CITY OF BELLINGHAM, WA

Municipal Broadband Study

DRAFT: MAY 2022

Magellan ADVISORS

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Executive Summary

Magellan Advisors studied the Bellingham broadband market, network infrastructure in the area, and the financial viability of various business models. Our financial analysis shows that retail broadband services to all premises in the city is not economically viable. Such infrastructure would cost approximately $450M to build and could involve over $600M in debt service. There were multiple providers active in the market, if not offering retail broadband to most residents, and no clear evidence of broadband gaps. Therefore, Magellan Advisors does not recommend the City become a retail broadband provider.

The City of Bellingham has extensive assets that were developed in an ad hoc, project-oriented, tactical manner. These assets can be economically transformed into an integrated backbone infrastructure capable of supporting a wide range of applications and services, including retail broadband. Extensive improvements and complementary investments in equipment and systems will be necessary to accomplish this. While additional information will be needed to estimate costs for this, the potential for impact, including direct revenue from wholesale services, clearly justifies pursuing this course of action. Magellan Advisors recommends the City of Bellingham invest in its network infrastructure in a manner that:

- Addresses specific objectives based on local public priorities,
- Capitalizes on existing assets,
- Catalyzes private investment,
- Fulfills specific needs of prospective customers and partners, and
- Creates opportunities for education, employment, health, safety, and other valued outcomes.

This means establishing a broadband department with an enterprise fund and adequate staffing to provide wholesale network services to community anchors, major enterprises, and retail providers. The City should develop detailed plans and practices to upgrade its network assets into a carrier-class backbone. Make focused investment for specific purposes. Input from prospective customers and partners will be critical for success, as will clear strategic objectives. The City should establish a vision and goals for the network and its impacts on the community. Methodically supplement and transform existing assets into carrier-class backbone infrastructure for wholesale services to achieve the vision and goals.

1. Introduction

The City of Bellingham established the Broadband Advisory Workgroup to evaluate options for municipally owned broadband infrastructure. The objectives were to assess current broadband access and affordability, along with the financial costs and benefits and policy considerations for expansion, improvement and use of the City's fiber optic network. The overall goals of the Workgroup were to increase availability, affordability, and equitable quality of broadband access across the community. The City hired Magellan Advisors to conduct the assessments and provide recommendations for broadband infrastructure policy. This report is the result of that work.

In this report, Magellan Advisors shows how the City of Bellingham might leverage its assets to expand broadband access to its community. The report includes an assessment of the current state of broadband within the City, a conceptual network design for leveraging existing infrastructure and expanding the City's broadband footprint to deploy fiber-to-the-home (FTTH) or fiber-to-the-premise (FTTP), and business model with financial analyses to provide the City with a clear understanding of the sustainability of a municipal broadband program. It culminates in an actionable plan that includes best practice approaches, sample documents, and data-driven recommendations.

BACKGROUND

The City of Bellingham is the county seat of Whatcom County, the most northwestern county in the continental United States, which extends from Bellingham Bay on the Salish Sea to the North Cascades mountains. With less than 40K households housing a population of 91.5K, 45% of whom have bachelor's degree or higher, Bellingham is a well-educated, large "small city." See Table 1-1 for other key demographic statistics. Unfortunately, the City has a relatively high poverty rate (relative to 12.8% nationwide poverty) and low household incomes (relative to $65k median nationwide household incomes), as shown in the table below.

Table 1-1. Key Demographic Statistics for Bellingham, WA[1]

TOPIC	STATISTIC
Total population	91,482
Annual growth rate	1.9%
Under 18 years	13.9%
65 years or over	15.7%
Population 25 years and over	56,569
Less than high school	5.8%
High school graduate or equivalent	17.0%
Some college, no degree	21.3%
Associate's degree	10.6%
Bachelor's degree	27.2%
Graduate or professional degree	18.2%
Population in households	86,305
Percentage in poverty	20.0%
Total households	38,680
With a computer	94.9%
With a broadband Internet subscription	89.7%
Mean household income	$73,555
Median household income	$56,198

The local economy has a strong base of professional services establishments, as shown in Table 1-2, particularly when administrative, health care, social assistance sectors are included. Wholesale trade is particularly strong in growth and presence. The arts, entertainment, and recreation sector also had solid growth in number of firms, followed by educational services, and administrative and support services.

Overall, with an annual establishments growth rate of 2.8%, Bellingham has 5.6k establishments at the writing of this report and should have nearly 5.7k in five years. The City is home to the Port of Bellingham, which has evolved into a recreation and tourism destination but maintains its mariner ties. The two largest employers are St. Joseph's Hospital (2.2K employees) and Western

[1] Source: U.S. Census Bureau, American Community Survey (ACS), 2020 5-year Estimates, https://data.census.gov/cedsci/

Washington University (1.5K employees), both of which have large campuses in the City.

Table 1-2. Projected Number of Establishments by Sector Based on U.S. Bureau Estimates by Percentage of Total[2]

Sector	2022	2027	Percent	Growth
All sectors	**5,608**	**5,663**	**100%**	**2.8%**
Professional, scientific, and technical services	744	776	14%	1.0%
Construction	770	770	14%	NA
Wholesale trade	510	678	12%	7.4%
Retail trade	648	577	10%	-2.9%
Health care and social assistance	563	520	9%	-2.0%
Accommodation and food services	478	462	8%	-0.8%
Administrative and support services	368	417	7%	3.2%
Manufacturing	342	348	6%	0.5%
Real estate and rental and leasing	271	250	4%	-1.9%
Arts, entertainment, and recreation	175	217	4%	5.4%
Other services (except public administration)	265	214	4%	-5.1%
Transportation and warehousing	154	135	2%	-3.3%
Educational services	90	104	2%	3.4%
Information	98	101	2%	0.8%
Finance and insurance	76	39	1%	-15.6%
Industries not classified	34	34	1%	NA
Management of companies and enterprises	21	21	0%	NA

The demographic and economic statistics provide important context for broadband planning. They define the size of the market to be served and suggest how they might use and value broadband. This background also informs the conceptual design, estimates and projections for costs, coverage, and revenue.

[2] Source: U.S. Census Bureau, 2012 and 2017, Annual Business Survey: Statistics for Employer Firms by Industry, Sex, Ethnicity, Race, and Veteran Status for the U.S., States, Metro Areas, Counties, and Places (Table AB1700CSA01). Estimates were not available for Agriculture, forestry, fishing and hunting, Mining, quarrying, and oil and gas extraction, or Utilities sectors.

2. Community Survey

To gain insight into the current state of broadband and need for future connectivity, Magellan Advisors and the City of Bellingham conducted a broadband survey among businesses and residents. The survey was open for approximately eight weeks between November 2021 and January 2022 and received a total of 1625 unique responses. As shown in the table below, most responses came from households in Bellingham.

While this was not a systematic survey with random sampling and non-response bias testing, the results can be considered statistically reliable. With a study population of approximately 44k business establishments and residential households, a sample of 381 is required for 95% confidence level with 5% margin of error. Not all respondents responded to all items on the survey. Specifically, 146 respondents did not have broadband. To address these issues, we report the number of responses per question and demographic characteristics of respondents. Geographic analysis of responses, below, shows responses from across the city.

Table 2-1. Survey Responses by Type

Response Type	Count
Household	1557
Organization	42
Individual without a physical address	26
Total	**1625**

Among residential respondents, the average household size was 2.58 people, very close to the 2.28 average size according to Census data. The median age of the youngest person in respondent households was 30 and the oldest was 48, compared to the median age of 31.5 years as reported in Census data, indicating that respondents were somewhat older than the population. Twenty five percent (261) of respondents indicated that they were retired or otherwise out of the workforce, which is somewhat lower than Census data estimates that 35.8% of Bellingham residents ages 16+ are no longer in the workforce.

Top industries included about 32% of respondents (329) who worked in Arts, Business, Management, or Science, 19% who worked in Service (189), and 14% who worked in Office or Sales (144). Nearly 80% of respondents (819) had Bachelor's degrees or higher compared to Census data indicating that 44.3% have a Bachelor's degree or higher, indicating that respondents have higher educational attainment than the general population. These statistics indicate substantial response from across the socioeconomic spectrum, albeit skewed toward better educated working age adults. The survey specifically asked about the highest educational level in the household and the occupation of the primary breadwinner, so such distribution of these characteristics among respondents is in line with expectations.

BROADBAND ADOPTION

Most of the respondents (91%) had broadband connections, defined as high-speed, always on service. Approximately 6% of respondents had low-speed service including cellular, dial-up, or satellite, and 2% were unsure of whether they had broadband. Approximately 1% (20 respondents) reported not having internet service.

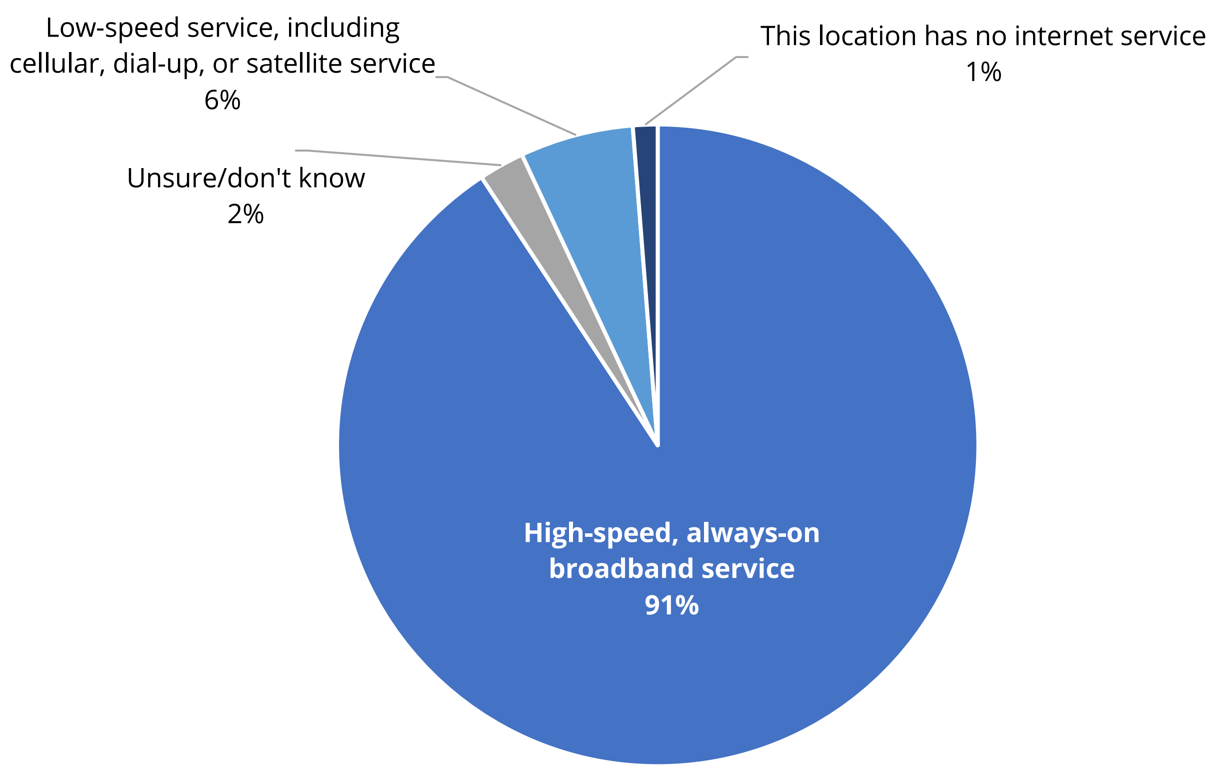


Figure 2-1. Respondents' Type of Connection by Percentage of 1609 Responses

Among respondents who did not have broadband, the top reason was that broadband was not available at their location. The second most cited reason was that available services are too expensive.

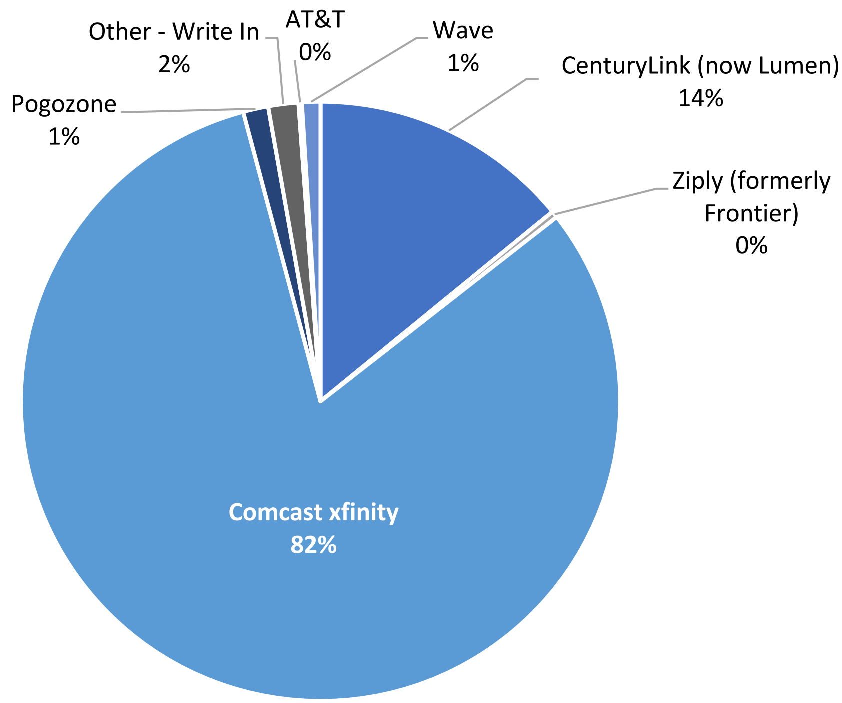


Figure 2-2. Respondents' Internet Service Provider by Percentage of 1107 Responses

Most respondents (901) were served by Comcast, as illustrated in Figure 2-2, followed by Lumen/Centurylink (156). Respondents also had service through a handful of other companies including Pogozone (15), Wave (11), Ziply (4), and AT&T (2). Eighteen respondents wrote in providers including Starlink, T-Mobile, and Verizon.

PERFORMANCE

Respondents were asked how much they paid for broadband and related services and what contracted speeds they paid for. These were "best guesses" by the person responsible for choosing and paying for the service. Variance would diminish with more responses but should be assumed high in this situation. Actual performance was recorded automatically via a speed test integrated into the survey. But performance will vary over time based on network congestion and other factors. Therefore, we report a full set of descriptive statistics, including average, maximum, median, and minimum speeds.

On average, survey respondents reported contracted to receive speeds of approximately 323 mbps download and 127 mbps upload. The actual speed test results were much lower than contracted speeds, with an average download speed of 150 mbps and an upload speed of 24 mbps.[3]

Table 2-2. Descriptive Statistics for Broadband Cost and Performance Among Survey Respondents

	Contracted		Actual			Cost Per
	Download	Upload	Download	Upload	MRC	Mbps[4]
Average	322.73	126.54	149.92	23.93	$113.81	$0.65
Median	150	15	92.08	6.67	$75.00	$0.76
Mode	100	5	6.29	3.25	$100.00	$10.48
Max	3000	5007	1218.89	914.66	$25,000.00	$11.72
Min	1	0.1	0.22	0.11	$1.00	$3.03
	Averages By Provider					
AT&T	60	47.5	44.02	7.04	$50.00	$0.98
Lumen	335.46	340.74	114.49	64.19	$63.48	$0.36
Comcast	328.33	88.28	159.17	15.99	$115.55	$0.66
Pogozone	123.77	129.23	37.34	17.11	$57.76	$1.06
Wave	251.25	192.14	161.89	161.86	$866.00	$2.67
Ziply	13.5	252.75	5.41	1.39	$61.67	$9.06

On average, respondents who subscribed to services through Comcast were paying more than Lumen/Centurylink customers, although their average upload speeds were much lower. Respondents who identified Ziply as their provider were paying the most per mbps, and respondents who identified Lumen/Centurylink as their provider were getting the best value per mbps per month.

The following images show the general location of internet survey responses' speed test results, including locations where broadband was not available, relative to Washington State's new broadband standard of 100 mbps download and 20 mbps upload or 120 mbps aggregate throughput. These maps indicate that lower speed

[3] In some cases, the speed test created results that were clear outliers with questionable accuracy. These responses were removed from the speed test analysis.

[4] Cost per Mbps is calculated by dividing the cost by the total throughput (actual download plus actual upload speed).

connections are dispersed throughout the City and do not point to any specific neighborhoods or areas that are underserved compared to their surroundings.

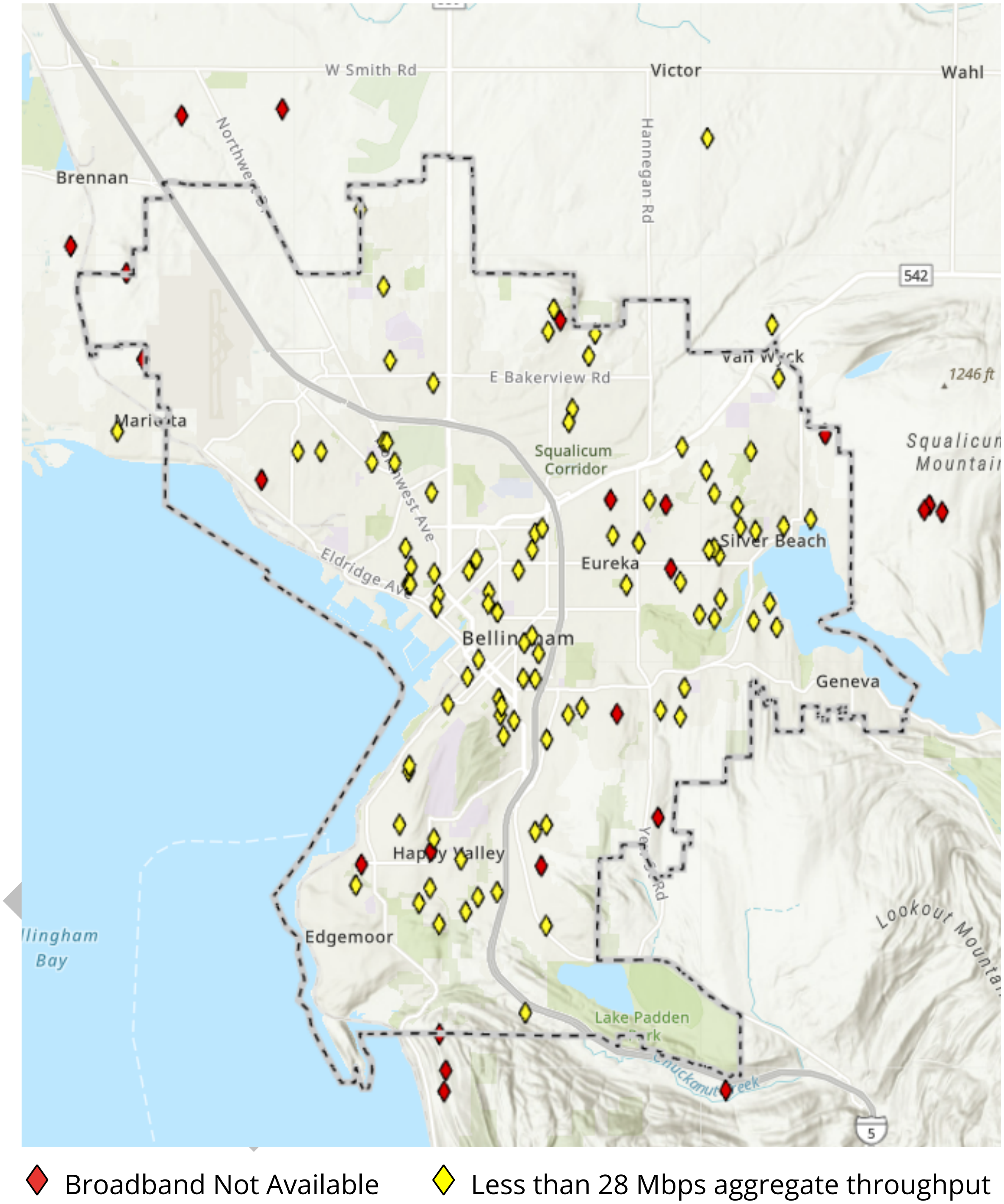
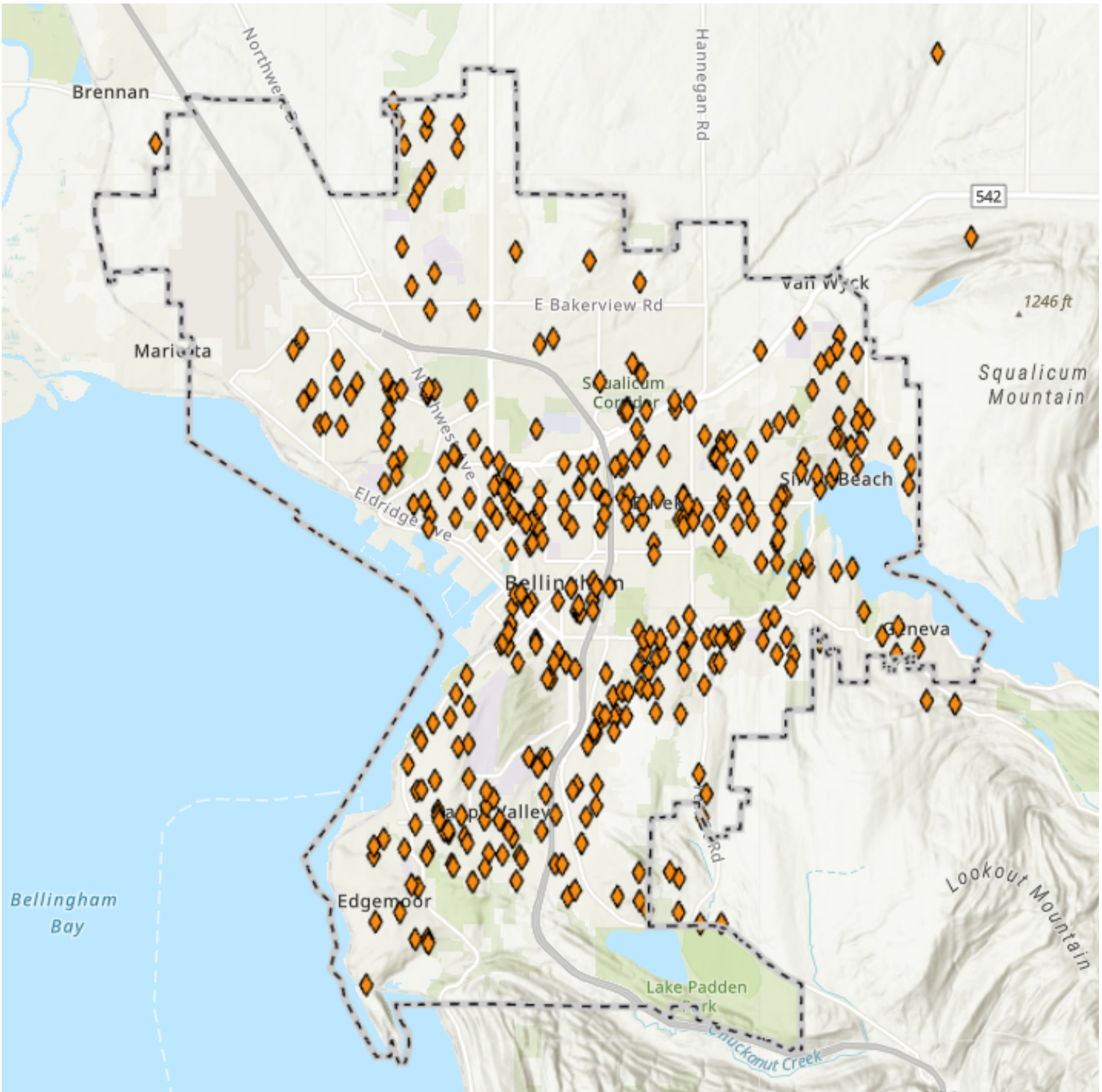
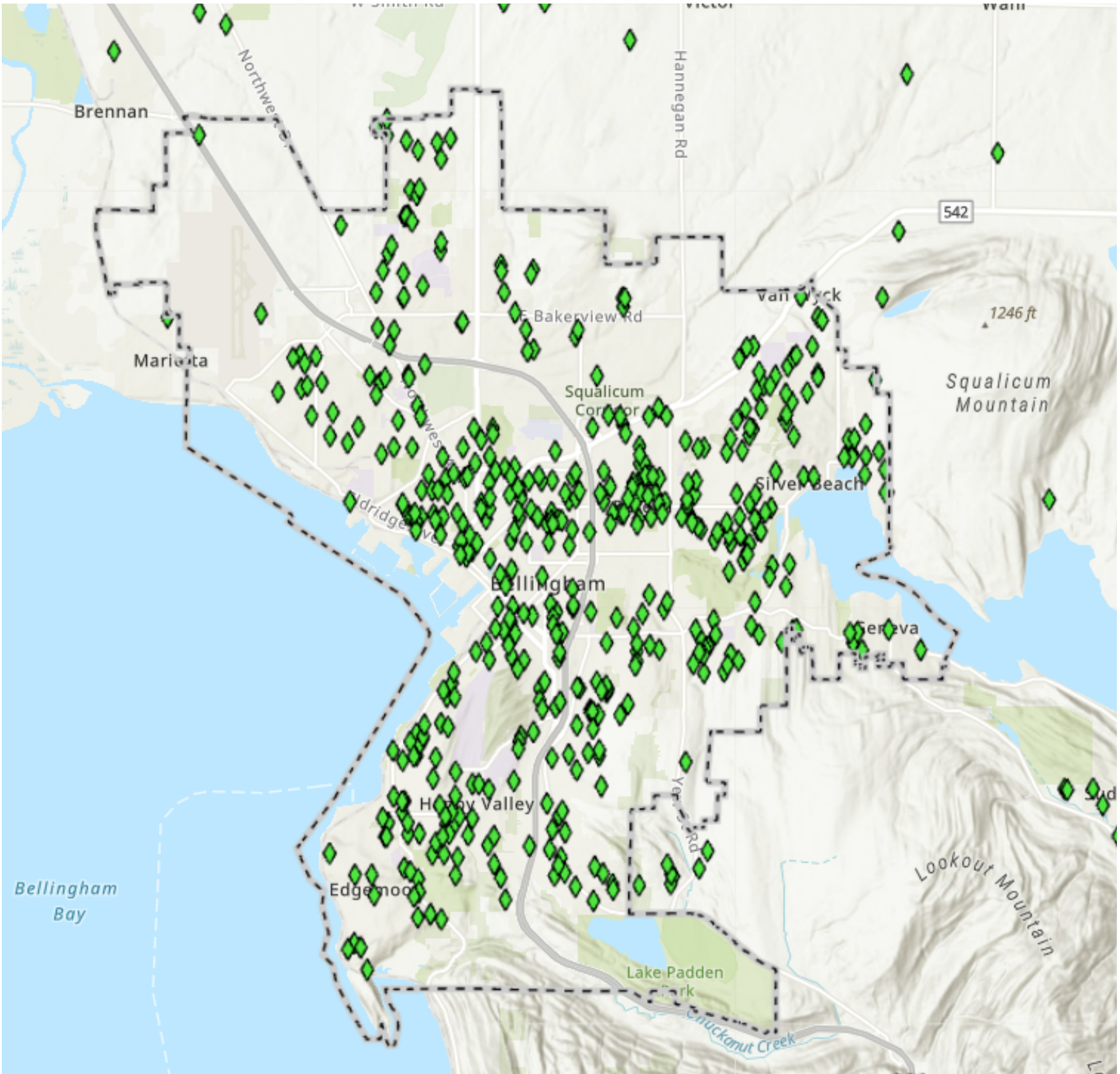


Figure 2-3. Locations of Speed Test Results Below the FCC Broadband Standard



28 Mbps but less than 120 Mbps aggregate throughput

Figure 2-4. Locations of Speed Test Results Below Washington State Broadband Standard but over FCC standard



120 Mbps aggregate throughput or higher

Figure 2-5. Locations of Speed Test Results Above Washington State Broadband Standard

To further assess whether any specific neighborhoods are unserved or underserved, the numbers of each tier of speed test results were analyzed by neighborhood, as shown in the table below. The larger proportion of results (8.1%) came from the Roosevelt neighborhood, which is home to 9% of the City's population. On average each neighborhood contributed 4.2% of speed test results. Fairhaven, which has 600 residents, and Meridian, which is largely commercial and industrial, had the lowest percentage of speed tests. Less than 3% came from the

South, King Mountain, City Center, Edgemoor, and Sehome neighborhoods. The neighborhoods with no results were a newer one that is zoned industrial (Irongate) and the campus of Western Washington University. Cornwall Park, Edgemoor, and Lettered Streets had the highest numbers of very slow speed test results.

Table 2-3. Speed Test Results by Neighborhood

Neighborhood	Fast	Slow	Very Slow	None	Total	Percent
Lettered Streets	18	16	9	0	43	4.3%
Silver Beach	21	24	8	0	53	5.3%
Columbia	28	13	7	0	48	4.8%
Alabama Hill	24	14	7	0	45	4.5%
Sehome	14	8	6	0	28	2.8%
King Mountain	9	9	6	1	25	2.5%
Barkley	35	16	5	1	57	5.7%
Happy Valley	27	28	5	1	61	6.1%
Birchwood	18	21	5	0	44	4.4%
York	13	13	5	0	31	3.1%
Roosevelt	39	36	4	2	81	8.1%
Sunnyland	20	13	4	0	37	3.7%
South	11	7	4	0	22	2.2%
Outside	38	25	3	3	69	6.9%
Samish	33	25	3	1	62	6.2%
Cordata	27	15	3	0	45	4.5%
Puget	23	22	3	1	49	4.9%
South Hill	21	19	3	0	43	4.3%
Whatcom Falls	20	21	3	0	44	4.4%
City Center	12	11	2	0	25	2.5%
Meridian	12	4	1	0	17	1.7%
Fairhaven	9	4	1	1	15	1.5%
Cornwall Park	21	10	0	0	31	3.1%
Edgemoor	17	10	0	0	27	2.7%
Irongate	0	0	0	0	0	0.0%
WWU	0	0	0	0	0	0.0%

CONSUMER SENTIMENTS

The survey also asked respondents to rank their current internet service on a variety of factors, as shown below. More than half of respondents ranked their services as Good or Excellent across all factors, with the exception of Price and Customer Service. Nearly half (46%) of respondents rated Price as either Bad or Terrible; similarly, nearly half (42.7%) rated Customer Service & Support as Bad or Terrible.

Table 2-4. Respondents' Assessment of Current Internet Service Performance

Topic	Terrible	Bad	Neither/ Not Sure	Good	Excellent	All
Overall	29 (2.8%)	125 (12%)	169 (16.2%)	579 (55.6%)	139 (13.4%)	1041
Performance/ Speed	27 (2.6%)	154 (14.8%)	168 (16.2%)	553 (53.3%)	136 (13.1%)	1038
Price	141 (13.6%)	335 (32.4%)	274 (26.5%)	225 (21.7%)	60 (5.8%)	1035
Reliability	32 (3.1%)	120 (11.5%)	220 (21.2%)	532 (51.2%)	136 (13.1%)	1040
Customer Service & Support	229 (22.3%)	210 (20.4%)	312 (30.3%)	223 (21.7%)	55 (5.3%)	1029

Most respondents reported slowdowns and service outages. Slowdowns appear to occur every few days to once a year and service goes out for an hour or two every few months to about once a year. About 13% of respondents did experience slow downs on a daily basis and about 3% of respondents were seeing brief outages on every day.

USE

To better understand how internet is being used, we asked household respondents to identify how essential it is for a variety of common uses. Most respondents found internet to be extremely useful or essential across all tasks, except generating income or selling things, for which only about 40% of respondents found it to be essential.

We also asked respondents how often someone in their household was using internet for critical services such as schoolwork or training, telecommuting, operating a home-based business, or health monitoring. The most common of these uses was telecommuting, with nearly half (46.9%) of respondents indicating that someone in their household used internet for this purpose more than once a week. More than a quarter (32%) of respondent households had someone in their household who did online schoolwork or training more than once a week, and a similar percentage (29.8%) had someone who used it for operating a home-based business including "gig" work. Few respondents (2.0%) had someone in their household who used it more than once a week for consulting a healthcare professional, but more than half of respondents (56.3%) did use it a few times a year for this purpose.

Among organizational respondents, digital technologies were absolutely essential or very useful for all uses including management and operations and supporting customers. To understand just how critical broadband is, we asked organizational respondents whether they would be willing to move their business for much faster, less expensive internet services. Of the 24 respondents, nearly one third (29.2%) said they definitely would not move, but the majority of respondents fell somewhere in the middle indicating that they would consider moving.

3. Asset Assessment

The City of Bellingham has a substantial amount of assets that are currently or could be used for communication purposes. These include both public and private assets. There are also key City locations and public facilities that are on a public high-speed fiber-optic network and many more that could be. This memo reviews the communication assets owned by the City and major private sector network infrastructure that exists today.

PUBLIC ASSETS

The City currently has a wide array of assets that are being used for communications or could be used for communications. These include towers, over 850,000 feet of conduit and over 440,000 feet of fiber-optic cables.

Conduit and Fiber-Optic Cables

Bellingham has substantial conduit and fiber-optic assets deployed throughout the City. The scope and scale of the City of Bellingham's network assets are illustrated on the next few pages.

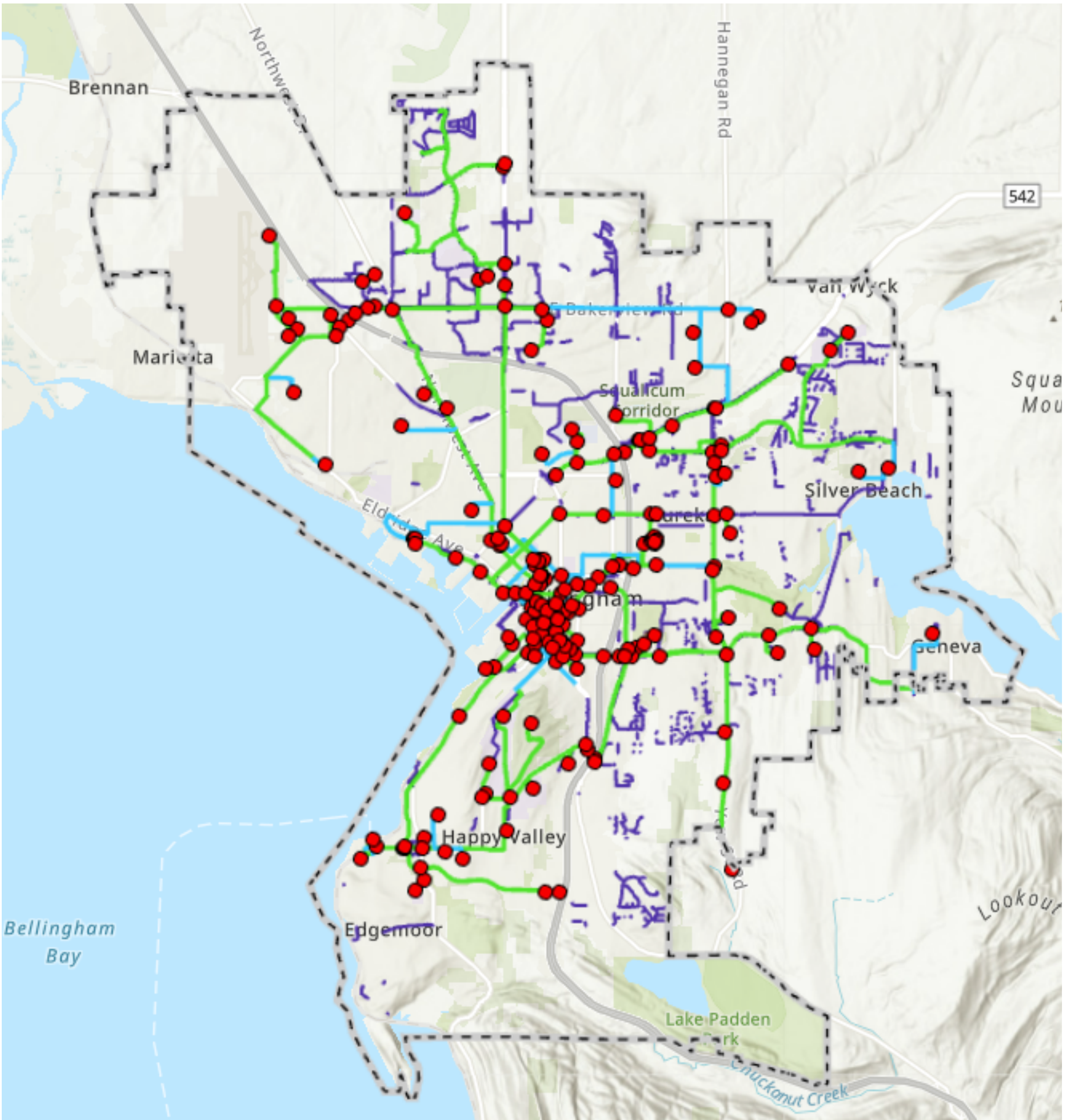
The City of Bellingham has 7,561 segments of conduit that add up to 853,945 feet (162 miles) in total. There is 89,500 feet of aerial conduit and 764K feet of underground conduit segments with an average length of 102 feet. Most of the conduit is 1.5" and 2" in diameter. The conduit network is shown in Figure 3-2, below.

Of all the conduit segments, 22% contain fiber optics with an average length of 254 feet. This fiber-filled conduit totals 419.7 K feet or 49% of the total length of conduit. Much of the conduit contains copper wire for traffic signal interconnects. All but 2 of the 80 aerial conduits[5] contain fiber.

The City of Bellingham has 84.8 route miles (447,837 feet) of fiber-optic cable. These are comprised of 344 individual spans of which 269 are underground, 52 are aerial, 15 are in cabinets and 8 are in ceilings. The number of fiber-optic cables in each strand ranges from 6 to 288, with 12 fibers being the most common. There are a total

[5] City of Bellingham documentation indicates aerial conduit, which we assume is laterally reinforced duct.

of 12,768 strands of fiber in the cable spans. The locations of these fibers is shown in Figure 3-3, above.



Aerial Fiber Cable
Underground Fiber Cable
Traffic Utility Conduit
Fiber Termination Point

Figure 3-1. City of Bellingham Network Infrastructure Assets

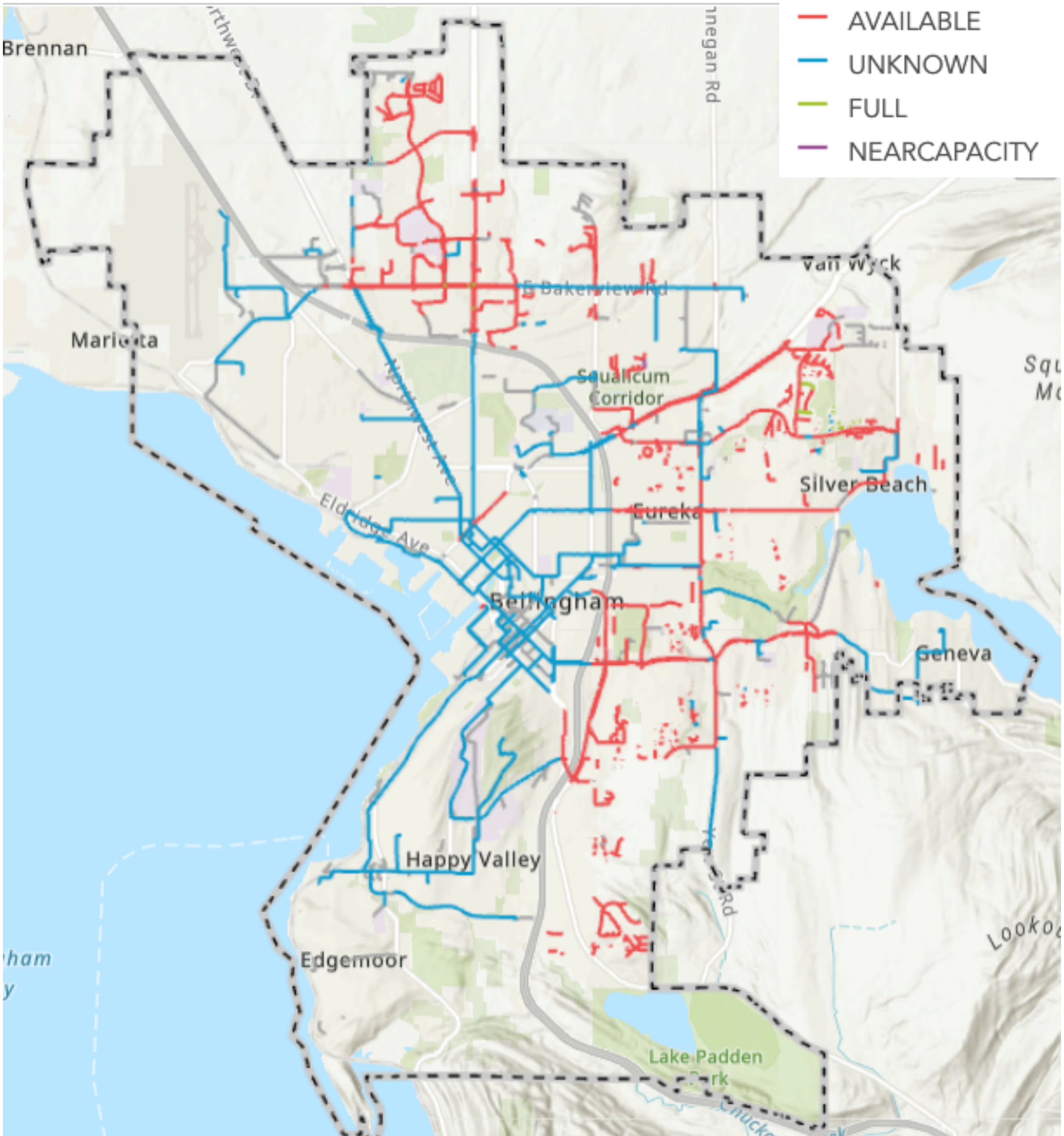


Figure 3-2. City of Bellingham Conduit Assets

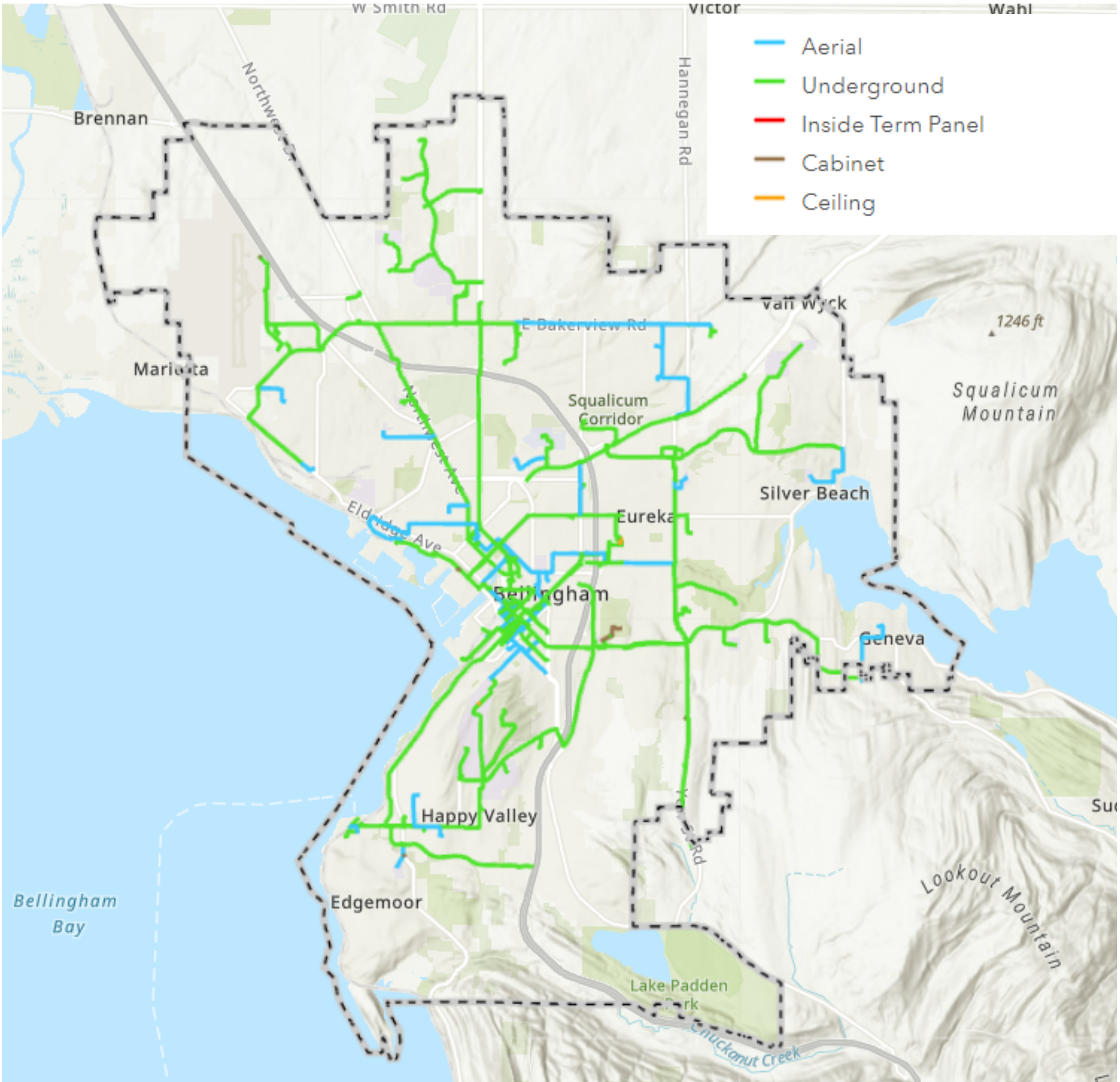


Figure 3-3. City of Bellingham Fiber Distribution

Lit Versus Dark Fiber

The 344 cable spans in Bellingham represent 12,768 individual strands of fiber. Of these, 42% are active, or lit. The remainder are unlit, or dark, and may be available for use. Of the 344 cable spans, 19 (6%) have only dark fiber. 53 (15%) spans have half lit and half dark and 44.4% have 50% or more of their strands active or lit. 26 spans are over 88% lit. The scale and scope of the dark fiber network is shown in Figure 3-4, below.

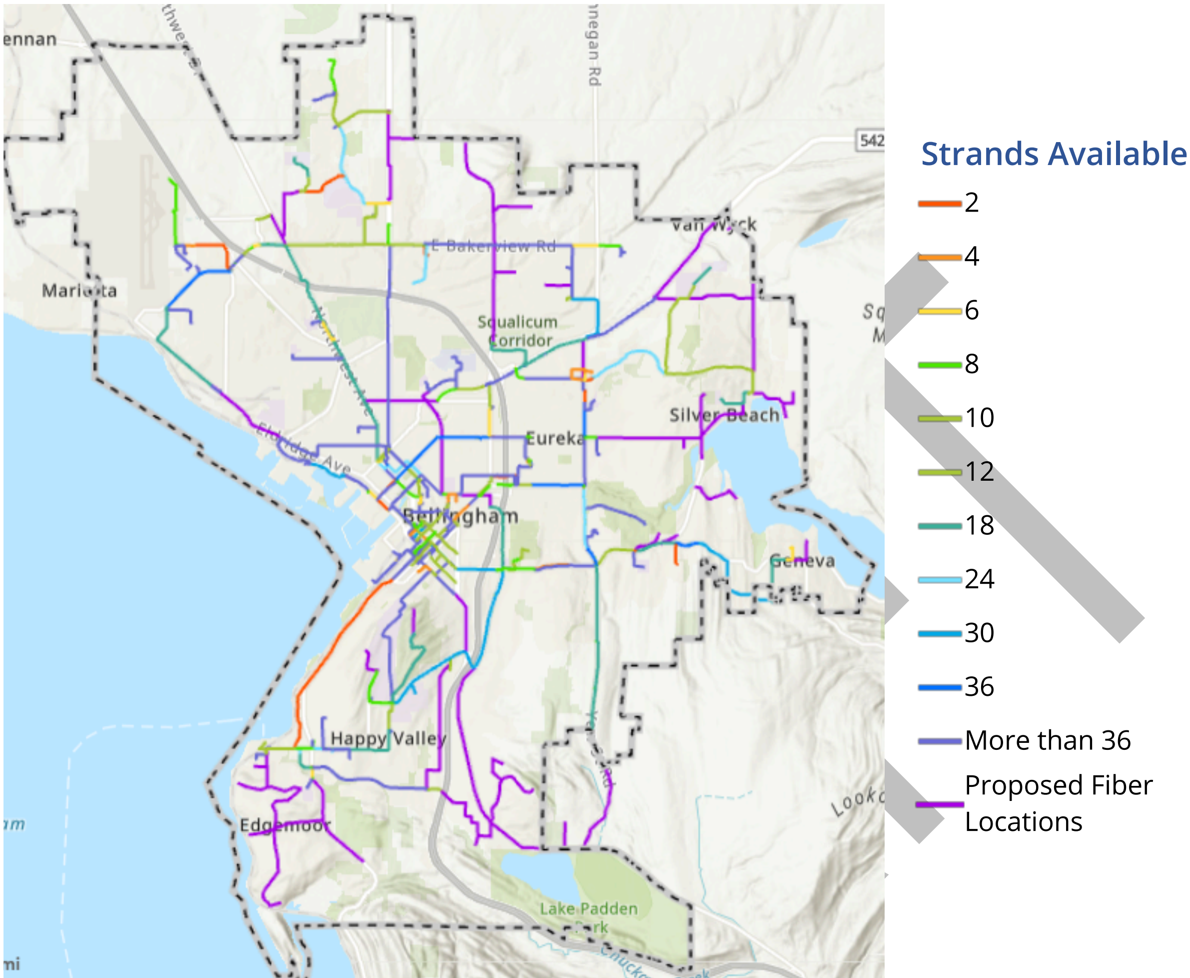


Figure 3-4. City of Bellingham Dark Fiber Strand Count

Usefulness of Fiber and Conduit Assets

The City owns many conduit and fiber assets, but there are some general issues regarding their usefulness for a Citywide network. Most notably, the existing segments of conduit and fiber do not constitute a well-defined backbone network. There are redundant rings interconnecting the network segments in some locations, but generally segments appear to be connected in an ad-hoc manner. Strategically filling in gaps to create additional rings throughout the City would allow Bellingham to more effectively use its existing assets.

It is also unclear whether existing conduit assets have room for pulling new fiber. In some cases, user of the conduit is unknown, as shown in Figure 3-2. Copper cable, although essentially outdated, can be costly to pull out. Fiber can be pulled in with pre-existing copper if the conduit is large enough to house both. If the conduit size is insufficient to pull fiber due to existing copper, the existing copper may need to be extracted to make room for fiber.

Finally, the strand count on the existing fiber is generally quite low to serve as a backbone. As shown in Figure 3-4, the vast majority of the existing fiber is less than 48 strands, which is insufficient to support a backbone network to serve the entire City. Magellan recommends that the backbone should ideally consist of 432 strand count fiber and in general, all network segments need additional fiber counts. The existing infrastructure will need to be augmented in a strategic manner.

Outside Plant Assets

In addition to the conduit and cable spans, the outside plant in Bellingham has a number of structures that facilitate access to the cable. These are referred to as outside plant (OSP) access points.

In the City of Bellingham, there are 280 OSP access points. These are predominantly controller cabinets, vaults and junction boxes. Bellingham has 96 controller cabinets such as the one shown at the corner of State St. and Maple St in Figure 3-5, below. There are also 73 vaults and 58 junction boxes (J-boxes). All but 17 are owned by the City of Bellingham. The remaining 17 devices are owned by the Whatcom Public Utility District and the Washington Department of Transportation.

Figure 3-5. Signal Control Cabinet (State and Maple Sts, Bellingham, WA)

PRIVATE COMMUNICATION ASSETS

Multiple private service providers have network assets in Bellingham. These include the incumbent last mile providers, Comcast and Lumen Technologies (formerly CenturyLink). It also includes metro fiber providers serving local businesses such as Wave and Ziply Fiber and long-haul fiber providers such as Mox Networks and Zayo.

As the legacy cable TV provider in Bellingham, Comcast has near 100% coverage of the City. They provide the traditional "Triple-Play Bundle" of voice, cable TV and internet over their hybrid fiber-coax (HFC) network. The HFC network deploys fiber from their centralized head-ends and hubs to neighborhood nodes serving 250 to 500 homes. At the node, the fiber is terminated, and the remaining network is coaxial cable. Their stated plans are to deploy additional fiber deeper into the network (closer to homes) and eliminate their aging coaxial cable. For internet access service, Comcast's offerings range from 50 Mbps for $20/month to 2 Gbps for $300/month.

The Incumbent Local Exchange Carrier (ILEC) is Centurylink, who recently renamed themselves to Lumen Technologies. As the ILEC, Lumen has close to 100% coverage of the City. In Bellingham, Lumen started deploying Fiber-to-the-Premises (FTTP) in the 2015-2016 timeframe. Based on our research, Lumen has gigabit fiber offerings in the City, though it appears to be only of the west side of Route 5. Their stated strategy is to deploy as much fiber as possible, making them a potential user of the current City of Bellingham-owned assets.

Where they have fiber, their offerings are very competitive. They offer up to 940 Mbps/940 Mbps symmetrical service for $65/month. This includes free installation and a free modem. They also do not have data caps. Where they do not have fiber, Lumen offers DSL services. Bellingham ZIP codes of 98226 and 98229 appear to be just DSL capable. Data rates range from 1.5 Mbps to 60 Mbps and are all priced at $50/mo. with a $15/mo. modem rental fee.

Metro Fiber

Fiber-optic networks are classified by the types of access they accommodate. Metro networks, as the name implies, are designed to connect major sites in relatively dense metropolitan areas to each other, to long-haul networks, and to other service providers, typically via colocation data centers or exchange facilities. Middle-mile networks are like metro networks but typically extend access to interconnection points in major cities.

Both long-haul and metro/middle-mile connectivity are priced on an individual case basis, based on the service level, number of sites, distance, and bandwidth required. Some of these companies—especially long-haul providers—will lease dark fiber strands on some routes, but these are generally lit services. Many of the companies prefer to sell connectivity as part of a suite of managed services.

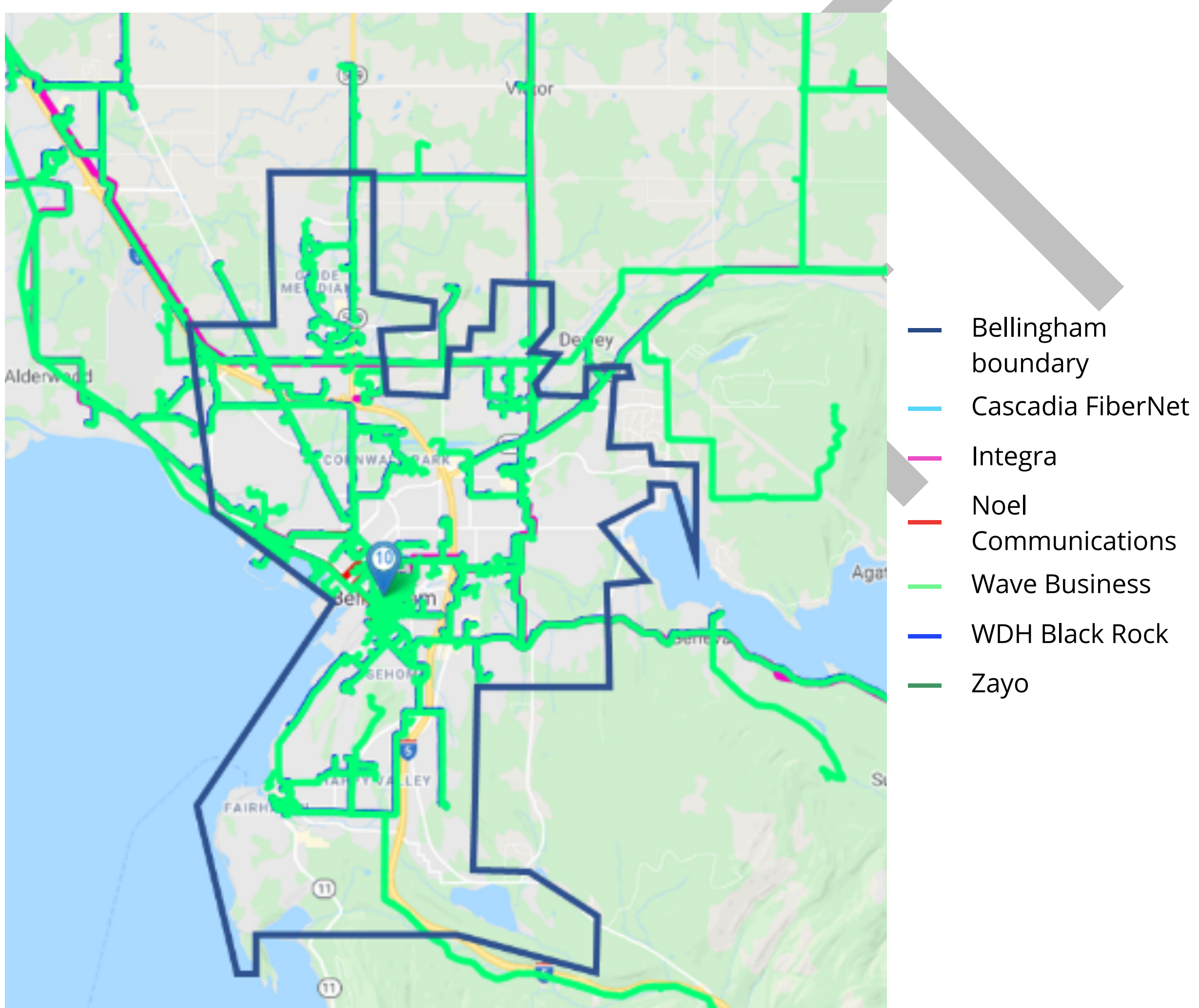


Figure 3-6. Metro Fiber in The City of Bellingham[6]

As illustrated in Figure 3-6 above, there is a substantial amount of metro, or local, fiber in the City of Bellingham. What is not evident is that there are multiple companies that own fiber along the same fiber route. Although it appears that Wave

[6] Source: FiberLocator.com

is the only provider, the other companies', such as Zayo's, fiber is shown beneath the bright green fiber of Wave. The companies likely own (as long-term capital lease) fiber strands within a single cable sheath or have separate cables in a shared conduit. Two key providers are Wave and Ziply due to their entrepreneurial approach and retail broadband operations in other areas of the western United States.

Ziply Fiber

Ziply Fiber is owed by Northwest Fiber, who also owns Wholesale Networks. In Bellingham, Wholesale Networks has applied for the franchise as a Competitive Local Exchange Carrier (CLEC) and not Ziply (the ILEC). Wholesale Networks plans to deploy fiber to commercial customers in the City with a focus on those companies with regional connectivity needs. They are not structured to serve residential customers and at this time have no plans to address the residential market within the City of Bellingham.

Wave Broadband

Wave, founded in 2003, is part of Wave Division Holdings, LLC, which currently serves over 455,000 residential and business customers in Washington, Oregon, Sacramento, and the San Francisco Bay Area. Wave is part of Astound Broadband, which was acquired by Private Equity firm Stonepeak Infrastructure Partners in 4Q2020.

Wave's strategy in Bellingham is to focus on serving small and medium businesses (SMB), large enterprises and data centers with fiber connections. They are not currently planning to deploy fiber to residential households since there are already two gigabit providers in the City and they do not want to compete as the third. Wave does serve residences with fiber in smaller under-served communities.

Long Haul Fiber

Long-haul networks allow access only at major carrier points-of-presence (POPs). Long-haul customers want as few points of failure as possible, which translates into limited access. For the City of Bellingham, long-haul fiber is important for both private and public entities to connect to major internet and cloud peering, or interconnect, sites in Seattle and to a lesser extent, Vancouver, British Columbia. These assets are illustrated in Figure 3-7, although we know of at least one provider—Mox Networks—that was not included in the source.

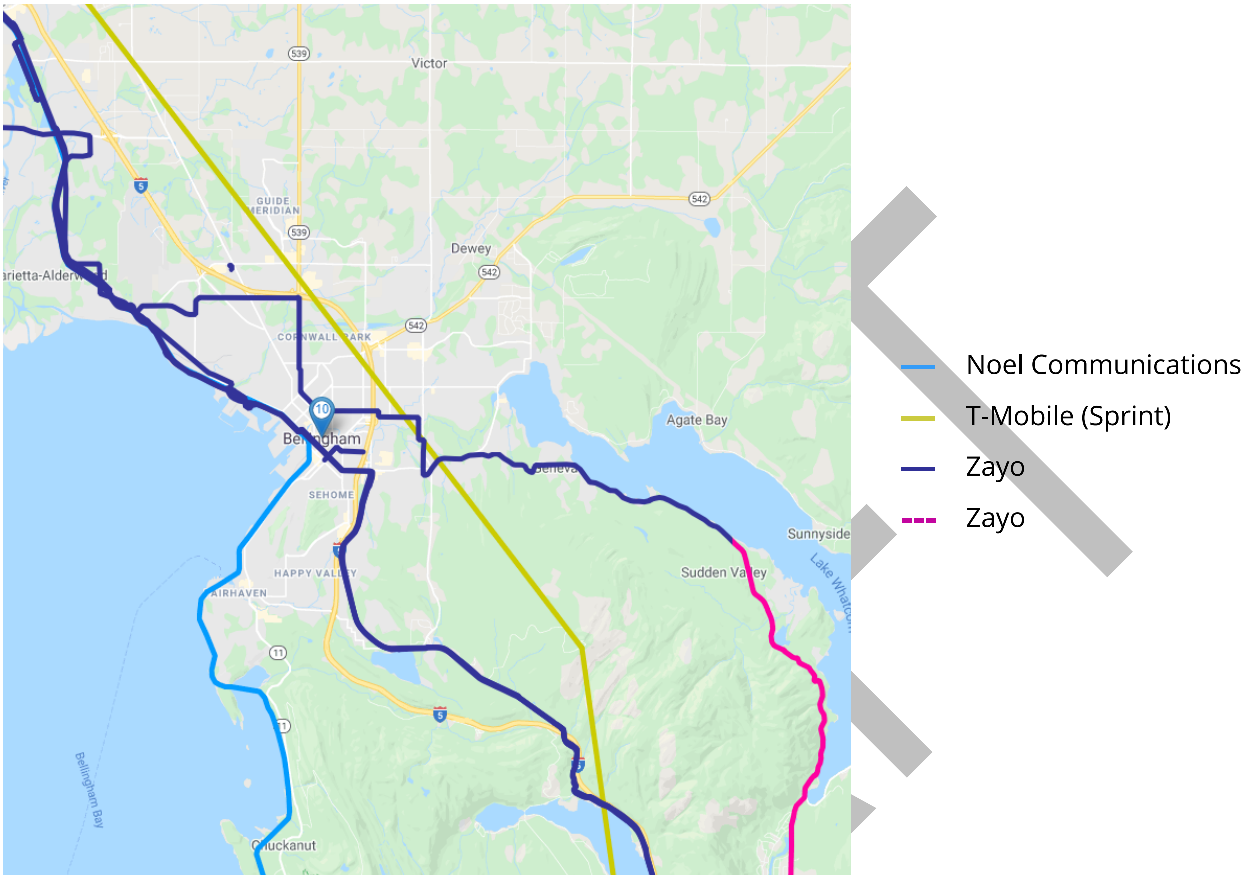


Figure 3-7. Long Haul Fiber in Bellingham[7]

Edge Data Centers

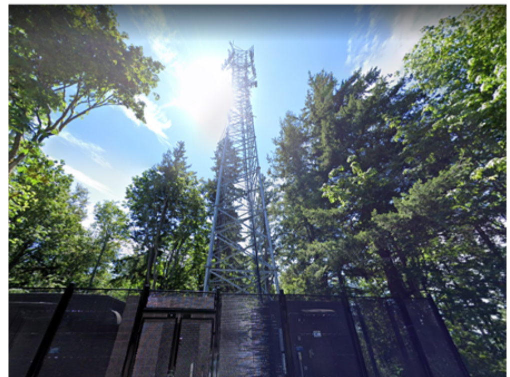
Currently, there is one public or neutral data center in Bellingham. Lunavi on Coho Way is an enterprise-class data center with fully redundant facilities for both hosted managed services and co-location space. Wave and Zayo provide connectivity including high-speed connections to Seattle's Tier 1 locations.

MOBILE COMMUNICATION ASSETS

Scattered throughout Bellingham's 27.7 square miles are 43 wireless communications towers. These include 7 lattice towers such as the ones at 2600 Mcleod Road and 600 25th St.

[7] Source: FiberLocator.com

2600 Mcleod



600 25th St.

Figure 3-8. Examples of Cellular Telephone Sites with Towers[8]

Also included are 16 rooftop antennas, such as those at 1400 12th Street and 2501 E. Street. In these locations, the mobile network operators lease space on rooftops, and they deploy their antennas. In many cases the operators attempt to camouflage the antennas to make them less obvious as shown in Figure 3-9, below.

1400 12thSt.

2501 E. St.

Figure 3-9. Examples of Antenna Attached to Buildings[9]

There are 7 monopoles in Bellingham such as the one at 716 Alabama Street and an additional 7 flag poles used for radio communications (see Figure 3-10, below). There are also 2 pseudo trees and 1 Obelisk at 231 Highland Drive.

[8] Source: Google

[9] Source: Google

716 Alabama St.

231 Highland Drive.

Figure 3-10. Examples of Monopole Small Cell Sites[10]

CITY ASSETS ON NETWORK

Today, there are 91 locations that are "On-Net," or connected to the City's fiber-optic network. Forty-seven (51.6%) are owned by the City. Other public buildings and assets such as traffic cameras and streetlights could be connected the City's fiber network. According to the data provided to Magellan Advisors, there are 577 buildings and locations that are considered "public." Of these, the City owns 223 or 38% of them. This includes all major facilities and 17 apartment buildings owned by the City and 18 houses owned by the City's Housing Department.

Educational institutions account for 235 (40%) of the public locations. The Bellingham School District owns 113 locations, Western Washington University owns 105 and Whatcom Community College owns 7. Governments and Authorities account for 13.4% of public locations. The County owns 38, the State owns 36 and the Port owns 3 buildings or public locations.

Streetlights and Traffic Control Cabinets

In the City of Bellingham, there are 6,219 streetlights managed by 385 controllers such as those shown below. The City of Bellingham Public Works department owns and maintains 4,083 (64.3%) of them and the City of Bellingham Park department owns and maintains 125. PSE owns and maintains 1,704 (27.4%) of the Bellingham traffic lights. Other owners include the Washington Department of Transportation

[10] Source: Google

(WSDOT) (179 lights), the Port (22), Whatcom Transportation Authority (WTA) (6) and Western Washington University (30).

2200 E. Lopez Street. 3617 Lemon Grove Drive

Figure 3-11. Examples of Traffic Signal Control Cabinets[11]

The City's Public Works Department owns 93% (357) of the traffic cabinets and maintains 97% of them. The WSDOT owns and maintains 12 cabinets in the City.

Other Assets

There are 21 traffic cameras in the City. Sixteen are owned by the City of Bellingham Public Works Department and 5 are owned by the Department of Transportation. Information was not provided about how they are connected.

Based on our research around the country, the number of cameras in urban applications is increasing, as is the resolution of the cameras with 1K and 4K resolutions become the standard. This increase in resolution translates into higher bandwidth requirements that are best served with direct connect fiber.

[11] Source: Google

4. Business Model Options

Various business models can be used to develop broadband, ranging from policy-only to full retail service provider, summarized in Table 4-1. A fundamental characteristic of these business models is that they necessarily involve addressing development in the public rights-of-way (PROW). Business models can be seen as a continuum of increasing scope of services, involving additional assets, that starts with managing public space.

Broadband impacts quality of life and qualify of place as well as the PROW. Therefore, it is clearly in the jurisdiction of local governments to address access to, construction in, and restoration of public property in a manner that fosters greater availability, better performance, and lower costs. To these ends, the City of Bellingham may invest in infrastructure for its own purposes (as it has done already), layer on services for other institutions and commercial providers, or even provide full retail, residential, broadband services.

Table 4-1. Broadband Business Models Compared

Model	Description	Pros	Cons	Examples
Public Policy Only	City uses policy tools and standards to streamline construction and reduce the cost of building infrastructure.	Low risk/reward option to support incentives to accelerate broadband investment	No “quick wins” to improve services	• Santa Cruz County, CA • Knoxville, TN • Monroe County, NY
Institutional/ Public Service	Dark fiber or data services to community organizations Sometimes retail services provided by the city to these organizations	Improves access and costs for public organizations, promotes collaboration	Little to no pressure or support for private broadband providers	• Seminole County, FL • Leesburg, FL • Columbia County, GA

Model	Description	Pros	Cons	Examples
Infrastructure-Only	City provides conduit and/or dark fiber to businesses, broadband providers, and other public organizations	Improves the cost and availability of fiber infrastructure to providers, businesses, and community organizations	Low impact on availability of retail broadband	• Santa Monica, CA • Palo Alto, CA[12] • Lakeland, FL
Open Access Wholesale	City financed and operated. Wholesale services only to retail broadband providers.	Enables more competition and choice of retail provider	Requires operations and active marketing to providers	• Palm Coast, FL • Danville, VA • Provo, UT
Commercial	City financed and operated; Fiber services, Internet and often telephone and data services to businesses	Enables the city to directly improve services to businesses	Requires competing with incumbent providers and operating the network.	• Fort Pierce, FL • Hudson, OH
Full Retail	Broadband internet, including voice possibly video services	Directly increases options for residential services	Requires substantial investment and operational capabilities	• Bristol, VA • Morristown, TN • Ashland, OR

[12] Palo Alto has recently begun developing municipal retail fiber broadband services.

As illustrated in Figure 4-1, the amount of investment involved increases with service offerings. Revenue potential increases but so does risk. Organizational capacity is part of the investment needed for optimal outcomes. The risk depends on where the infrastructure is deployed but also the level of effort put into selling physical connections and services. Focus on revenue, return on investment, and profits runs the risk of missing other benefits and impacts. Good governance reduces these risks as do strong, clear partnerships.

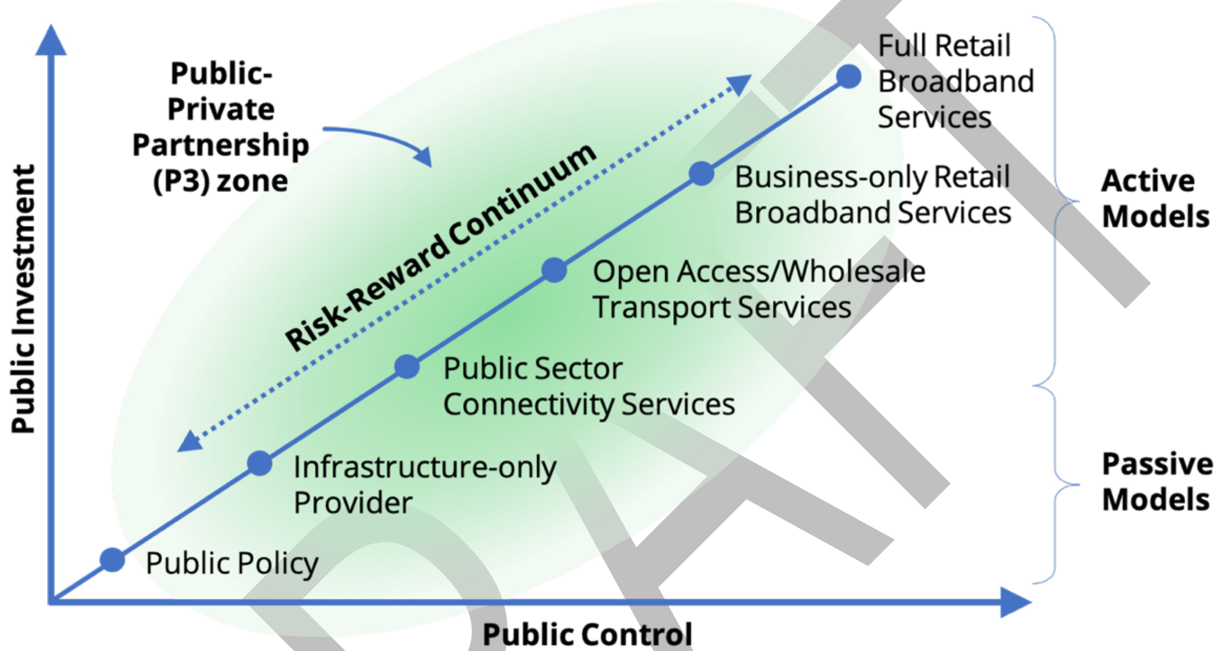


Figure 4-1. Broadband business models compared

The critical considerations for selecting a model are shown in Figure 4-2. Most of these are analyzed in detail in other sections of this report. Others are open issues to be decided by City officials. Conclusions and recommendations about the most appropriate model for the City based on these considerations follow analysis of a conceptual network design and associated financial estimates, below.

Figure 4-2. Considerations for a Broadband Business Model

Broadband is a means to access culture, education, health, recreation, and work resources, not an end in and of itself. Network services such as broadband have traditionally been evaluated simply in terms of price and performance. With increasing importance of digital connectivity, equity and inclusion have become critical issues, as have social outcomes. Broadband planning involves assessing and addressing all the considerations based on overall goals and priorities. Evaluation of broadband business models requires economic and social metrics as well as basic price/performance metrics.

A fundamental business issue for the City of Bellingham is its purpose for investing in broadband and related assets. While the goal of more affordable and equitably of available quality broadband access across the community is admirable, it needs a purpose or a "why" as a basis for evaluating impacts. The purpose also provides a basis for engaging community members, particularly vis-a-vis municipal operations. "Why" determines "how." A practical implication is it may be necessary to expand the City's organization and services if the purpose does not fit within the mission of an existing department.

5. Conceptual Network Design

A conceptual network design identifies the components and scale of a broadband system to estimate cost, coverage, and revenue potential. For this study, the scope of the network is the entire City of Bellingham, including areas within its urban growth boundaries. The City is considering the full range of business options; therefore the scope of services includes retail broadband. Such network infrastructure would be necessary to deliver broadband as defined by the City's Broadband Workgroup for all residents and businesses, municipal agencies and smart city initiatives, and anchor institutions.

Given the amount and diversity of local public assets, our analytical approach is to start with full fiber-to-the-premise (FTTP) design, to understand the maximum scale of the investment, then consider how costs might be reduced. Broadband networks typically have a hierarchical architecture with a very high-capacity core network, feeder network deployed in rings for redundancy and reliability, and distribution network extending to access hubs in neighborhoods. Passive Optical Network (PON) is the standard for FTTP access infrastructure capable of gigabit-speed broadband. This section describes each element of that design, along with total "full build" costs. These costs can be greatly reduced by various tactics, including use of existing public assets.

NETWORK ARCHITECTURE

The Bellingham Conceptual Network is a backbone for access and transport services via PON and active Ethernet. The basic requirements are to interconnect distributed customer access equipment and commercial data centers and retail ISPs. Fiber should be deployed in a ring topology to minimize impact of an equipment failure or fiber cut. The basic architecture is interconnecting rings—like a length of chain—of high-capacity fiber cable in underground conduit with access points (hand holes, pull boxes, vaults) at regular intervals.

The routes follow major thoroughfares, as well as some secondary streets, where appropriate, to complete a ring. There are a few spurs to water plants and wireless tower infrastructure. The rings can be grouped into phases for financial and practical purposes. The routes are designed to connect as many City and community assets as practical with this architecture. Therefore, the conceptual network design is very extensive and is intended to generate maximum cost estimates for budgeting and planning purposes.

Fiber Backbone

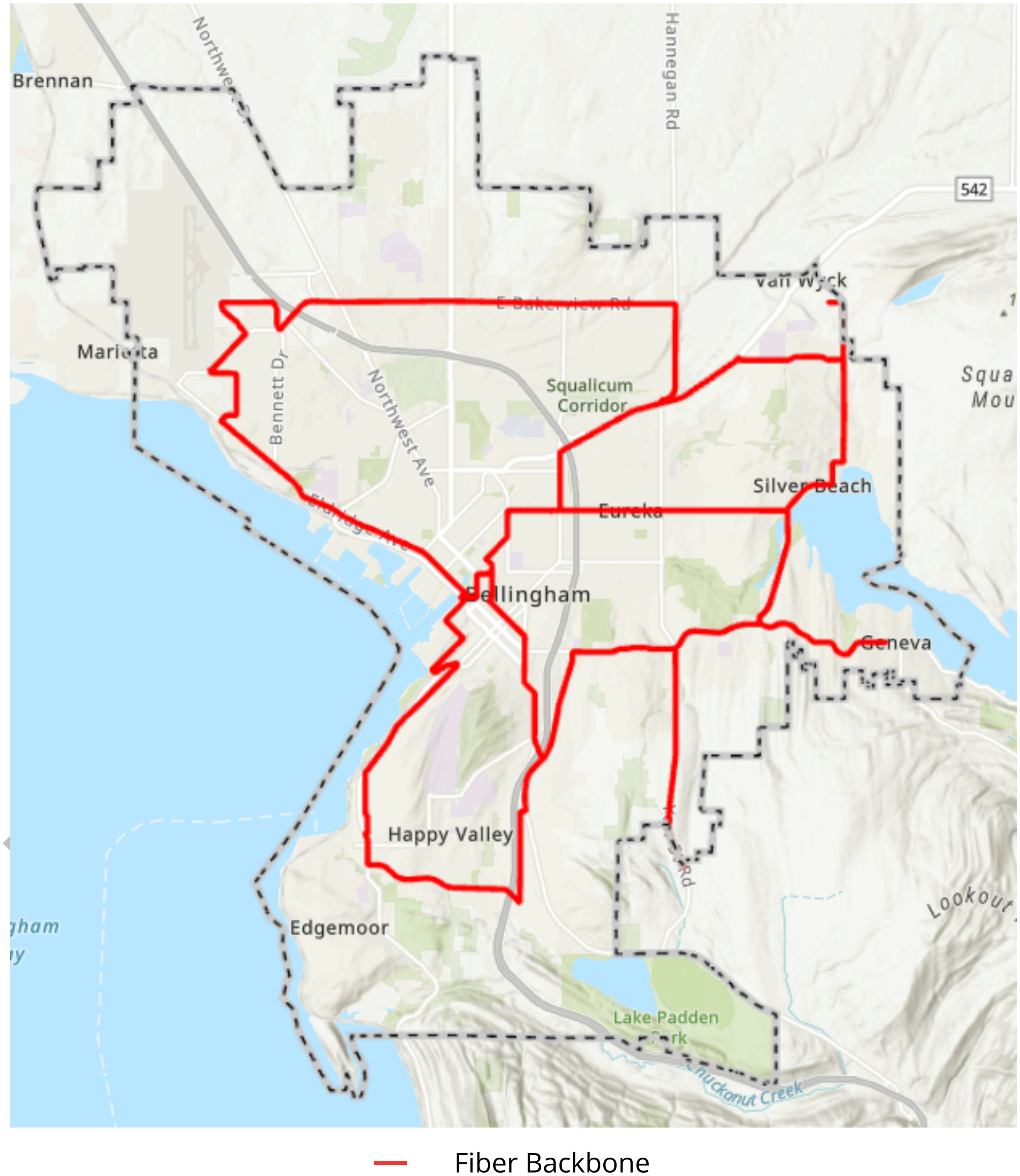


Figure 5-1. Bellingham Municipal Backbone Conceptual Network

The conceptual design is for “backbone” network infrastructure, illustrated in Figure 5-1, which interconnects and support multiple other networks. Typically, broadband networks have a core network that forms a ring between a few key sites. For Bellingham, we designed four rings throughout the City, with two legs extending into its eastern neighborhoods resulting in 44.4 route miles of high strand-count (e.g., 144-strand) fiber cable for the backbone.

The backbone in this conceptual design is entirely underground because this approach is the financially conservative for costing and risk avoidance. It also tends to be more aesthetically acceptable. **Underground has a higher initial cost to build, however is less costly to maintain** (although this varies by specific method: bore verses trench verses direct bury/micro-trench). It would cost approximately $12.4M to build this backbone in its entirety from scratch, including 20% construction contingency, without using existing assets or incorporating network assets into other capital improvement projects.

The City of Bellingham has substantial fiber assets currently that could be integrated into the backbone. Indeed, the total length of cable spans along the backbone route with dark fibers is greater than the backbone’s total length. See Table 5-1. Some available conduit and much of the planned fiber also follow backbone routes. Construction costs can be greatly reduced by developing the backbone incrementally and opportunistically, along with other infrastructure projects, as well as using existing assets.

Table 5-1. City of Bellingham Fiber Cable Spans Along Backbone Conceptual Design Route

Dark Strands	Cables Spans	Total Length
Up to 12	136	144,133
Over 12 to 24	27	58,462
Over 24 to 36	17	45,835
Over 36 to 48	10	32,957
Over 48 to 60	3	3,486
Over 60 to 100	6	15,095
More than 100	7	6,902
All	**206**	**306,870**

The backbone infrastructure can be used to directly serve or enable services to customers. There are 149 community anchor institution locations within 750 feet of the backbone illustrated above, as shown in Table 5-2. These would require additional distribution infrastructure—drops or laterals, as described below. Most could be economically connected to via a backbone like the conceptual design.

Table 5-2. Community Anchor Locations on the Backbone

Stakeholder	COUNT
Bellingham School District 501	37
Bellingham-Whatcom County Library	2
City Of Bellingham	50
City Of Bellingham Housing Authority	9
City Of Bellingham Parks	8
Community and Technical Colleges	14
Fire Stations	4
Other	9
St. Joseph's Hospital	3
Western Washington University	1
Whatcom County	6
Whatcom County Parks	2
Whatcom Transportation Authority	2
Whatcom YMCA	2
Total	**149**

Transport Equipment and Facilities

Traffic from across the network is aggregated to core network sites with powerful equipment to route data to the global network. At least one, ideally two, sites must connect to high-capacity dedicated internet services, ideally via different providers with fiber following separate routes, for bulk IP. These sites must be secure, with high reliability power, and preferably centrally located.

The network equipment required to deliver broadband services to customers is comprised of several functional groups and multiple components within each group. Each functional group and a brief overview of how it is used to deliver service to the end customer follows below. Retail internet service providers (ISPs) may operate a mix of access network consisting of both PON and active Ethernet services. The diagram below demonstrates the functional components of the network and how customers connect to the network to receive services. The total estimated costs for a Bellingham Broadband Department to deploy transport equipment, including upgrading an existing building to function as a central office/co-location facility, is

$2.8M. The City should expect to budget at least $225K annually for core/transport network maintenance and operations.

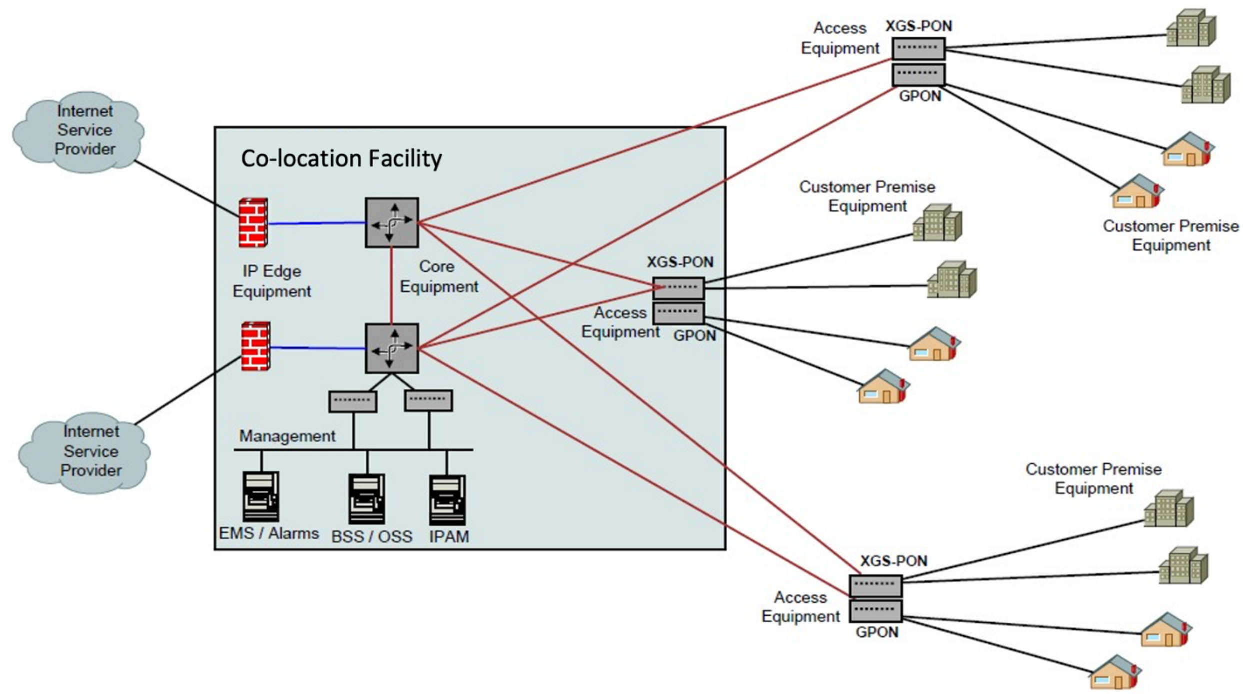


Figure 5-2. Passive Optical Network Broadband Model

Core Equipment

The core equipment aggregates traffic from all access equipment, connecting customers and routing their data to and from the IP edge equipment or other end-point destinations. Standard network protocols provide link redundancy and dynamic traffic re-routing in the event of an equipment failure or fiber cut. Core equipment can easily support thousands of customers and hundreds of gigabits of traffic throughput at deployment and will accommodate future system growth through the addition of service modules, optical interfaces, and/or software licenses. Figure 5-2 shows the key components and how they are integrated into a broadband system.

Optical Network Terminal

An Optical Network Unit (ONU), sometimes called an Optical Network Terminal (ONT), serves as the demarcation point between the retail fiber network and the router or firewall connecting to the customer's local area network (LAN). There are two general methods for installing ONTs. The first method involves mounting an outdoor rated ONT on an exterior wall of the structure and extending service wiring inside the premise. The second method involves extending the fiber into the premise and installing an indoor-rated ONU inside.

In either case, the ONT is typically installed somewhere near the fiber entrance and an AC power source. The ONT terminates the fiber based PON signals and provides customer access to their services through traditional copper interfaces. XGS-PON ONT's supporting greater than 1 Gbps data service may also support optical small form-factor pluggable (SFP) interfaces for connection to enterprise-class LAN equipment.

Internet Protocol Edge (IP Edge) Equipment

Separate from the core switches, the Municipal Network should maintain an "internet perimeter." The internet perimeter will include internet routers and internet firewalls to be used to manage routing throughout the network. Firewalls will be utilized to protect critical back-office systems, including provisioning, network management, data storage, and other information. The Department's two core switches will be interconnected to two internet routers providing redundancy for internet services in the event of a single interface or equipment failure. As mentioned above, the Department should acquire bulk IP from at least two providers using diverse paths, one of which should be a Tier 1 provider.

Fiber Distribution Infrastructure

The backbone will traverse the entire City to customer premises via access equipment and distribution hubs. Feeder lines, which are also typically deployed in rings, connect the core sites to distribution hubs. Distribution lines are branches from the hubs. Access lines drop off the distribution lines—hence the term "fiber drops"—into customer premises. Major sites can be directly connected to the core. These lines are referred to as "laterals" rather than feeders. Radio access networks (RANs) may also serve as broadband access infrastructure, with cell sites as hubs. The 144 strands of fiber in one cable of backbone infrastructure may be used for a feeder network and/or laterals, as well as core network. The particular use of specific fiber strands is a matter of how they are spliced together and where they terminate.

The distribution infrastructure, shown in Figure 5-3, enables retail services to all parts of Bellingham. The backbone network provides redundant feeder fiber connections to hubs. POPs require powered cabinets, prefabricated shelters, or existing structures with sufficient space for equipment racks and other components. The conceptual network is designed to connect POPs via diverse routes to multiple bulk upstream providers for fault protection.

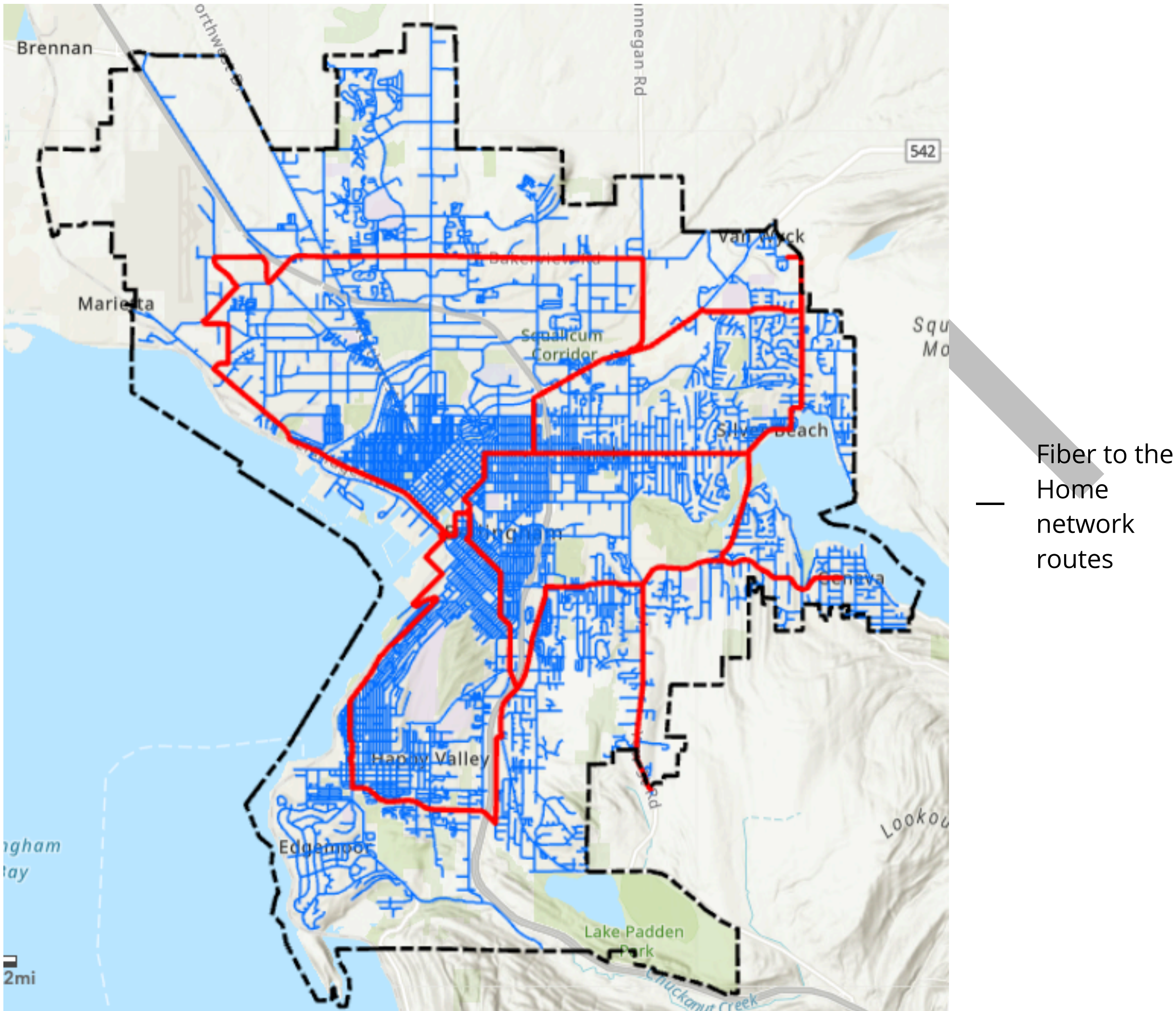


Figure 5-3. Bellingham Fiber-to-the-Home Broadband Network Conceptual Design for Full Digital Inclusion

This distribution infrastructure design includes 29 powered cabinets, 421 passive hubs, and 678.1 route miles of underground fiber, in addition to the backbone infrastructure. This design would enable retail broadband service delivery to nearly 43K customers, including 4.2K businesses and effectively all community institution sites within the City's urban growth boundaries. It would cost approximately $400.1M to build, would require approximately $21.2M in equipment, and $1M annual operating budget.

This design is for a “full-build” approach that accommodates all business models, including advanced retail broadband to the entire City including urban growth areas. It can be scaled back based on City priorities; little if any of the distribution network would be necessary for wholesale. The backbone routes cover many City assets and other systems, including traffic, surveillance cameras, SCADA, and AMI, for example, to reduce operating costs and increase operational benefits. The Department may provide limited access infrastructure for enterprise/wholesale services, so investment can be very targeted. The conceptual design also accommodates various partnership arrangements, including open access, pick-your-provider broadband services.

Feeder Fiber

Feeder fiber extends from the POPs to neighborhoods and business districts, connecting OLT ports to passive splitters located in outdoor cabinet enclosures called fiber distribution hubs (FDHs), placed strategically throughout the service area. Splitters may also be located within the access POP itself. In areas where aerial fiber deployment may be used, FDHs may be placed aerially or transitioned from the aerial pole to a ground-mounted FDH. Distribution fibers are sized based on the demand forecast and sizing of each enclosure to ensure that each service area is well equipped for both PON and Active Ethernet services. These details are set in the high-level design and engineering processes.

Distribution fiber

Distribution fiber, illustrated in Figure 5-3 on page 42 extends from the splitters in the FDHs to network access points (NAPs) which provide access to the individual fibers required for customer connections. NAPs may be attached to aerial strand, located in ground level pedestals or placed in underground vaults or hand holes located near the sidewalk or curb in residential neighborhoods or business districts. Fiber distribution to NAPs will be sized based on the service area density to provide service to between 8-12 premises per NAP.

Fiber Service Drops

Fiber drops connect from each NAP to the customer premise equipment that delivers broadband service. At the customer premise, the drop cable terminates in a protective “clamshell” enclosure attached to a home or building for storage of slack and connection to the home equipment. Drop fiber may be installed aerially or underground, typically for a flat fee. Providers may charge additional drop costs for special circumstances such as burying fiber through difficult landscapes or under driveways.

OPERATIONAL REQUIREMENTS

A retail broadband enterprise has substantial overhead and operating costs. Payroll can account for 90% or more of ongoing costs for a broadband enterprise. Equipment licenses, maintenance, refresh, and upgrades create recurring costs and large periodic costs. Management and marketing are much less for wholesale. Limiting operations to underground backbone also greatly reduces on-going costs.

Management

The City of Bellingham should plan to add a Broadband Director on day one. The Director will need a part-time Marketing Manager by the end of year one. The Director should have some experience with or knowledge of broadband and fiber but must have strong understanding of facilities leasing and maintenance. The Director will be responsible for overall organizational performance, focused on finances and governance.

Operations and Maintenance

A Network Infrastructure Manager is already on staff with the City and is required for any business model on day one. This individual will be responsible for any customer adds, changes, or moves to the backbone. The Broadband Department must purchase a fiber management system (FMS) and should have a maintenance fund to cover repair costs.

Costs for software vary greatly so we recommend budgeting approximately $75,000 for one-time costs with annual fees of 15%. Major maintenance or repair tasks—anything requiring excavation—may be contracted out or may be handled by Public Works. For the purpose of this analysis, we assume the City funds maintenance and repairs in lieu of network service charges or lease payments. Just to be conservative, we assume the Department will need dedicated full-time Network Engineer by year four.

Marketing

The Marketing Manager would be responsible for identifying and managing lessees, so this person should know the community well and have basic knowledge of the broadband industry. The Marketing Manager may also work with wholesale customers to promote their internet services to the community. The City of Bellingham should budget for marketing and other professional services as appropriate. We use $20,000 per year as an estimate for events, materials, and services, including research, social media, and web presence.

Other operating costs, beyond salaries, include facilities leases and maintenance. As discussed below, various equipment and systems are required for lit services, which generates additional operating costs. The Broadband Department should budget approximately $450,000 to $500,000 per year for operating expenses.

Table 5-3. Staff Positions and Fully Loaded Annual Cost Estimates

Position	Annual Cost
Telecom Director	$178,200
Accounting Manager	$126,360
OSP/Engineering Supervisor	$157,140
Sales & Marketing Manager	$129,600
Headend/Network Engineer	$113,400
Customer Support Manager	$105,300
Technical/NOC Support Manager	$129,600
Business/Enterprise Account Manager	$72,900
Network/NOC Technician (Data Center/Inside)	$97,718
Technical Service Rep Level 1	$50,544
Technical Service Rep Level 2	$60,653
Field Services Technician (in-house)	$77,501
Field Locates Technician (in-house)	$72,446

6. Financial Analysis

Full FTTH across the City of Bellingham could require a total capital investment of as much as $512M. The issues for financial analysis are how much revenue the network might generate and how revenues stack up against expenses over time. The fundamental question is whether and when the revenue will exceed the expenses. Of course, there are broader impact considerations, including increasing digital inclusion and support for key municipal operations—emergency preparedness, public safety, recreational facilities, traffic, etc. Broadband investment could keep more capital in the local economy even as it spurs additional private investment in technology infrastructure. Direct revenue can come from dark fiber leasing, enterprise/wholesale transport, and retail broadband. Because retail is the most demanding, we look at three scenarios for it.

INFRASTRUCTURE LEASING

The infrastructure leasing business model involves only providing backbone fiber or conduit for monthly or long-term capital leases. Demand for dark fiber can be a challenge to estimate due to evolving markets. Conduit (2-inch) in core urban areas outside major metros leases for $3.00 to $5.00 per foot. Generally, Magellan Advisors does not recommend leasing entire conduits because it reduces ability and flexibility to capitalize on the asset. Where the City has 3-inch or larger conduits, it is possible to install inner-duct and lease one or more of those. We recommend only leasing larger conduit to a private partner committed to building out fiber-to-the-premises for the entire area and providing deeply discounted services to anchor institutions.

Fiber leases can be boiled down to a cost per strand-mile. So, for example, a 10-mile long 432-strand backbone would have 4,320 strand miles, each of which could be leased separately.[13] Typically, fiber leases have a minimum distance amount and an annual maintenance fee. A wide range of discounts may be offered, including leasing an entire buffer tube within the cable, entire end-to-end strands (rather than a portion), entire rings, and/or for longer terms. If structured as a long-term (20 years

[13] Leasing a portion of a fiber strand can physically strand the rest of that strand. For example, if a 1-mile section of a strand is leased in the middle of a cable, the remainder on each end may be practically unusable. This is another reason for deploying fiber in rings: It reduces risk of stranded strands.

or more) capital lease—also known as indefeasible right to use or IRU—lessees pay the entire lease amount upfront.

Table 6-1. Dark Fiber Lease Rates for Bellingham Broadband Department Revenue Projections

Service Component	Cost	Per
Monthly Dark Fiber Lease	$150	Strand Mile
20-year Dark Fiber IRU	$3,500	Strand Mile
Minimum Lease	3	Strand Miles
Annual Fee	$250	Route Mile

Based on our analysis of the Bellingham market and lease rates in other cities, particularly on the West Coast, the rates shown in Table 6-1 are reasonable. Three scenarios for various levels of dark fiber leasing are shown in Table 6-2. For these scenarios, we assume all lessors lease equal portions of the backbone, which has 144 strands over 44.4 miles for a total of 6,389 strand-miles. We also assume that each monthly lessor has 4 strands, and each long-term capital lessor has 12 strands.

Table 6-2. Dark Fiber Lease Scenarios

	Scenario		
Revenue Factor	1	2	3
Monthly Lessors	5	10	15
Backbone Leased	1%	5%	10%
Annual Revenue	$595,002	$5,950,017	$17,850,051
Capital Lessors	1	2	3
Backbone Leased	10%	30%	50%
Annual Revenue	$2,012,623	$6,037,870	$10,063,116
Total Annual Revenue	**$2,607,625**	**$11,987,887**	**$27,913,167**

ENTERPRISE/WHOLESALE TRANSPORT SERVICES

Rather than separate retail services into commercial and residential, we recommend wholesale transport services with dedicated bandwidth and a service agreement as a separate service from retail. Wholesale revenue may generally come from either leasing capacity—fiber paths and lambdas[14]—or from a revenue share by wholesale customers, i.e., retail ISPs. Generally, enterprise customers pay per circuit—a lit fiber or a portion thereof (a lambda)—connecting one or more sites along with other services such as dedicated internet or firewall. Actual fees can vary greatly depending on market conditions, service levels, and other factors. A simple approach is to charge a premium—such as 150%—of dark fiber rates. See Table 6-3 for revenue scenarios for this business model. Typically, each customer would purchase dedicated internet as well as site interconnections.

Table 6-3. Enterprise Transport Services Revenue Scenarios

	Scenario		
Revenue Factor	**1**	**2**	**3**
Enterprise Customers	20	40	60
Average Path Length (mi.)	2	2	2
Average Paths per Customer	3	4	5
Annual Revenue	**$354,000**	**$944,000**	**$1,770,000**

Revenue share can make sense where the City owns all infrastructure including access and distribution lines. This approach ensures the City has stake in providers' success and providers only pay for actual revenue. Typical revenue shares are between 20% and 40% or around $30 average per residential subscriber. It isn't practical to provide meaningful estimates for revenue sharing due to complex dependencies, including build-out strategy.

RETAIL BROADBAND

Retail broadband involves full operations as well as backbone and distribution infrastructure, transport equipment, and access equipment. The scale of this investment is such that construction will need to be financed, so any estimates must include the cost of money. For this business model we looked at three scenarios based on take rate. All three used the assumptions about services laid out in Table 6-4.

[14] A fiber path is a set of contiguous strands between two or more points. A lambda is a portion or "color" of laser light within a strand.

Table 6-4. Retail Broadband Service Assumptions

Tier	Speed Symmetrical	Percentage of Subscribers	Monthly Charge
Basic	100 Mbps	45%	$39.99
Enhanced	500 Mbps	35%	$69.95
Fast	1 Gbps	19%	$79.99
Ultimate	10 Gbps	1%	$499.99

Table 6-5 lays out costs of infrastructure and equipment for each of the three scenarios, each of which assumes the City finances approximately 90% of the capital expenses. The bottom line is that cumulative end of year cash flow after 30 years is negative, approaching and exceeding the total capital outlays.

Table 6-5. Long-run Financial Performance of Retail Broadband Scenarios

		Take Rate	
Financial Consideration	**25%**	**35%**	**45%**
Fiber Plant/Facilities	$388,009,717	$391,456,438	$394,898,085
Network Equipment & Buildings	$16,312,520	$16,312,520	$16,312,520
Home Equipment	$24,897,172	$34,868,918	$44,825,677
Total Investment	$429,219,409	$442,637,876	$456,036,282
Amount Financed	$388,211,818	$396,029,554	$403,836,359
30-year Cumulative			
Revenue	$265,795,202	$371,239,339	$476,837,578
Costs of Services	$123,557,068	$125,252,692	$126,953,117
Operating Expenses	$49,441,251	$52,524,415	$55,611,911
Total Debt Service	$589,157,918	$599,649,703	$610,126,731
EBITDA	-$326,363,745	-$235,602,531	-$144,681,867
Net Income	-$527,309,845	-$415,269,604	-$319,376,112
End of Year Cash Flow	**-$511,012,434**	**-$415,269,604**	**-$319,376,112**

Figure 6-1 illustrates the fundamental issue with this business model: the scale of investment and consequent debt service keeps them from breakeven. The marginal cash flow changes from negative to positive around year 24 but it is too little, too late for even the most ambitious scenario.

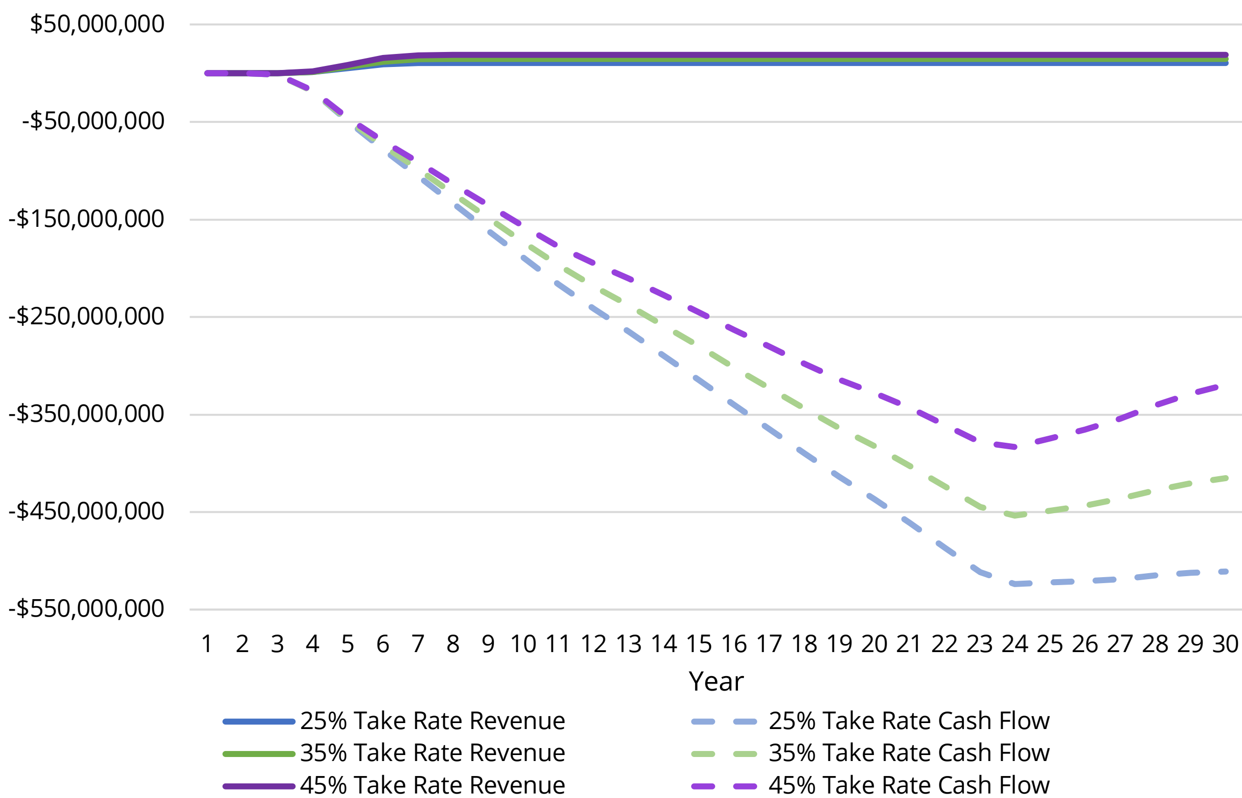


Figure 6-1. Revenue and Cash Flow for Retail Broadband Scenarios Compared

COST REDUCTION TACTICS

There are numerous ways to reduce the actual construction costs. First of all, fiber route optimization could reduce mileage by a third off the road center-line routing used in the conceptual design. Aerial deployment could also greatly reduce deployment costs, although on-going maintenance costs would increase. Information about attachment and make ready costs for utility poles in the area, most of which are owned by Puget Sound Energy, is needed to fully assess this approach. Similarly, much of existing and planned conduit and fiber aligns with the conceptual design backbone route, as shown in but additional, more detailed assessment is needed to determine how many of these assets would be useable. For the financial analysis we assumed 50% of the backbone could be deployed in existing conduit. Use of additional conduit and use of existing fiber could further reduce costs. There are numerous economical, new access technologies and construction methods emerging that could increase flexibility while decreasing costs.

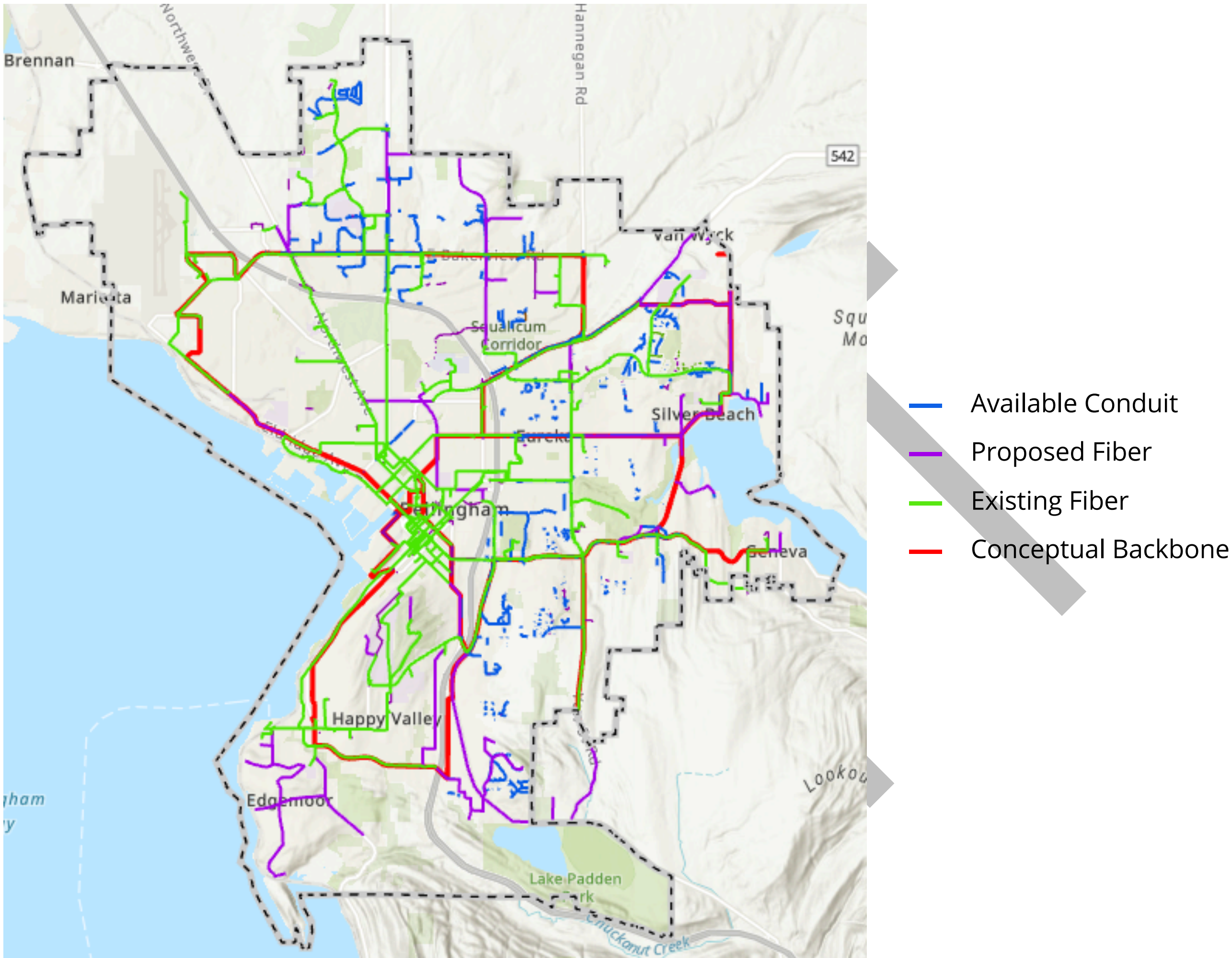


Figure 6-2. Conceptual Backbone Network Design Compared to City of Bellingham Conduit and Fiber Assets

Incremental, opportunistic development can greatly reduce deployment costs, combining network infrastructure with other types of capital projects. This approach requires broadband-friendly policies and consistent practices, and it benefits greatly from an overall strategy. A dedicated network enterprise fund is strongly recommended to ensure capital is available to cover incremental costs. Such a fund can also be used for internal charge backs and external customer fees to fund network development.

Joint-builds and other public partnerships may be the best way to improve financial performance. Such partnerships vary with business model. At one extreme the City may build fiber where providers need it and then lease it to them or have a revenue sharing agreement. Demand-driven development can be very economical but doesn't generally help with digital inclusion. A similar approach is to focus public investment on under-served, low-income areas based on commitment of provider partners to serve those areas. Generally, for these approaches the City should own the assets to ensure maximum return on public investment.

A more practical partnership approach, especially with current availability of private dollars, is to commit to lease portions of infrastructure built by private providers. This can be particularly effective where there are specific locations or clusters that need connectivity. The downside of this approach is that at the end of the lease period the City would have to relinquish the assets and would not own them. There are hybrid approaches such as the City deploying conduit then leasing it to providers with fiber access in lieu of monetary payment.

Of course, grant funding can greatly reduce cost by eliminating the need for financing. Other means to generate capital for broadband development without taking on debt include local improvement districts and special option taxes. The former is best for targeted development and latter is best suited for general improvement, although each must be carefully governed if digital inclusion is an important goal.

7. Conclusions and Recommendations

Strategies for Bellingham to develop comprehensive FTTP network are limited due to the scale of investment required. The local market has the cable/telco retail broadband duopoly, dominated by Comcast, that is common across the country. There are other active providers, including local startup PogoZone, T-Mobile wading into residential wireless broadband, and Whatcom County PUD focusing on under-served areas. The City of Bellingham has extensive assets and capacity to effectively manage those assets. Actionable steps for the City to expand its broadband infrastructure to support a municipal broadband offering to its community are relatively simple depending on strategic priorities.

For this study we assessed market conditions by surveying the community about internet services. Results show there are multiple providers in the area but options for retail broadband are limited to the traditional cable and telephone companies. Comcast, the legacy cable TV provider, serves most of the City with gigabit broadband via their hybrid fiber-coax network. Lumen Technologies, the legacy telephone company, also serves most of the City. Their fiber-based gigabit offering appears to be limited to the west of Route 5. Zip codes of 98226 and 98229 appear to be just DSL capable.

Overall, respondents were happy with their current services, although price and customer service were an issue for some respondents. Although broadband speeds were acceptable in most locations, some neighborhoods had a relatively high number of low-speed tests, indicating low affordability. The neighborhoods of Cornwall Park, Edgemoor, and Lettered Streets had the highest number of low speed tests. Many results did not meet the definition of broadband by Washington's standards, and several fell below Federal standards.

Existing network assets were assessed during this study to determine infrastructure supply and gaps. There is substantial private fiber in the City, portions of which are owned by multiple companies. Several fiber routes connect Bellingham area assets to the Seattle Internet Exchange where top-level peering connections are available. The City of Bellingham's extensive public network assets are currently used for internal City purposes. They could be used to accelerate fiber deployment to less affluent neighborhoods, capitalize on traffic, utility, and other assets, generate revenue, and support of community institutions and economic development.

It seems the City developed its network infrastructure in an as-needed, project-driven manner, which inevitably results in gaps, overlaps, and inconsistencies. A carrier-class network, capable of providing high-capacity/high-reliability services to other parties, requires careful design, consistent equipment, materials, and practices, and management system. While the City has a great base of assets, major improvements are needed to create coherent, consistent, fully usable fiber infrastructure. Processes for thorough evaluation and prioritization are required along with adequate capital financing and staffing.

Our assessment of various broadband business models shows that it would not be economical build a fiber optic network that reaches all premises with debt financing. Leasing conduit and dark fiber have limited revenue opportunities that do not outweigh limits on control and flexibility. A wholesale model focused on business enterprises and retail broadband providers could be both economical and impactful. The key to this is evolving the City's fiber infrastructure into a carrier-class backbone that increases bandwidth availability. This approach enables the City to guide private investment to disadvantaged areas.

Generally, converged and integrated networks make sense because they are more economical. Having separate infrastructure for various applications or user groups multiplies costs. Unconnected networks with separate management systems reduces benefits and reliability. Private carriers understand these points but tend to want their own infrastructure as capital assets increase their stock value. This means huge amounts of capital are necessary for new market entrants. The City of Bellingham has the relatively unusual opportunity to provide shared infrastructure, which could open up the local market to more providers, generate revenue to the City from an under-utilized asset, and improve the availability, cost, and range of network services for the community.

A backbone is simply high-capacity fiber that traverses the area through major corridors. Fiber strands in the backbone are primarily for core and feeder network and transport across the area. Backbone fibers can also be used for a distribution network and laterals into major sites. A clear ring architecture provides high levels of resilience and flexibility, allowing for multiple paths to major sites and distribution hubs. High-strand-count fiber literally multiplies the value of a backbone, including for distribution and access infrastructure, and can be very economically deployed in existing conduit, even when replacing smaller fiber cables.

The essential issue is how much the community values network infrastructure. How much broadband is adequate, and is "adequate" enough for digital inclusion and innovation-based economic development? Public investment in network infrastructure could be a catalyst for additional private investment. It is likely to increase options, drive down costs, and boost performance—and customer service, too. Economic benefits would accrue to the City in the form of lower costs, new revenue, and operational improvements, as well as to residents. All of this depends on the community valuing these outcomes and investing in network infrastructure to ensure the area's digital development. If these are the goals, Magellan Advisors recommends the following:

1. Develop a carrier-class city-wide backbone network infrastructure focused on anchor institutions, business enterprises, and retail broadband providers as customers. Invest in access infrastructure where necessary to achieve digital inclusion in partnership with wholesale customers.
    a. Clearly define goals for the network and develop a plan to achieve them.
    b. Establish an enterprise fund or similar to ensure the network can be developed according to plan.
    c. Engage prospective customers and partners in the network development process.
    d. Transform existing assets into a comprehensive, integrated carrier class network infrastructure.
2. Leverage the existing network, including adding redundancy and resiliency, to build to carrier-class network, monetizing current assets including leasing infrastructure.
    a. Establish a network team that includes economic development "sales and marketing" capabilities.
    b. Conduct detailed assessment of assets and prioritize for improvements and inclusion in the backbone.
    c. Use fiber management system to identify short-term needs and opportunities for network asset development.
    d. Make targeted investment to address specific customer/partner needs and opportunities, particularly as a catalyst for additional investment that increases digital inclusion.
3. Build on existing "Dig Once" policies to create joint-trench and other shared development in the public right-of-way, particularly any relevant capital

improvement projects and private development conditioning to expand network infrastructure.

   a. Condition new develop with network assets, establish a wireless master license agreement, provide expedited permitting, and implement other broadband-friendly policies and practices.
   b. Establish means to inform relevant stakeholders about construction activities, if not already in place, and carrot-and-stick mechanisms for encouraging joint builds (lower restoration costs, construction moratorium following joint build opportunities, etc.).
   c. Integrate broadband into the range of municipal planning processes, including land use, transportation, and water/wastewater.

4. Develop network services as well as infrastructure in an incremental, methodical, strategic manner, focused on the goals from recommendation 1.a.
   a. Invest in software infrastructure and staff capabilities to meet operational and security requirements of this approach.