ctc technology & energy

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Design and Cost Estimate for a Town I-Net

Prepared for the Town of Milton, Massachusetts
January 2019

Columbia Telecommunications Corporation

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1 Executive Summary

In September 2018, the Town of Milton (the Town) engaged CTC Technology & Energy (CTC) to develop a design, cost estimate, and financial analysis related to the feasibility of deploying a Town-owned fiber optic network (I-Net) to serve Town departments, schools, and public safety agencies. As specified in the Town's request for proposals, the proposed network should also be able to serve as a foundation for future applications and uses, potentially including dark fiber leasing and broadband service to sites not now connected by the existing Comcast-owned I-Net. We understand that for 17 years the Town has relied on portions of this six-strand fiber network, and now faces uncertainty about the future of this privately-owned asset.

This report provides our findings, including a recommended design for a network under Town control and ownership that has substantial capacity and strategic physical routing and could serve the Town for decades.

1.1 Methodology

In October 2018, CTC team members and Town officials conducted a strategy session to discuss the Town's goals. CTC also used this strategy session and later phone conferences to confirm the site list, discuss the potential range of current and future uses, learn about the Town's existing network electronics, and discuss other matters related to the study. The CTC team also circulated questionnaires to the Town and School Department about current network uses and future requirements and reviewed the responses from the Town of Milton (representing input from all Town departments including public safety departments), and from the Milton Public Schools.

From these responses, it was clear that robust I-Net connectivity was vital to all Town and School operations, including public safety radio transmissions and public safety cameras. Both the Town and the Schools expressed a desire for greater bandwidth to meet anticipated future needs. As the Town explained in its response: "All avenues of communication are essential. With an upgraded I-Net, dedicated fibers would be welcomed for several services. Examples would be surveillance equipment and public safety radio transmissions." The Town also expressed a desire for "redundancy at all locations," which isn't provided by the current I-Net but would be provided by the design CTC is recommending in this report.

The CTC team then

- Completed an engineering assessment of the existing network, as well as of the assets (including utility poles and existing fire alarm cable attachments) that may enable replacement network construction;

- Developed recommended technical solutions, including a high-level network design and cost estimates with options for redundant routing;
- Developed a financial analysis for the fiber network (including all capital and anticipated operating expenses under two different deployment models) and described how these expenses could be paid back over 20 years as monthly per-site costs to Town departments; and
- Researched third-party pole attachment agreements in other Massachusetts municipalities to inform and familiarize the Town with these processes and provide the Town examples of such agreements. (CTC does not provide legal advice on executing such agreements.)

1.2 Cost Estimate

The recommended design is shown and described in Section 2. CTC estimates that the cost to construct this network—including certain recommended optional routes along Blue Hill Avenue and Pleasant Street, ensuring greater redundancy and resiliency, and providing a more extensive backbone for future uses—would total between $802,000 (low-cost estimate) and $982,000 (high-cost estimate). The range results from several factors related to construction methodology, as described in detail in Section 3. If the Town were to elect to build only a "baseline" network without the optional redundant routes, the cost estimate range would be $635,000 to $784,000. Table 1 summarizes these costs.

Table 1: Summary of Fiber Construction Costs

Scenario	Low-Cost Estimate	High-Cost Estimate
Baseline Network	**$635,000**	**$784,000**
Optional Redundant Routes	167,000	198,000
Total With Redundancy	**$802,000**	**$982,000**

In addition, we estimate a cost of $75,000 for new core electronics, which are necessary to aggregate connections over the fiber network (see Section 2.3.4). As noted in Section 2.3.4, the Town would need to pay the cost of edge site switches (estimated at $77,500) in any case, even if it continued to use the Comcast fiber or lease managed data services from a commercial provider.

1.3 Financial Analysis

We next performed a financial analysis encompassing the costs of network deployment, operations, maintenance, and financing using a variety of assumptions provided in Section 4. Table 2 summarize the costs over 20 years on an annual and monthly per-site cost for the 19 sites, encompassing both the fiber and core electronics.

Table 2: Town I-Net Monthly Cost Summary

Scenario	Monthly Per-Site Cost	Annual Cost
High-Cost With Redundancy	$1,000	$228,000
Low-Cost With Redundancy	$950	$217,000
High-Cost Without Redundancy	$930	$212,000
Low-Cost Without Redundancy	$890	$203,000

1.4 Advantages Over Leased Services

The Town-owned network proposed in this report offers the Town certain advantages over the alternative—commercial leased services[1]—including a higher level of control over the network and the ability to scale the network as data demands increase and new applications emerge which leverage fiber. A robust, reliable, and secure fiber network supports many current and future technologies and capabilities, from Smart City applications to enhanced first responder connectivity.

Leased services, of course, offer the advantage of lower upfront costs, but in our estimation the advantages offered by a Town I-Net outweigh the disadvantages. Leased services present no opportunity for the Town to increase its capabilities without incurring higher recurring fees or additional capital investment.

Additional benefits are possible. Once a Town-owned network is in place, the Town may be able to generate additional revenue by leasing out spare fiber strands. The cabling deployed in our network design contains 288 strands, which is more than the Town will need in the immediate future. Excess strands, which add a very small amount to the overall project cost, could be leased to businesses needing enterprise-grade services or private providers (either new market entrants or incumbents) who may then provide services to residents and businesses. (To be clear, our analysis is conservative and does not build in any assumptions about such leasing revenue.)

[1] In CTC's experience, the cost of commercial services can range from $60 per month for a broadband internet connection without either a service level agreement (SLA) or any ability to create a private network, to several thousand dollars per month for a 10 Gbps connection with an SLA.

2 Fiber Network Conceptual Design and Cost Estimate

This section details technical recommendations, provides a high-level design, and explains costs. The costs in this model are comprehensive and include labor, replacement electronics (even though the Town would have to pay for this in any case at Town sites served by any network), and fiber maintenance costs for the lifetime of the model. The resulting cost estimates are a key part of the business case analysis presented in Section 3.

We assessed the Town's existing network, including network schematics provided by the Town, and used this as a starting point in our analysis and resulting design. The technical approach reflected in the design is intended to meet the Town's internal connectivity needs today and well into the future, and to provide a foundation from which the Town could promote access to innovative and cost-effective broadband services for the anchor institutions, businesses, and residents of the Town. The fiber network would replace the functionality currently provided by the Comcast I-Net, and greatly expand the existing I-Net's capabilities for expanded public purposes.

While we understand that the primary goal of the Town's fiber network is to support current and likely future data communications needs by existing municipal users, the design reflects the secondary goal to create infrastructure that could provide dark fiber leasing opportunities and potentially be a foundation for future wired or wireless broadband services to residents, businesses, and others in the Town.

(Exploring the feasibility or business model for such an endeavor is beyond the scope of this report, but CTC has deep experience in this area. The lack of Verizon Fios service in Milton makes such a concept more feasible and worthy of investigation than if both Comcast Xfinity and Verizon Fios services were available. It is also worth noting that wireless carriers are seeking to install more and smaller antennas, often called "small cells." To provide the data backhaul to these smaller and more densely deployed devices, the wireless carriers—or infrastructure providers serving the carriers—may, in the future, want to lease dark fiber from a variety of sources, including municipal fiber networks.)

2.1 Technical Approach and Cost Considerations

In this section, we provide an overview of the technical approach and cost estimates developed to examine the feasibility of the Town constructing a fiber network.

The priorities informed by the Town's input and targeted by this conceptual design include:

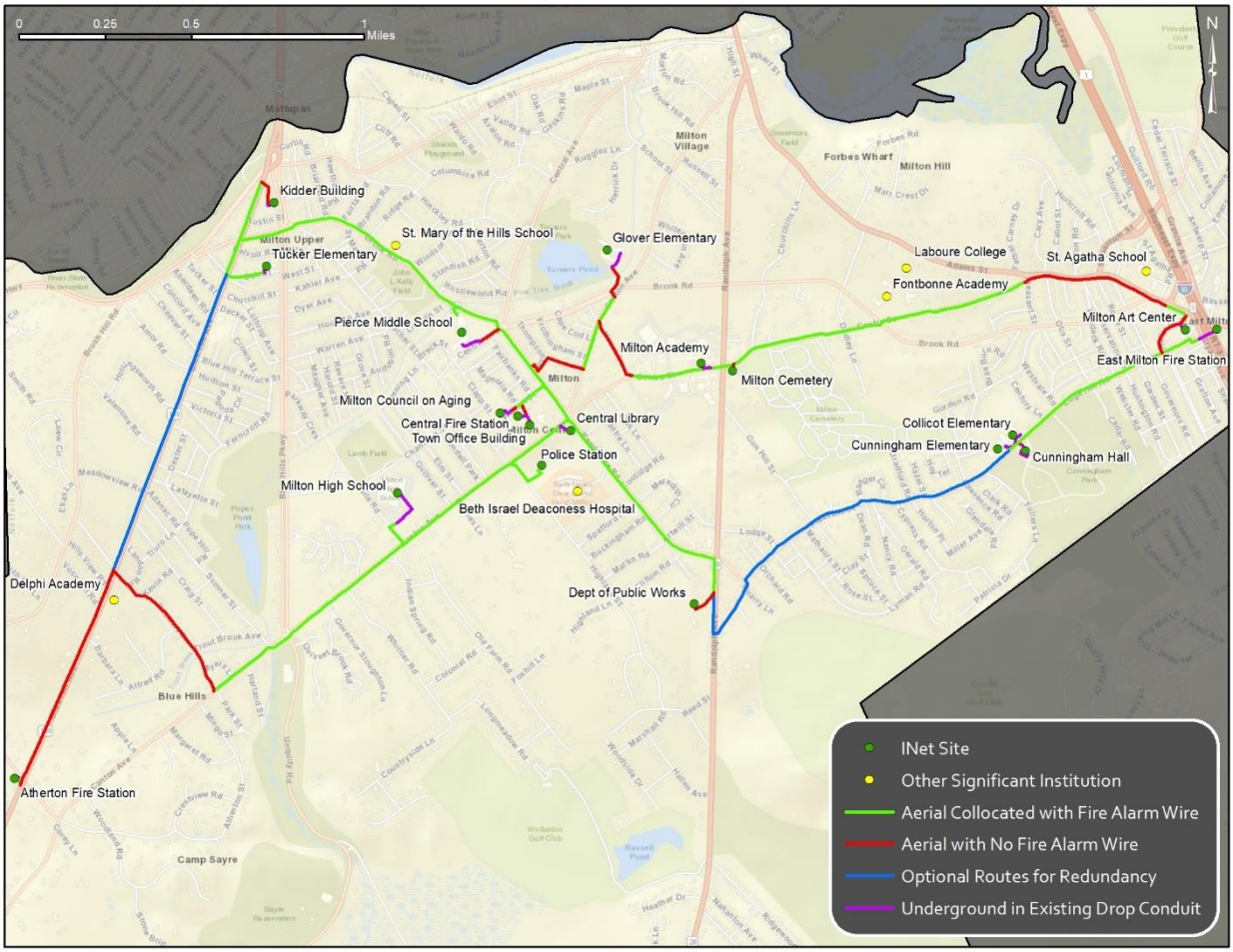
- Provide fiber connectivity to 19 Town, School, and other community anchor institutions;

- Route fiber paths near eight additional significant institutions that may be opportunities for future connectivity to the Town network, or that might be targets of commercial providers seeking to serve these entities;
- Select routes that minimize construction costs associated with utility pole "make-ready" construction and/or more expensive underground construction, as discussed below;
- Provide adequate capacity within the backbone for future uses, including fiber leasing to a commercial broadband provider and/or directly to local businesses;
- Utilize existing I-Net site building entry points where feasible, particularly where spare capacity in existing underground conduit may be available;
- Provide optional diversity of physical fiber paths to facilitate increased network resiliency through redundant connections to core network sites (namely, the Town Office Building and Pierce Middle School).

In addition to these priorities, the design was further optimized to follow existing routes for the Town's fire alarm call box system wiring to the extent this did not conflict with other priorities. This alignment may offer opportunities to: 1) leverage existing fire alarm wire attachment locations on utility poles to potentially minimize utility pole make-ready construction costs; and 2) perform upgrades and/or maintenance to the fire alarm system more cost-effectively in conjunction with the fiber construction.

The resulting physical architecture of the network is illustrated in Figure 1 (see Appendix A for larger format network maps). This fiber design, while not fully vetted in the manner necessary for permitting and construction, is likely to closely approximate a final design meeting the stated design objectives.

Figure 1: System-Level Fiber Network Architecture



A range of logical topologies are feasible given the physical architecture of the proposed network. Depending on fiber strand splicing configurations, connections can be established with or without route diversity over backbone rings (where available) and provide dedicated paths between any sites without the need for "patching" between intermediate sites. The cost estimates are based on a flexible approach to splicing and fiber termination, providing a backbone consisting of a 288-strand fiber optic cable.

Beyond the physical fiber cable routing, there are several technical design and construction attributes that impact construction and operating costs, discussed in the following sections.

2.1.1 Fiber Strand Count

The number of individual fiber strands provided in a single cable correlates to the capacity of the cable. Due to the vast effective bandwidth of fiber, it is feasible to scale the rate of data transmission carried by even a single fiber strand to meet the Town's foreseeable needs. However, the cost of network electronics increases exponentially with this capacity. On the other

hand, the material cost of fiber strands represents a very minor component of the overall cost of fiber construction (about $0.01 per strand per foot, compared to $10 to $20 per foot for the total cost of typical aerial construction). Given this, it is prudent to install a cable of sufficient size to meet any conceivable requirements to ensure that these needs can be met with the lowest-cost configuration of electronics possible.

Given the number of sites to connect on the network, the potential desire to provide redundant connections to some or all Town sites, we recommend that a 288-count fiber cable be installed along all backbone paths. A 288-count cable will provide the strand capacity needed to connect all the sites using low-cost electronics and will leave spare capacity for future uses. In the future, if additional fibers are needed, the Town can establish aggregation sites to combine network traffic from multiple end locations. This approach will free up fiber in the backbone for additional uses.

Moreover, the basic physical path construction, whether in underground conduit or attached to messenger strand on existing utility poles, will provide scalability to support additional cables installed in the future at a fraction of the cost of the initial installation.

2.1.2 Aerial Construction and Utility Pole Make-Ready

Aerial (or "overhead") construction, in which fiber optic cables are supported by existing utility poles, can sometimes provide the lowest cost option for construction of fiber optic infrastructure. The construction can occur rapidly, requires minimal disruption to the public rights-of-way (ROW), and does not require the costly restoration to paved surfaces associated with underground construction methods.

Utility pole condition determines the degree to which aerial construction is viable. The number of existing attachments, age of the poles, and size of the poles are all factors that impact what level of effort and cost is required to prepare a utility pole for a new attachment. This "make-ready" work must be performed to ensure minimum physical separations are observed between different types of attachments on the pole, between the ground and the communications cables, and between other nearby structures and the communications cables[2]. Where make-ready is not required, aerial construction of fiber may cost as little as $5 per foot for labor and materials – likely 50 percent (or much more) less than the cost of new underground construction – but may also be substantially more expensive than underground construction depending on the degree to which make-ready is necessary.

[2] All Dielectric Self-Supporting (ADSS) cables, comprised of non-conductive materials and requiring no metallic messenger strand for support, can sometimes be installed within close proximity to the electric distribution cables on utility poles by the utility pole owner for their own purposes.

The area on a pole in which communications cable can be attached to maintain minimum midspan clearance to ground (usually requiring an attachment height of 16 feet or more), while also maintaining a minimum clearance of 40 inches to the lowest electrical distribution cable, is referred to as the "communications space." These clearances are required for the safety of communications line workers and the public, as well as to reduce the risk of cable damage due to tall vehicles passing beneath the cables. These clearances are generally determined by the National Electric Code (NEC), the National Electric Safety Code (NESC), and by the pole owner's own standards.

In many cases, existing attachments may need to be shifted in height to make room for the new attachment. Where poles are short, the communications space is at full capacity, or the utility pole is unable to safely support the additional structural load of the new attachment, pole replacements are required. Traditional make-ready involving moving attachments on a pole may cost only a few hundred dollars per pole, adding perhaps only $2 to $3 per foot to the total construction cost. On the other hand, utility pole replacement costs—sometimes exceeding $15,000 per pole due to the complexity and safety precautions associated with poles supporting electric transmission lines—can easily drive per-foot costs above that of underground construction.

Once the make-ready is complete, a new messenger strand can be placed to support one or more fiber optic cables. The messenger strand is a strong steel cable attached to the poles and tensioned between each span. The communications cable is generally "lashed" to the messenger strand with a thin and flexible steel lashing wire so that nearly all the strain is transferred to the messenger strand, rather than to the fiber optic cable. The messenger must be tensioned to limit the sag of the lashed cable and messenger strand to ensure to that the vertical clearance above the ground and other obstructions are met, and that undue strain is not placed on the cable or clearances because of sag (particularly when loaded with ice during cold weather).

The proposed design reflects an approach that maximizes aerial construction for cost savings, and cost estimates examine the impact of variable factors related to the use of the existing utility pole attachment location for the Town's existing fire alarm call box wiring and variances in the likely amount of make-ready construction, as discussed in Section 2.3.

2.1.3 Utility Pole Attachment Licensing

Because the Town does not own utility poles and is not a telecommunications carrier or cable television provider, it is not provided any particular rights or protections under federal or state law to ensure its ability to make new attachments for its own purposes in a timely and cost-effective manner. As such, the Town would be considered a third-party attacher and would need to negotiate a pole attachment agreement with the utility pole owner(s). These agreements will determine the Town's responsibility for incurring costs related to make-ready, as well as ongoing

utility pole licensing (or lease) fees. Although different in each market and with each pole owner, typical utility pole lease rates fall in the broad range of $10 to $25 per pole per year. For sake of our financial analysis, we are assuming a cost of $15 per pole.

In the case of jointly owned poles, the Town will need agreements with both owners – likely Eversource and Verizon. (Section 6 describes how this agreement process worked in the Town of Leverett, Massachusetts, as a representative example. In addition, we have provided copies of the Leverett agreements in the appendices.) Pole ownership must be validated in a later phase of the network design process involving a pole-by-pole field survey.

2.1.4 Underground Construction

Underground construction generally involves trenching or horizontal directional drilling to place communications conduit in which the fiber cable can be placed. This process involves significant costs associated with excavation to locate existing utilities to prevent inadvertent damage and restoration of any disturbed surfaces.

Underground construction is likely only required for the Town's network in a few locations where existing utility poles do not exist, and possibly in certain cases where existing utility pole conditions are not conducive to cost-effective construction.

Key factors influencing underground construction costs include the following:

Conduit size and quantity –While it is possible to install fiber cable directly underground, this complicates installation and makes repairs difficult to implement without creating permanent impairments to the communications path. Instead, the cost estimates are based on the installation of flexible plastic conduit that provides a path into which fiber cable can be installed, allowing for cable slack to be pulled to accommodate repairs, or for new cable to be installed to expand capacity. Cost estimates are based on the placement of two conduits along all backbone routes to provide capacity for future scalability, conduit leasing, etc. It should be noted that placing additional conduits simultaneously results in relatively minor increases in cost, within limits. Depending on material prices, 2-inch conduit is preferable along backbone routes, as it can accommodate one or more additional large-strand-count fiber cables in each, with sufficient space for placing additional smaller cables to for purposes of placing "lateral" connections to future locations.

Underground construction methodology—A wide range of methodologies are available for underground construction of conduit. Trenching is common in unpaved areas, allowing for relatively quick installation of any number of conduits. Where paved surfaces are concerned, this requires special cutting equipment and generally expensive restoration.

More recently, "micro-trenching" has begun to gain popularity, wherein narrow cuts are made at a depth of less than 12 inches, generally along the edge between the asphalt paving and concrete curb or gutter. These micro-trenches support placement of a narrow, specialized conduit, and the cuts can generally be restored quickly with common asphalt patching materials. As micro-trenching is relatively new, its long-term impact on total cost of ownership is not well understood, with reduced upfront costs in some circumstances, but potentially higher costs for maintenance and repairs due to the shallow placement of the conduit.

Our cost estimates are based on the placement of conduit using horizontal directional drilling (or "directional boring"). Directional boring allows conduit to be installed long distances, ranging from several hundred to over 1,000 feet at a time, between two small pits dug on either end. One advantage of directional boring is the ability to place conduit at varying depths to avoid existing utilities. Another advantage is that the surface above the bore does not have to be disturbed, except at the entrance and receiving pits, as well as at small "test pits" dug to verify existing utilities to prevent accidental damage where the bore will cross.

Although generally considered more expensive in the past, labor costs for directional boring are now comparable to that of trenching through unpaved surfaces, while reducing surface restoration costs. Furthermore, unlike micro-trenching, large conduits can be placed to offer longer term scalability. The cost benefit of directional boring in terms of reducing restoration is diminished as congestion of existing utilities increases. Whereas directional boring and conduit placement in relatively uncongested and unpaved areas may cost less than $15 per foot for large underground construction projects, we anticipate per-foot costs to average approximately $25 per foot for construction crew mobilization and labor for the small amounts of underground construction that may be required.

Handhole placement and size—Handholes are enclosures installed underground in which conduit terminates for providing access to conduit for installing cable, as well as to house cable splice enclosures and cable slack loops required for future repairs. Handholes generally must be placed at intersections of multiple conduit paths, or where the conduit path makes a sharp change in direction. Handholes provide important access points to underground conduit, enabling expansion of the conduit infrastructure (i.e., installation of a lateral connection to a new network location) without disrupting conduit or installed cables. While cable can be pulled upwards of several thousand feet at a time, cost estimates for the Town network assume installation of handholes every 500 feet on average, ensuring that the infrastructure supports cost-effective expansion to new sites, including access to businesses that might be targets of commercial network operators seeking to lease Town fiber (or conduit space).

2.1.5 Special Crossing Fees

The network cost estimates assume that the Town will pay no encroachment fees for construction along or under Town and State roads but may incur bridge crossing engineering and construction fees totaling in the range of $15,000 to $25,000 for the one crossing over I-93 in East Milton to reach the East Milton fire station. This includes civil engineering designs for conduit attachment to the bridge structure, and special construction involving more complex equipment, traffic control, and engineered installation materials.

2.2 Outside Plant Review Findings

To determine certain key metrics that impact aerial construction costs, CTC engineers performed a survey of Milton via Google Earth Street View. Our surveys informed the route selections reflected in the system-level design. We estimated necessary make-ready on poles and pole replacement—all of which have been factored into the design and cost estimate. Additionally, CTC used Comcast cable television design maps provided by the Town to assist in determining the most likely routing and building points of entry for I-Net site laterals.

2.2.1 Make-Ready Assessment

Given our preliminary assessment of the pole condition along the proposed fiber routes, we estimate that more than 90 percent of the network can be constructed overhead cost-effectively with attachments to existing utility poles in the communications space, subject to a third-party attachment agreement(s) with Verizon and/or Eversource, to drive the upper range of our cost estimates.

Table 3 summarizes a conservative assessment of the utility pole conditions determined through our field and desk survey to drive the upper range of our cost estimates.

Table 3: Field Survey Findings

Attribute	Assumption
Aerial construction percentage	94%
Poles per mile	45
Cost per move of existing attachment	$400
Poles potentially requiring make-ready	35%
Average number of existing attachments on poles requiring make-ready	2.5
Poles requiring replacement	< 1%
Average estimated pole replacement cost	$10,000

Using these make-ready assumptions, we determined an average make-ready cost of $3.84 per foot, which assumes that each attachment owner must independently perform the make-ready work for their attachments[3].

We noted that the quality of the poles and pole attachments along proposed routes varied—as they do in many localities—but are in good condition overall. We expect that more than two-thirds of poles would support an additional cable in the communications space with little make-ready and few pole replacements required. There are limited segments of the proposed routes in which there are three to four existing attachments that would need to be rearranged (Figure 2), and in a few cases, poles replaced (Figure 3). Pleasant Street, for example, has some of the more congested poles, and was thus incorporated into the design primarily as an option to support redundant connections. In cases where pole replacement percentages are low, it is generally preferable (and in some cases required by the pole owner) to constructing underground for a short distance equivalent to only a few pole spans.

2.2.2 Fire Alarm Call Box Wiring

The Town's fire alarm call box system has an existing wire attachment to many of the utility poles in the Town. As noted, the proposed network design routes were aligned with these to the extent that this alignment would not impact other higher priority design objectives.

It may be possible to install a new messenger strand in the same location on the utility pole as the existing fire alarm wire attachment, to which the existing (or replacement) fire alarm wire and new fiber cable could be lashed together. In limited cases, this might provide a mechanism for avoiding more substantial make-ready costs. We are not recommending this approach as a cost savings mechanism in general, as it likely would cost the same or more as a new attachment in the communications space on most poles given the overall good condition of the poles. Also, we have concerns that there may not be enough slack in the wire to allow it to be easily moved, and in some cases may necessitate remediation of what appear to be NEC clearance violations related to this attachment.

Thus, using the fire alarm wire attachment is likely to provide limited or no cost savings in most locations, but may offer an opportunity to more cost effectively perform maintenance to, or replace, the fire alarm wire. Costs associated with this maintenance or replacement are not included in the cost estimates detailed in Section 2.3.

The following images show examples of Milton's pole lines we reviewed as part of our survey.

[3] Although uncommon, "one-touch" make-ready in which a single authorized contractor is allowed to perform the make-ready for all attachment owners can reduce cost and time required.

Figure 2: Congested Pole - Make-Ready Will Be Necessary

(Adams Street and Rowe Street)

Figure 3: Congested Pole / NEC Clearance Violations - Likely to Require Replacement

(Blue Hill Avenue and Robbins Street)

2.3 Cost Estimates

CTC estimates that the cost to construct the fiber network described in the previous section will total between $635,000 (the low-cost estimate for a baseline network without redundant routes) and $982,000 (the high-cost estimate for a network that includes the redundant routes), not including optional network electronics upgrades. This range is produced through the consideration of several factors related to construction methodology and optional network design attributes.

We have provided our complete cost estimates in Excel format in Appendix C (high cost) and Appendix D (low cost).

2.3.1 Outside Plant Construction Costs

Construction of the physical fiber optic network involves the many different processes described in preceding sections, involving several variables that can widely impact certain cost components. The prevalence of uncongested utility poles is conducive to cost-effective aerial construction in Milton, allowing for greater predictability of construction costs. Subject to negotiation of suitable utility pole attachment agreements, the most likely areas of risk to project costs in Milton are visible aboveground, in contrast to predominantly underground networks in which costly and time-consuming utility locating and geotechnical analysis are required to remove uncertainty.

Our cost estimates are provided as a range formed from toggling key variables determined to be significant to certain design choices and construction approaches. We present the following two main scenarios to establish reasonable upper and lower bounds to the likely construction costs:

- ***High-Cost Estimate*** – assumes 1) all aerial construction will involve new utility pole attachments in the communications space, entailing a conservative estimate of likely make-ready work required; and 2) space in existing conduit for I-Net site building entrances is unavailable, requiring construction of new conduit where applicable.

- ***Low-Cost Estimate*** – assumes 1) up to half of the aerial construction routes can be accommodated with little or no make-ready by using the existing fire alarm wire attachment location on corresponding utility poles to install a new messenger strand to support both the new fiber cable and fire alarm wire; 2) the remaining aerial construction will involve new utility pole attachments in the communications space, entailing a conservative estimate of likely make-ready work required; and 3) existing conduit for I-Net site building entrances is usable and has existing space to accommodate new lateral fiber cables, where applicable.

For both scenarios, we break out the cost for optional fiber route segments that would facilitate diverse paths for redundant connections, forming the two interconnected fiber rings illustrated

in Figure 1 and Appendix A. This enhancement is not necessary to replace the basic functionality of the existing I-Net but would allow for more resilient network architectures to enhance the reliability of critical services.

The cost estimates are summarized in the following tables.

Table 4: Summary of Fiber Construction Costs

Scenario	Low-Cost Estimate	High-Cost Estimate
Baseline	**$635,000**	**$784,000**
Optional Redundancy	167,000	198,000
Total	**$802,000**	**$982,000**

These estimates encompass several key cost components derived from estimated unit pricing and unit quantities associated with the system-level design. These cost components reflect a turnkey implementation of the physical fiber optic architecture, consisting of the following:

- **Engineering:** Includes system-level architecture planning, preliminary designs and engineering field walk-outs to determine candidate fiber routing; development of detailed engineering prints and preparation of permit applications; and post-construction "as-built" revisions to engineering design materials.
- **Project Management / Quality Assurance**: Includes expert quality assurance field review of final construction for acceptance, review of invoices, tracking progress, and coordination of field changes.
- **General OSP Construction**: Consists of all labor and materials related to "typical" aerial OSP construction, including messenger strand and cable placement, utility pole make-ready construction, and slack loop installation; includes all work area protection and traffic control measures inherent to all roadway construction activities.
- **Railroad, Bridge, and Highway Crossings**: Consists of specialized engineering, permitting, and incremental construction (material and labor) costs associated with crossings of railroads, bridges, and interstate/controlled access highways – we note that only a single bridge crossing—over I-93 in East Milton—is anticipated to be required for the Milton I-Net.
- **OSP Fiber Splicing**: Includes all labor related to fiber splicing of outdoor fiber optic cables.
- **Fiber Termination/Building Entrance**: Consists of all costs related to fiber lateral installation into network sites, including OSP construction on private property, building

penetration, inside plant construction to a typical backbone network service "demarcation" point, fiber termination, and fiber testing.

Table 5 and Table 6 provide the cost breakdowns for the High-Cost and Low-Cost scenarios, respectively.

Table 5: Component Breakdown of High-Cost Fiber Construction Costs

Cost Component	Backbone	Laterals	Redundancy	Estimated Cost
Engineering	$56,000	$17,000	$19,000	$92,000
Project Management / Quality Assurance	12,000	4,000	4,000	20,000
General Outside Plant Construction	386,000	157,000	135,000	678,000
Railroad, Bridge, and Interstate Crossings	-	19,000	-	19,000
Outside Plant Fiber Splicing	21,000	23,000	24,000	68,000
Fiber Termination / Building "Entrance"	-	89,000	16,000	105,000
Fiber Construction Subtotals	**$475,000**	**$309,000**	**$198,000**	**$982,000**

Table 6: Component Breakdown of Low-Cost Fiber Construction Costs

Cost Component	Backbone	Laterals	Redundancy	Estimated Cost
Engineering	$56,000	$17,000	$19,000	$92,000
Project Management / Quality Assurance	12,000	4,000	4,000	20,000
General Outside Plant Construction	320,000	74,000	104,000	498,000
Railroad, Bridge, and Interstate Crossings	-	19,000	-	19,000
Outside Plant Fiber Splicing	21,000	23,000	24,000	68,000
Fiber Termination / Building "Entrance"	-	89,000	16,000	105,000
Fiber Construction Subtotals	**$409,000**	**$226,000**	**$167,000**	**$802,000**

2.3.2 Network Electronics

Existing equipment used to light the existing I-Net fiber is suitable for migration to the new I-Net fiber without replacement or upgrade. Although physical routes may differ, the logical topology of the network can be retained by splicing fiber strands to mirror the current configuration. The fiber optic design is flexible, providing sufficient strand counts to support a variety of network electronic architectures. Additional application-specific connections can be activated at any time

now or in the future over dedicated fiber strands to enhance network security, simplify network management, and/or deploy new services, such as:

- Dedicated video surveillance feeds
- Separate network for public Wi-Fi
- Storage Area Network (SAN) fabric connections for data replication and disaster recovery
- Backhaul circuits for public safety radio

School network electronics have recently been upgraded, and support 10 Gbps capacity between all sites to meet current and near-term future needs. Furthermore, this equipment can continue to be upgraded according to normal refresh cycles without necessitating additional costs resulting from the I-Net fiber replacement.

Similarly, the Town network leverages equipment that could be migrated to the new I-Net fiber but is likely reaching the end of its useful lifecycle in terms of manufacturer support and equipment age. The main network switch platform supporting the Town network will begin to lose significant manufacturer support at varying levels beginning in October of 2019[4]. Newer versions of similar hardware will provide a tenfold increase in capacity (from 1 Gbps to 10 Gbps connections over I-Net fiber) at an equivalent cost to the current deployment. Moreover, the network can be configured to offer enhanced survivability by leveraging redundant equipment and logical link topologies in conjunction with diverse fiber routes to virtually eliminate the possibility of network outages due to fiber cuts and equipment failures.

Thus, we offer a recommended architecture, candidate bill of materials, and budgetary cost estimate for a refresh of the Town network electronics to more fully take advantage of diverse fiber paths and mitigate risks posed by aging equipment, which can be deployed to coincide with the fiber network to facilitate a more graceful transition with less disruption to network services and end-users.

2.3.3 Recommended Town Network Electronics Architecture

The recommended architecture places core switches at both core network sites – Pierce Middle School and the Town Office Building – capable of supporting 10 Gbps connections to all edge sites and 40 Gbps or greater connections between core sites.

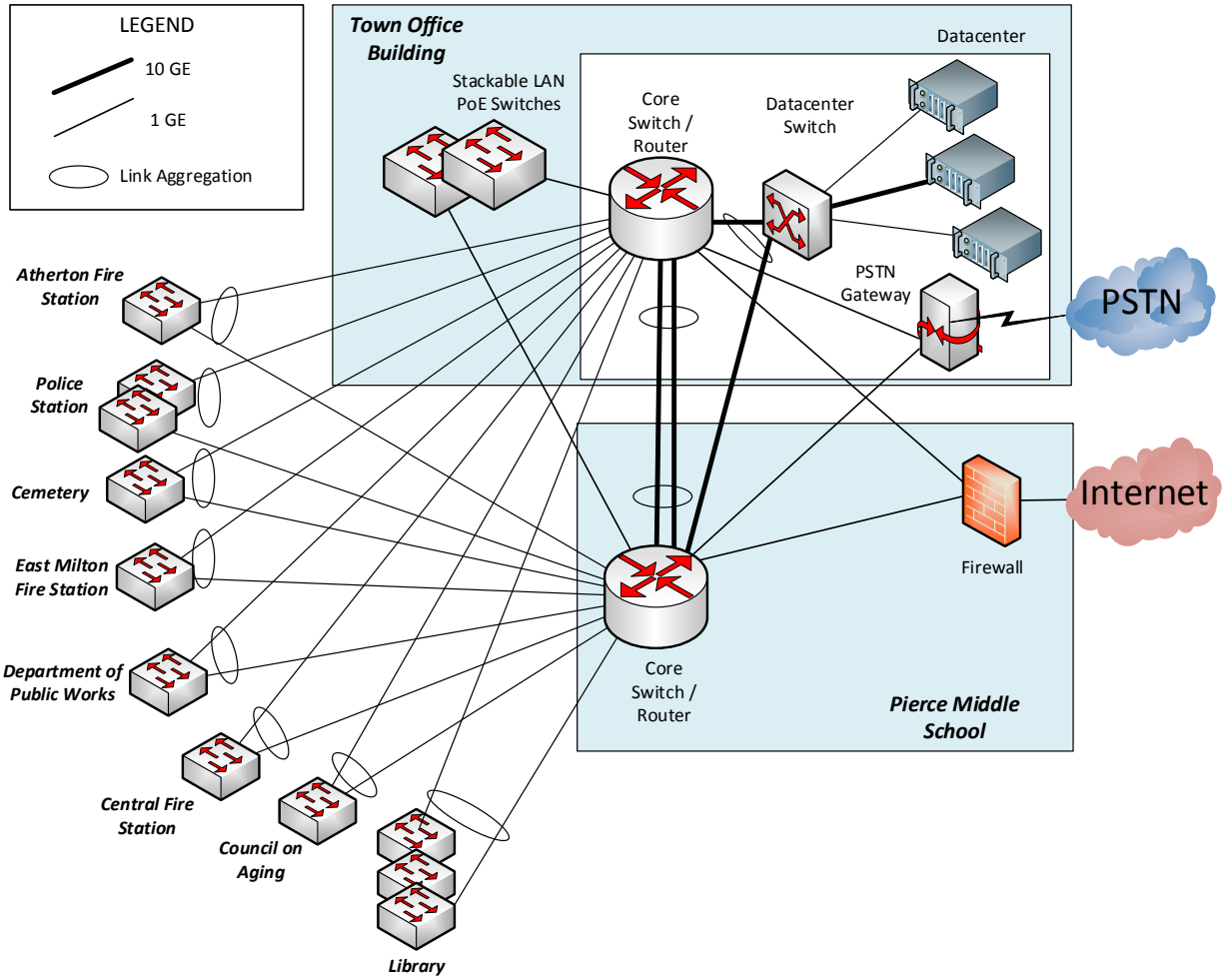
The network core switches should allow for multi-chassis switch virtualization (for example, the Cisco Catalyst 4500-X or Catalyst 9500) to support full core redundancy necessitating complicated switch configurations. The two core switches can be interconnected over link aggregated,

[4] Cisco announced end-of-life (EOL) status for the Catalyst 3570-X and Catalyst 3650-X platforms on October 31, 2015. Hardware support began to diminish beginning on October 30, 2017 with the End of Software Maintenance Releases. Further significant hardware EOL dates are as follows: 1) End of Vulnerability/Security Support on October 30, 2019; and 2) Last Date of Support for hardware replacements on October 31, 2021.

redundant 10 Gbps links (scalable to 40 Gbps or more). This eliminates the need for higher-layer protocols – Rapid Spanning Tree Protocol (RSTP), Virtual Router Redundancy Protocol (VRR), etc. - to leverage switch/router redundancy for automatic failover in the event of fiber break or core switch failure.

Edge switch replacement can leverage newer hardware capable of redundant 10GE uplinks and GE access layer connections (for example, Cisco Catalyst 2960-X or Catalyst 9200). These switches can support aggregated GE or 10 GE uplinks to the core switches, carried over diverse paths within the fiber backbone to each of the two core sites.

Figure 4: Candidate Town Network Architecture



2.3.4 Network Electronics Cost Estimates

To develop a budgetary estimate, we used the architecture outlined in the previous section. **We estimate that the total cost for network electronics will be $152,500[5] as shown in Table 7.** A sample bill of materials is provided in Appendix E. The following table breaks down the estimated cost of these network electronics, installation service, and associated support contracts. (As noted below, the Town would need to pay the $77,500 cost of edge site switches in any case, even if it continued to use the Comcast fiber.)

[5] In addition, we estimate annual maintenance contracts at $3,300 for the redundant core switches and $4,200 for the edge site switches.

Table 7: Summary of Network Electronic Costs

Cost Component	Redundant Core Network Switches	Edge Site Switches *(w/redundant uplinks)*	Total
Hardware	$60,000	$62,000	**$122,000**
Installation	15,000	15,500	**30,500**
Total	**$75,000**	**$77,500**	**$152,500**

We note that most of the estimated costs for network electronics are not attributable to the I-Net fiber replacement project from the perspective of a financial analysis, because a refresh of existing equipment would be required with any likely alternative approach to meeting the Town's network needs and would require a similar configuration of equipment – whether Town-owned infrastructure or leased services. Thus, only the new core switches ($75,000 plus $3,300 in annual maintenance contracts), which are necessary to aggregate connections over the fiber network, are factors in the financial analysis presented in Section 3.

3 Financial Analysis

This section investigates the financial implications of a new Milton I-Net, including necessary financing, capital additions, and network operations and maintenance expenses. Our analysis describes the total cost per site to finance, deploy, maintain, and operate the network. These per-site costs provide the Town a valuable metric—a monthly per-site cost over 20 years—to understand the cost of deployment and operation.

Further, the costs in this model are comprehensive, including labor, replacement electronics, and fiber maintenance costs for the lifetime of the model.

Our analysis considers two potential deployment models; one with redundancy (the optional routes along Blue Hill Avenue and Pleasant Street) and one without. For each, we have analyzed both a high- and a low-cost scenario, as discussed in Section 2.3. The primary difference between these scenarios is the cost to deploy the fiber OSP (outside plant), which impacts the necessary bond and depreciation reserve amounts. Otherwise, key assumptions including labor costs, operating and maintenance expenses, and network electronics costs remain the same between the high- and low-cost scenarios. We also further analyzed the impact of the Town only deploying the baseline network (without the optional redundant paths).

We have summarized the monthly per-site costs for the High- and Low-Cost Scenarios, as well as each model without redundancy in Table 8.

Table 8: Town I-Net Monthly Cost Summary

Scenario	Monthly Per-Site Cost	Annual Cost
High-Cost With Redundancy	$1,000	$228,000
Low-Cost With Redundancy	$950	$217,000
High-Cost Without Redundancy	$930	$212,000
Low-Cost Without Redundancy	$890	$203,000

3.1 Operating and Maintenance Expenses

The cost to deploy a Town I-Net goes far beyond fiber implementation. Network deployment requires maintenance and technical operations, support personnel, and other functions. Please note that the analysis does not include the implementation and operations and maintenance costs for the network edge electronics, because these remain the same as with the existing I-Net.

The model assumes a straight-line depreciation of assets, and that the OSP and materials will have a 20-year life span. We assume a 10-year depreciation on core electronics. The model includes a depreciation reserve account of 30 percent in the high-cost scenario and 35 percent in the low-cost scenario to fund necessary replacements.

While the Town network will require additional personnel for maintenance, this model assumes that the Town will use its existing staff to cover most labor expenses. We assume the Town will need to acquire a 0.5 full time-equivalent (FTE) geographic information systems (GIS) support position.

Salaries and benefits are based on estimated market wages, and benefits are estimated at 30 percent of base salary. We have applied a 2 percent labor expense escalation factor, resulting in $52,000 in labor expenses in year one, growing to $61,000 in year 10.

Additional key operations and maintenance assumptions include:

- Locates and ticket processing are estimated at $150 per month per mile of underground fiber, resulting in $1,100 annually.
- Insurance is estimated at $25,000 annually.
- Fiber maintenance and repair fees are estimated at $600 per year per mile, resulting in:
    - For the redundant option
        - $1,600 in year one,
        - $4,700 in year two, and
        - $6,300 from year three on.
    - For the non-redundant option
        - $1,200 in year one,
        - $3,700 in year two, and
        - $5,000 from year three on.
- Legal and consulting support is estimated at $20,000 in year one only.
- Contingency is estimated at $10,000 annually.
- Attachment fees are estimated at $15 per year per pole, or $5,200 annually.
- Training is estimated at 2 percent of total labor costs, or roughly $1,100 annually beginning in year three.
- Annual maintenance contract of $3,300 per year starting in year 2.

We have included a summary of these costs for the first 10 years of the 20-year model for the options with redundancy in Table 9.

Table 9: Town I-Net Operating and Maintenance Expenses

Operating and Maintenance Expenses	Year 1	Year 3	Year 5	Year 10
Locates and Ticket Processing	$300	$1,100	$1,100	$1,100
Insurance	25,000	25,000	25,000	25,000
Fiber Maintenance and Repairs	1,600	6,300	6,300	6,300
Vendor Maintenance Contacts	-	3,300	3,300	3,300
Legal and Consulting Support	20,000	-	-	-
Contingency	10,000	10,000	10,000	10,000
Total	$56,900	$44,300	$44,300	$44,300
Training, Attachments, Utilities				
Attachment Fees	$5,200	$5,200	$5,200	$5,200
Education and Training	-	1,100	1,100	1,200
Total	$33,600	$35,300	$35,400	$35,500
Salaries				
GIS Support	$52,000	$54,000	$56,000	$61,000
Total	$52,000	$54,000	$56,000	$61,000
Total Expenses	$114,100	$106,000	$108,000	$113,100

For the non-redundant options, the fiber maintenance and repairs will be slightly less.

3.2 High-Cost Scenario Financial Analysis

In this scenario, we propose the operating budgets[6] and financing that would be necessary provided the deployment costs are equal to our high-cost estimate, discussed in Section 2.3. We have provided in Appendix F a complete financial model in Excel format that can be used to show the impact of changing assumptions.

To provide services to all sites, the Town would need to construct just over $982,000 of OSP plus $75,000 in the core network electronics. In addition, we estimated $105,000 in fiber maintenance equipment and software. In this high-cost scenario, over the course of 20 years, network deployment, operations, maintenance, and financing will cost the equivalent of $1,000 per site per month. For a total of 19 sites, this will cost roughly $19,000 per month, or $228,000 annually.

We have included a financial summary for this high-cost scenario in Table 10.

[6] The financial analysis is presented as a stand-alone enterprise which charges other Town departments for connecting facilities. The charges for the service are recorded as the enterprise revenues. If the Town pursues the proposed I-Net it may to choose to set-up an enterprise and assign costs to the various Town departments, or other structure.

Table 10: Town I-Net High-Cost Scenario Financial Summary

Income Statement	Year 1	Year 3	Year 5	Year 10
Total Budget Revenues	$91,000	$228,000	$228,000	$228,000
Total Cash Expenses	(114,100)	(106,000)	(108,000)	(113,100)
Depreciation	(77,600)	(77,600)	(77,600)	(77,600)
Interest Expense	(37,500)	(36,010)	(32,890)	(24,220)
Net Income	$(138,200)	$8,390	$9,510	$13.080

Cash Flow Statement	Year 1	Year 3	Year 5	Year 10
Unrestricted Cash Balance	$14,400	$27,560	$34,020	$32,270
Depreciation Operating Reserve	-	60,000	120,000	165,000
Debt Service Reserve	-	-	-	-
Total Cash Balance	$14,400	$87,560	$154,020	$197,270

The model does maintain positive cash throughout the 20 years, including funding for replenishments.

3.2.1 High-Cost Scenario Financing

This financial analysis scenario assumes that the Town will cover all its capital requirements with 20-year general obligation (GO) bonds totaling $1.25 million. We assume the bond rate will be 3 percent. (The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the Town's long-term financial requirements.

We project that the bond issuance costs will be equal to 1 percent of the principal borrowed. For the bond, we assume neither a debt service nor interest reserve account are required. Principal repayment on the bonds will start in year two.

We have included a detailed income statement in Table 11.

Table 11: Town I-Net High-Cost Scenario Income Statement

Income Statement		Year 1	Year 3	Year 5	Year 10
Revenues					
Transport Services		$91,000	$228,000	$228,000	$228,000
	Total	91,000	228,000	228,000	228,000
Operating Expenses - Cash (not including taxes)					
Operating & Maintenance Expenses		$56,900	$45,700	$45,700	$45,700
Training, Attachments, Utilities		5,200	6,300	6,300	6,400
Salaries		52,000	54,000	56,000	61,000
	Total	$114,100	$106,000	$108,000	$113,100
Revenues less Cash Operating Expenses		$(23,100)	$122,000	$120,000	$114,900
Operating Expenses - Non-Cash					
Depreciation		$77,600	$77,600	$77,600	$77,600
Operating Income		$(100,700)	$44,400	$42,400	$37,300
Non-Operating Income					
Interest Expense (Long-Term)		$(37,500)	$(36,010)	$(32,890)	$(24,220)
	Total	$(37,500)	$(36,010)	$(32,890)	$(24,220)
Net Income		$(138,200)	$8,390	$9,510	$13,080
Taxes		$-	$-	$-	$-
Net Income After Fees & In Lieu Taxes		$(138,200)	$8,390	$9,510	$13,080

The enterprise will generate a negative net income of $138,200 in year one. By year three, it will recover positive to a net income of $8,390, growing to $9,510 in year five. The network will generate a positive net income of over $13,080 by year 10.

We have included a detailed cash flow statement in Table 12.

Table 12: Town I-Net High-Cost Scenario Cash Flow Statement

Cash Flow Statement	Year 1	Year 3	Year 5	Year 10
Net Income (From Income Statement)	$(138,200)	$8,390	$9,510	$13,080
Cash Outflows				
Depreciation Operating Reserve	$-	$(30,000)	$(30,000)	$(30,000)
Financing	(13,000)	-	-	-
Capital Expenditures	(1,162,000)	-	-	-
Total	$(1,175,000)	$(30,000)	$(30,000)	$(30,000)
Cash Inflows				
Long Term Financing (Bond)	$1,250,000	$-	$-	$-
Total	$1,250,000	$-	$-	$-
Total Cash Outflows and Inflows	$75,000	$(30,000)	$(30,000)	$(30,000)
Non-Cash Expenses - Depreciation	$77,600	$77,600	$77,600	$77,600
Adjustments (Proceeds from)				
Long Term Financing (Bond)	$(1,250,000)	$-	$-	$-
Total	$(1,250,000)	$-	$-	$-
Adjusted Available Net Revenue	$(1,235,600)	$55,990	$57,110	60,680
Principal Payments on Debt				
Long Term Bond Principal	$-	$51,260	$54,380	$63,050
Total	$-	$51,260	$54,380	$63,050
Net Cash	$14,400	$4,730	$2,730	$(2,370)
Adjusted Net Cash	$14,400	$4,730	$2,730	$(2,370)
Cash Balance (Enterprise)				
Unrestricted Cash Balance	$14,400	$27,560	$34,020	$32,270
Depreciation Operating Reserve	-	60,000	120,000	165,000
Debt Service Reserve	-	-	-	-
Total Cash Balance	$14,400	$87,560	$154,020	$197,270

3.2.2 High-Cost Scenario Capital Additions

Significant network expenses—known as "capital additions"—are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building the fiber network. As assets age, capital additions are necessary to replace equipment.

This analysis projects that the capital additions (including fiber, support equipment, and core electronics) in the high-cost scenario will total roughly $1.162 million in year one, $105,000 in

year six (repeating every six years), and $75,000 in year 11 totaling over $1.6 million over the 20-year period of this model.

A summary table of these capital additions is included in Table 13.

Table 13: Town I-Net High-Cost Scenario Capital Additions

Capital Additions		Year 1	Year 6
a. Fiber Implementation Costs			
Fiber (20-year depreciation)		$982,000	$-
Core Electronics (10-year depreciation)		75,000	-
	Total	$1,057,000	$-
b. Support Equipment (5-year depreciation)			
Misc. Equipment		$25,000	$25,000
Fiber Management System		40,000	40,000
Emergency Restoration Kit		30,000	30,000
Fiber OTDR and Other Tools		10,000	10,000
	Total	$105,000	$105,000
	Total Capital	$1,162,000	$105,000
	Total Accrued Capital	$1,162,000	$1,267,000

3.2.3 High-Cost Scenario Without Redundancy Financial Analysis

If the Town were to only construct the baseline network, without the optional redundant network elements, the overall cost of the network OSP would reduce by roughly $198,000. In this scenario, the Town would need to deploy OSP totaling $784,000, and pursue bond financing totaling $1.05 million. Because the Town would deploy less fiber, operating and maintenance expenses are slightly less than the complete model discussed above.

Consequently, the total cost of ownership of the I-Net would reduce to $930 per site per month. This would total approximately $17,670 monthly for all sites, or $212,000 annually.

We have provided a financial summary for this model in Table 14.

Table 14: Town I-Net High-Cost Scenario Without Redundancy Financial Summary

Income Statement	Year 1	Year 3	Year 5	Year 10
Total Revenues	$85,000	$212,000	$212,000	$212,000
Total Cash Expenses	(112,600)	(103,500)	(105,500)	(110,600)
Depreciation	(67,700)	(67,700)	(67,700)	(67,700)
Interest Expense	(31,500)	(30,250)	(27,620)	(20,350)
Net Income	$(126,800)	$10,550	$11,180	$13,350

Cash Flow Statement	Year 1	Year 3	Year 5	Year 10
Unrestricted Cash Balance	$15,900	$29,700	$37,100	$37,700
Depreciation Operating Reserve	-	60,000	120,000	165,000
Debt Service Reserve	-	-	-	-
Total Cash Balance	$15,900	$89,700	$157,100	$202,700

Although this scenario will operate with a negative net income in the initial years, by year three, it will generate a net income of roughly $10,550, which will grow to just under $11,180 in year five, and $13,350 in year 10. The model operates cash positive throughout, generating a cumulative unrestricted cash balance (or surplus) of $15,900 by the end of year one, $37,100 by the end of year five, and $37,700 by the end of year 10.

We have provided the entirety of this model in an Excel workbook in Appendix G.

3.3 Low-Cost Scenario Financial Analysis

In this scenario, we propose the fees and financing that would be necessary for the Town to maintain positive cash flow, provided the deployment costs are equal to our low-cost estimate, discussed in Section 2.3. We have provided in Appendix H a complete financial model in Excel format that can be used to show the impact of changing assumptions.

To provide services to all sites, plus the optional redundancy, the Town would need to construct roughly $802,000 of OSP plus $75,000 in the core network electronics. In addition, we estimated $105,000 in fiber maintenance equipment and software. In this Low-Cost Scenario, to maintain positive cash flow over the course of 20 years, network deployment, operations, maintenance, and financing will cost the equivalent of $950 per site per month. For a total of 19 sites, this will cost a total of roughly $18,080 per month, or roughly $217,000 annually.

We have included a financial summary for this Low-Cost Scenario in Table 15.

Table 15: Town I-Net Low-Cost Scenario Financial Summary

Income Statement	Year 1	Year 3	Year 5	Year 10
Total Revenues	$87,000	$217,000	$217,000	$217,000
Total Cash Expenses	(114,100)	(106,000)	(108,000)	(113,100)
Depreciation	(68,600)	(68,600)	(68,600)	(68,600)
Interest Expense	(32,100)	(30,820)	(28,150)	(20,740)
Net Income	$(127,800)	$11,580	$12,250	$14,560

Cash Flow Statement	Year 1	Year 3	Year 5	Year 10
Unrestricted Cash Balance	$17,800	$34,100	$43,700	$49,800
Depreciation Operating Reserve	-	60,000	120,000	165,000
Debt Service Reserve	-	-	-	-
Total Cash Balance	$17,800	$94,100	$163,700	$214,800

Although this scenario will operate with a negative net income in the initial years, by year three, it will generate a net income of roughly $11,580, which will grow to $12,250 in year five, and $14,560 in year 10. The model does operate cash positive throughout, generating a cumulative unrestricted cash balance (surplus) of $17,800 by the end of year one, just over $43,700 by the end of year five, and almost $49,800 by the end of year 10.

3.3.1 Low-Cost Scenario Financing

This financial analysis scenario assumes that the Town will cover all its capital requirements with 20-year general obligation (GO) bonds totaling $1.07 million. We assume the bond rate will be 3 percent. (The difference between the financed amount and the total capital costs represents the amount needed to maintain positive cash flow in the early years of network deployment.) The resulting principal and interest (P&I) payments will be the major factor in determining the Town's long-term financial requirements.

We project that the bond issuance costs will be equal to 1 percent of the principal borrowed. For the bond, we assume neither a debt service nor interest reserve account are required. Principal repayment on the bonds will start in year two.

We have included a detailed income statement in Table 16.

Table 16: Town I-Net Low-Cost Scenario Income Statement

Income Statement		Year 1	Year 3	Year 5	Year 10
Revenues					
Transport Services		$87,000	$217,000	$217,000	$217,000
	Total	$87,000	$217,000	$217,000	$217,000
Operating Expenses - Cash (not including taxes)					
Operating & Maintenance Expenses		$ 56,900	$ 45,700	$ 45,700	$ 45,700
Training, Attachments, Utilities		5,200	6,300	6,300	6,400
Salaries		52,000	54,000	56,000	61,000
	Total	$114,100	$106,000	$108,000	$113,100
Revenues less Cash Operating Expenses		$(27,100)	$111,000	$109,000	$103,900
Operating Expenses - Non-Cash					
Depreciation		$68,600	$68,600	$68,600	$68,600
Operating Income		$(95,700)	$42,400	$40,400	$35,300
Non-Operating Income					
Interest Expense (Long-Term)		$(32,100)	$(30,820)	$(28,150)	$(20,740)
	Total	$ (32,100)	$(30,820)	$(28,150)	$(20,740)
Net Income		$(127,800)	$11,580	$12,250	$14,560
Taxes		$-	$-	$-	$-
Net Income After Fees & In Lieu Taxes		$(127,800)	$11,580	$12,250	$14,560

The enterprise will generate a negative net income of $127,800 in year one. By year three, it will reach positive to a net income of $11,580, growing to $12,250 in year five. The network will generate a positive net income of over $14,560 by year 10.

We have included a detailed cash flow statement in Table 17.

Table 17: Town I-Net Low-Cost Scenario Cash Flow Statement

Cash Flow Statement	Year 1	Year 3	Year 5	Year 10
Net Income (From Income Statement)	$(127,800)	$11,580	$12,250	$14,560
Cash Outflows				
Depreciation Operating Reserve	$-	$ (30,000)	$ (30,000)	$ (30,000)
Financing	(11,000)	-	-	-
Capital Expenditures	(982,000)	-	-	$-
Total	$(993,000)	$(30,000)	$(30,000)	$(30,000)
Cash Inflows				
Long Term Financing (Bond)	$1,070,000	$-	$-	$-
Total	$1,070,000	$-	$-	$-
Total Cash Outflows and Inflows	$77,000	$(30,000)	$(30,000)	$(30,000)
Non-Cash Expenses - Depreciation	$68,600	$68,600	$68,600	$68,600
Adjustments (Proceeds from)				
Long Term Financing (Bond)	$(1,070,000)	$-	$-	$-
Total	$(1,070,000)	$-	$-	$-
Adjusted Available Net Revenue	$(1,052,200)	$50,180	$50,850	$53,160
Principal Payments on Debt				
Long Term Bond Principal	$-	$43,880	$46,550	$53,960
Total	$-	$43,880	$46,550	$53,960
Net Cash	$17,800	$6,300	$4,300	$(800)
Adjusted Net Cash	$17,800	$6,300	$4,300	$(800)
Cash Balance (Enterprise)				
Unrestricted Cash Balance	$17,800	$34,100	$43,700	$49,800
Depreciation Operating Reserve	-	60,000	120,000	165,000
Debt Service Reserve	-	-	-	-
Total Cash Balance	$17,800	$94,100	$163,700	$214,800

The Town I-Net enterprise will operate cash positive throughout, generating a cumulative unrestricted cash balance (surplus) of $17,800 by the end of year one, $34,100 by the end of year three, $43,700 by the end of year five, and $49,800 by the end of year 10.

3.3.2 Low-Cost Scenario Capital Additions

As we noted, significant network expenses known as “capital additions” are incurred in the first few years during the construction phase of the network. These represent the equipment and labor expenses associated with building the fiber network. As assets age, capital additions are necessary to replace equipment and software.

This analysis projects that the capital additions (including fiber, support equipment, and core electronics) in the low-cost scenario will total $907,000 in year one, $105,000 in year six (repeating every six years), and $75,000 in year 11 totaling just under $1.4 million over the 20-year period of this model.

A summary table of these capital additions is included in Table 18.

Table 18: Town I-Net Low-Cost Scenario Capital Additions

Capital Additions		Year 1	Year 6
a. Fiber Implementation Costs			
Fiber (20-year depreciation)		$802,000	$-
Core Electronics (10-year depreciation)		75,000	-
	Total	$877,000	$-
b. Support Equipment (5-year depreciation)			
Misc. Equipment		$25,000	$25,000
Fiber Management System		40,000	40,000
Emergency Restoration Kit		30,000	30,000
Fiber OTDR and Other Tools		10,000	10,000
	Total	$105,000	$105,000
	Total Capital	$982,000	$105,000
	Total Accrued Capital	$982,000	$1,087,000

3.3.3 Low-Cost Scenario Without Redundancy Financial Analysis

If the Town were to only construct the baseline network, without the optional redundant network elements, the overall cost of the network OSP would reduce by roughly $167,000. In this scenario, the Town would need to deploy OSP totaling $635,000, and purse bond financing totaling $880,000. Because the Town would deploy less fiber, operating and maintenance expenses are slightly less than the complete model discussed above.

Consequently, the total cost of ownership of the I-Net would reduce to the equivalent of $890 per site per month. This would total just over $16,900 monthly for all sites, or approximately $203,000 annually.

We have provided a financial summary for this model in Table 19.

Table 19: Town I-Net Low-Cost Scenario Without Redundancy Financial Summary

Income Statement	Year 1	Year 3	Year 5	Year 10
Total Revenues	$81,000	$203,000	$203,000	$203,000
Total Cash Expenses	(112,600)	(103,500)	(105,500)	(110,600)
Depreciation	(60,300)	(60,300)	(60,300)	(60,300)
Interest Expense	(26,400)	(25,350)	(23,150)	(17,050)
Net Income	$(118,300)	$13,850	$14,050	$15,050

Cash Flow Statement	Year 1	Year 3	Year 5	Year 10
Unrestricted Cash Balance	$(2,000)	$17,520	$30,640	$45,540
Depreciation Operating Reserve	-	60,000	120,000	165,000
Debt Service Reserve	-	-	-	-
Total Cash Balance	$(2,000)	$77,520	$150,640	$210,540

Although this scenario will operate with a negative net income in the initial years, by year three, it will generate a net income of roughly $13,900, which will grow to $14,100 in year five, and $15,100 in year 10. The model generates a cumulative unrestricted cash balance (surplus) of $17,500 by the end of year five, which will grow to $45,500 by the end of year 10.

We have provided the entirety of this model in an Excel workbook in Appendix I.

4 The Advantages, Disadvantages, and Opportunities of a Town I-Net

In deciding upon a course of action, it is important for the Town to consider both its short- and long-term goals to identify the option which best suits its needs.

In our estimation, the advantages offered by a Town I-Net outweigh the disadvantages and offer the Town opportunities to expand and enhance its capabilities as time passes. On the other hand, the disadvantages of leased services outweigh the advantages, and present no opportunity for the Town to increase its capabilities without significant additional capital investment.

4.1 Town I-Net

Benefits of this network include:

- **Scalability** – There is a minimal incremental cost to add new sites to the network, and as more sites are added, the per-site cost declines. It is important to note that a new site could be anything from a physical facility to a public safety camera. Further, with the electronics included in our network design, increasing a site's connection speed from 1 Gbps to 10 Gbps will not increase the Town's costs.
- **Longevity** – The inherent nature of fiber provides a "future-proof" network. That is, if the Town needs additional speeds beyond 10 Gbps, it is merely a matter of replacing the hardware on the ends of the fiber—no additional construction is needed. Further, Town will be financing over a 20-year period for a 30-year asset, which translates to lower long-term costs.
- **Control** – The fiber network will be completely under the Town's control, and additional sites (e.g. Town facilities, security cameras, etc.) can be added quickly once the initial fiber is deployed.

Disadvantages of this network include:

- **Initial Capital** – To deploy the network, the Town will need to invest a significant amount of capital at the outset.
- **Deployment Time** – The network will not be immediately available for use if and when the Town decides to proceed, and the timetable will depend on construction timelines and environmental factors.

Opportunities for this network include:

- **Excess Fiber Strands** – The cabling deployed in our network design contains a strand count beyond what the Town will need in the immediate term. These excess strands could be leased to businesses who need enterprise-grade services or private providers (either new market entrants or incumbents) who wish to provide connectivity services to residents and businesses in the Town.

- **Future Opportunities** – A robust, reliable, and secure fiber network offers the capability to support many technologies. From Smart Cities applications to enhanced first responder connectivity, the Town would be well-positioned to adopt developing data-intensive applications.

4.2 Leased Services

There are undeniable benefits to the Town pursuing leased I-Net-type services as its solution to meet its connectivity needs. But these advantages are primarily short-term, and our analysis suggests they are eclipsed by the long-term advantages of a Town I-Net. Further, there are no future opportunities for the Town if it elects to pursue leased services.

That said, advantages of leased services include:

- **No Significant Initial Investment** – The Town's initial investment would only entail a monthly cost per site, and any applicable activation/connection fees.
- **Availability** – The Town would be able to begin receiving services as soon as the chosen provider connects sites to its existing network.

Disadvantages of leased services include:

- **Cost to Scale** – Each additional site needing connectivity will add additional recurring charges to the telecom budget, and leased services are significantly more expensive for increased speeds (our analysis in a similar market indicated a factor of 3.64 to increase from 1 Gbps to 10 Gbps). Further, speed increases may necessitate hardware upgrades, the cost of which is often the responsibility of the customer.
- **Uncertain Pricing** – Providers frequently quote and advertise speeds solely for fixed-term contracts. Pricing beyond that period is not guaranteed, and may increase, resulting in greater expenditures over time.

5 Milton's Pole Attachment Rights

To this point in this report, pole attachment considerations have been considered from the engineering perspective. The report has described what work will likely be required for construct the network on utility poles in town. As noted in Section 2.1.3, because the Town does not own utility poles and is not a telecommunications carrier or cable television provider, it is not provided any particular rights or protections under federal or state law to ensure its ability to make new attachments for its own purposes in a timely and cost-effective manner.

As such, the Town would be considered a third-party attacher and would need to negotiate a pole attachment agreement with the utility pole owner(s). These agreements will determine the Town's responsibility for incurring costs related to make-ready, as well as ongoing utility pole licensing (or lease) fees. From our experience, we understand that the Town will need to enter into third-party attachment agreements with Eversource and/or Verizon, which co-own the poles.

CTC is not a law firm and cannot provide legal advice to the Town with respect to making such agreements. But we can discuss common practice and how this has taken place in other jurisdictions.

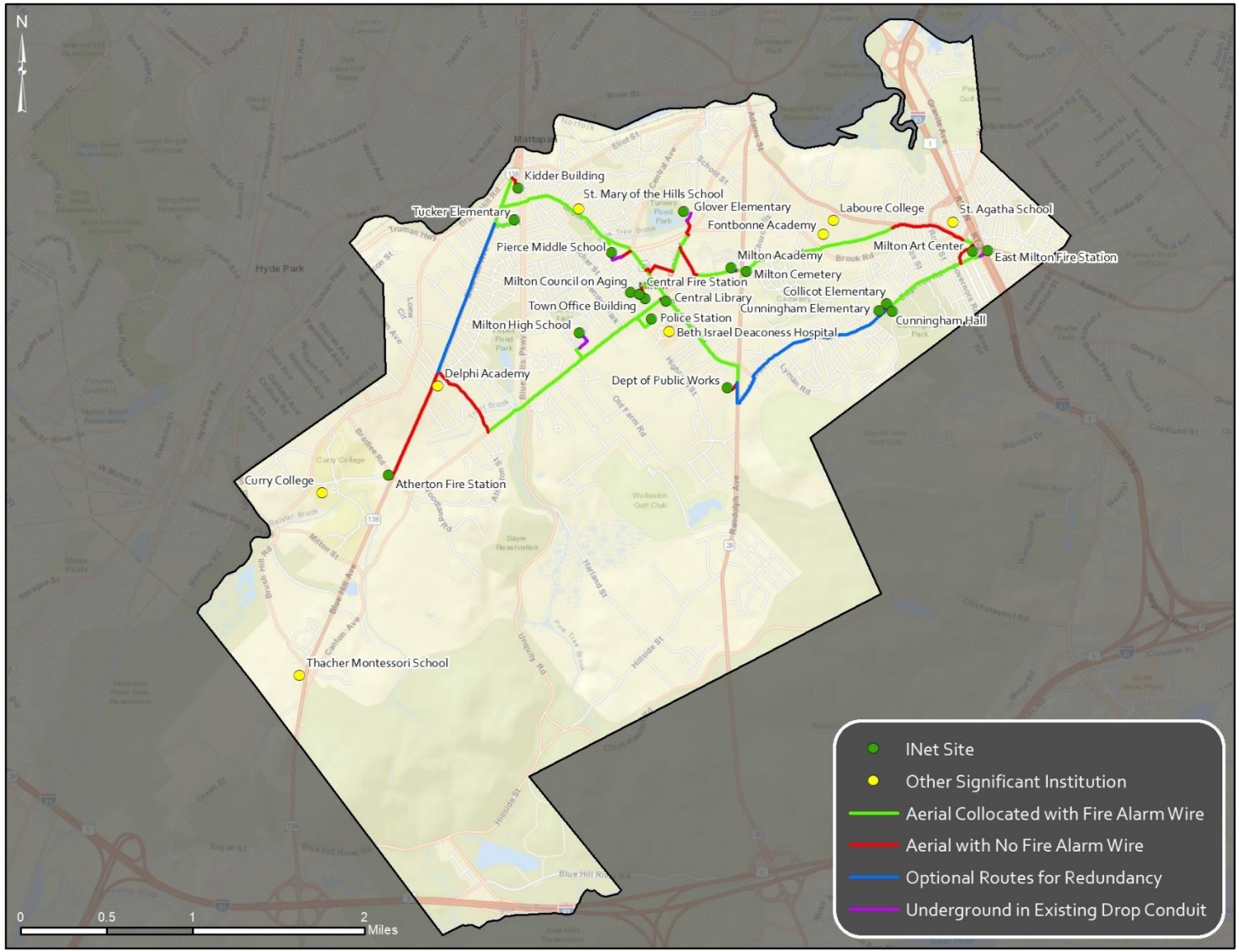
CTC are aware of several Towns in Massachusetts which have gone through the process of entering into such agreements, performing make-ready work, and paying annual fees to the pole owners. To provide Milton with an example of how this has been done in another Massachusetts town, CTC contacted the Town of Leverett, which decide to build a Town network for purposes of starting a fiber-to-the premises (FTTP) broadband network.

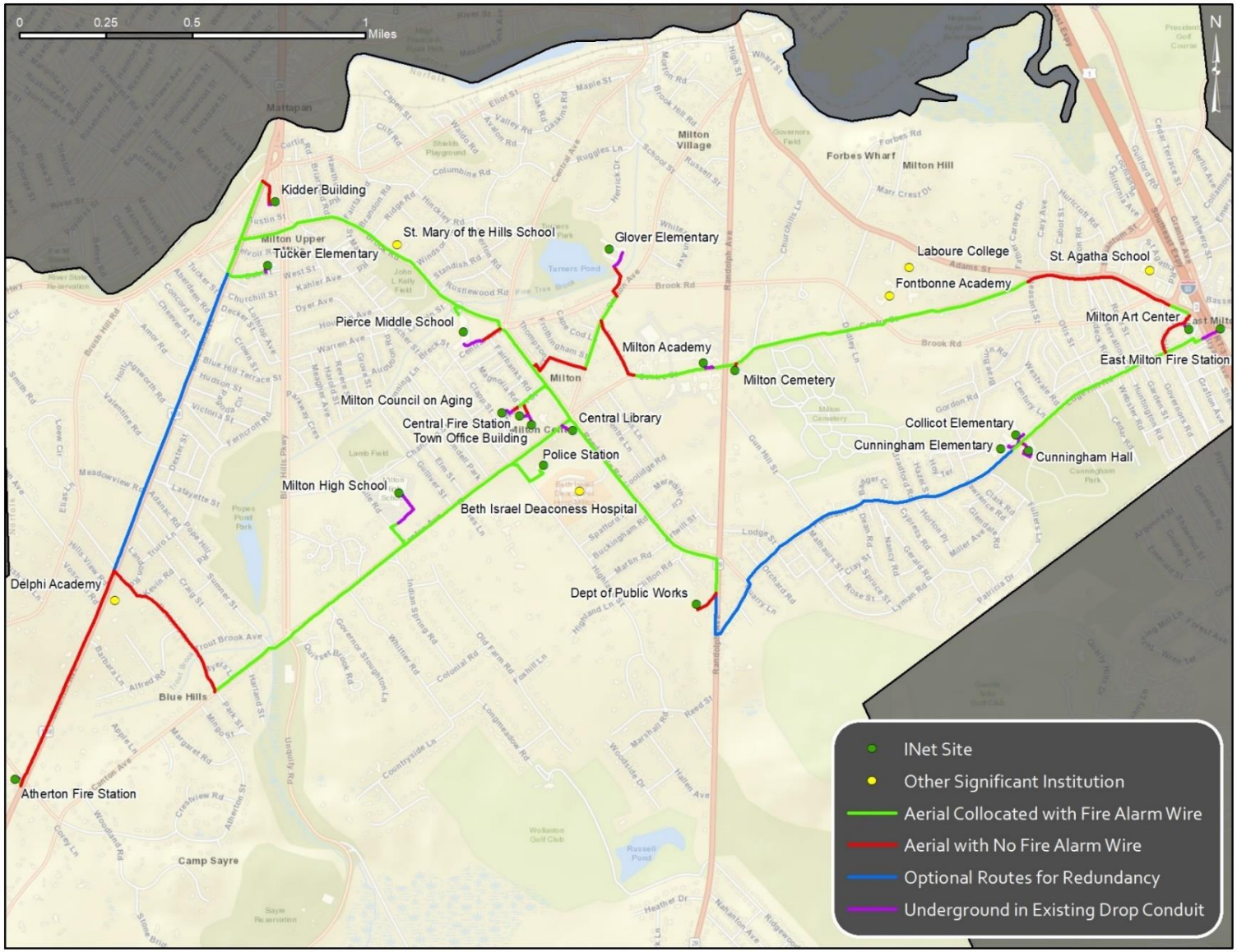
In 2013, the Town of Leverett entered into third-party attachment agreements with Western Massachusetts Electric Company or WMECO (now simply called Eversource), Verizon New England, and Massachusetts Electric Company (National Grid), according to Marjorie McGinnis, Leverett's Town Administrator. She said all three agreements are the same and were drafted by the pole owners. One of these agreements, with WMECO, is appended to this report as Appendix J. The Town also agreed to pay ongoing fees to the three entities, with slightly different rates for each. The rates for solely-owned and co-owned poles are provided in Table 18. The underlying fee schedule and agreement, provided by the Town of Leverett, is included as Appendix K.

Table 20: Annual Pole Attachment Fees Paid by the Town of Leverett, Massachusetts

Pole Owner	Annual fee for solely-owned poles	Annual fee for co-owned or co-used poles
Western Massachusetts Electric Company (WEMCO)	$9.00	$4.50
Massachusetts Electric Company (National Grid)	$11.85	$5.93
Verizon New England	$10.06	$5.03

Appendix A: Preliminary Fiber Route Maps


N
Kidder Building
St. Mary of the Hills School
Glover Elementary
Tucker Elementary
Laboure College
St. Agatha School
Fontbonne Academy
Pierce Middle School
Milton Academy
Milton Art Center
East Milton Fire Station
Milton Cemetery
Milton Council on Aging
Central Fire Station
Collicot Elementary
Central Library
Town Office Building
Cunningham Elementary
Cunningham Hall
Police Station
Milton High School
Beth Israel Deaconess Hospital
Delphi Academy
Dept of Public Works
Curry College
Atherton Fire Station
Thacher Montessori School
Hyde Park
0
0.5
1
2
Miles
INet Site
Other Significant Institution
Aerial Collocated with Fire Alarm Wire
Aerial with No Fire Alarm Wire
Optional Routes for Redundancy
Underground in Existing Drop Conduit


0
0.25
0.5
1
Miles
N
Kidder Building
Milton Upper
Tucker Elementary
St. Mary of the Hills School
Glover Elementary
Laboure College
St. Agatha School
Fontbonne Academy
Milton Art Center
East Milton Fire Station
Pierce Middle School
Milton Academy
Milton Cemetery
Milton Council on Aging
Central Fire Station
Town Office Building
Central Library
Police Station
Collicot Elementary
Cunningham Elementary
Cunningham Hall
Milton High School
Beth Israel Deaconess Hospital
Delphi Academy
Dept of Public Works
Atherton Fire Station
Mattapan
Milton Village
Forbes Wharf
Milton Hill
Blue Hills
Camp Sayre
INet Site
Other Significant Institution
Aerial Collocated with Fire Alarm Wire
Aerial with No Fire Alarm Wire
Optional Routes for Redundancy
Underground in Existing Drop Conduit

Appendix B: Network Site Lists

Table 21: Current I-Net Sites

Municipal Buildings
Town Office Building, 525 Canton Avenue
Dept. of Public Works, ,29 Randolph Avenue
Milton Cemetery, 211 Centre Street
Milton Council on Aging, 10 Walnut Street
Public Safety
Police Station, 40 Highland Street
Central Fire Station, 515 Canton Avenue
Atherton Fire Station, 815 Blue Hill Avenue
East Milton Fire Station, 525 Adams Street
Present or Former Libraries
Central Library, 476 Canton Avenue
Milton Art Center, 334 Edge Hill Road
Kidder Building, 101 Blue Hills Parkway
Schools
Central Library, 476 Canton Avenue
Milton Art Center, 334 Edge Hill Road
Kidder Building, 101 Blue Hills Parkway
Central Library, 476 Canton Avenue
Milton Art Center, 334 Edge Hill Road
Kidder Building, 101 Blue Hills Parkway
Central Library, 476 Canton Avenue
Milton Art Center, 334 Edge Hill Road
Non-Municipal Buildings
Cunningham Hall, 77 Edge Hill Road

Table 22: Significant Anchor Institutions

Hospitals
Beth Israel Deaconess Hospital, 199 Reedsdale Road
Higher Education
Curry College, 1071 Blue Hill Avenue
Laboure College, 303 Adams Street
Private Schools
St. Mary of the Hills School, 250 Brook Road
Delphi Academy, 564 Blue Hill Avenue
Fontbonne Academy, 930 Brook Road
St. Agatha School, 440 Adams Street
Thacher Montessori School, 1425 Blue Hill Avenue

Appendix C: Network Cost Estimate (High-Cost)

This Appendix is included as a separate Microsoft Excel file.

Appendix D: Network Cost Estimate (High-Cost)

This Appendix is included as a separate Microsoft Excel file.

Appendix E: Sample Network Electronics BOM

Part Number	Description	Unit List Price	Qty	Unit Net Price	Disc(%) Est.	Extended Net Price
WS-C4500X-F-32SFP+	Catalyst 4500-X 32 Port 10G IP Base	28,000.00	1	16,800.00	40.00	16,800.00
C4KX-PWR-750AC-F/2	Catalyst 4500X 750W AC	2,000.00	1	1,200.00	40.00	1,200.00
C4KX-PWR-750AC-F	Catalyst 4500X 750W AC	2,000.00	1	1,200.00	40.00	1,200.00
C4KX-NM-BLANK	Catalyst 4500X Network Module Blank	0.00	1	0.00	40.00	0.00
C4500X-IPB	IP Base license for Catalyst 4500-X	0.00	1	0.00	40.00	0.00
CAB-US515-C15-US	NEMA 5-15 to IEC-C15 8ft US	0.00	2	0.00	40.00	0.00
S45XUK9-38E	CAT4500-X Universal Crypto Image	0.00	1	0.00	40.00	0.00
SFP-10G-SR	10GBASE-SR SFP Module	995.00	1	497.50	50.00	497.50
SD-X45-2GB-E	Catalyst 4500 2GB SD Memory Card	500.00	1	250.00	50.00	250.00
GLC-LH-SMD	1000BASE-LX/LH SFP transceiver module, MMF/SMF	995.00	9	497.50	50.00	4,477.50
SFP-10G-LR	10GBASE-LR SFP Module	3,995.00	2	1,997.50	50.00	3,995.00
GLC-SX-MMD	1000BASE-SX SFP transceiver module, MMF	500.00	1	250.00	50.00	250.00
WS-C4500X-F-32SFP+	Catalyst 4500-X 32 Port 10G IP Base	28,000.00	1	16,800.00	40.00	16,800.00
C4KX-PWR-750AC-F/2	Catalyst 4500X 750W AC	2,000.00	1	1,200.00	40.00	1,200.00
C4KX-PWR-750AC-F	Catalyst 4500X 750W AC	2,000.00	1	1,200.00	40.00	1,200.00
C4KX-NM-BLANK	Catalyst 4500X Network Module Blank	0.00	1	0.00	40.00	0.00
C4500X-IPB	IP Base license for Catalyst 4500-X	0.00	1	0.00	40.00	0.00
CAB-US515-C15-US	NEMA 5-15 to IEC-C15 8ft US	0.00	2	0.00	40.00	0.00
S45XUK9-38E	CAT4500-X Universal Crypto Image	0.00	1	0.00	40.00	0.00
SFP-10G-SR	10GBASE-SR SFP Module	995.00	1	497.50	50.00	497.50
SFP-10G-LR	10GBASE-LR SFP Module	3,995.00	3	1,997.50	50.00	5,992.50
SD-X45-2GB-E	Catalyst 4500 2GB SD Memory Card	500.00	1	250.00	50.00	250.00
GLC-LH-SMD	1000BASE-LX/LH SFP transceiver module, MMF/SMF	995.00	9	497.50	50.00	4,477.50
SFP-10G-LR=	10GBASE-LR SFP Module	3,995.00	0	1,997.50	50.00	0.00
GLC-LH-SMD=	1000BASE-LX/LH SFP transceiver module, MMF/SMF	995.00	16	497.50	50.00	7,960.00
WS-C2960S-48FPD-L	Catalyst 2960S 48 GigE PoE 740W, 2 x 10G SFP+	8,795.00	4	5,277.00	40.00	21,108.00
CAB-16AWG-AC	AC Power cord, 16AWG	0.00	4	0.00	40.00	0.00
C2960S-STACK	Catalyst 2960S FlexStack Stack Module optional for	1,315.00	4	789.00	40.00	3,156.00
CAB-STK-E-0.5M	Cisco FlexStack 50cm stacking cable	0.00	4	0.00	40.00	0.00
WS-C2960S-24PD-L	Catalyst 2960S 24 GigE PoE 370W, 2 x 10G SFP+	5,055.00	3	3,033.00	40.00	9,099.00
CAB-16AWG-AC	AC Power cord, 16AWG	0.00	3	0.00	40.00	0.00
C2960S-STACK	Catalyst 2960S FlexStack Stack Module optional for	1,315.00	3	789.00	40.00	2,367.00
CAB-STK-E-0.5M	Cisco FlexStack 50cm stacking cable	0.00	3	0.00	40.00	0.00
WS-C2960S-24PD-L	Catalyst 2960S 24 GigE PoE 370W, 2 x 10G SFP+	5,055.00	6	3,033.00	40.00	18,198.00
CAB-16AWG-AC	AC Power cord, 16AWG	0.00	6	0.00	40.00	0.00
CON-SNT-C45XF32S	SNTC-8X5XNBD Catalyst 4500-X 32 Port 10G IP Base	1,800.00	1	1,620.00	10.00	1,620.00
CON-SNT-C45XF32S	SNTC-8X5XNBD Catalyst 4500-X 32 Port 10G IP Base	1,800.00	1	1,620.00	10.00	1,620.00
CON-SNT-2960S4FD	SNTC-8X5XNBD Cat 2960S Stk48 GigE PoE	504.00	4	453.60	10.00	1,814.40
CON-SNT-2960S2PD	SNTC-8X5XNBD Cat2960S Stk24 GigE	289.00	3	260.10	10.00	780.30
CON-SNT-2960S2PD	SNTC-8X5XNBD Cat2960S Stk24 GigE	289.00	6	260.10	10.00	1,560.60

Product/Subscription Total:	120,975.50
Service Total :	7,395.30
Total Price:	**128,370.80**

Appendix F: High-Cost Financial Analysis

This Appendix is included as a separate Microsoft Excel file.

Appendix G: High-Cost Without Redundancy Financial Analysis

This Appendix is included as a separate Microsoft Excel file.

Appendix H: Low-Cost Financial Analysis

This Appendix is included as a separate Microsoft Excel file.

Appendix I: Low-Cost Without Redundancy Financial Analysis

This Appendix is included as a separate Microsoft Excel file.

Appendix J: Eversource (Western Massachusetts Electric Co.) Pole Attachment Agreement

This Appendix was provided by the Town of Leverett as an example and is included as a separate PDF file.

Appendix K: Pole Attachment Fee Schedules

This Appendix was provided by the Town of Leverett and describes the fees paid by Leverett to National Grid, Western Massachusetts Electric Company (Eversource), and Verizon New England. It is included as a separate PDF file.