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April 25, 2023

Ms. Leeann Butschlick, Director of Public Works
Village of Shorewood
3801 North Morris Boulevard
Shorewood, WI 53211

Re: Street Lighting System Replacement Plan

Dear Leeann,

Enclosed is an electronic copy of the draft Street Lighting System Replacement Plan for review and comment.

Please call me with questions at 414-271-0771.

Sincerely,

STRAND ASSOCIATES, INC.®

Richard G. Thimm, P.E.

Enclosure: Report

c/enc: Rebecca Ewald, Village Manager, Village of Shorewood

Report for Village of Shorewood, Wisconsin

Street Lighting System Replacement Plan



Prepared by:

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April 2023



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INTRODUCTION

This study evaluates replacing significant portions of the Village of Shorewood's (Village) existing lighting system infrastructure because of age (original system was installed in the early 1970s) and condition of the infrastructure; to improve the safety and reliability of the system; and to lower operational and maintenance costs. The scope of this Street Lighting System Replacement Plan is to review the existing lighting infrastructure with Village staff, summarize identified deficiencies, and provide budgetary opinion of probable cost (OPC) information to the Village. This includes phased annual costs for systematic replacement of the street lighting control cabinets east of the fire station and at Lake Bluff Elementary, replacement of all direct buried street lighting wiring with a three-wire grounded system in conduit, upgrading or replacing existing lighting fixtures with light emitting diode (LED) lighting sources, and replacement of all 1970s light poles. Additionally, third-party upgrades to LED lamps were investigated, but it was determined that LED lamp replacement alone would not address the more important underlying Code, condition, and safety-related issues within the system.

This plan is the first step in a systematic replacement of the street lighting infrastructure. The next step (not included in the scope of this plan) is to develop design documents for the street lighting system replacement followed by construction. Due to the significant project size, design and construction are proposed to be divided into multiple phases completed over a period of 5 to 10 years. The design for each phase is expected to occur one year with the associated construction to occur the following year (e.g., Phase 1 design expected 2024 with Phase 1 construction expected 2025). Several items should be evaluated as part of the first phase design effort to establish a basis of design for all phases including product selections (light poles, light fixtures, light color temperature, compliance with Dark Sky association requirements, energy efficiency and light fixture distribution); specific design elements such as circuit routing, wire sizing, and voltage configuration; and final control cabinet locations and quantities. Approximations were made for these items as needed to establish a budgetary OPC for this plan.

SYSTEM INFRASTRUCTURE REVIEW

This section provides an overview of the existing Village street lighting system infrastructure including existing system characteristics, deficiencies, and a summary of recent improvements.

A. Existing Infrastructure Background Information

The Village street lighting system is comprised of a mix of 120/240-volt (V) and 480-V lighting control cabinets that are wired to a mix of direct burial concrete light poles and metal light poles with concrete bases using a combination of wire in conduit and direct burial wire. Pull boxes are installed in various locations throughout the Village street lighting system to provide access to the street lighting wiring and underground wire splices for maintenance. The relationship between these components is shown schematically in Figure 1. Some of the existing lighting system infrastructure has been replaced since its original installation as summarized later in this section, but the majority of the Village street lighting system still remains from the early 1970s and includes various street lighting control cabinets and a network of direct buried electrical wire (two wires [hot and grounded phase with no dedicated grounding wire]), pull boxes, and direct burial light poles. Several of the original 1970s street lighting control cabinets as well as various segments of light fixtures and wiring within the system have been replaced as summarized later in this report. The original 1970s street lighting control cabinets that still remain are

powered by medium voltage services from We Energies and stepped down to 480 V at each lighting control cabinet for power distribution.

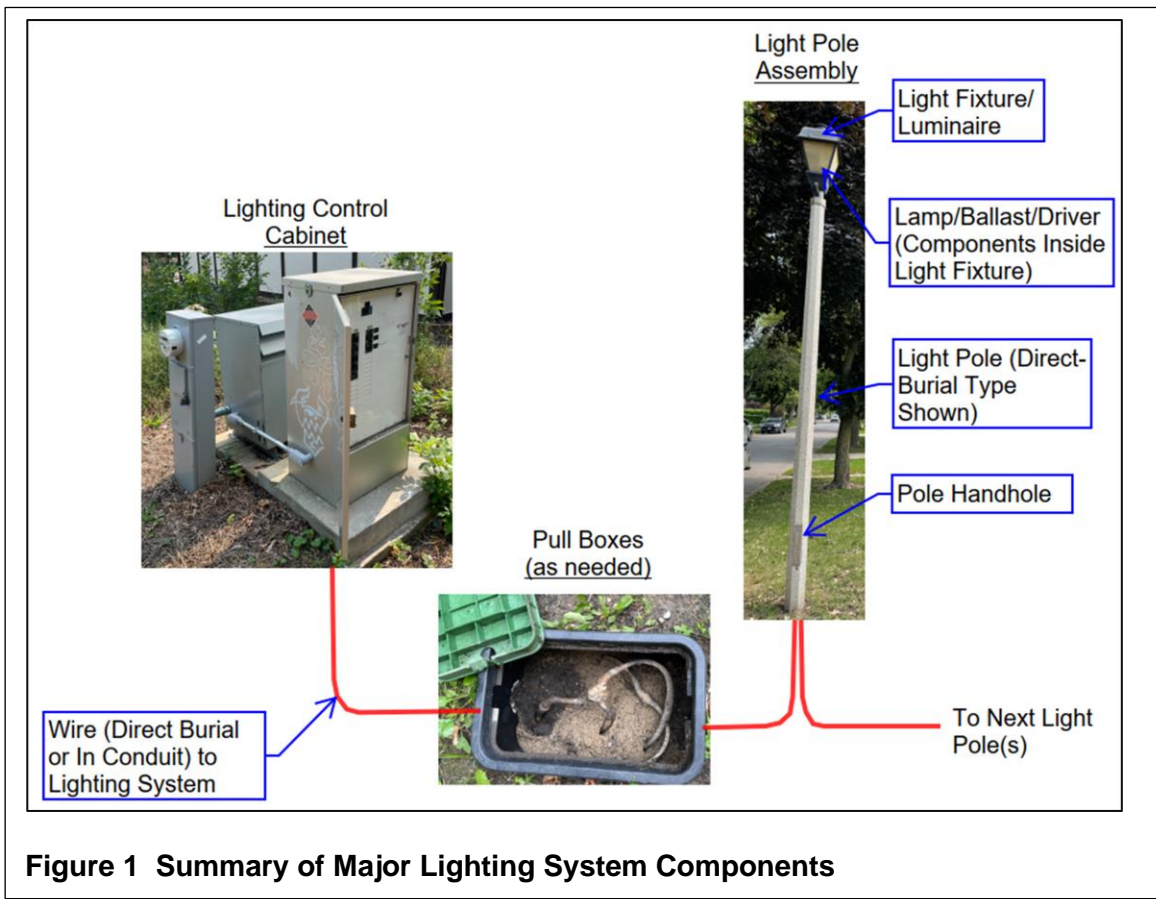


Figure 1 Summary of Major Lighting System Components

The following is a list of major issues and/or potential improvements that have been identified through previous reports and projects, and as a part of this analysis, leading to a desire to replace the remaining original 1970s infrastructure.

1. **Aged Wiring and Lighting Control Cabinets**—A significant amount of the system wiring and several of the existing lighting control cabinets are original to the 1970s lighting installation, which is past the typical life expectancy of 30 to 40 years. Faults in the aging wiring are prevalent throughout the Village based on feedback from Village staff, leading to an unreliable lighting system, significant staff maintenance efforts, and safety issues. Additionally, the existing wiring is direct buried (versus wire in conduit), which makes it more prone to issues and difficult to access for troubleshooting and maintenance.
2. **Outdated System Voltage with No Dedicated Grounding Conductor**—A significant amount of the existing lighting system is wired using an outdated system voltage (480-V, phase-to-grounded phase) with no dedicated grounding conductor. This violates current National Electrical Code (NEC) requirements for equipment grounding and can lead to safety issues such as undetected wiring ground faults that could cause injury. Additionally, since the voltage to ground is 480 V, the NEC requires the existing

- high-pressure sodium (HPS) light fixtures to be mounted at a minimum height of 22 feet (versus existing 13-foot-pole mounting height within the Village) and does not allow LED light fixtures to be powered from this voltage at any height. Switching to a standard voltage (either 120/240-V [120 V to ground] or 240/480-V [240 V to ground]) and adding a dedicated ground wire is recommended to improve safety, to meet current NEC requirements while maintaining existing pole mounting heights, and to allow LED light fixtures to be installed. It should also be noted that if a voltage conversion is made without replacing the existing wiring, it should be expected that significant wiring faults in the existing grounded phase conductors will be exposed and require significant man hours to troubleshoot and fix based upon experiences on past voltage conversion projects within the Village.
3. **Insufficient Electrical Working Clearance Around Existing Fire Station Lighting Control Cabinets**—The existing street lighting control cabinets east of the fire station, which are as close as 30 inches to the fire station walls, do not have the NEC-required electrical working clearances of 42 inches.
 4. **Outdated and Inefficient Light Fixtures**—Most of the street lighting within the Village uses high-pressure sodium lamps. There is a desire to convert the lighting system to LED light sources to save energy and reduce operating costs. In addition, the majority of the light fixtures within the Village are approximately 50 years old, which is past the expected useful life.
 5. **Pull Boxes Are Not Code-Compliant**—Some of the electrical pull boxes within the Village that have been replaced since the 1970s installation do not meet NEC requirements for pull boxes (see Figure 2). Specifically, they are not identified as “Electrical” on the pull box covers and the covers can be opened without using any tools. This means that the public could have access to 480-V wires, which poses a safety hazard.



Figure 2 Some Existing Pull Boxes Do Not Require Tools to Access 480-V Wiring

B. Existing Infrastructure Review

Major upgrades to the original 1970s lighting system installation were identified based on discussions with Village staff and a review of available record drawings. The Village lighting system map, included as Figure 3, provides a general overview of the portions of the lighting system that have had upgrades since the original lighting system installation or have upgrades planned as a part of an upcoming project.

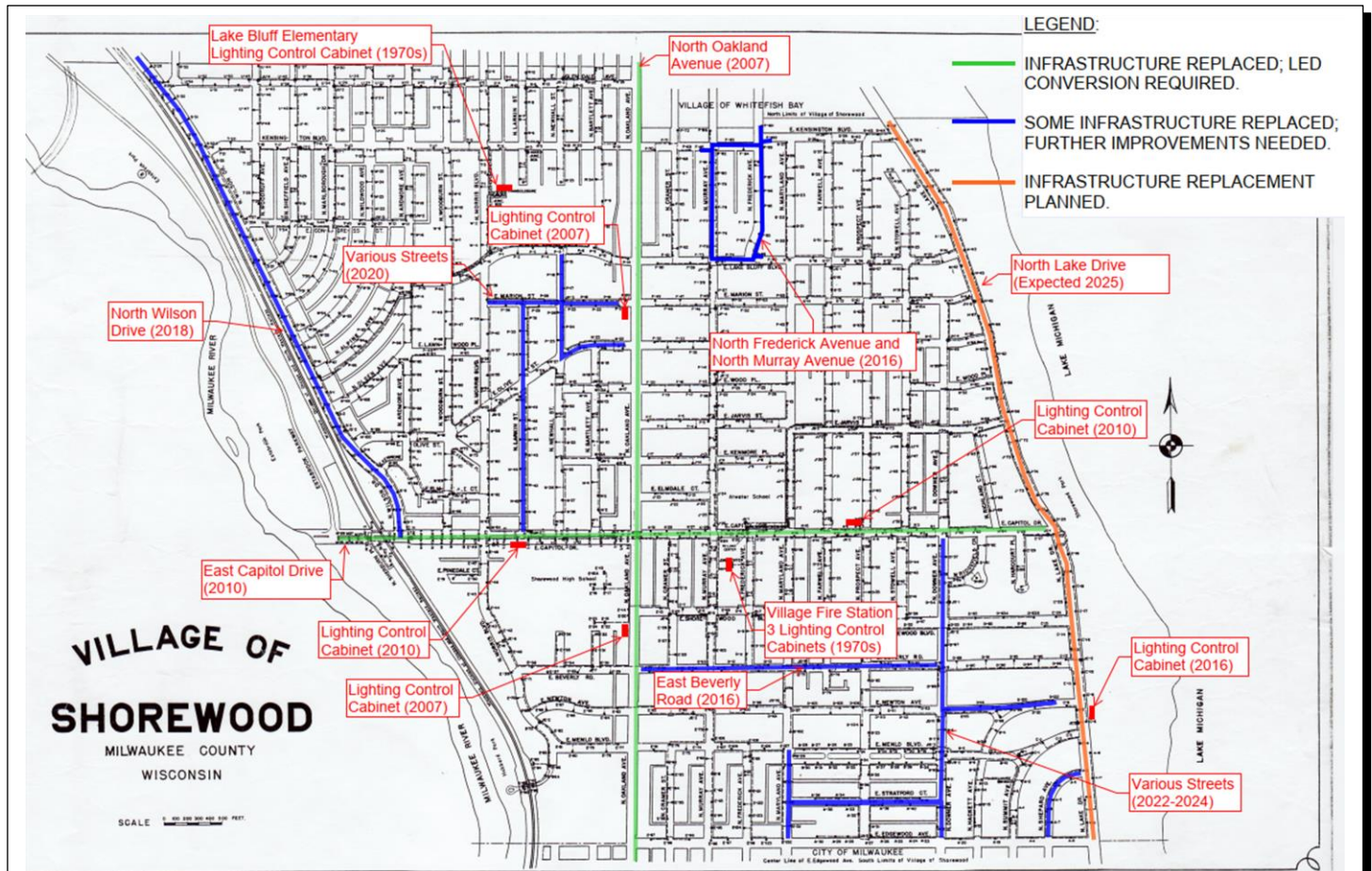


Figure 3 Summary of Completed and Planned Street Lighting System Improvements Since 1970s Installation

1. 2007–North Oakland Avenue
 - a. Upgrades Completed:
 - i. All existing lighting infrastructure was replaced along North Oakland Avenue including light poles, light fixtures, wiring (with ground wire), conduit, pull boxes, and lighting control cabinets. Light fixtures installed were high-pressure sodium.
 - ii. Lighting circuits along North Oakland Avenue were powered from two new 120/240-V lighting control cabinets installed along North Oakland Avenue.

- iii. Village staff have replaced high-pressure sodium lamps within some of the light fixtures along North Oakland Avenue with LED lamps within the last couple years.
 - b. Upgrades Still Required:
 - i. Replace remaining high-pressure sodium lamps with LED lamps within all existing light fixtures along North Oakland Avenue.
- 2. 2010–East Capitol Drive
 - a. Upgrades Completed:
 - i. All existing lighting infrastructure was replaced along East Capitol Drive including light poles, light fixtures, wiring (with ground wire), conduit, pull boxes, and lighting control cabinets. Light fixtures installed were high-pressure sodium.
 - ii. Lighting circuits along East Capitol Drive were powered from two new 120/240 volt lighting control cabinets installed along East Capitol Drive.
 - iii. Existing lighting circuit N was repowered at 480 V from the new East Capitol Drive 120/240-V lighting control cabinets through a step-up transformer. Lighting circuit N wire was not replaced and ground wire was not added.
 - iv. Village staff have replaced high-pressure sodium lamps within some of the light fixtures along East Capitol Drive with LED lamps within the last couple years.
 - b. Upgrades Still Required:
 - i. Replace existing lighting circuit N direct burial wire with new wire (including ground wire) in conduit.
 - ii. Replace remaining high-pressure sodium lamps with LED lamps within all existing light fixtures along East Capitol Drive.
- 3. 2016–Segments of East Beverly Road
 - a. Upgrades Completed:
 - i. Direct burial wiring was replaced with wiring (no ground wire) in conduit within project limits. New wiring was reconnected to existing light poles within project limits and spliced at the project limits with existing direct burial wiring going back to the existing lighting control cabinet.
 - b. Upgrades Still Required:
 - i. Replace remaining direct burial wire with new wiring (with ground wire) in conduit outside of project limits back to lighting control cabinet.
 - ii. Add ground wire to existing conduit system within project limits if pulling into existing conduit is possible.
 - iii. Replace light poles and install new LED light fixtures on new poles.
 - iv. Replace pull boxes with code-compliant pull boxes.

4. 2016—Segments of North Frederick Avenue and North Murray Avenue
 - a. Upgrades Completed:
 - i. Direct burial wiring was replaced with wiring (no ground wire) in conduit within project limits. New wiring was reconnected to existing light poles within project limits and spliced at the project limits with existing direct burial wiring going back to the existing lighting control cabinet.
 - b. Upgrades Still Required:
 - i. Replace remaining direct burial wire with new wiring (with ground wire) in conduit outside of project limits back to lighting control cabinet.
 - ii. Add ground wire to existing conduit system within project limits if pulling into existing conduit is possible.
 - iii. Replace light poles and install new LED light fixtures on new poles.
 - iv. Replace pull boxes with code-compliant pull boxes.
5. 2016—North Lake Drive Lighting Control Cabinet
 - a. Upgrades Completed:
 - i. The lighting control cabinet serving lighting circuits along North Lake Drive and portions of the Village southeast quadrant was replaced with a new 240/480-V lighting control cabinet.
 - ii. Direct burial wire was replaced with wiring (no ground wire) in conduit across North Lake Drive to reconnect to the existing circuit direct burial wire.
 - b. Upgrades Still Required:
 - i. Replace remaining direct burial wire outside of 2016 project limits with new wiring (with ground wire) in conduit back to the lighting control cabinet.
 - ii. Add ground wire to the existing conduit system within 2016 project limits.
 - iii. Replace light poles and install new LED light fixtures on new poles for associated lighting circuits.
 - iv. Replace pull boxes with code-compliant pull boxes.
6. 2018—North Wilson Drive
 - a. Upgrades Completed:
 - i. Lighting was replaced with 100-watt (W) LED light fixtures on new light poles.
 - ii. Direct burial wire was replaced with wiring (no ground wire) in conduit along North Wilson Drive. New wire was spliced with existing direct burial wiring at North Alpine Avenue going back to the existing lighting control cabinet.
 - b. Upgrades Still Required:
 - i. Replace remaining direct burial wire with new wiring (with ground wire) in conduit from North Alpine Avenue back to the lighting control cabinet.
 - ii. Add ground wire to the existing conduit system along North Wilson Drive if pulling into existing conduit is possible.
 - iii. Replace pull boxes with code-compliant pull boxes.

7. 2020–Various Segments Along East Marion Street, East Olive Street, North Larkin Street, and North Newhall Street
 - a. Upgrades Completed:
 - i. Direct burial wire was replaced with wiring (no ground wire) in conduit within the project limits. New wiring was reconnected to existing light poles within the project limits and spliced at the project limits with existing direct burial wiring going back to the existing lighting control cabinet.
 - b. Upgrades Still Required:
 - i. Replace remaining direct burial wire with new wiring (with ground wire) in conduit outside of project limits back to lighting control cabinet.
 - ii. Add ground wire to the existing conduit system within the project limits if possible.
 - iii. Replace light poles and install new LED light fixtures on new poles.
 - iv. Replace pull boxes with code-compliant pull boxes.
8. 2023 through 2024–Various Segments Along North Maryland Avenue, East Stratford Court, North Downer Avenue, East Newton Avenue, and North Shepard Avenue (Construction Ongoing)
 - a. Upgrades Expected to be Completed:
 - i. Direct burial wire will be replaced with wiring (with ground wire) in conduit within project limits. New wiring will be spliced with existing direct burial wiring going back to the existing lighting control cabinet at project limits.
 - ii. Damaged light poles will be replaced and all existing light poles within project limits will be rewired.
 - iii. Pull boxes within project limits will be replaced with code-compliant pull boxes.
 - b. Upgrades Still Required:
 - i. Replace remaining direct burial wire with new wiring (with ground wire) in conduit outside of the project limits back to lighting control cabinet.
 - ii. Replace light fixtures with LED light fixtures on existing light poles.
 - iii. Provide miscellaneous improvements required to convert circuit voltage from 480-V phase-to-grounded phase to 480-V phase-to-phase (e.g. modify identification and install fusing to convert grounded phase conductor to a standard phase conductor).
9. 2025–North Lake Drive (Expected in Upcoming Wisconsin Department of Transportation [WisDOT] project)
 - a. Upgrades Expected to be Completed:
 - i. All existing lighting infrastructure will be replaced along North Lake Drive including light poles, wiring (with ground wire), conduit, pull boxes, and lighting control cabinets.
 - ii. New light fixtures are expected to be LED light fixtures.
 - iii. Lighting circuits along North Lake Drive will be powered from new 120/240-V lighting control cabinets installed along North Lake Drive.
 - b. Upgrades Still Required:
 - i. None expected.

There are also small areas of lighting within Hubbard Park, along Estabrook Parkway, and other areas of the Village not identified on the map that have had upgrades completed and do not require further improvements at this time. All other areas within the lighting system have not had any improvements made since the original lighting installation other than miscellaneous general maintenance and repair activities. The upgrades required for these remaining areas include the following:

1. Replace direct burial wire with new wiring (with ground wire) in conduit.
2. Replace light poles and install new LED light fixtures on new poles.
3. Replace pull boxes with code-compliant pull boxes.
4. Replace four lighting control cabinets remaining from the original 1970s lighting installation (three at the Village Fire Station; one at Lake Bluff Elementary).

ESTIMATION OF COSTS

This section provides a summary of the criteria reviewed with the Village and selected for the basis of cost, an overall OPC for the selected improvements, and an annual energy use comparison of the existing lighting system versus the proposed LED replacement lamps and light fixtures.

A. Basis of Costs

Quantities for the areas of the lighting system infrastructure identified as requiring upgrades were approximated based on street lighting system record information and geographical information system (GIS) mapping information provided by the Village. This included existing lighting circuit configurations and wire lengths, light fixture types, light fixture and light pole quantities, and pull box quantities. Existing lighting system infrastructure components expected to remain were not included in these quantities. Refer to the OPC later in this plan for a tabulation of the quantities.

The OPC and energy usage costs were generally based upon in-kind replacement of existing lighting system infrastructure except where noted otherwise. Several infrastructure replacement options were discussed with the Village staff to establish a basis for generating an OPC. Products and infrastructure installation requirements were selected to establish reasonable cost opinions, but evaluating and selecting exact replacement products was not a part of this analysis. Exact product selections should be determined as a part of a future design project based upon factors such as Village preferences, specific project requirements, product availability, and any applicable regulatory or funding requirements. Options discussed include the following.

1. Replacement LED Light Fixtures

The majority of the existing street lighting fixtures within the Village use high-pressure sodium lamps. A major goal of future lighting system upgrades is to replace the existing high-pressure sodium lamps with more energy efficient LED light sources. Options for this lamp replacement could potentially include:

- a. Replacing just the lamps and ballasts with LED lamps and drivers within the existing light fixture housings

- b. Replacing the complete internal components (lamps, ballasts, internal optical reflectors) of the light fixture with an LED retrofit module kit from the original light fixture manufacturer
- c. Replacing the entire light fixture with a new LED light fixture.

In general, lamp replacements have the lowest cost, but have the worst performance and shortest life expectancy while full light fixture replacements have the highest cost, but have the best performance and longest life expectancy. There are a couple different main light fixture styles within the Village as indicated below. The LED conversion options selected for budgetary purposes were different for each light fixture style based on age, available products, and existing Village practices.

The areas along East Capitol Drive and North Oakland Avenue use decorative teardrop high-pressure sodium light fixtures (Figure 4) that were installed from 2007 to 2010. Based upon their relatively new age versus the rest of the existing lighting system and the fact that no other upgrades are needed to the lighting infrastructure along these two corridors, it was determined that the cost to replace the entire light fixtures is not justifiable at this time. Village staff have replaced a few of the high-pressure sodium lamps within light fixtures along these two corridors with LED lamps and have been satisfied with their performance. As a result, these lamps were used as the budgetary basis for LED upgrades along these two corridors to provide a cost-effective solution for upgrading to LED lighting. LED retrofit module kits manufactured by the original light fixture manufacturer were not investigated as a part of this analysis, but may be available at a higher cost if the Village desired to investigate them as an option in the future.



Source: Google Street View

Figure 4 Holophane Atlanta and Memphis Teardrop Fixtures Used Along East Capitol Drive and North Oakland Avenue

All other areas of the Village included in this analysis currently use 70- and 150-W high-pressure sodium decorative post-top light fixtures. While some of these light fixtures have been replaced during general maintenance activities over the years as a result of operational issues or damage, Village staff have indicated that many of them are from the original 1970s installation. Additionally, unlike the 240 -V light fixtures installed along East Capitol Drive and North Oakland Avenue, these light fixtures are powered at 480 V. The majority of these light fixtures have 70-W high-pressure sodium lamps and the Village staff was only able to find 240-V LED replacement lamps for that low of a wattage through their typical suppliers when searching for LED replacement lamps. An idea to install a 480 to 240-V transformer within each light fixture was investigated to accommodate 240-V LED lamps. However, it was determined that this does not meet the NEC (2020 NEC 210.6) based on correspondence with the State Electrical Inspection group because the LED retrofit solution should be a complete Underwriters Laboratories (UL)-listed

retrofit kit, and a separate transformer would not be considered a valid part of a UL-listed light fixture modification solution. The third-party LED leasing company discussed later in this report did indicate that they were able to identify a special order 70-W equivalent LED lamp that could be powered directly at 480 V. This could be an option if the system operating voltage were changed to 480 V phase-to-phase (240 V to ground). However, due to the advanced age of many of these existing light fixtures, it was determined that the best option for these light fixtures is to budget for full light fixture replacement.

The Village provided a decorative post-top LED replacement light fixture (See Figure 5) selection similar to the light fixtures recently installed along North Wilson Drive to use for this analysis. The full light fixture model numbers used for budgetary purposes were determined by matching the operational characteristics and aesthetic look of the existing decorative post-top high-pressure sodium light fixtures, and then selecting appropriate LED light fixture wattages to obtain street lighting illumination levels similar to the existing lighting using the existing pole locations along a sample roadway segment. Because light fixture layouts and street geometry vary throughout the Village, it may be pertinent to perform additional calculations when making final light fixtures selections during future design phases.

In order to select appropriate LED light fixture wattages, photometric calculations were performed for the existing light fixtures as well as the proposed LED light fixtures using AGI32 lighting software. The existing light pole mounting heights, light pole spacing, and street widths within a typical segment within the recent Southeast Area Combined Sewer Improvements Phase 1 project area were used for these calculations. Refer to Figure 6 for the photometric calculation results. Existing light fixture model number information and photometric calculation files are not available for the original 1970s light fixtures due to the age of the existing light fixtures. However, the Village provided product selection information for the light fixtures they have been purchasing to replace broken light fixtures so the photometric characteristics for that light fixture were used to generate the existing photometric calculations instead. Based on the calculations performed using manufacturer-provided photometric data, it appears the LED fixture model and lens type selected by Village staff may lead to bright and dark spots versus the existing installation, but it is outside the scope of this project to provide assistance with making an exact light fixture selection. The LED light fixture wattage modeled provides the closest approximation to the existing installation for the light fixture type selected by the Village and is sufficient for budgetary purposes. It is recommended that the exact LED light fixture selection be evaluated further in a future design phase to obtain a more even light distribution. The following characteristics were used for the LED-equivalent light fixtures in the photometric analysis and OPC. Items identified as outside of



Source: Google Street View

Figure 5 Eaton Cooper UTLD Traditionaire LED Light Fixtures Similar to North Wilson Drive Used for Analysis

the scope of this analysis should be reviewed in further depth as a part of a future design project for final selection:

- a. Light Fixture Model—Eaton Cooper Streetworks UTLD Traditionaire LED Decorative Post-Top Light Fixture.
- b. Color Temperature—A detailed color temperature selection analysis was not performed as a part of the scope of this analysis. Photometric calculations were performed for both 3,000- and 4000-Kelvin options to determine worst-case budgetary cost. The 3000-Kelvin color temperature option was used for budgetary purposes since it resulted in the highest wattage and highest light fixture cost.
- c. Voltage—A final voltage selection was not made since this does not have a significant impact on light fixture cost.
- d. Lighting Distribution Type—Type 5 (to match existing high-pressure sodium light fixtures). The use of different distribution types or house-side shields could be evaluated as a part of a future light fixture design phase, but were not reviewed as a part of this analysis.
- e. Lens Type—Refractive Lens Panels. The refractive lens used in the analysis appears to lead to poor lighting distribution, but was selected to match existing light fixtures. This selection should be reviewed further during a future design phase.
- e. Additional Features Included—Factory-Installed Ladder Rest (to match existing light fixtures), National Electrical Manufacturers Association (NEMA) 7-pin Twistlock Photocontrol Receptacle (to allow for future light fixture dimming controls if desired).

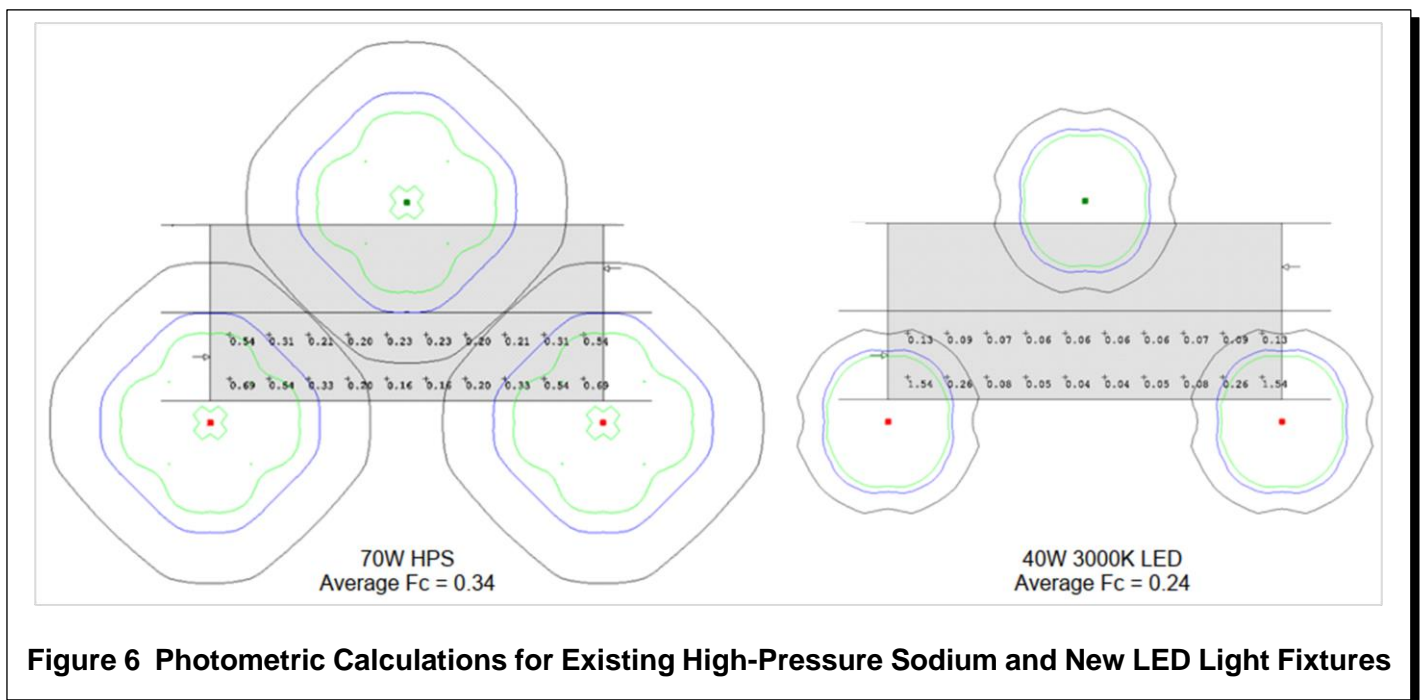


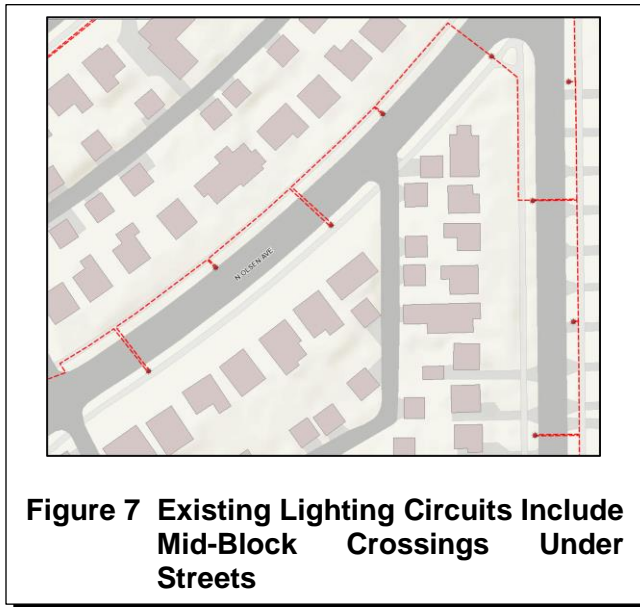
Figure 6 Photometric Calculations for Existing High-Pressure Sodium and New LED Light Fixtures

2. Wire and Conduit

The wire and conduit types and lengths within the OPC are based on the following and were modified to account for upgrades desired by Village staff as a part of replacement activities.

- a. Wire types are based on the standard WisDOT specifications for roadway lighting wiring.
- b. The conduit type used for the OPC is 2-inch directionally-drilled high density polyethylene (HDPE) conduit. It is expected to be directly buried in the ground in most locations. Conduit at roadway crossings will be routed through 3-inch directionally-drilled Schedule 80 polyvinyl chloride (PVC) conduit for additional protection. These conduit types were selected to match conduit sizes installed within the Village in recent projects, to allow for the largest existing circuit wiring sizes (2/0 American Wire Gauge [AWG]) to fit within the conduit, and to avoid the need for digging trenches throughout the Village for conduit installation. It may be possible to reduce the conduit size to a smaller size if it is determined that wire sizes are able to be reduced in future design phases based on wire sizing calculations.
- c. New wire sizes were assumed to match the existing wire sizes for the OPC. It is outside the scope of this analysis, but wire sizes should be reviewed by performing voltage drop calculations as a part of each future project design phase. Wire sizing can be impacted by many factors such as final circuit routing, voltage selection, lighting control cabinet locations and quantities, circuit reconfiguration, final control cabinet locations, and final LED light fixture wattages. It is not possible at this point to know what all of those factors will be to be able to provide accurate wire sizing calculations.
- d. Wire and conduit lengths were based on existing GIS system lighting circuit lengths and have been increased to account for improvements expected to be included in future replacement projects. These include:
 - i. The existing lighting circuits contain two wires and no ground wire. Wire lengths were increased by 50% to account for the addition of a grounding wire for each circuit.

- ii. The existing lighting system wiring is configured to include numerous mid-block crossing under streets as shown in Figure 7, which is not ideal



for roadway construction activities (increases chances of accidental lighting circuit interruption) or wiring maintenance and repair activities. In recent projects involving lighting circuit wire replacement, Village staff have opted to modify the circuit routes so that new wire and conduit street crossing locations are limited to intersections and then routed along both sides of the street to eliminate mid-block street crossings where possible. This change would lead to an increase of about 35 percent in the overall wire and conduit lengths based on a review of a few existing circuits. The wire and conduit lengths used for the budgetary OPC were increased by 35 percent to account for these improvements.

3. Light Poles

The existing light poles expected to be replaced are direct burial concrete light poles. Other than miscellaneous pole replacements completed during maintenance activities over the years, Village staff have indicated that many of the existing light poles are from the original 1970s lighting installation. In addition to being approximately 50 years old, the original light poles do not have handholes, which are traditionally used as locations to connect the underground wiring to the wiring going up to the light fixture. The existing light pole installations transition from the underground wiring to the wiring going up the light pole using splices buried underground adjacent to each light pole. Buried splices are possible failure points and require Village maintenance staff to excavate the ground to complete troubleshooting or maintenance on the wiring splices. For new installations, Village staff want to avoid direct-buried splices for improved system reliability, ease of maintenance, and troubleshooting.

In addition to the issues with the original 1970s light poles, Village staff have also indicated that the age and condition of poles that have been replaced varies. For these reasons, Village staff have provided direction to budget for replacement of all existing light poles as a part of this analysis. An on-site survey of the existing poles could be performed to determine whether any existing light poles are worth reusing as a part of a future design phase.

The OPC is based on replacing each existing direct burial light pole in-kind with a Traditional Concrete model D113-SG-EA-3T direct burial pole, as selected by the Village staff. In addition, the cost to install a pull box next to each light pole similar to Figure 8 has been included in each light pole cost for budgetary purposes because grounding conductors will be added to the new lighting installation, and it is unclear whether the direct burial pole wireways and handholes will be large enough to accommodate this additional wiring. A pull box will allow for the underground wire to be consolidated down to three wires before being routed into the pole as shown in Figure 9. The need for these pull boxes should be investigated within each future design phase. It might be possible to eliminate these pull boxes in some or all locations if it is found that the wire can be connected to each light pole without them or if it is found that the wire size can be reduced (as discussed under the wire and conduit section above).



Figure 8 Example Handhole Installed Near Light Pole

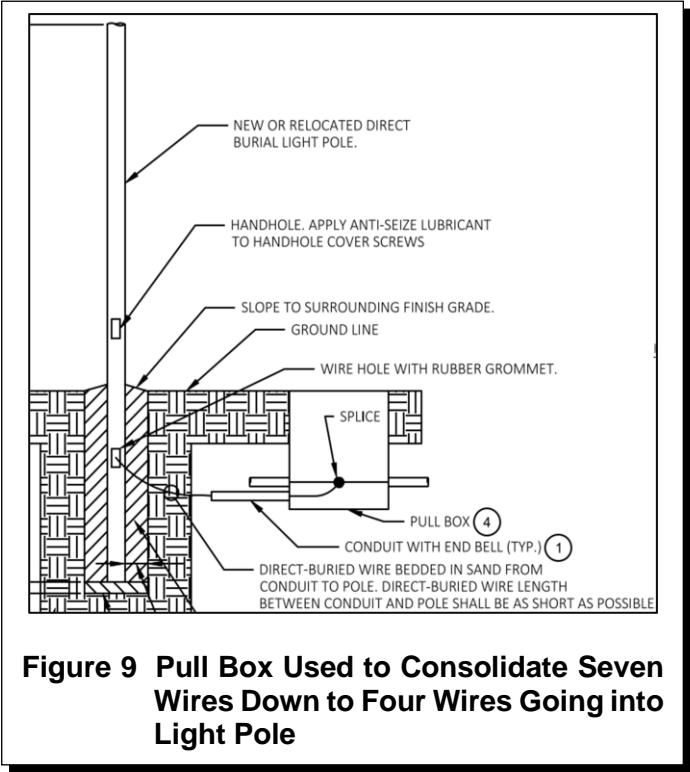


Figure 9 Pull Box Used to Consolidate Seven Wires Down to Four Wires Going into Light Pole

4. Pull Boxes

The pull box quantities within the OPC are based on replacing all existing pull boxes in-kind with Code-compliant nonmetallic electrical pull boxes similar to Hubbell 17- by 30-inch PG-style boxes. Based on input from Village staff, pull box quantities were also doubled versus existing pull box quantities to allow for the installation of additional pull boxes within the lighting system (such as on each side of roadway crossings) to provide improved wiring and conduit access for installation and maintenance.

5. Lighting Control Cabinets

The OPC includes the cost to replace the lighting control cabinets within the Village that have not been replaced from the original 1970s installation in approximately the same locations with the same style of lighting control cabinet. Items that may impact the final quantity, location, and cost of the control cabinets for consideration in a future design phase include the following:

- a. As mentioned earlier in this report, the existing lighting control cabinet voltages (480-V phase-to-ground phase) are outdated and are recommended to be

converted to either 120/240- or 240/480-V when replaced. The OPC is based on using 240/480-V lighting control cabinets so that the operating voltage of each light fixture is not changed from the existing system. Changing the system operating voltage from 480 to 240 V would have a direct impact on the system wire size and circuit loading. As a result, switching to 120/240-V power would require a detailed design to be completed and may require a complete redesign of the existing lighting system and additional lighting control cabinets, which is outside the scope of this analysis.

- b. Previous studies have been performed to discuss the differences between replacing the existing medium voltage lighting transclosure-style control cabinets in-kind with new medium voltage lighting transclosures or with WisDOT-style lighting control cabinets similar to the newer lighting control cabinets within the Village. The OPC is based on replacing the existing lighting control cabinets in approximately the same locations with the same medium voltage lighting transclosure-style control cabinets. It may be pertinent to investigate switching to a WisDOT-style control cabinet as a part of a future design phase to eliminate medium voltage power from the Village-maintained equipment.
- c. The remaining existing lighting control cabinets are grouped in two locations within the Village. It may be beneficial to change the locations and quantities of the lighting control cabinets to reduce the required wire lengths and wire sizes, which could lower overall project costs.

B. Overall Opinion of Probable Cost

Table 1 presents a summary of the opinion of probable cost using present-day costs and assuming all work is completed as a part of one contract. However, it is expected that this project will be too large to realistically accomplish in any less than 5 years as outlined under the project implementation plan portion of this report. Unit prices have been generated based on past WisDOT and Village project bid prices, correspondence with contractors, and manufacturer quotes.

Item	Quantity	Unit	Unit Price	Total Cost
Wire (4 AWG)	525,000	Linear Feet (LF)	\$3.00	\$1,575,000
Wire (2/0 AWG)	159,000	LF	\$6.70	\$1,065,000
Conduit–2-Inch HDPE Directionally Drilled	216,000	LF	\$25.00	\$5,400,000
Conduit–3-Inch Schedule 80 PVC	7,500	LF	\$24.00	\$180,000
Remove/Replace Existing 70W/150W HPS Light Pole Assemblies	921	Each (EA)	\$6,000.00	\$5,526,000
Remove/Replace 70W/150W HPS Light Fixture on Existing Pole	46	EA	\$1,500.00	\$69,000
Replace 150W/250W HPS Teardrop Lamps with LED	302	EA	\$375.00	\$113,000
Remove and Replace Existing Pull Box	170	EA	\$1,400.00	\$238,000
Add Pull Box	170	EA	\$1,200.00	\$204,000
Lighting Control Cabinet	4	EA	\$100,000.00	\$400,000
				\$14,800,000
Undeveloped Costs (Restoration, Traffic Control, etc.), Contingencies, and Engineering 40%				\$5,920,000
Total Project Cost				\$20,720,000

Table 1 Summary of Total OPC for Installation of Entire Lighting System as One Contract in Present Day Dollars

C. Energy Usage Cost Comparison

An annual energy usage cost comparison was performed to compare the energy usage of the existing HPS street lighting system to the energy usage of the system after the proposed conversion to LED sources is completed. Refer to Tables 2 and 3 for a summary of the calculations, which indicates an expected total annual energy savings of about \$50,000 after conversion to LED sources is completed. The following data was used for this comparison:

- Existing high-pressure sodium Light Fixture Power Consumption–Lamp wattage x 1.25 ballast factor.
- Replacement LED Light Fixture Power Consumption - Based on Village-selected light fixture manufacturer product information.
- Replacement LED Lamp Power Consumption–Based on Village-selected LED lamp manufacturer product information.
- Total Annual Energy Usage (in kilowatt-Hours [kWh])–Total Power Consumption (in kilowatts) x 12-hour on-time average per day x 365 days.

- 5. Utility cost per kWh—Based on average cost from past street lighting bills in 2022.

Light Fixture Type	Light Fixture Power Consumption (W)	Light Fixture Quantity	Total Annual Energy Usage (kWh)	Utility Cost per kWh	Total Annual Utility Cost
70-W HPS Post-Top	87.5	949	363,704.25	\$0.12	\$43,644.51
150-W HPS Post-Top	187.5	18	14,782.5	\$0.12	\$1,773.90
150-W HPS Teardrop	187.5	252	206,955	\$0.12	\$24,834.60
250-W HPS Teardrop	312.5	50	68,437.5	\$0.12	\$8,212.50
Total	-	1,269	653,879.25	-	\$78,465.51

Table 2 Annual Electric Cost for Existing High-Pressure Sodium Lighting System

Light Fixture Type	Light Fixture/Lamp Power Consumption (W)	Light Fixture Quantity	Total Annual Energy Usage (kWh)	Utility Cost per kWh	Total Annual Utility Cost
70-W Equivalent LED Post-top Fixture	40	949	166,264.8	\$0.12	\$19,951.78
150-W Equivalent LED Post-top Fixture	100	18	7,884	\$0.12	\$946.08
150-W Equivalent Teardrop LED Lamp	36	252	39,735.36	\$0.12	\$4,768.24
250-W Equivalent Teardrop LED Lamp	63	50	13,797	\$0.12	\$1,655.64
Total	-	1,269	227,681.16	-	\$27,321.74

Table 3 Annual Electric Cost for Proposed Replacement LED Lighting System

THIRD-PARTY LED LAMP LEASE EVALUATION

The Village has been approached by Murphy Energy, who completed the street lighting LED lamp conversion in the Village of Whitefish Bay (Whitefish Bay). They have a light fixture lamp replacement lease program available where they would propose to replace existing high-pressure sodium lamps with new LED lamps within existing light fixtures at no upfront cost to the Village in exchange for receiving a portion of the energy cost savings that the Village would experience over a certain number of years after the lamp replacement. A summary of the information gathered on this program is included in this section.

A. Murphy Energy Correspondence Summary

The following information was gathered based upon correspondence with Village Staff and Murphy Energy and has been divided into two separate discussions for the 50-year-old residential lighting and the 12- to 15-year-old business district lighting. Additional follow-up could be performed with Murphy Energy outside of this analysis to get formal proposals and make a final determination on whether to proceed with using them for any LED conversion efforts.

1. In regard to the 50-year-old residential area lighting, Murphy Energy indicated it was able to identify a supplier that could provide custom-ordered LED replacement lamps for the existing 70-W, 480 V lighting used within the residential areas of the Village. It was noted that the lighting system operating voltage would need to be changed from 480 V, phase-to-grounded phase to 480 V, phase-to-phase (240 V to ground) in order for this to be a Code-compliant solution, which would need to occur outside of Murphy Energy's scope of work. Using Murphy Energy's lamp replacement program would be a way to transition to LED lighting for less cost, but would still leave the Village with 50-year-old light fixtures. Additionally, doing this alone would not address the more important underlying code, condition, and safety-related issues within the system. As discussed in the Whitefish Bay correspondence summary section in the following, these additional factors make the situation for the Village residential area lighting different than what Whitefish Bay was faced with. Based upon the age of the existing light fixtures in the residential areas, Village staff indicated that using the lamp replacement program is likely not a preferred option for these light fixtures.
2. Murphy Energy indicated it would be able to install replacement LED lamps within the existing business district high-pressure sodium light fixtures along East Capitol Drive and North Oakland Avenue, which are approximately 12 to 15 years old and operate at 240 V. This would be similar to the LED lamp replacement that was performed for Whitefish Bay and would not be expected to require any other infrastructure upgrades like the residential area lighting. If this was pursued, it would remove the OPC line item cost associated with replacing 150W/250W high-pressure sodium Teardrop Lamps with LED. While this approximately \$100,000 cost is low relative to the overall cost of the project, it may be worth investigating further in the future as an alternative to having a contractor do this as a part of the other lighting system infrastructure upgrades projects.

B. Whitefish Bay Correspondence Summary

Whitefish Bay has replaced all of their original street lighting system direct burial wiring and recently used Murphy Energy to complete a Village-wide conversion from high-pressure sodium lamps to LED lamps. Whitefish Bay was contacted to discuss its existing system and identify similarities and differences between Whitefish Bay and the Village to assist in the decision-making process.

1. The age of the existing lighting fixtures within Whitefish Bay is unknown, but it was not thought that they are as old as the 50-year-old light fixtures in the Village. As a result, replacing the lamps in their existing light fixtures was a viable option.

2. The service voltage for the Whitefish Bay street lighting system is a standard voltage (277/480 V with dedicated equipment ground wire) and the light fixtures operate at 277 V(phase-to-neutral) whereas much of the Village street lighting system operates at 480 volts (phase-to-grounded phase). As a result of this, standard LED lamps operating in the 120-277 V range could be used within Whitefish Bay in a code-compliant manner without needing to change the lighting system operating voltage. This is not possible for most parts of the Village.
3. Whitefish Bay noted that it has been generally happy with the new LED lamps and has not received public complaints about the new LED lamps. From a maintenance standpoint, it has had to replace very few lamps since the new LED lamps were installed (approximately five in the last year), but indicated to remember that LED lamps may eventually require bulk replacement as they approach the end of their useful life and fail.
4. Miscellaneous characteristics of Whitefish Bay's lighting system infrastructure unrelated to the LED lamp installation were also discussed. Whitefish Bay did replace all of its original direct burial underground wiring with wire in directionally drilled conduit and did so in phases of unknown quantity or duration. Wiring within Whitefish Bay is smaller than the existing wiring within the Village, enabling them to install the wiring in smaller conduit and splice it within the existing direct burial light pole handholes without issues. As a part of the upgrades, it also replaced light poles in poor condition. Light poles continue to be replaced as they deteriorate or get hit. Whitefish Bay did not replace their lighting control cabinets as a part of this phased replacement.

PROJECT IMPLEMENTATION PLAN

In order to implement the improvements discussed in this report, it is expected that the project will need to be executed in phases because of the large project size. The costs for three different implementation periods as well as the trade-offs between a shorter versus longer implementation plan have been summarized in the following. Based upon discussions with contractors, it is understood that the fastest the improvements could be made would be 5 years, which has been used as a baseline case for implementation. The longest it is recommended that the project should be implemented is 10 years.

A. Implementation Plan

The implementation plan assumes design for the first phase of the implementation plan begins in 2024 with construction work beginning in 2025. Costs are based on evenly dividing the overall OPC by the number of phases, with the design for each phase occurring each year except the last year and the associated construction for each phase occurring in following year. In addition, the costs have incorporated an assumed 3 percent annual inflation rate. There are 16 major lighting circuits of varying length and four lighting control cabinets within the Village requiring improvements. It is expected that the circuit and lighting control cabinet replacements will be divided up between phases so the overall annual costs fall within the budgeted costs. For example, the 5-year implementation plan would include approximately three to four circuit replacements and one lighting control cabinet replacement each year. The first year includes additional design cost to allow for initial design decisions such as product analysis

and selection, voltage configuration, and control cabinet placement for all phases to be completed. Table 4 summarizes the annual costs for each of the three implementation plan timelines.

Year	Total (5-Year)	Total (8-Year)	Total (10-Year)
2024	\$310,000	\$190,000	\$150,000
2025	\$4,350,000	\$2,720,000	\$2,180,000
2026	\$4,530,000	\$2,830,000	\$2,270,000
2027	\$4,670,000	\$2,910,000	\$2,330,000
2028	\$4,800,000	\$3,010,000	\$2,400,000
2029	\$4,650,000	\$3,100,000	\$2,470,000
2030		\$3,190,000	\$2,550,000
2031		\$3,290,000	\$2,630,000
2032		\$3,170,000	\$2,710,000
2033			\$2,790,000
2034			\$2,690,000
Total	\$23,310,000	\$24,410,000	\$25,170,000

Table 4 Summary of Annual Implementation Plan Option Costs Assuming 3 Percent Annual Inflation

B. Trade-Offs Based on Project Implementation Plan Duration

There are many factors that can be impacted based upon the implementation plan duration. Some of these factors are highlighted in the following for review and consideration to assist the Village in making a decision on selecting a project implementation plan.

1. Annual Cost Versus Overall Cost Impacts—Annual costs decrease for a longer implementation period, but this is at the expense of an increased overall implementation cost.
2. Inflation—Inflation will increase project costs over time. In addition, inflation is unpredictable and can potentially lead to significantly different costs as the project is split into more phases.
3. Product Availability and Regulatory Changes—The longer the lighting system upgrades are stretched out, the higher the probability of product availability changing part way through the implementation plan, especially in relation to the LED lighting products. In addition, codes and regulations can change, potentially leading to a non-uniform lighting system architecture or unpredicted costs associated with needing to meet additional regulations.
4. Probability of Existing Lighting Control Cabinet Failures—The remaining lighting control cabinets from the 1970s are already past their expected useful life. The longer the

- implementation plan takes, the higher the probability of a failure and unexpected replacement, which tends to cost more than planned equipment replacement.
5. Maintenance Cost and Safety Concerns—The original lighting system wiring infrastructure from the 1970s is already showing signs of failure. While not quantified in the budgetary numbers presented in this report, a shorter implementation plan will reduce the costs associated with maintenance and address safety concerns associated with the existing lighting system with more immediacy.
 6. Administration costs associated with items such as mobilization, bonds, submittals, insurance, and permitting are common to each project and will add cost. The projects are expected to be large enough regardless of the implementation option selected that these costs should have negligible impacts on the overall project cost.

ITEMS FOR FUTURE CONSIDERATION

In addition to the items identified for future consideration throughout the report, several topics were raised during the process of generating this plan that, while outside the scope of this plan, could be reviewed for further consideration as a part of a future project. It is recommended that any items of interest to the Village be investigated as a part of the design for the first phase of the implementation plan.

A. LED Light Source Selections

LED light source selections for this analysis were based on products selected by the Village staff and were generally made to only establish reasonable criteria for budgetary purposes. When making final LED light source (LED lamp and LED light fixture) selections in the future, some items for consideration based on Village staff and public input could include:

1. Compliance with International Dark Sky Association Requirements—The new LED light fixtures used for budgetary purposes do currently meet these requirements, but product approvals can change over time. Additionally, the existing light fixtures that are expected to only have lamp replacements done were not reviewed for compliance.
2. Energy Efficiency—While a reduction in energy usage is expected after the transition to LED light sources is complete, no analysis was completed to evaluate different manufacturers for energy efficiency. In addition, in order to be eligible for financial incentive programs, lighting products are often required to have minimum efficiencies and/or energy efficiency approvals such as Design Lighting Consortium (DLC) approvals. Lastly, dimming controls could be investigated if desired to reduce energy usage after a certain time (e.g. 12 A.M.).
3. Light Color Temperature—Public opinion on desired light color temperature as well as environmental impacts on wildlife and residents based on color temperature could be reviewed for consideration.

4. Light Fixture Distribution Types—As discussed in the report, light fixture distribution types were selected to match the existing light fixtures. These could be investigated further to minimize the impacts of light glare into homes or to change roadway and/or sidewalk lighting levels from existing lighting levels.

B. Rebate Program Investigation

Possible funding and rebate sources for LED upgrade projects such as Wisconsin Focus on Energy, WisDOT, Federal Bipartisan Infrastructure Law (BIL) funding, and other federal programs could be investigated at the start of each project phase to determine whether funds might be available for the work to be performed. These programs are typically administered on an annual basis, with eligibility requirements and dollar amounts changing each year.

C. Lighting Control Cabinet Quantities and System Operation Voltage Review

The impacts of relocating or increasing lighting control cabinet locations as well as reducing the system operating voltage from 480 V down to 240 V could be investigated. This could impact things such as constructability, wire and conduit sizes, the quantity of lighting control cabinets, uniformity with other new lighting control cabinets within the Village, and lighting system maintenance safety.

SUMMARY/CONCLUSIONS

The Village's existing street lighting system was installed in the early 1970s, with the exception of some areas that have had upgrades, and is approaching the end of its' useful life. The existing street lighting system has several deficiencies including the following:

1. Lighting control cabinets and street lighting system wiring beyond their expected useful lives of 30 to 40 years.
2. Outdated system voltage with no dedicated grounding conductor—This coupled with frequent faults in the aging wiring has led to an unreliable lighting system, significant staff maintenance efforts, and safety issues.
3. Existing wire is direct buried (versus wire in conduit), which is difficult to troubleshoot and maintain versus wire installed in conduit.
4. Insufficient electrical working clearance around existing fire station lighting control cabinets.
5. Outdated and inefficient light fixtures.
6. Pull boxes are not code-compliant.

Based on the deficiencies described above, a full replacement on the street lighting infrastructure from the 1970s is recommended. A present-day OPC for full replacement of the street lighting system is \$20,720,000. Full replacement of the system in one year is not practical from a budgetary standpoint for the Village or from a construction standpoint for contractor availability so three phased alternatives are provided to implement the improvements. A summary of the costs for the three phases are summarized in Table 5 below assuming 3 percent annual inflation.

Year	Total (5-Year)	Total (8-Year)	Total (10-Year)
2024	\$310,000	\$190,000	\$150,000
2025	\$4,350,000	\$2,720,000	\$2,180,000
2026	\$4,530,000	\$2,830,000	\$2,270,000
2027	\$4,670,000	\$2,910,000	\$2,330,000
2028	\$4,800,000	\$3,010,000	\$2,400,000
2029	\$4,650,000	\$3,100,000	\$2,470,000
2030		\$3,190,000	\$2,550,000
2031		\$3,290,000	\$2,630,000
2032		\$3,170,000	\$2,710,000
2033			\$2,790,000
2034			\$2,690,000
Total	\$23,310,000	\$24,410,000	\$25,170,000

Table 5 Summary of Annual Implementation Plan Option Costs Assuming 3 Percent Annual Inflation

It is recommended that the Village proceed with a 5-year implementation plan to reduce overall project costs, minimize the possibility of product changes during implementation, and improve system reliability and safety as quickly as possible.