609	-75.55888802
4	17327 Kegotank Rd Bloxom 23308	37.79907773	-75.55945632
5	17274 Kegotank Rd Bloxom 23308	37.80187568	-75.56198682
6	17278 Kegotank Rd Bloxom 23308	37.80071843	-75.56001818
7	17405 Kegotank Rd Bloxom 23308	37.79696702	-75.55954645
8	16414 Kegotank Rd Bloxom 23308	37.81071627	-75.56645441
9	16444 Kegotank Rd Bloxom 23308	37.81046584	-75.56589931
10	17072 Kegotank Rd Bloxom 23308	37.80581647	-75.55987442
11	17028 Kegotank Rd Bloxom 23308	37.80681527	-75.56076063
12	16501 Kegotank Rd Bloxom 23308	37.81008116	-75.56366722
13	18298 Kegotank Rd Bloxom 23308	37.78698606	-75.56229858
14	17041 Kegotank Rd Bloxom 23308	37.80692228	-75.55960075
15	16386 Kegotank Rd Bloxom 23308	37.81126964	-75.56719149
16	17355 Kegotank Rd Bloxom 23308	37.79860075	-75.559766
17	29454 South Pt Bloxom 23308	37.7866281	-75.56059006
18	29588 South Pt Bloxom 23308	37.78330799	-75.55740897
19	29516 South Pt Bloxom 23308	37.78651222	-75.55940453
20	29528 South Pt Bloxom 23308	37.78544741	-75.55893825
21	27411 Third St Bloxom 23308	37.80190556	-75.59488694

6.4 Parker Neck

Parker Neck is an area bounded on all sides by farms or water. There are 71 households or passings that we counted. We estimate that three feeder lines can service most of these households. There were no dependencies on fiber being run to adjacent areas and existing utility poles are available in the area.

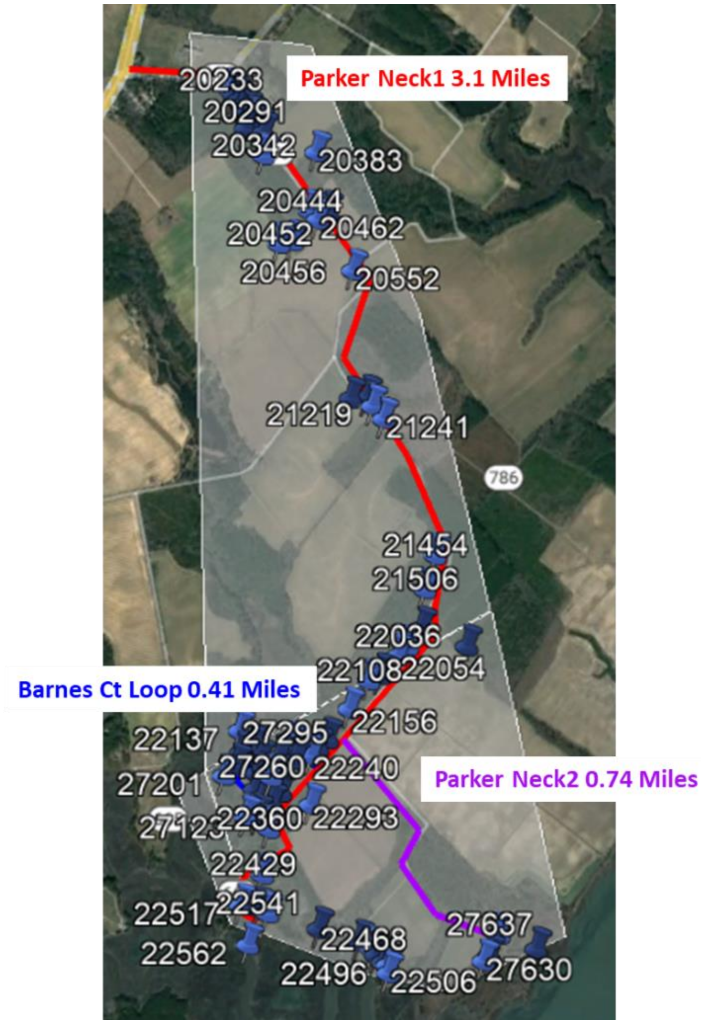

Figure 22 Parker Neck GIS Layout with Annotated Circuits

Table 10 Parker Neck Fiber Segments and Cost Estimates

Circuit Designator		**Length**	**Cost** (Distance X Mile Cost)	**Shared Cost Per Household**
PN1	Parker Neck1	3.1 miles	3.1 * $17,000/mile = $52,700	100% (71 households) $1,017/household
PN2	Parker Neck2	0.74 miles	0.74 * $17,000/mile = $12,580	
PN3	Barnes Ct Loop	0.41 miles	0.41 * 17,000/mile = $6,970	75% (53 households) $1,363/household
Totals		**4.25 miles**	**$72,250**	

Table 11 Parker Neck Locations and Details

	Full Address	Latitude	Longitude
1	22496 Parker Creek Rd Parksley 23421	37.72731663	-75.60159559
2	22468 Parker Creek Rd Parksley 23421	37.72791719	-75.60233192
3	22506 Parker Creek Rd Parksley 23421	37.72700649	-75.60156967
4	22486 Parker Creek Rd Parksley 23421	37.72743034	-75.60182519
5	22434 Parker Creek Rd Parksley 23421	37.7282116	-75.60301095
6	22478 Parker Creek Rd Parksley 23421	37.72769945	-75.60218017
7	27662 Metompkin Bay Dr Parksley 23421	37.72767384	-75.59661709
8	27665 Metompkin Bay Dr Parksley 23421	37.72792935	-75.59432528
9	27630 Metompkin Bay Dr Parksley 23421	37.72747287	-75.59690405
10	27637 Metompkin Bay Dr Parksley 23421	37.72849348	-75.59616525
11	22314 Fox Grove Rd Parksley 23421	37.73396741	-75.60698127
12	22156 Fox Grove Rd Parksley 23421	37.73720965	-75.60365012
13	22293 Fox Grove Rd Parksley 23421	37.73348973	-75.60549954
14	22395 Fox Grove Rd Parksley 23421	37.72870875	-75.6050112
15	22054 Fox Grove Rd Parksley 23421	37.73928922	-75.6012593
16	22090 Fox Grove Rd Parksley 23421	37.73853674	-75.60212856
17	22108 Fox Grove Rd Parksley 23421	37.73831813	-75.6027061
18	22036 Fox Grove Rd Parksley 23421	37.73965185	-75.60082314
19	22360 Fox Grove Rd Parksley 23421	37.73257103	-75.60753788
20	22326 Fox Grove Rd Parksley 23421	37.73352133	-75.60741568
21	22224 Fox Grove Rd Parksley 23421	37.73570317	-75.60518036
22	22240 Fox Grove Rd Parksley 23421	37.73540171	-75.60550956
23	22206 Fox Grove Rd Parksley 23421	37.736034	-75.60471472
24	20290 Fox Grove Rd Parksley 23421	37.76016139	-75.60925531
25	20462 Fox Grove Rd Parksley 23421	37.75651037	-75.60556208
26	20444 Fox Grove Rd Parksley 23421	37.75685909	-75.60596777
27	20452 Fox Grove Rd Parksley 23421	37.75554561	-75.60748537
28	20456 Fox Grove Rd Parksley 23421	37.75565117	-75.6068047
29	20552 Fox Grove Rd Parksley 23421	37.75447712	-75.60377123
30	20461 Fox Grove Rd Parksley 23421	37.75681082	-75.60506246
31	20233 Fox Grove Rd Parksley 23421	37.76172912	-75.61006124
32	20241 Fox Grove Rd Parksley 23421	37.76151068	-75.60985121
33	20251 Fox Grove Rd Parksley 23421	37.76129892	-75.60963215
34	20261 Fox Grove Rd Parksley 23421	37.76110184	-75.6094461
35	20273 Fox Grove Rd Parksley 23421	37.76086571	-75.60918348
36	20281 Fox Grove Rd Parksley 23421	37.7606515	-75.60898806
37	20291 Fox Grove Rd Parksley 23421	37.760445	-75.60878458

	Full Address	Latitude	Longitude
38	20301 Fox Grove Rd Parksley 23421	37.76023726	-75.60858627
39	20311 Fox Grove Rd Parksley 23421	37.76001256	-75.60834638
40	21186 Fox Grove Rd Parksley 23421	37.74939854	-75.60378776
41	21211 Fox Grove Rd Parksley 23421	37.74946012	-75.60299254
42	21241 Fox Grove Rd Parksley 23421	37.74858831	-75.60213456
43	21562 Fox Grove Rd Parksley 23421	37.74035641	-75.60013468
44	21506 Fox Grove Rd Parksley 23421	37.74188494	-75.59998834
45	21454 Fox Grove Rd Parksley 23421	37.74322308	-75.59948963
46	22429 Fox Grove Rd Parksley 23421	37.73080722	-75.60781189
47	22517 Fox Grove Rd Parksley 23421	37.72961511	-75.60885506
48	22541 Fox Grove Rd Parksley 23421	37.72930854	-75.60753009
49	22535 Fox Grove Rd Parksley 23421	37.72948958	-75.6079805
50	21219 Fox Grove Rd Parksley 23421	37.74909524	-75.60270027
51	21563 Fox Grove Rd Parksley 23421	37.73964787	-75.59787958
52	20342 Fox Grove Rd Parksley 23421	37.75908976	-75.60834136
53	20383 Fox Grove Rd Parksley 23421	37.75921098	-75.60569167
54	22562 Fox Grove Rd Parksley 23421	37.72809119	-75.60846934
55	27123 Sunset Landing Parksley 23421	37.73302556	-75.60867433
56	23171 Taylor Ln Parksley 23421	37.79864264	-75.67370854
57	23172 Taylor Ln Parksley 23421	37.7987643	-75.67402601
58	27295 Barnes Cir Parksley 23421	37.73589893	-75.60633439
59	27283 Barnes Cir Parksley 23421	37.73535965	-75.60708003
60	27201 Barnes Cir Parksley 23421	37.73461747	-75.60979378
61	27160 Barnes Cir Parksley 23421	37.73408676	-75.60824805
62	27238 Barnes Cir Parksley 23421	37.73472318	-75.60819848
63	27260 Barnes Cir Parksley 23421	37.73456521	-75.60746017
64	27298 Barnes Cir Parksley 23421	37.73522684	-75.60630283
65	27239 Barnes Cir Parksley 23421	37.73522587	-75.60802894
66	27209 Barnes Cir Parksley 23421	37.73504113	-75.6091765
67	27141 Barnes Cir Parksley 23421	37.7330842	-75.60809504
68	27164 Barnes Cir Parksley 23421	37.73379528	-75.60788685
69	22157 Mason Ln Parksley 23421	37.73576868	-75.60836775
70	22137 Mason Ln Parksley 23421	37.73636531	-75.60904462
71	22170 Mason Ln Parksley 23421	37.73549724	-75.608965

6.5 Cheapside

Cheapside was a bit of an enigma for us. It was shown uncovered/unserved in the VATI grant application for 2022, but it appears to be an area that should have service based on the passings we counted. We experienced some difficulty reconciling the addresses we had with Google Earth, but have labelled all the passings we noted. Since our address data was flawed, we did not include a table of addresses for Cheapside, but we do feel confident out total of 152 passings is accurate. The passings are listed in our Google Earth file available in the public domain.

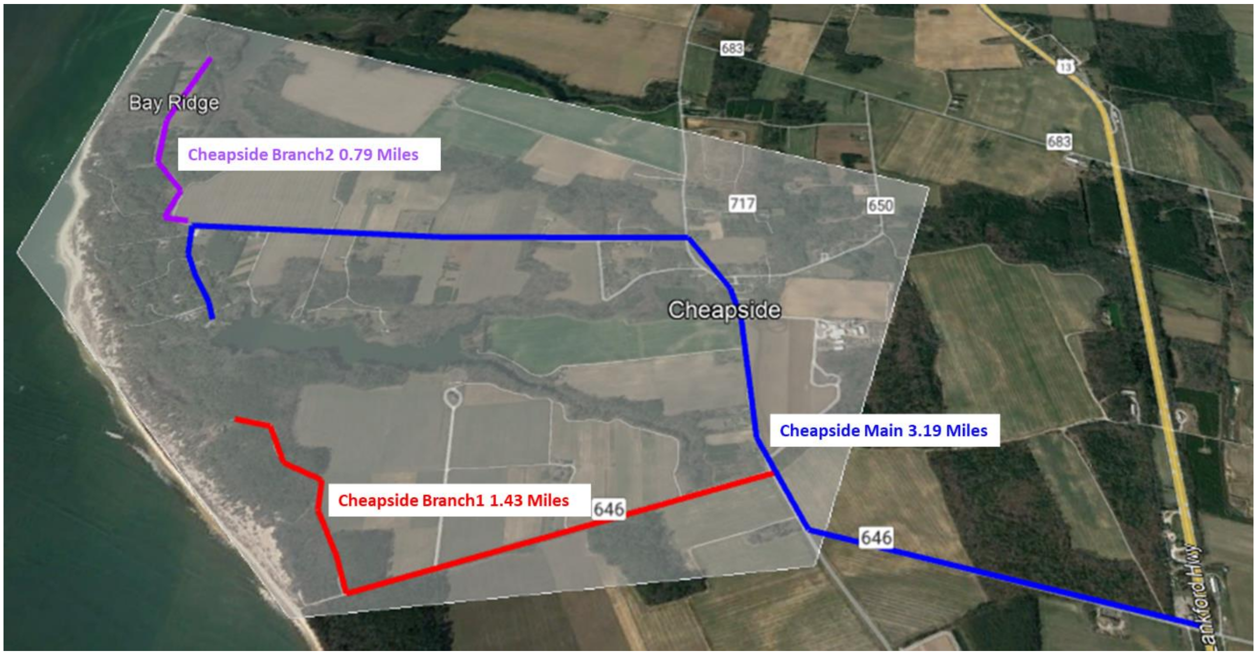

Figure 23 Cheapside GIS Layout with Annotated Circuits

Table 12 Cheapside Fiber Segments and Cost Estimates

Circuit Designator		**Length**	**Cost** **(Distance X Mile Cost)**	**Shared Cost Per Household**
CS1	Cheapside Main	3.19 miles	3.19 * $17,000/mile = $54,230	100% (152 households) $605/household
CS2	Cheapside Branch1	1.43 miles	1.43 * $17,000/mile = $24,310	
CS3	Cheapside Branch2	0.79 miles	0.79 * 17,000/mile = $13,430	75% (114 households) $807/household
Totals		**5.41 miles**	**$91,970**	

7 Newly Served Sites Not in the 2022 VATI Grant Application

Since the Fall 2021 and Spring 2022 classes, the ESVBA has been very busy and aggressive in connecting passings/neighborhoods. We originally planned on including the locations below based on the Spring 2022 study, but determined from interviews and from drive-by surveys that fiber has been newly run to these neighborhoods. The newly connected sites are referred to as (in their order of occurring going from North to South):

1. Society-Hogneck
2. Modest Town
3. Gargathy Neck

7.1 Society-Hogneck

Society-Hogneck is a prototypical example where government intervention could impact the residents. From a cursory view, the poverty of this neighborhood is distressingly evident and we believe broadband will be impactful for future generations.

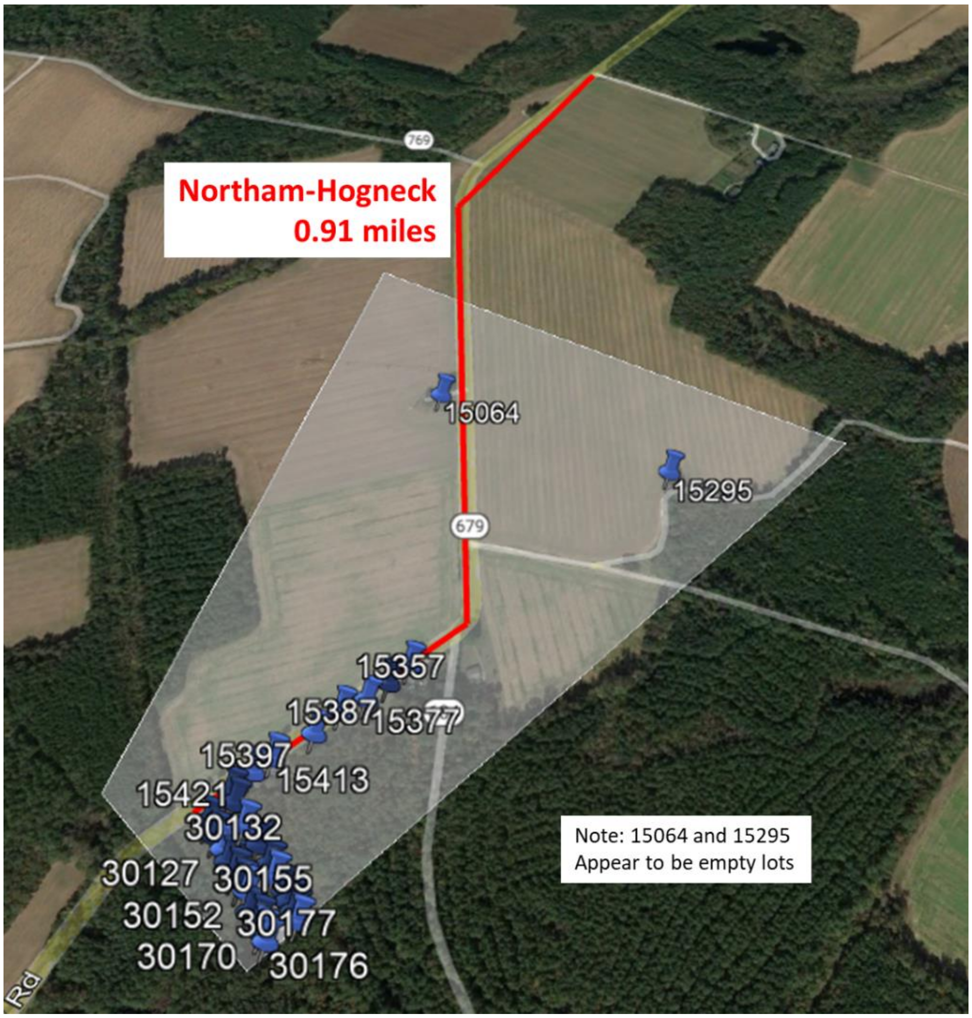

Figure 24 Society-Hogneck GIS Layout with Annotated Circuit Paths

7.2 Modest Town

Modest Town is situated between Society-Hogneck and South Point. It appears to be a lovely town with a small knit vibe. The mini neighborhood situated at the end of Hopeland Way and extending onto Assawoman Drive is one of those ones that can be best described as “the house is nice, but the view is worth a million bucks.” There is some dense housing on the north end of the area with a trailer community, but the remainder are single family homes spaced at fairly regular intervals. The broadband feed is provided via a line running up the road from Nelsonia at the Rt 13 intersection.

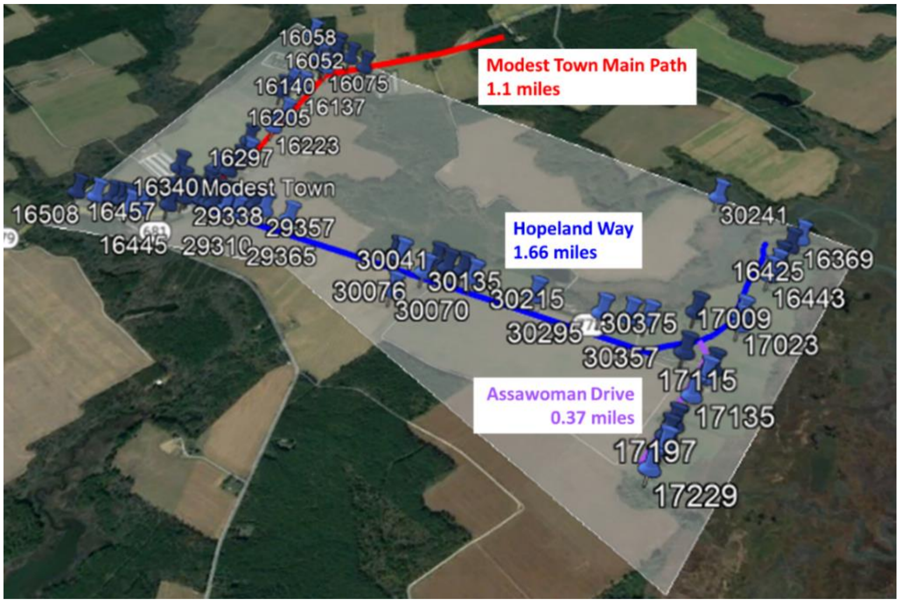

Figure 25 Modest Town GIS Layout with Annotated Circuit Paths

7.3 Gargathy Point

Gargathy Point appears to be a sequence of planned neighborhoods and from our drive through survey it appears there are multiple planned but unused lots with room for significant growth.

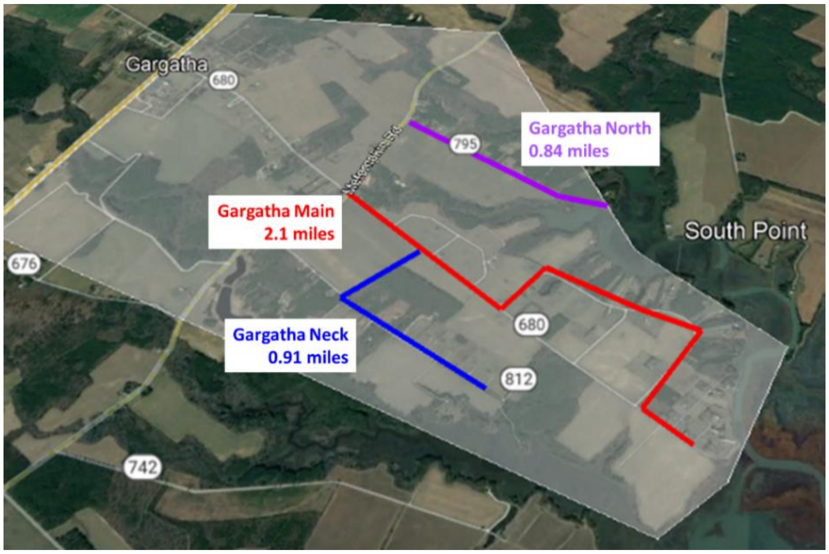

Figure 26 Gargathy Point GIS Layout with Annotated Circuit Paths

8 Recommendations

The TCOM 750 graduate students recommend the following actions to enhance Virginia's Eastern Shore Broadband coverage.

- Build out the five remaining identified sites
- Leverage existing ESVBA fiber and treat ESVBA fiber as the default option
- Extend the ESVBA Fiber Plant to the five neighborhoods using ANEC Power Poles and Lines
    - Consider leveraging fiber deployment by a robot or similar solution such as NetEquity Networks (spun off from Facebook in 2020) that can drive costs down to as low as $2/meter[49]
- Expand and formalize partnerships with wireless broadband service providers Neubeam and ESCC
- Expand and formalize partnership with Charter Spectrum
- Provide bulk reseller discounts to wireless broadband service provider to enhance service providers business case
- Ensure independent ISP investments are protected by a franchise agreement
- Mandate companies work in a collaborative manner to qualify for incentives
- Leverage Eastern Shore Chamber of Commerce and/or the Boards of Supervisors as a Key Partner/Arbiter

Table 13 Options for Connecting Homes to the Internet using Distance as a Discriminator

Category	Backbone Provider	Middle-Mile Providers	Last-Mile Provider
Homes < 500 meters from fiber backbone	ESVBA	ESVBA	ESVBA
Homes (5+) < 1 mile from fiber backbone	ESVBA	ANEC/NetEquity/WISP	ESVBA
Neighborhood (5+) < 5 miles from fiber backbone	ESVBA	ANEC/NetEquity	ESVBA
Remote Homes 1+ mile(s) from fiber backbone; no near neighbors	Starlink	N/A	Starlink[50]

[49] NetEquity Networks website, https://www.netequity.net/, accessed 11 November 2022.
[50] Potentially eligible for support from FCC Rural Broadband fund.

9 Appendix A - Point-to-Point Wireless Technology

The last-mile has traditionally been referred to as the hardest part of deploying any service to remote customers. With the cost of physically laying infrastructure as well as the cumbersome process and the disruption to constituencies and infrastructure it is usually a daunting task. Virginia's Eastern Shore is fortunate to have at least two wireless providers who employ last-mile distribution technologies and a process for determining how to efficiently extend their footprints. We were also impressed by the ESVBA approach in providing towns with "boilerplate" Request for Proposal documents (RFP documents to help the towns plan for and acquire Internet services for their towns).

In our limited onsite surveys, we noted some point-to-point links and would like to see more of this. It appears the favored antenna is a mANT30 PA Parabolic dish antenna[51] for 5GHz with 30dBi gain. This model includes precision alignment mount and is designed to be mounted on a pole as illustrated. We understand this a good way to increase the range of coverage.

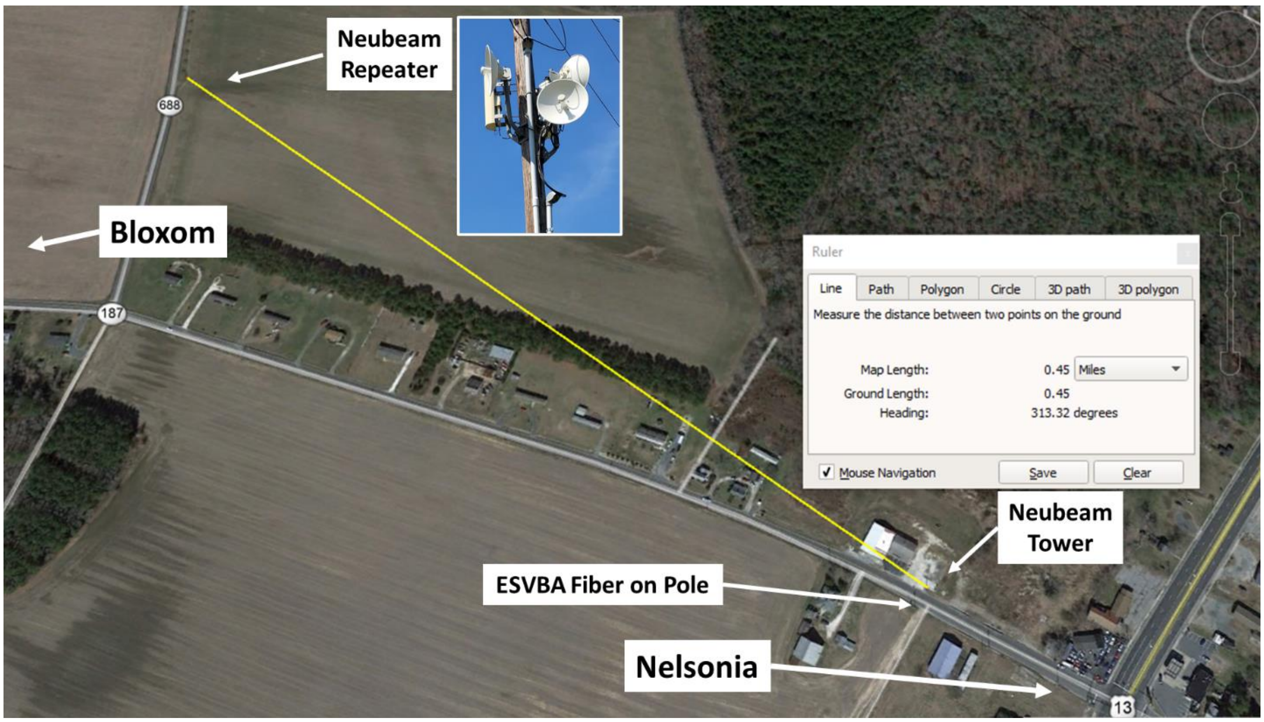

Figure 27 Neubeam has employed 5GHz Repeaters

Where communities are served through a WISP, there is typically a transmission tower and numerous local residential receive antennas throughout the community. The primary RF to Home pole shown in **Figure 26 Microwave Antenna, Local Antennas and Service Box** and homes have a receiver dish similar to the one shown in **Figure 27 Typical RF to Home (RFTH) Residential Installation – a 6' Pole with a Directional or Flat Panel Antenna**.

The Flat Panel antenna is a Cambium Networks PMP 450 antenna that features GPS synchronization, advanced scheduling algorithms, the cnMedusa™ technology that provides Multi-User MIMO (Multiple-Input, Multiple-Output) capability for nearly infinite beamforming patterns in the uplink and downlink and MU-MIMO in each direction as well. cnMedusa increases capacity per sector by allowing simultaneous

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51 mANT30 PA Product Information, website https://mikrotik.com/product/MTAD-5G-30D3-PA, accessed 21 April 2021.

data transfer to multiple subscriber modules (SM) within a sector for 5 GHz and 3 GHz bands and is certified for use in the new CBRS (U.S.) spectrum.[52]

The other residential antenna we observed was a Cambium Networks ePMP™ Force 200 5 GHz parabolic reflector antenna. This model adds a subscriber module and point-to-point (PTP) radio to provides superior throughput of over 200 Mbps of real user data. Long range deployment is enabled by the 25 dBi antenna. Configurable Modes of operation ensure robust adaptivity to both symmetrical and asymmetrical traffic while providing high performance and round-trip latency as low as 2 – 3 ms.[53]

Figure Typical RF to Home (RFTH) Residential Installation – a 6' Pole with a Directional or Flat Panel Antenna

[52] Website "PMP 450 – The Ultimate in Point-to-Multipoint Performance", https://www.cambiumnetworks.com/products/pmp-450/, accessed 27 April 2021.
[53] Website "ePMP Force 200 5 GHz", https://www.cambiumnetworks.com/products/epmp/force-200-5-ghz/, accessed 27 April 2021.

10 Appendix B - Point to Point Wireless Siting

With our use of Cambium Networks LinkPlanner we have seen that end point placement in a point to point (PTP) or a point to multipoint (PMP) link can have a dramatic effect on performance. As shown in the next four graphics when using 26-meter poles the link budget is much greater with much higher capacity and reliability. Going to 13-meter poles essentially exposes the communications path to much greater attenuation and interference and makes the link essentially unusable in all but optimum conditions.

The total cost of the PTP link is $21,886.88 which includes two 80-foot poles to help gain elevation and reduce interference in the Fresnel zone and gain a large performance gain over the standard 40-foot poles. By comparison to pull fiber from Conquest Point to the same location in Persimmon Point (ignoring that the portion of Pettit Road we traverse has underground utilities) is 1.31 miles long and using our $17,000 per mile estimate is $22,270. Given the choice our preference would be to take the advantage performance that the fiber offers.

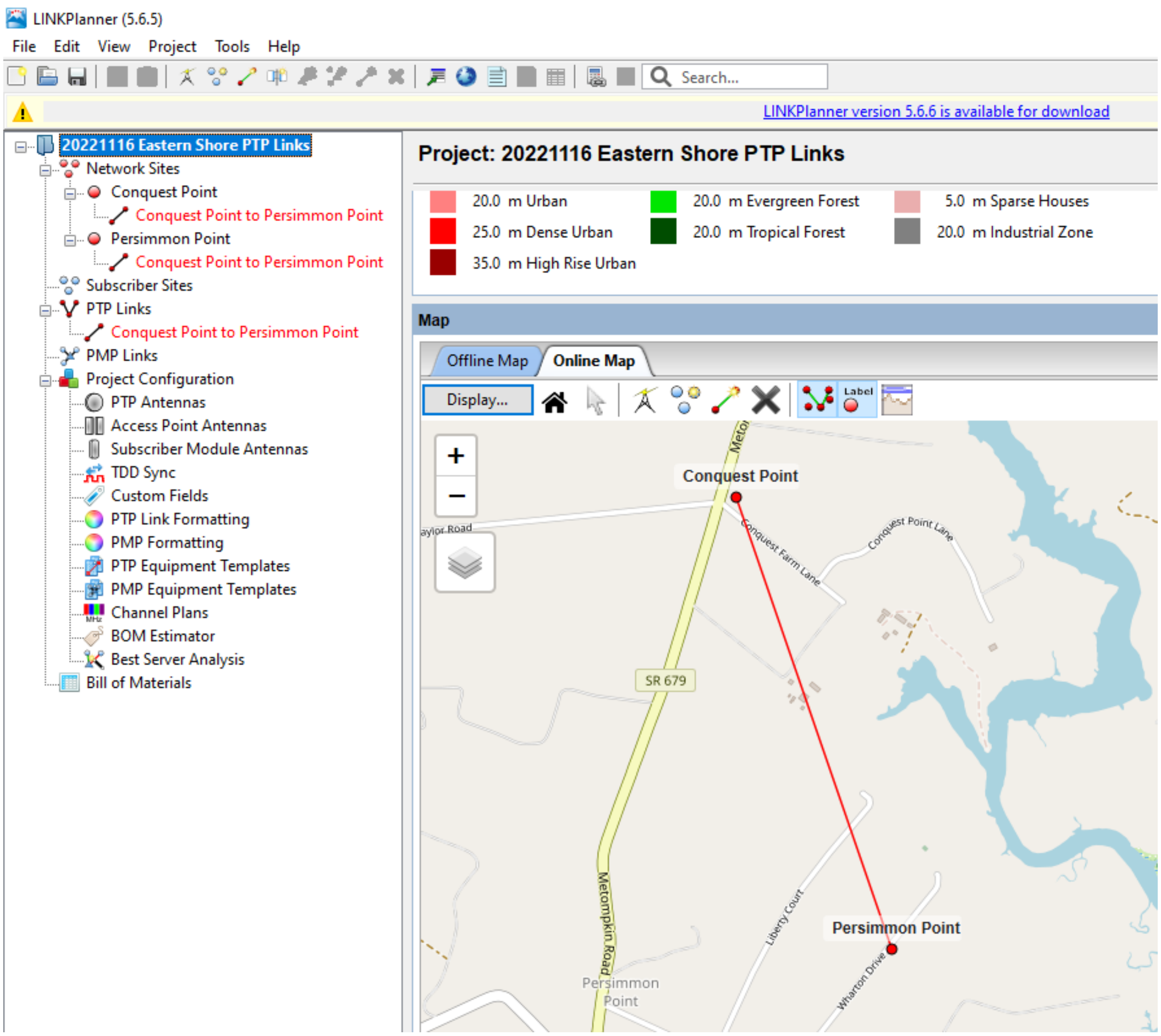

Figure 30 LinkPlanner Geographic View Showing Siting of the PTP end points

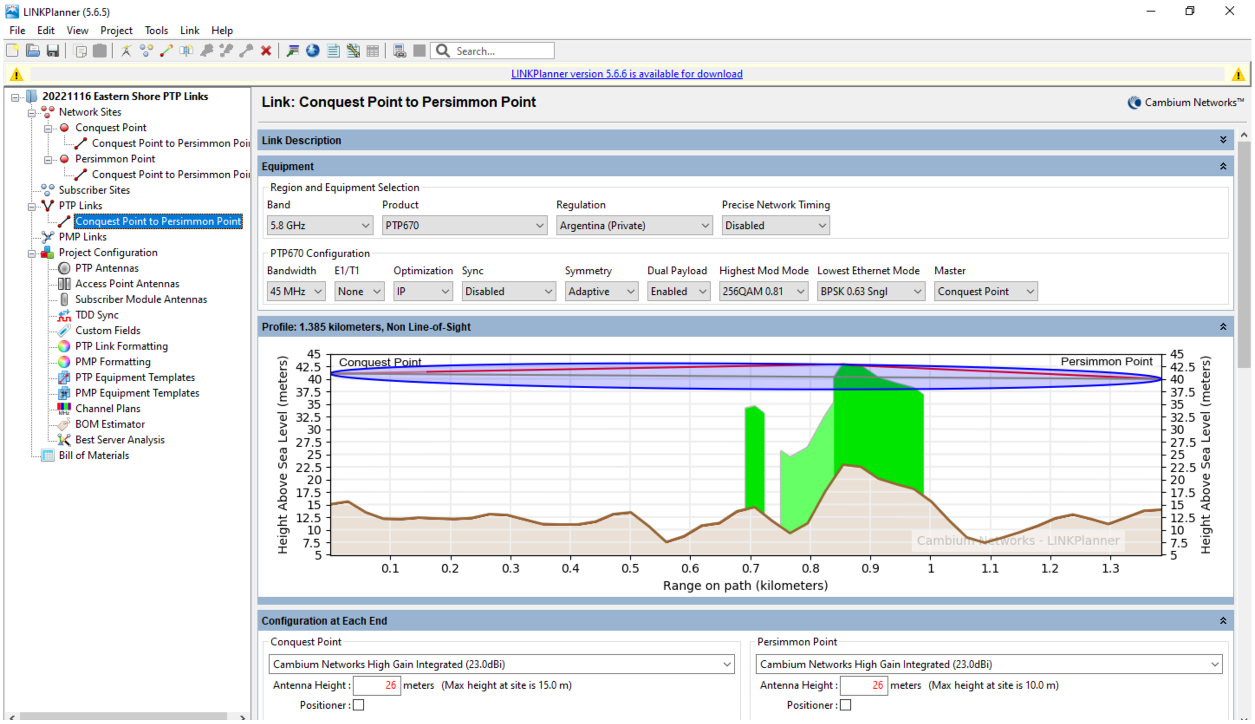

Figure 31 LinkPlanner PTP Network Profile with 26-meter poles

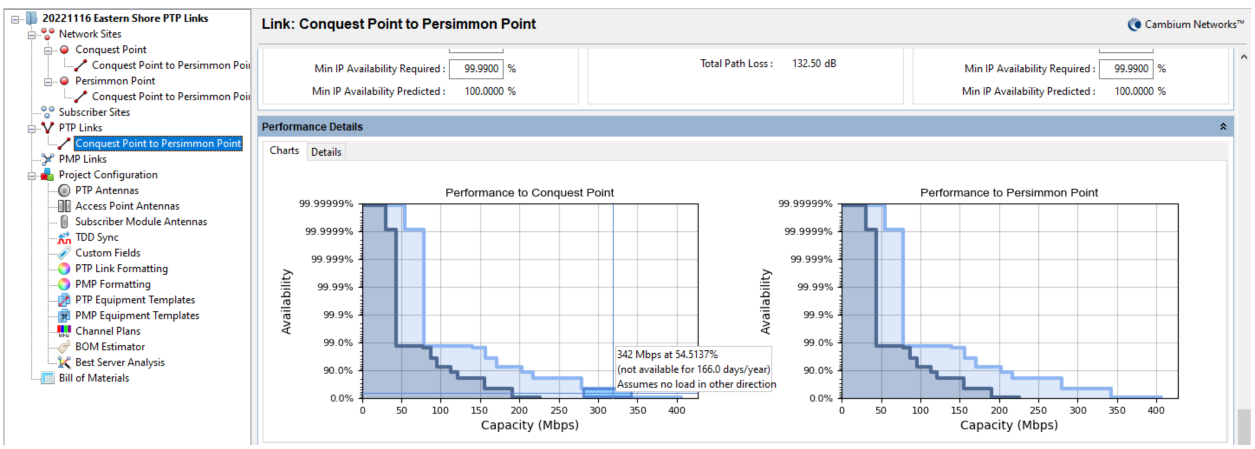

Figure 32 LinkPlanner PTP Network Performance with 26-meter poles and acceptable link performance

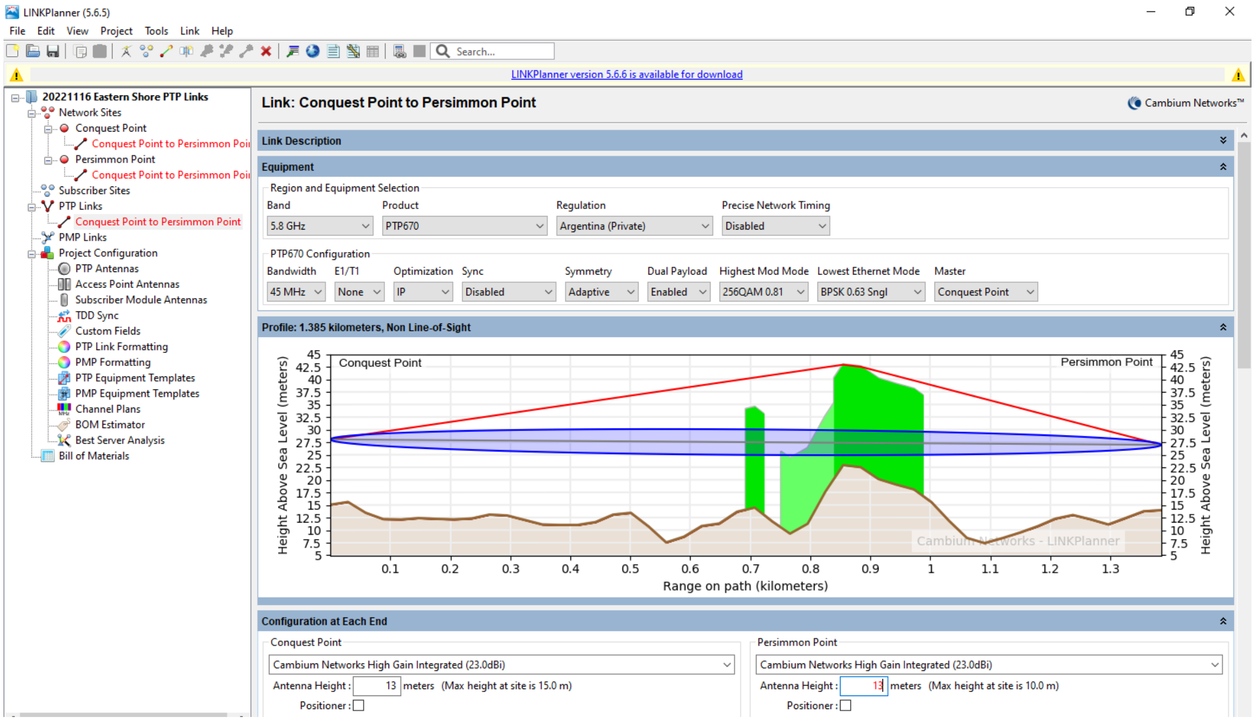

Figure 33 LinkPlanner PTP Network Profile with 13-meter poles

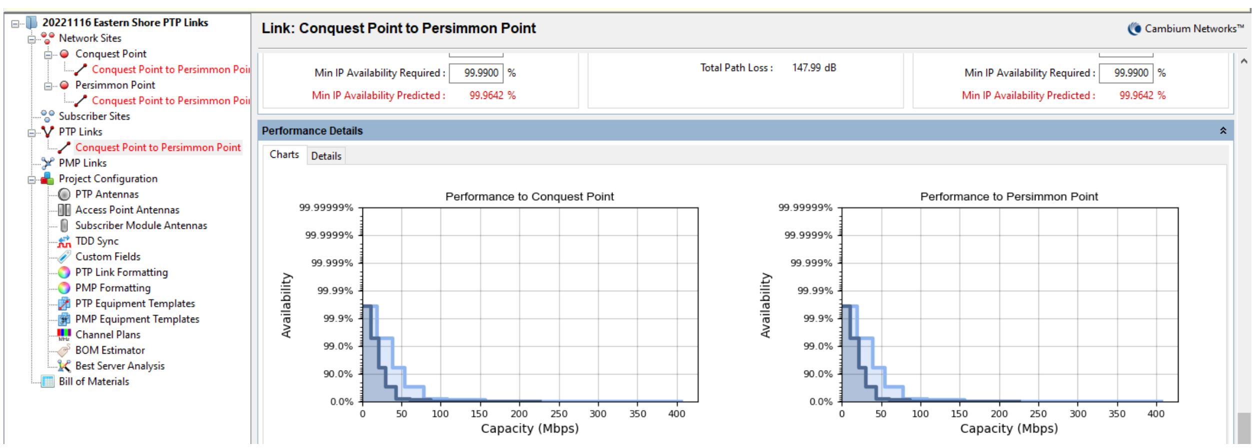

Figure 34 LinkPlanner PTP Network Performance with 13-meter poles with unacceptable link performance

Table 14 PTP Network Equipment Bill of Materials Cost for Conquest Point to Persimmon Point Link

Part Number	Description	Quantity	Unit Cost	Cost	Notes
01010419001	Coaxial Cable Grounding Kits for 1/4" and 3/8" Cable	6	$28.08	$168.48	

Part Number	Description	Quantity	Unit Cost	Cost	Notes
AR-E4PT6XX-WW	PTP 670 All Risks Advance Replacement, 4 additional years (per END)	2	$336	$672	
C000065L007	LPU and Grounding Kit (1 kit per ODU)	2	$432	$864	
C050067H010	PTP 670 Integrated 23dBi END with AC+DC Enhanced Supply (ROW - U.S. Line Cord)	2	$2824.2	$5648.4	Kit includes ODU, power supply, mounting bracket and US line cord
WB3176	328 ft (100 m) Reel Outdoor Copper Clad CAT5E (Recommended for PTP)	1	$534	$534	
Telephone Pole	80' Telephone Pole	2	$7,000	$14,000	ANEC Quote
Total				**$21,886.88**	

We have to admit to some frustration with LinkPlanner related to the lack of topographical maps. Many times when planning for RF component positioning it is critical to account for topography such as that shown in **Figure 31 LinkPlanner PTP Network Profile with 26-meter poles** where moving the tower or receiver 10 meters can make a dramatics distance in coverage and range. Cambium Networks did respond that they would take that feature request under advisement and did note there was a mode to calculate a Line of Sight (LOS) Viewshed for Optical and Radio. Two examples of this viewshed are shown in **Figure 35 LinkPlanner with the Optical Line of Sight (LOS) Viewshed** shown for Conquest Point and **Figure 36 LinkPlanner with the Radio LOS Viewshed Shown**, respectively.

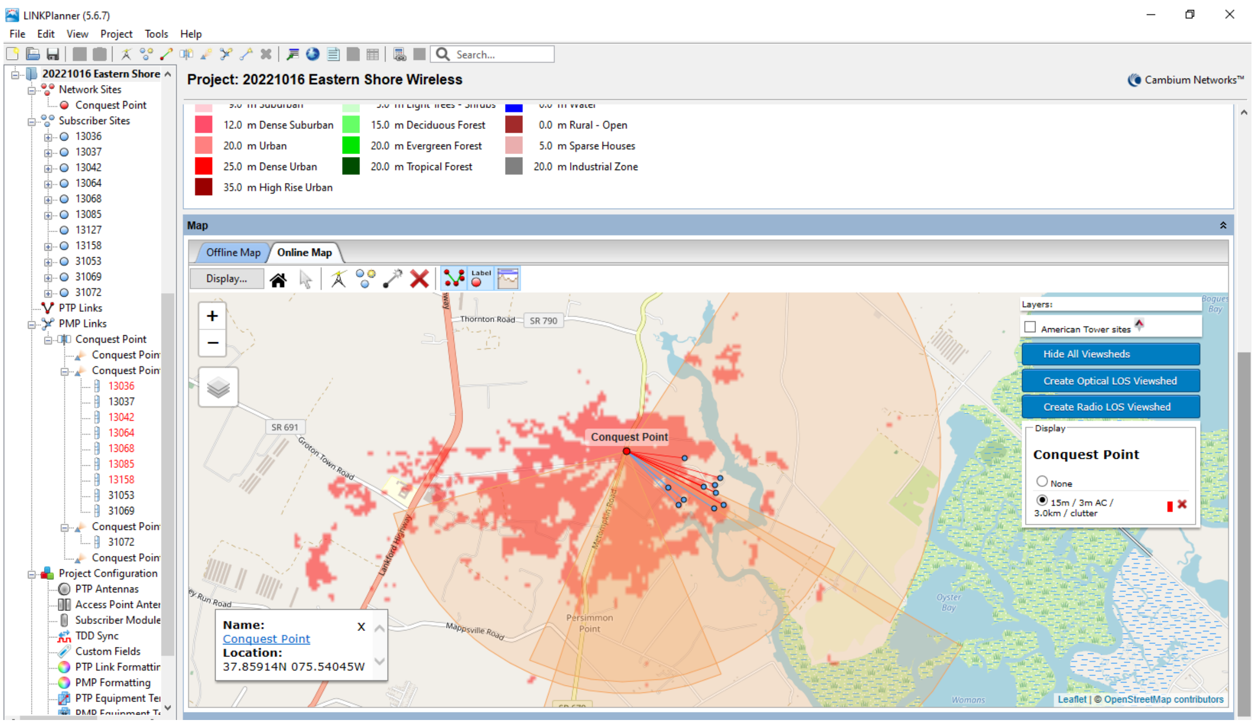

Figure 35 LinkPlanner with the Optical Line of Sight (LOS) Viewshed shown for Conquest Point

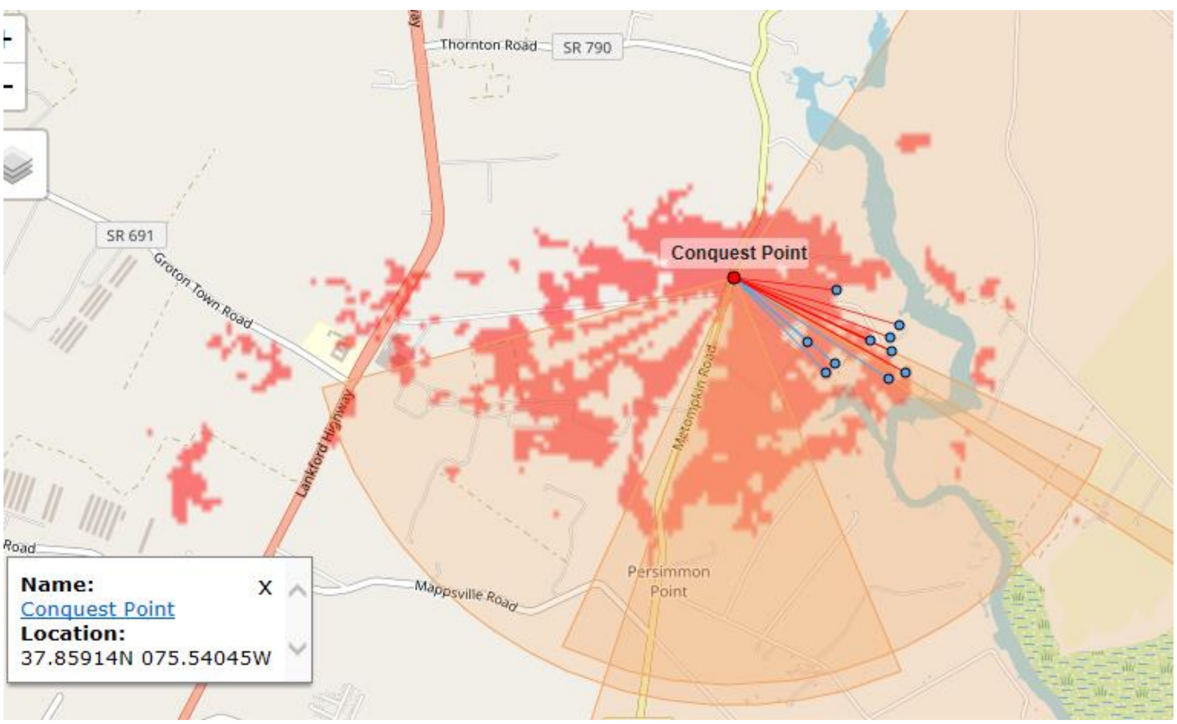

Figure 36 LinkPlanner with the Radio LOS Viewshed Shown

11 Appendix B - Cost Allocation Case Studies

11.1 Tennessee One Stop Infrastructure Governors Guidance[54]

Tennessee has a jobs allocation approach to promote jobs. The Governor published a document and part of that is how infrastructure costs are to be allocated in order to receive state matching funds. Key provisions are:

- Contribute to infrastructure costs of one-stop centers based on proportionate use and relative benefits received.
- Proportionate Use - Amount that represents required partner's portion of comprehensive Job Center infrastructure costs based on its proportionate use of the Job Center, relative to benefits received. Amount is determined through a reasonable cost allocation methodology that assigns costs to co-located partners in proportion to relative benefits received.
- Cost Allocation Methodology - Local board must select a methodology for allocation of infrastructure costs. Any methodology selected must be consistent with federal laws that authorize each partner's programs, comply with the Uniform Guidance cost principles to include allowable, allocable reasonable and necessary costs, and be based on the proportionate use and benefit received by each partner's programs.
- Identification of the infrastructure costs budget, which is a component of the one-stop operating budget.
- Identification of all one-stop partners, CEO(s), and the Local WDB participating in the IFA.
- Description of the periodic modification and review process to ensure equitable benefit among one-stop partners.
- Information on the steps the Local WDB, CEO(s), and one-stop partners used to reach consensus or the assurance that the local area followed the SFM process.
- Description of the process used among partners to resolve issues related to infrastructure funding during the MOU duration period when consensus cannot be reached.

11.2 Co-Investment in France

France is unusual in that the co-investment scheme was developed by the national regulatory authority, the Electronic Communications, Postal and Print media distribution regulatory authority (ARCEP). In less densely populated areas, representing the whole of France other than 17% of the population living in urban municipalities, the French regulation imposes specific obligations on providers that roll out Fiber To The Home (FTTH) infrastructure. These obligations require advanced notice be given by any operator that plans to install FTTH infrastructure and they are obliged to accept co-investment from other operators in allocation of 5% of the total installed capacity. There is also a requirement to provide full coverage within 5 years. The price of co-investment is lower for those that make the initial investment and for those who make the largest investment. Co-investors that come in after launch pay a higher fee (reflecting the lower level of risk they are taking); and wholesale line rental is also available, again for a higher fee.

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[54] "Tennessee One Stop Infrastructure Governors Guidance", website https://www.tn.gov/content/dam/tn/workforce/documents/wfs/OneStopInfrastructureGovernorsGuidance.pdf, accessed 19 October 2022.

One academic paper[55] has shown that the co-investment obligation has both increased the adoption of FTTH by 7.9% and simultaneously decreased the market share of the SMP operator, Orange, by 5.9%.

"Does co-investment enhance fiber to the home (FTTH) coverage, adoption and competition? We combine several French municipality-level datasets and use a two-stage control-function approach to answer this question. In the first stage, we estimate an equilibrium model of entry that predicts the number of FTTH investors in a municipality. In the second stage, we insert the correction term derived from the entry model in the FTTH coverage (adoption, competition) regression to correct for endogeneity of investor entry. The two stages make two contributions. First, we find some FTTH demand and cost factors, which are significant determinants of investor entry. Second, we show that the presence of co-investors does not impact coverage dynamics at the municipality-level, which appears to be determined by French regulatory coverage obligations, i.e., full coverage in five years. In addition, we observe that the presence of co-investment, leads to an increase of 7.6% in FTTH adoption during the 2015-2018 study period and also a more intense competition as shown through the decrease in Orange total retail broadband market penetration by 7.8% for Orange, which is the incumbent operator in France. Our findings confirm that co-investment supports the policy objectives of adoption and competition and should be supported by regulation."

[55] Paper "Estimating the impact of co-investment on fiber to the home coverage, adoption and competition", Louise Aimene, Marc Lebourges and Julienne Liang, website https://www.econbiz.de/Record/estimating-the-impact-of-co-investment-on-%EF%AC%81ber-to-the-home-coverage-adoption-and-competition-aimene-louise/10012151918, accessed 19 October 2022.

12 Appendix C - Acknowledgements

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On a final note, for this semester we changed the graphic on our title page. The house graphic was appropriated from the Citizens for a Better Eastern Shore (CBES) website. We liked it a lot and so in the best of traditions established by the great author T.S. Eliot who said "Smart people copy, genius steals" we borrowed their graphic. We asked for permission to use it and hope the artist is flattered.