46th Street Pilot Street Lighting Project

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Hennepin County Housing, Community Works and Transit

January 2013

Research Project
Final Report 2013-04

Minnesota Department of Transportation

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16. Abstract (Limit: 250 words)

Street lighting improvements provide an opportunity for governments to save money and to reduce their environmental footprint. New energy-efficient technologies are being perfected that are more efficient than standard high-pressure sodium streetlights. Light-emitting diode (LED) and induction are two types that hold promise of saving money while using less energy to reach light standards. Many manufacturers have developed energy-efficient lighting products with a variety of performance claims. There has been limited in-field, head-to-head testing of these products, particularly in cold weather climates, to help governments choose the most suitable product.

This research project had two aims: (1) compare lighting performance among induction, LED, and standard high-pressure sodium streetlights, and (2) compare lighting performance among six LED brands/manufacturers and three induction brands/manufactures to evaluate consistency by vendor. This research evaluates the LED and induction streetlights on several measures: (1) energy consumption, (2) operating costs, (3) maintenance calls, (4) light levels and quality, and (5) public reaction/acceptance.

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Executive Summary

One of the largest studies of energy-efficient, street lighting options in Minnesota was installed in 2010 as part of the Minnehaha-Hiawatha Community Works program. The lights are located in south Minneapolis along 46th Street from 34th to 46th avenues. Hennepin County worked with the city of Minneapolis, Longfellow Community Council, and Standish-Ericsson Neighborhood Association on this project to enhance the walking, biking, and driving environment along 46th Street connecting to the light rail transit station. The project cost approximately $475,000, including a 20 percent contribution from the city of Minneapolis and the Local Road Research Board (LRRB).

Energy-Efficient Street Lighting

Induction and light-emitting diode (LED) are two commonly used energy-efficient light sources. Energy efficiency means these types of lights require less energy to function at commonly acceptable outputs. The county, city, and Local Road Research Board collaborated to evaluate the operation of these new streetlights. For this evaluation, collected light data was compared to city of Minneapolis streetlight standards.

The project involved the installation of 55 energy-efficient lights on 46th Street, including:

- 43 **LED lights** from six manufacturers installed east of Hiawatha Avenue, including a mixture of 30-foot poles with shoebox-style fixtures and 15-foot poles with acorn fixtures.
- 12 **induction lights** from three manufacturers installed west of Hiawatha Avenue, all 15-foot poles with acorn fixtures.

Energy-efficient lights typically have higher initial costs than standard high-pressure sodium (HPS) lights. These costs are somewhat offset by lower energy bills from a projected 50 percent or greater reduction in energy use. A second potential source of cost savings is lower cost of maintenance. A standard street light lasts approximately 25,000 hours, while manufacturers claim LED and induction fixtures last approximately 50,000 hours. Cost savings could be realized by not having crews replace lights as frequently.

Hennepin County and Minneapolis monitored light performance for two years using multiple parameters: operating cost, energy use, maintenance, and light quality. The project identified a comparison block with standard HPS lights located along Lyndale Avenue in south Minneapolis.

Project Results

Installation costs: The typical high pressure sodium streetlight cost $350. On average, the installed induction lights cost $450 more per light than standard HPS lights. The acorn-style LEDs had a $750 cost premium and the shoebox-style LEDs a $1,050 premium. This project found a large price variation among manufactures.

Energy: Field tests indicated that the induction lights drew 0.4 to 1.1 amps per light, and the LED lights drew 0.5 to 1.2 amps per light. The control case HPS lights drew 1.6 to 2.1 amps per light – indicating a decrease of 50 to 75 percent in energy use versus the standard HPS streetlights.

Light output levels: Light levels produced by low-level induction lights were, in general, more suited for residential applications. They generally met the Residential Area lighting goals established in the city of Minneapolis Lighting Policy in all collected locations but were too low for pedestrian areas. The high/low-level LED light combinations provided illumination better suited for more commercial areas.

The footcandle goals defined in the city of Minneapolis Lighting Policy for Pedestrian Areas were achieved by approximately half the lights in all the tested locations. There also seemed to be a difference in the uniformity of light, with LED having the highest light coverage, HPS the lowest, with induction somewhere in between. The induction lights experienced a slight degradation in light output levels during cold temperatures. LED light output levels varied greatly among manufacturers.

Maintenance: One LED and one induction light failed – both were replaced by spare LED/induction lights. One LED light was damaged in an accident and was replaced with an HPS light.

Payback: Estimated payback for the induction lights ranged from 2.9 to 9.5 years. Estimated payback for the LED lights ranged from 2.6 to 21 years for acorn-style and 5.3 to 24 years for shoebox-style lights. In general, streetlights with higher cost (and longer paybacks) tended to have better light quality. Approximately 80 percent of cost savings from the efficient streetlights comes from reduced maintenance costs and 20 percent from energy savings.

Public Response: Just over 100 households/businesses within one block of 46th Street responded to a mail survey on the new lights. Overall, respondents had a positive impression of the new lights, particularly in comparison to the previous lights: 76 percent indicated a good/very good impression of roadway and sidewalk light levels today – compared to 27 percent for the old lights (the improved perception could be expected since this project doubled the number of lights in the corridor). Respondents also gave high marks to the new street lights' fixtures, visibility, light color, and glare.

I. Introduction

The 46th Street Pilot Street Lighting Project was the first major investment funded under the Minnehaha-Hiawatha Community Works project (MHCW). In early 2010, the city of Minneapolis installed 55 street lights on 46th Street between 34th and 46th avenues. The result is a corridor with much improved lighting for walkers, bikers, transit users, and drivers and better connections to the 46th Street light rail transit (LRT) station and nearby neighborhoods.

The 46th Street Pilot Street Lighting project is a direct outgrowth from the stakeholder engagement process for MHCW. Area stakeholders brought up a variety of ideas and outcomes they would like to see in the Minnehaha-Hiawatha corridor, including better lighting, safety enhancements, enhanced connections to LRT stations, improved walking and biking environment, and support for sustainability.

In response, Hennepin County and the city of Minneapolis worked with the Longfellow Community Council and Standish-Ericsson Neighborhood Association on a project to improve walking, biking, and driving along 46th Street connecting to the LRT station. The Hennepin County Board and city of Minneapolis approved this project in summer 2009, and the Local Road Research Board (LRRB) provided additional funding in spring 2010. The project began operation in April 2010, and was installed with no assessments to nearby property owners.

An innovative component of this project is the testing of two energy-efficient lighting technologies: LED (light-emitting diode) on the east side of Hiawatha Avenue and induction on the west side of Hiawatha. Both technologies claim to have the potential to reduce energy use and operating costs while benefiting the environment. Through long-term tracking of energy use, maintenance and operating costs, and light quality, this project helped define costs and benefits of each technology versus city-standard high-pressure sodium (HPS) lights.

II. Background and Process

The Hennepin County Board initiated Minnehaha-Hiawatha Community Works in 2007 to capitalize on the Hiawatha LRT line by targeting county investments in infrastructure to promote economic development and vitality, improve the area's natural systems, enhance transportation connections, and improve quality of life. Since then, the county has managed a multi-year community and stakeholder engagement process to identify projects that would achieve these benefits. As part of this effort, the county created a Community Advisory Committee (CAC) – with representation from area neighborhoods and businesses – to oversee a stakeholder engagement process to identify issues, solutions, and desired outcomes from this project.

In summer 2009, the project team looked at several potential projects for immediate implementation within the corridor area. CAC and stakeholder review of community input identified the 46th Street Pilot Street Lighting project as an opportunity to address several outcomes desired by the community: improved pedestrian and bike access to transit stations, safety, connectivity, sustainability, and support for economic development.

Hennepin County worked with the city of Minneapolis and consultant, Stonebrooke Engineering, on the planning, design, and implementation of the project. County staff distributed information at properties within one block of the project area and at the 46th Street LRT station. The county partnered with the Longfellow Community Council and Standish-Ericsson Neighborhood Association to hold two public meetings to review the project and get public input. Residents and community leaders, overall, were supportive of the project. Initial questions focused on the proposed appearance of the lights, construction and assessment, and potential use of energy-efficient technologies.

III. Technology

Overview of Energy-Efficient Lighting Options

In response to community representative and resident inquiry, Hennepin County pursued the systematic installation of energy-efficient street lights within the project corridor. Energy efficiency for street lights means the lights require less energy to function at defined outputs while being constructed of environmentally sensitive materials. Compact florescent, induction, LED (light-emitting diode), and next-generation halogen are the most commonly identified energy-efficient light sources. These lighting types have been around for many years, but some have been applied only recently as a practical street lighting option. This project focuses on LED and induction lighting technologies. These lighting types were selected for study due to their increasing application as an alternative street light source throughout the US.

Induction Lights – Detail

Induction lights are an electrodeless lamp where light is created outside the lamp envelope by means of an electromagnetic field and uses fluorescent lamp phosphors to provide luminance. Mercury vapor in the discharge vessel is electrically excited to produce short-wave ultraviolet light, which then excites the phosphors to produce visible light.

Advantages of Induction

- Immediate activation
- Lower energy consumption
- Long lifespan
- Minimal lumen depreciation
- White color spectrum light

Disadvantages of Induction

- Light loss in cold weather
- Poor light focus
- Higher cost compared to typical standards

Applications

- Parking garage lighting
- Street lighting
- TV monitors

Induction lights have a mercury tip, which must be properly disposed as hazardous waste; however, the rest of the induction lamp is not hazardous and does not require special disposal.

LED Lights – Detail

LED's are a semiconductor light source. Energized electrons recombine with electron holes within each diode, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor.

Advantages of LEDs

- Cool light
- Light dimming ability
- Light focus
- Lower energy consumption
- Immediate activation
- White color spectrum light

- Long lifespan
- Low toxicity
- Improved robustness – compensation for partial failures

Disadvantages of LEDs

- Directed light dispersion
- Voltage sensitivity
- High cost compared to typical standards

Applications

- Flashlights
- Street lighting
- Traffic signals
- TV and computer monitors
- Architectural lighting with color change
- Aviation, vehicle, and bicycle lighting
- Stage production and camera lights

LED fixtures are made of materials that are generally considered non-hazardous.

IV. Project Design and Installation

Project Layout

The city of Minneapolis has published street light standards that they aim to meet with any street light installation (http://www.ci.minneapolis.mn.us/streetlighting/index.asp). These standards were used as the basis for desired light levels for this project. Additionally, these standards identify street light layout patterns that are recommended for varying areas of the City.

The Project area was broken into two areas to align with corridor characteristics defined in the city of Minneapolis Street Lighting Policy. The area west of Hiawatha Avenue is considered "residential" and the area east of Hiawatha Avenue is considered "pedestrian." The layout recommendation for a "residential" area is to stagger space four low-level (15') streetlights per block. The layout recommendation for a "pedestrian" area is to alternate high-level (30') and low-level (15') streetlights soldier spaced. Induction light type was selected for the "residential" area due to lack of availability of a high-level induction streetlight. All streetlights in the "pedestrian" area are LED. **Table 1** details the city of Minneapolis lighting goals for the varying layout areas of this analysis:

Table 1: City of Minneapolis Streetlight Area Lighting Goals

Criteria/Area	Pedestrian Area	Residential Area
Foot Candles	0.8 to 1.2 fc	0.3 to 0.6 fc

Low-level project lights have an acorn fixture style. This fixture type was selected by community meeting input and to match surrounding area fixtures. (Note: Acorn style fixtures are no longer utilized by the city of Minneapolis as they do not meet full-cutoff standards.) High-level lights are a series of modified shoe-box fixtures. Induction and LED light layouts with collected light levels can be found in Attachment A.

Table 2: Street Light Layout

Layout Areas		
Segment	34th Av to Hiawatha Av	Hiawatha Av to 46th Av
Area	Residential	Pedestrian
Layout	Staggered	Soldier: alternating 30' high level & 15' low level
Fixture	Acorn	Modified shoebox
Type	Induction	LED

Project Timeline

July 8, 2009	First neighborhood meeting – review concept and lighting options
Aug. 11, 2009	Project approved by Hennepin County Board
Aug. 14, 2009	Project approved by Minneapolis City Council
Sept. 15, 2009	Second neighborhood meeting – review draft layout and lighting styles
Oct. 2009	Installation begins

Jan. 2010	Resident survey conducted of pre-installation impressions
April 2010	Streetlights turned on
Nov. 8, 2010	Streetlight event / celebration
Dec. 6, 2010	Field Test #1 – Light Output and Quality
May 26, 2011	Field Test #2 – Light Output and Quality
Nov. 26, 2011	Amperage reading
Nov.-Dec. 2011	Resident survey conducted of post-installation impressions
Jan. 30, 2012	Field Test #3 – Light Output and Quality
June 6, 2012	Field Test #4 - Light Output and Quality
Aug. 2012	Final Report

Construction and Installation

The city of Minneapolis began installation of the project streetlights in October 2009 and completed installation in April 2010. Installation consisted of boring conduit, installing light bases and poles, pulling and installing wiring, installing cabinets, and installing each light fixture. Lighting units were wired such that in the event of a failure, a standard Minneapolis streetlight could be installed. The acorn style lights used "retrofit" kits in the fixtures, while the modified shoeboxes were entirely new units. Upon completion of the street light installation, project indication signs (created specifically for project area identification) were attached to light poles at the ends of each study block.

The project design included a variety of light manufacturers to allow direct comparison of performance between brands. Three different induction manufacturers represented by three vendors were applied west of Hiawatha Avenue: AITI, Hadco, and Lumec. Nine different LED manufacturers represented by six vendors were applied east of Hiawatha Avenue: American Electrical, Beta, Elumen, Hadco, Hanover, Holophane, Light Emitting Design, Lumec, and Sylvania. Each light manufacturer was installed in a one-to-two block area to facilitate comparison of light levels, color, and public appeal.

Project Costs

Total cost for the project was $475,000. The project was funded under Hennepin County's Minnehaha-Hiawatha Community Works umbrella, with contributions from the city of Minneapolis and Local Road Research Board. A funding breakdown is detailed below:

$375,000	Hennepin County Capital Bond Funds
$50,000	City of Minneapolis Energy Conservation and Emission Program
$50,000	Local Road Research Board Funds
$475,000	Total

The cost of the LED and induction lights varied widely by manufacturer. On average, the cost of an LED fixture used in this study was approximately 3-1/2 times that of an equivalent High Pressure Sodium (HPS) fixture currently used as the city standard. The average cost of an induction fixture was approximately double that of an equivalent HPS fixture currently used as the city standard.

Table 3: Streetlight Costs by Type

Streetlight Type	Average Price	Installed Fixtures – Price Range
HPS	$350	$350
Induction (Low Level)	$800	$543 to $975
LED (Low Level)	$1,100	$523 to $1,711
LED (High Level)	$1,400	$700 to $2,018

Many of the LED and induction manufacturers claimed fixture lives of at least 50,000 or more hours versus 20,000 hours for HPS, and all use about half the wattage. Color temperatures for study lights ranged from 4000 to 5000 kelvin.

In-Place Lighting Comparison / HPS Location

Minneapolis staff identified Lyndale Avenue South between 46th Street and 48th Street as comparison blocks with recently installed high-pressure sodium lights. This roadway section was rebuilt in 2008 and contains a HPS soldier-style high-low streetlight layout similar to the Pilot Light Study layout east of Hiawatha Avenue. Because this section has both high and low-level lights, comparison field readings for both were achieved in one location.

V. Evaluation - Energy & Maintenance Costs

Estimated paybacks for the LED and induction lights were calculated using the following assumptions:

- **Electricity Rate:** Current rate of 4.6 cents per kilowatt hour (Purchase Year - 2010)
- **Operation Duration:** Streetlights are operational an average of 12 hours per day during the year
- **Maintenance costs:** The LED and induction lights are expected to last at least 10 years as compared to the average lifespan of four to five years for an HPS fixture. The LED/induction lights would save one light "change out" – estimated to cost $250 per time or $55/year annual savings amortized over the fixture life.

15' low-level LED: The low-level LED lights have an average $750 cost premium but save 50 watts of electricity. The average payback for the 15' LED is estimated at:

$$\frac{\text{\$750 cost premium}}{\text{((.5*8760 hours/year*.05 kw saved*\$.046/kwhr) + \$56/year maintenance savings)}}$$

= approximate **11.4 year payback**.

Looking at the specific lights used in this pilot project, the estimated payback ranges from 2.6 years for the lights in Section I (manufacturer- Light Emitting Diode) to 21 years for the lights in Section D and H (Hanover).

30' high-level LED: Power levels drop from 150-watt HPS to an 80-watt LED and carry an average premium of $1,050/fixture for an approximate 50,000 hour lifespan. Average payback is estimated at:

$$\frac{\text{\$1,050 premium}}{\text{((.5*8760 hours/year*.07 kw saved*\$.046/kwhr)+\$56/yr maintenance savings)}}$$

= approximate **15 year payback**

Payback estimates for the various manufacturers used in the pilot project ranges from 5.3 years for the lights in Section E (Hadco) to 24 years in Section D (Beta).

15' induction light: Power levels drop from 100 watts down to 50 watts, same as the LED. The average price premium for induction lights compared to HPS appears to be around $450. Average payback is estimated at:

$$\frac{\text{\$450 premium}}{\text{((.5*8760 hours/year*.05 kw saved *\$.046/kwhr) + \$55/year maintenance savings)}}$$

= approximate **6.9 year payback**

Payback estimates for the various manufacturers used in this pilot project range from 3 years for the lights in Section A (AITI) to 9.5 years for the lights in Section C (Lumec). Attachment B details the exact payback and performance data for each of the participating light manufacturers.

The greatest opportunity for cost savings with these types of fixtures appears to be the potential maintenance savings due to longer life. In fact, almost 80 percent of the estimated payback for these lights is from maintenance savings and 20 percent is from energy savings. Looking at energy savings alone, the paybacks are up to 40 years based on current average product pricing.

VI. Evaluation – On-Site Assessments

On-Site Assessment #1 (Winter 2010)

Initial light output levels in footcandles (fc) for both the Pilot Lighting Study Area and the HPS Comparison Area were originally collected on December 4 and 6, 2010. Light level readings were measured with a hand-held foot candle reader roadside and sidewalk-side to evaluate directional light output.

Induction: On the three blocks with induction lights, the light quality appeared to be satisfactory for residential lighting but did not appear to be bright enough for commercial node lighting. The lights had satisfactory 360-degree distribution. One manufacturer appeared to be slightly more luminous than the rest. Upon the initial light metering walkthrough, temperature 15 degrees, there appeared to be slight degradation in light levels.

LED: Most of the 15' LED test fixtures were very directional in their light output. They were very bright on the street side direction but could be fairly dim on the side not facing the actual LED. Two manufacturers had 15' LEDs with more of a 360-degree spread. The City would prefer any future focus put on fixtures with more circular distribution. The 30' high-level lighting is well suited to the directional nature of LEDs, and a couple of the manufacturers really stood out with high quality of light.

For all lights, the color spectrum provided was very evident and seems to provide sharper perception of illuminated objects. There are varying degrees of white color provided. Some manufactures provide a sharp white light and some a more dull color, even though most light temperatures were consistent.

On-Site Assessment #2 (Summer 2011)

Secondary light output levels in footcandles for both the Pilot Light Study Area and the HPS Comparison Area were taken on May 26 and June 13, 2011, respectively. Testing temperature was 60 degrees.

LED: Overall, the LED lights maintained light output levels with scattered minor losses in footcandles, approximately 0.1 fc. Block F was noted for very dim color and Block G was noted for good color and distribution.

Induction: On the three blocks with induction lights, a minor drop in footcandles was consistently recorded. The drop was typically within 0.1 fc, which could be due to slight changes in the light collection location, slight changes in ambient light, or differences in ground surface reflection. Again, the induction light type does not appear bright enough for a commercial area. This is especially noticeable in the darker western end of the study area in between study lights. No change in light distribution was noticed.

HPS: The comparison lights along Lyndale Avenue appear to be consistently functioning with regards to study analysis parameters. Footcandle readings were within a few tenths of previous

readings, which could be due to slight changes in the light collection location, slight changes in ambient light, or differences in ground surface reflection.

On-Site Assessment #3 (Winter 2011)

Due to an unseasonably warm winter in the project area, subfreezing performance was not able to be recorded. The field test temperature was recorded at 34 degrees.

Induction: Footcandle readings were consistent (except for two light areas) with previous data collection values. Small gains or drops +/- 0.1 fc were recorded, which could be due to slight changes in the light collection location, slight changes in ambient light, or differences in ground surface reflection due to minor amounts of snow. Induction lights located on the west end of the project were viewed to experience a slight fluttering effect.

LED: These lights maintained light output levels with scattered minor losses in footcandles, approximately 0.1 fc. Blocks E and F continue to be produce a more dim color compared to the rest of the test lights, and Block G continues to produce good color and distribution.

Maintenance: There was one induction light failure and one induction light removed due to area construction during this study period. LA2 failed due to operational issues, and LA9 was removed to allow for construction in the northwest corner of 46th Street and Hiawatha Avenue . The fixture from LA9 was used as a replacement at LA2. This explains the two locations where fc disparity was greater than the average.

HPS: The comparison lights along Lyndale Avenue continue to function consistently with regards to study analysis parameters. Footcandle readings were within a few tenths of previous readings, which could be due to slight changes in the light collection location, slight changes in ambient light, or differences in ground surface reflection.

On-Site Assessment #4 (Summer 2012)

The final assessment of light output levels for both the Pilot Light Study Area and the HPS Comparison Area were recorded the week of June 6, 2012. The spring season prior to testing was marked with a substantial amount of rainfall leading to above average vegetative growth amongst the adjacent trees.

Induction: On the three blocks with induction lights, the fc readings were mostly consistent with previous data collection values. Small gains or drops +/- 0.1 fc were recorded, which could be due to slight changes in the light collection location, slight changes in ambient light, or differences in ground surface reflection. There were marked data collection locations that experienced footcandle drops greater than 0.1 fc. These lights were located in areas with fully bloomed vegetation.

The induction light type does not appear bright enough for a commercial area – especially noticeable in the darker western end of the study area in between study lights. However, from a strictly qualitative user perspective, the lights appear to be more dynamic during warmer temperatures than colder temperatures and the slight fluttering noted in the previous winter has appeared to have subsided. The induction lights located on the east end of the study area have

consistently performed much better than those located on the west end. No change in light distribution was noticed.

LED: Overall, the LED lights experienced scattered minor losses in footcandles, approximately 0.2 to 0.3 fc. The extra vegetative cover in the area seemed to interfere with light projection as many of the test lights were overwhelmed by nearby tree growth that had not been noticed over the past two years. Study blocks noted for observed better performance continue to outperform the previously reported poorer performing blocks.

HPS: The comparison lights along Lyndale Avenue appear to be functioning consistently with regards to study analysis parameters. Footcandle readings were within a few tenths of previous readings.

Maintenance: There were no induction light failures since the last readings; however, there was continued construction of a large residential complex in the northwest corner of Hiawatha Avenue and E 46th Street. Construction in this area has slightly changed nearby ambient light generated by the property due to shifts in site lighting and building complex expansion. There has also been slight ambient light changes due to shifts in the location of the traffic signal at 36th Avenue S to accommodate access to the new development area.

The lack of additional failures during this field test helped quell some previous concern over the sustainability of the lights, However, the lights have been only operational for two year which is not close to the 10 to 20 year lifespan claims. Sustainability will be continually monitored throughout the lifespan of the street lights.

Light Failure Summary

Since the initial field review, there have been two light failures and one fuse failure for various reasons (dates are approximate based on reports to the City):

- **05/27/11:** LED test light **LB 33** suffered a failure. City crews determined the cause to be a fixture failure. This fixture was replaced with an extra LED in the City's storage facility and continues to function.
- **05/27/11:** LED test light **LB 43** suffered a failure. City crews determined the cause to be a faulty fuse. The fuse was replaced and the light is once again operational.
- **09/26/11:** Acorn test light **LA 2** suffered a failure. City crews are unsure of the cause.

One light was lost to wreck.

- **03/01/11:** LED test light **LB 11**.. This light was replaced with an HPS standard acorn fixture and continues to function.

In addition, **Acorn test light LA 9,** was removed by the city during construction of an apartment building. The light will be replaced when the area is no longer needed for construction.

Initially, the various manufacturers claimed between 50,000 and 100,000 hour plus life expectancies for their fixtures. It is still too soon to tell if these claims are valid from field test data as they have been installed nowhere near the length of each light's claimed lifespan. With

each of the fixture failures performance length claims lost some validity. However, since the failure recorded in September 2011, there have been no further issues. In retrospect, there has been a high amount of consistent performance over the two-year test period.

Additional Field Test - Amperage Reading Evaluation

At the request of participating agencies, amperage readings were taken in the associated service cabinets of the induction, LED, and HPS test lights to evaluate the power draw from each light. Below is a summary of amperages collected on November 26, 2011, for the three study areas:

Induction Lights:	0.4 - 1.1 Amps/Light
LED Lights:	0.5 - 1.2 Amps/Light
Lyndale HPS Comparison Lights:	1.6 - 2.1 Amps/Light

For both the pilot and comparison test areas, fixtures are wired to specific streetlight service cabinets; however, due to project funding constraints all lights were not wired to individual meters. Therefore, amperage data was collected by using an amperage reading clamp meter on each of the service feeds. This gave an averaged general indication of the power draw from the streetlights wired to each cabinet. The exact location of each light to specific service cabinet cannot be related to individual lights as wiring diagrams for all systems are not available.

As noted in the data above, the induction and LED lights consume two to three times less energy than the City standard HPS lights. These ranges are mostly consistent with manufacturer claims for power usage. Induction lights LA-1 to approximately LA-6 were recorded to consume less energy than LA-7 to LA-12. For LB-1 to approximately LB-17 the power levels recorded were on the higher end of the LED range and LB-18 to LB-43 were on the lower end of the power consumption range.

General

The LED and induction lights both project a white light versus the yellowesque glow from HPS streetlights. All light types give off enough light to meet the requirements defined in the city of Minneapolis Streetlight Guidelines. However, there does appear to be a difference in the uniformity of light, with LED having the highest light coverage, HPS the lowest, with induction somewhere in between. This difference can be seen in photos of the test area where there is fairly dispersed light coverage in the better performing LED areas and dark pockets between the induction and HPS lights.

Many of the vendors promoted warranties associated with their representative LED and induction lights. Several vendors were contacted to discuss manufacturer replacement policies for the failed test lights. However, some of these vendors are no longer affiliated with the light manufactures they specified for the project. Therefore, it was determined that warranty replacements would not be sought and street lights would be reviewed from a total lifespan performance perspective only.

Study Caveats

Photometric Design: Photometric layouts were not evaluated with this study for two reasons: (1) at the onset of the project, IES photometric files were available for some but not all of the lights, and (2) streetlights were placed based on the city of Minneapolis Street Light Policy which dictate the amount and height of lights per block.

Ambient Light: All study areas are located along urban streets with varying adjacent land uses and traffic levels. Some bordering businesses were open during earlier winter data collection times and closed during later summer data collection times. Therefore, ambient light levels constantly changed along the corridor. In addition, seasonal changes brought surface cover variances.

Lyndale Avenue Street Light Layout: The Lyndale Avenue Comparison Corridor follows the City Guidelines for street light installation; however, the test block spacing exceed those of 46th Street due to the overall length of the roadway blocks. Therefore, the light uniformity collected between lights is not an exact comparison but more of an indication.

Acorn Style Fixtures: The city of Minneapolis no long allows the use of acorn style fixtures as these types of fixtures do not meet the full cut-off guidelines for streetlights defined in the city of Minneapolis Lighting Policy.

Retrofit Components: The city of Minneapolis will no longer consider retrofit streetlight components due to the inability to maintain UL Listings.

VII. Public Reaction

In late November 2011, Hennepin County sent a mail survey to over 600 residences and businesses located within one block of 46th Street. The survey measured opinions of the lighting conditions on 46th Street 1½ years after the installation of the new street lights. The survey was 1½ pages long and included return postage. The county received 100 completed surveys – full results are included in Attachment C.

Overall, respondents have had a *positive* impression of the new lights, particularly in comparison to the previous lights: 76 percent indicated a good/very good impression of roadway and sidewalk light levels today – compared to 27 percent for the old lights.

- Respondents were impressed with the visibility, light color, glare, and "look" of the new street lights: 79 percent rated *appeal of lamps and fixtures* good/very good, 74 percent rated *visibility* good/very good, 73 percent rated *light color* good/very good, and 65 percent rated the *glare* good/very good.
- Most respondents (68%) said the new lights give off the right amount of light, compared to only 30 percent with the old lights.
- Three quarters of respondents indicated they felt safe walking along 46th Street after dark.
- On average, respondents drove 17 times, walked five times, and biked once along 46th Street during a typical week in October/November 2011.

Observations

Given all the metrics considered under this project, the overall viability of energy-efficient light technology remains mixed. The following table summarizes the performance of each brand of light (based on 2009 installed technology):

Table 4: Performance of Lights by Brand

Sec - tion	Type	Head	Manufacturer	Ave. Light Levels (foot candle)	Estimated Payback (years)	Failures?
A	**Ind**	**Acorn**	**AITI**	**.66**	**2.9**	**1 – acorn**
B	**Ind**	**Acorn**	**Hadco**	**.61**	**6.3**	
C	**Ind**	**Acorn**	**Lumec**	**1.19**	**9.5**	
D	**LED**	**Acorn**	**Hanover**	**1.62**	**20.7**	
E	**LED**	**Acorn**	**Hadco**	**.86**	**11.4**	**1- accident**
F	**LED**	**Acorn**	**Holophane**	**.50**	**n/a**	
G	**LED**	**Acorn**	**Lumec**	**.63**	**4.7**	
H	**LED**	**Acorn**	**Hanover**	**.85**	**20.5**	
I	**LED**	**Acorn**	**Light Emitting Design**	**.64**	**2.6**	**1 - fuse**
D	**LED**	**Hi Lvl**	**Beta**	**1.57**	**24.0**	
E	**LED**	**Hi Lvl**	**Hadco**	**1.34**	**5.3**	
F	**LED**	**Hi Lvl**	**American Electrical**	**.73**	**12.4**	
G	**LED**	**Hi Lvl**	**Lumec**	**.93**	**15.2**	
H	**LED**	**Hi Lvl**	**Beta**	**1.21**	**22.7**	**1 - LED**
I	**LED**	**Hi Lvl**	**Elumen**	**1.16**	**15.8**	

Visibility: Light levels produced by low-level induction lights are, in general, more suited for residential applications. They generally met the Residential Area lighting goals established in the city of Minneapolis Lighting Policy in all collected locations but were too low for pedestrian areas.

The high/low-level LED light combinations provided illumination better suited for more commercialized areas. The footcandle goals defined in the city of Minneapolis Lighting Policy for Pedestrian Areas were achieved by approximately half the lights in all the tested locations.

In comparison to the induction and LED lights, the test HPS streetlights along Lyndale Avenue produced light levels in accordance with City goals for Pedestrian Areas under or near the lights and footcandle levels slightly below defined City goals for Residential Areas in the areas between the lights.

Payback: As the table shows, there seems to be a slight relationship between cost/payback and observed light levels – with less expensive lights tending to have lower light output levels.

- For both the **induction** and **LED** low-level lights, the fixtures with the lowest cost and payback (Study Blocks - A, B, F, G, I) tend to produce lower average light levels.
- For the **LED** lights, higher light levels are associated with paybacks in the 12 to 24 year range.
- The biggest exception to this relationship is the Hadco LED street lights (Study Block E) with high light levels and a 5 year payback.
- The highest light levels for the **induction** lights are associated with the highest payback lights – 9.5 years

Using current data on energy, maintenance, and lighting costs, the following calculations identify when it would be cost effective to install induction or LED lights, strictly from a payback perspective:

- Low level induction = the price premium would have to be less than $330 to meet a 5-year payback.
- Low Level LED = the price premium would need to be less than $330 to meet a 5-year payback.
- High level LED = the price premium would need to be less than $350 to meet a 5-year payback.

Failures: The project has experienced two light failures (one induction and one LED) among its 55 lights – a failure rate of 4 percent. Consideration of these failures would add more time to the payback calculations, making these lights less financially viable. In addition to these failures, on light was impacted by a faulty fuse and one was destroyed in a car accident.

Public Perception: Public perception of the lights has been strongly positive.

Final Thoughts: Improvements in technology and reductions in cost over the past three years may have reduced the payback period enough to make these lights a viable option. In addition, correspondence with participating manufactures/vendors as well as interested public agency observers has indicated that product output throughout the LED and induction light industry has normalized over the timeframe of the study to a point where drastic changes in promoted products have greatly reduced.

However, this study has shown considerable variability in operation and cost associated with various manufacturers' products; therefore, comprehensive background research is strongly recommended prior to picking a product. In addition, responsive warranty claim resolution, availability of photometric files, consistent vendor support, and historical operational success should be considered during the purchasing process.

Appendix A: Field Test #4 Light Level Readings Along 46th Street and Control Corridor

FIELD TEST #4

06/06/12
75° F
10:00 - 11:30 PM

LEGEND

- LOW LEVEL LIGHTING UNIT
- HIGH LEVEL LIGHTING UNIT
- IN-PLACE LIGHTING UNIT (TO REMAIN)
- XXX — PILOT LIGHT ILLUMINANCE IN FC
- LA / X — INDUCTION LIGHT
- LB / X — LED LIGHT

N

33RD AVE. S.

34TH AVE. S.

35TH AVE. S.

46TH ST. E.

100

105

MATCH LINE STA. 106+96.0

(2) BLOCK A BACK TO BACK SIGNS

LA 1: 0.6 / 0.8

LA 2: 0.4 / 0.3 / 1.7 / 0.8

LA 3: 0.5 / 0.5 / 0.5 / 0.5

LA 4: 0.3 / 0.3 / 0.5 / 0.4

(2) BLOCK A BACK TO BACK SIGNS

0.5 / 0.5 / 0.2 / 0.3

PLOT DRIVER: pdf_bw.plt
PLOT DATE: 7/3/2012 9:14:49 AM
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USER: kmidthun
SHEET: 1 - Lighting Plan

REV. NO.	DATE	BY	CHK	DESCRIPTION

0 25 50
SCALE FEET

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

NAME _____ LIC. NO. _____ DATE 7/3/2012

DESIGNED
DRAWN
CHECKED

Stonebrooke Engineering Responsible Solutions™

LIGHTING LAYOUT
ATTACHMENT A - INDUCTION & LED LIGHTS
46th STREET PILOT LIGHTING PROJECT

SHEET 1 OF 6

FIELD TEST #4

06/06/12
75° F
10:00 - 11:30 PM

LEGEND

- LOW LEVEL LIGHTING UNIT
- HIGH LEVEL LIGHTING UNIT
- IN-PLACE LIGHTING UNIT (TO REMAIN)
- XXX — PILOT LIGHT ILLUMINANCE IN FC
- LA / X — INDUCTION LIGHT
- LB / X — LED LIGHT

N

MATCH LINE STA. 106+96.0

MATCH LINE STA. 114+21.0

46TH ST. E.

36TH AVE. S.

110

(2) BLOCK B
BACK TO BACK SIGNS

(2) BLOCK C
BACK TO BACK SIGNS

(2) BLOCK B
BACK TO BACK SIGNS

(2) BLOCK C
BACK TO BACK SIGNS

LA 5: 0.4, 0.5
0.3, 0.5
LA 7: 0.4, 0.5
NA, NA
LA 9 (1): NA, NA
0.6, 0.5
LA 11 (1): 0.9, 1.6
0.4, 0.4
LA 6: 0.5, 0.5
0.4, 0.3
LA 8: 0.6, 0.5
0.6, 0.5
LA 10: 2.0, 0.8
0.3, 0.3
LA 12: 1.8, 0.9

(1) NOTE:
OPTIONAL STREET LIGHT - FUNDING BASED

REV. NO.	DATE	BY	CHK	DESCRIPTION

SCALE 0 25 50 FEET

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LIGHTING LAYOUT
ATTACHMENT A - INDUCTION & LED LIGHTS
46th STREET PILOT LIGHTING PROJECT

SHEET 2 OF 6

PLOT DRIVER: pdf_bw.plt PLOT DATE: 7/3/2012 9:14:52 AM PEN TABLE: T-00198_planset.tbl FILE: S:\PROJECTS\TRANS\0037_HennepinCo\T-00198\Road_Design\traffic\report figures\T-00198_pilot_project_06-06-12.DGN USER: kmidthun LEVEL: 2 - Lighting Plan

FIELD TEST #4

06/06/12
75° F
10:00 - 11:30 PM

LEGEND

- LOW LEVEL LIGHTING UNIT
- HIGH LEVEL LIGHTING UNIT
- IN-PLACE LIGHTING UNIT (TO REMAIN)
- XXX — PILOT LIGHT ILLUMINANCE IN FC
- LA / X — INDUCTION LIGHT
- LB / X — LED LIGHT

N

SNELLING AVE. S.

(1) BLOCK D SIGN LOCATED ON WEST SIDE OF POLE

(1) BLOCK D SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK E SIGN LOCATED ON WEST SIDE OF POLE

LB 1 — 1.5 — 2.0 — 0.6 — 0.6

LB 3 — 1.3 — 1.5 — (INPLACE BASE) — 2.2 — 1.3

LB 5 — 2.1 — 2.2 — (INPLACE LIGHT)

LB 7 — 0.8 — 1.3 — 0.2 — 0.4

115

120

MATCH LINE STA. 114+21.0

MATCH LINE STA. 121+46.0

46TH ST. E.

LB 2 — 1.2 — 1.7

(1) BLOCK D SIGN LOCATED ON WEST SIDE OF POLE

LB 4 — 0.8 — 0.8 — 1.2 — 0.6 — 0.5 — 0.4

LB 6 — 1.3 — 1.2 — 1.1 — 1.0

LB 8 — 1.7 — 0.6 — 0.7 — 0.9

(1) BLOCK D SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK E SIGN LOCATED ON WEST SIDE OF POLE

HIAWATTA AVE.

NAWADAHA BLVD.

REV. NO.	DATE	BY	CHK	DESCRIPTION

0 25 50
SCALE FEET

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LIGHTING LAYOUT
ATTACHMENT A - INDUCTION & LED LIGHTS
46th STREET PILOT LIGHTING PROJECT

SHEET 3 OF 6

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USER: kmidthun
SHEET: 3 - Lighting Plan

FIELD TEST #4

06/06/12
75° F
10:00 - 11:30 PM

LEGEND

- LOW LEVEL LIGHTING UNIT
- HIGH LEVEL LIGHTING UNIT
- IN-PLACE LIGHTING UNIT (TO REMAIN)
- XXX — PILOT LIGHT ILLUMINANCE IN FC
- LA / X — INDUCTION LIGHT
- LB / X — LED LIGHT

N

MINNEHAHA AVE. S.

41ST AVE. S.

46TH ST. E.

125

MATCH LINE STA. 121+46.0

MATCH LINE STA. 128+71.0

(1) BLOCK E SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK F SIGN LOCATED ON WEST SIDE OF POLE

(1) BLOCK E SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK F SIGN LOCATED ON WEST SIDE OF POLE

NOTES:

1. LIGHT BASE TO BE LOCATED ADJACENT TO FRONT OF SIDEWALK
2. REVISED STREET LIGHT LOCATION

REV. NO.	DATE	BY	CHK	DESCRIPTION

SCALE 0 25 50 FEET

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LIGHTING LAYOUT
ATTACHMENT A - INDUCTION & LED LIGHTS
46th STREET PILOT LIGHTING PROJECT

SHEET 4 OF 6

PLOT DRIVER: pdf_bw.plt
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USER: kmidthun
SHEET: 4 - Lighting Plan

FIELD TEST #4

06/06/12
75° F
10:00 - 11:30 PM

LEGEND

- LOW LEVEL LIGHTING UNIT
- HIGH LEVEL LIGHTING UNIT
- IN-PLACE LIGHTING UNIT (TO REMAIN)
- XXX — PILOT LIGHT ILLUMINANCE IN FC
- LA / X — INDUCTION LIGHT
- LB / X — LED LIGHT

N

42ND AVE. S.

43RD AVE. S.

46TH ST. E.

MATCH LINE STA. 128+71.0

MATCH LINE STA. 135+97.0

130

135

(1) BLOCK F SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK G SIGN LOCATED ON WEST SIDE OF POLE

(1) BLOCK G SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK G SIGN LOCATED ON WEST SIDE OF POLE

(1) BLOCK F SIGN LOCATED ON EAST SIDE OF POLE

LB 19: 0.3, 0.4, 0.5, 0.9
LB 22: 0.3, 0.5, 0.2, 0.3, 0.4, 0.5
LB 24: 0.7, 1.1, 0.3, 0.4
LB 26: 0.5, 0.6
LB 28: 0.4, 0.5, 0.7, 1.1, 0.2, 0.4
LB 30: 0.5, 0.5, 0.7, 1.0
LB 20: 0.5, 0.2, 0.6, 0.3
LB 21: 0.7, 0.4, 0.9, 0.4, 0.3, 0.2
LB 23: 0.6, 0.5, 0.3, 0.3
LB 25: 1.1, 0.6
LB 27: 1.9, 1.2, 0.6, 0.5, 0.5, 0.2
LB 29: 1.2, 0.7, 0.3, 0.2

REV. NO.	DATE	BY	CHK	DESCRIPTION

0 25 50
SCALE FEET

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LIGHTING LAYOUT
ATTACHMENT A - INDUCTION & LED LIGHTS
46th STREET PILOT LIGHTING PROJECT

SHEET 5 OF 6

PLOT DRIVER: pdf_bw.plt
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PEN TABLE: T-00198_planset.tbl
USER: kmidthun
SHEET: 5 - Lighting Plan

FIELD TEST #4

06/06/12
75° F
10:00 - 11:30 PM

LEGEND

- LOW LEVEL LIGHTING UNIT
- HIGH LEVEL LIGHTING UNIT
- IN-PLACE LIGHTING UNIT (TO REMAIN)
- XXX — PILOT LIGHT ILLUMINANCE IN FC
- LA / X — INDUCTION LIGHT
- LB / X — LED LIGHT

N

MATCH LINE STA. 135+97.0

44TH AVE. S.

45TH AVE. S.

46TH AVE. S.

46TH ST. E.

140

(1) BLOCK H SIGN LOCATED ON WEST SIDE OF POLE

(1) BLOCK I SIGN LOCATED ON WEST SIDE OF POLE

(1) BLOCK H SIGN LOCATED ON EAST SIDE OF POLE

(1) BLOCK I SIGN LOCATED ON EAST SIDE OF POLE

LB 31: 0.9, 0.4

LB 32: 1.2, 1.1

LB 33: 1.5, 1.3, 0.3, 0.3

LB 34: 0.8, 1.0, 0.4, 0.9, 0.4, 0.5

LB 35: 0.9, 1.1, 1.0, 0.6, 1.3, 1.1

LB 36: 1.1, 1.0, 0.3, 0.7

LB 37: 1.3, 1.1

LB 38: 0.3, 0.7

LB 39: 0.4, 0.3, 0.7, 0.4

LB 40: 1.0, 1.1, 0.4, 0.7

LB 41: 1.2, 1.0, 0.3, 0.2

LB 42: 0.3, 0.6

LB 43: 0.7, 0.4

SCALE 0 25 50 FEET

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LIGHTING LAYOUT
ATTACHMENT A - INDUCTION & LED LIGHTS PLAN PAGE 6 of 6
46th STREET PILOT LIGHTING PROJECT

SHEET 6 OF 6

REV. NO.	DATE	BY	CHK	DESCRIPTION

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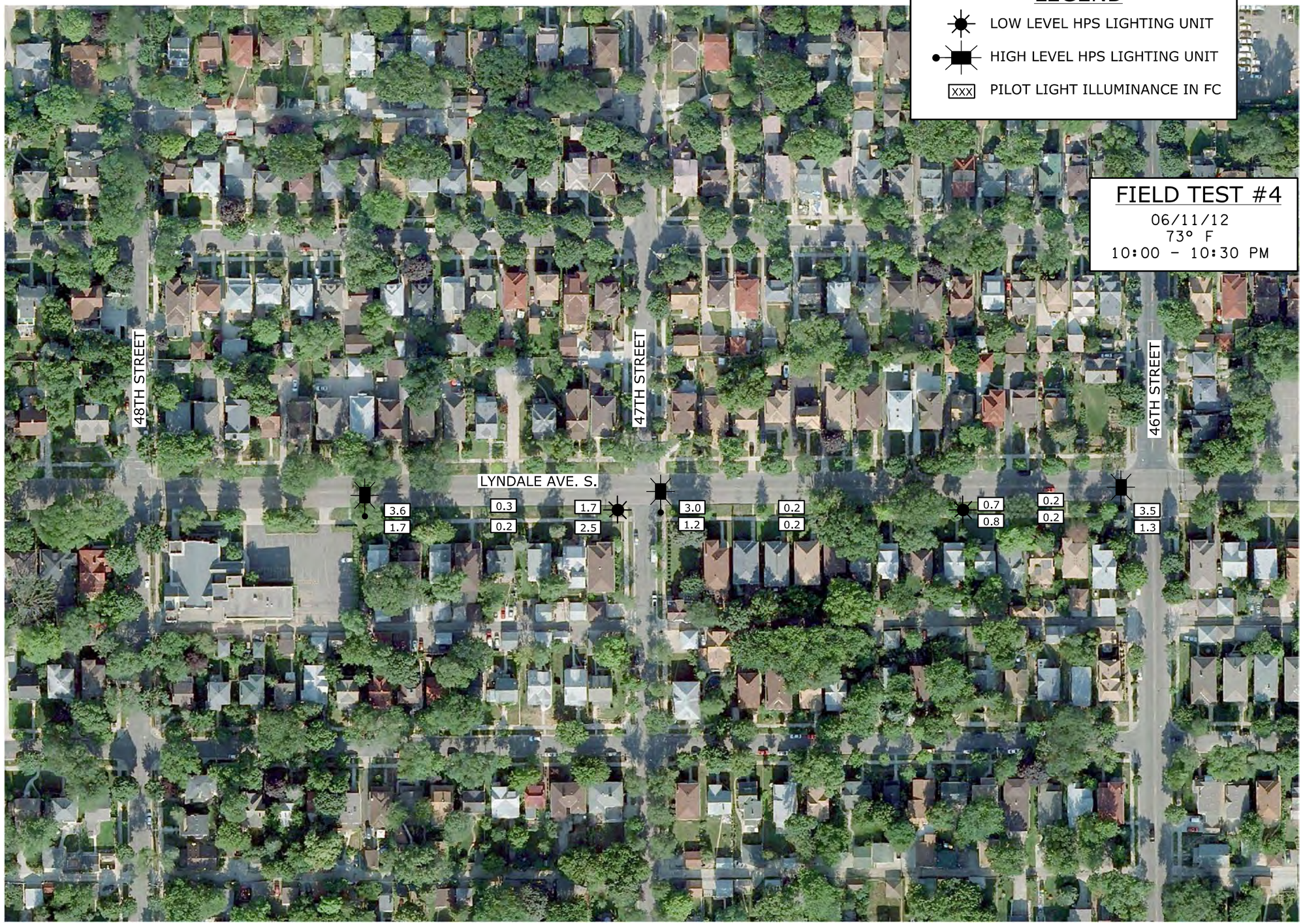
USER: kmidthun
LEVEL: 6 - Lighting Plan



REV. NO.	DATE	BY	CHK	DESCRIPTION

NOT TO SCALE

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

NAME _____ LIC. NO. _____ DATE 7/3/2012

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LIGHTING LAYOUT - LYNDALE AVE - 48TH TO 46TH

ATTACHMENT B - HPS LIGHTS

46th STREET PILOT LIGHTING PROJECT

SHEET 1 OF 1

PLOT DRIVER: pdf_bw.plt PLOT DATE: 7/3/2012 9:15:10 AM PEN TABLE: T-00198_planset.tbl FILE: S:\PROJECTS\TRANS\0037_HennepinCo\T-00198\Road_Design\traffic\report figures\T-00198_pilot_project_06-06-12.DGN USER: kmidthun 20 - Lighting Plan - Lyndale

Appendix B: Data Table

Appendix B: Data Table

ID Number	Section	High	Low	Type		Manufacturer	12/06/10 Light Levels	05/25/11 Light Levels	01/30/12 Light Levels	06/30/12 Light Levels	Cost Per Light	Wattage	Est Amps	Cost Diff. - Per Light (Induction/ LED / HPS)	Operational Hours per Year	Kilowatts Reduction	Electric Rate	Maintenance Savings / Year	Payback (years)
LA1	A		1	INDUCTION	ACORN	AITI	1.35	1.40	0.65	0.70	$ 543	80	0.75	$ 193	4,380	50%	0.046	$ 56	2.94
LA2	A		1	INDUCTION	ACORN	AITI	0.45	0.45	1.40	1.25	$ 543	80	0.75	$ 193	4,380	50%	0.046	$ 56	2.94
LA3	A		1	INDUCTION	ACORN	AITI	0.45	0.50	0.40	0.50	$ 543	80	0.75	$ 193	4,380	50%	0.046	$ 56	2.94
LA4	A		1	INDUCTION	ACORN	AITI	0.50	0.40	0.40	0.45	$ 543	80	0.75	$ 193	4,380	50%	0.046	$ 56	2.94
LA5	B		1	INDUCTION	ACORN	HADCO	0.65	0.45	0.55	0.45	$ 765	85	0.75	$ 415	4,380	50%	0.046	$ 56	6.32
LA6	B		1	INDUCTION	ACORN	HADCO	0.65	0.55	0.55	0.50	$ 765	85	0.75	$ 415	4,380	50%	0.046	$ 56	6.32
LA7	B		1	INDUCTION	ACORN	HADCO	0.65	0.55	0.55	0.45	$ 765	85	0.75	$ 415	4,380	50%	0.046	$ 56	6.32
LA8	B		1	INDUCTION	ACORN	HADCO	1.20	0.90	0.60	0.55	$ 765	85	0.75	$ 415	4,380	50%	0.046	$ 56	6.32
LA9	C		1	INDUCTION	ACORN	LUMEC	1.15	1.35	n/a	n/a	$ 975	100	0.75	$ 625	4,380	50%	0.046	$ 56	9.52
LA10	C		1	INDUCTION	ACORN	LUMEC	0.70	0.80	1.60	1.40	$ 975	100	0.75	$ 625	4,380	50%	0.046	$ 56	9.52
LA11	C		1	INDUCTION	ACORN	LUMEC	0.85	1.25	1.20	1.25	$ 975	100	0.75	$ 625	4,380	50%	0.046	$ 56	9.52
LA12	C		1	INDUCTION	ACORN	LUMEC	0.75	1.40	1.60	1.35	$ 975	100	0.75	$ 625	4,380	50%	0.046	$ 56	9.52
LB1	D		1	LED	ACORN	HANOVER	1.55	1.25	1.85	1.75	$ 1,711	100	0.75	$ 1,361	4,380	50%	0.046	$ 56	20.74
LB4	D		1	LED	ACORN	HANOVER	1.05	1.00	1.05	0.90	$ 1,711	100	0.75	$ 1,361	4,380	50%	0.046	$ 56	20.74
LB5	D		1	LED	ACORN	HANOVER	2.10	2.15	2.60	2.15	$ 1,711	100	0.75	$ 1,361	4,380	50%	0.046	$ 56	20.74
LB11	E		1	LED	ACORN	** REPLACED WITH HPS	0.90	HPS	HPS							50%		$ 56	
LB8	E		1	LED	ACORN	HADCO	0.95	0.95	1.00	1.15	$ 1,100	50	0.75	$ 750	4,380	50%	0.046	$ 56	11.43
LB10	E		1	LED	ACORN	HADCO	0.80	0.80	0.90	0.60	$ 1,100	50	0.75	$ 750	4,380	50%	0.046	$ 56	11.43
LB14	E		1	LED	ACORN	HADCO	0.85	0.75	0.85	0.70	$ 1,100	50	0.75	$ 750	4,380	50%	0.046	$ 56	11.43
LB15	F		1	LED	ACORN	HOLOPHANE	0.65	0.40	0.45	0.35		60	0.75		4,380	50%	0.046	$ 56	-
LB18	F		1	LED	ACORN	HOLOPHANE	0.65	0.50	0.60	0.35		60	0.75		4,380	50%	0.046	$ 56	-
LB20	F		1	LED	ACORN	HOLOPHANE	0.70	0.45	0.50	0.45		60	0.75		4,380	50%	0.046	$ 56	-
LB22	F		1	LED	ACORN	HOLOPHANE	0.55	0.45	0.50	0.40		60	0.75		4,380	50%	0.046	$ 56	-
LB23	G		1	LED	ACORN	LUMEC	0.70	0.50	0.60	0.55	$ 655	90	0.75	$ 305	4,380	50%	0.046	$ 56	4.65
LB26	G		1	LED	ACORN	LUMEC	0.70	0.60	0.65	0.55	$ 655	90	0.75	$ 305	4,380	50%	0.046	$ 56	4.65
LB27	G		1	LED	ACORN	LUMEC	0.65	0.55	0.65	0.55	$ 655	90	0.75	$ 305	4,380	50%	0.046	$ 56	4.65
LB30	G		1	LED	ACORN	LUMEC	1.15	0.55	0.65	0.50	$ 655	90	0.75	$ 305	4,380	50%	0.046	$ 56	4.65
LB31	H		1	LED	ACORN	HANOVER	0.75	0.85	0.95	0.65	$ 1,694	100	0.75	$ 1,344	4,380	50%	0.046	$ 56	20.48
LB34	H		1	LED	ACORN	HANOVER	0.90	0.65	0.70	0.65	$ 1,694	100	0.75	$ 1,344	4,380	50%	0.046	$ 56	20.48
LB35	H		1	LED	ACORN	HANOVER	1.00	1.10	0.95	1.00	$ 1,694	100	0.75	$ 1,344	4,380	50%	0.046	$ 56	20.48
LB38	I		1	LED	ACORN	LIGHT EMITTING DESIGNS	0.75	0.55	0.60	0.50	$ 523	70	0.75	$ 173	4,380	50%	0.046	$ 56	2.64
LB39	I		1	LED	ACORN	LIGHT EMITTING DESIGNS	0.75	0.55	0.70	0.55	$ 523	70	0.75	$ 173	4,380	50%	0.046	$ 56	2.64
LB42	I		1	LED	ACORN	LIGHT EMITTING DESIGNS	0.75	0.55	0.55	0.45	$ 523	70	0.75	$ 173	4,380	50%	0.046	$ 56	2.64
LB43	I		1	LED	ACORN	SYLVANIA	0.95	0.85	0.65	0.55	$ 523	70	0.75	$ 173	4,380	50%	0.046	$ 56	2.64
LB2	D	1		LED		BETA	1.55	1.75	1.85	1.45	$ 2,018	136	1.15	$ 1,693	4,380	50%	0.046	$ 56	23.96
LB3	D	1		LED		BETA	1.25	1.80	2.10	1.40	$ 2,018	136	1.15	$ 1,693	4,380	50%	0.046	$ 56	23.96
LB6	D	1		LED		BETA	1.65	1.30	1.45	1.25	$ 2,018	136	1.15	$ 1,693	4,380	50%	0.046	$ 56	23.96
LB7	E	1		LED		HADCO	1.10	1.05	1.45	1.05	$ 700	100	1.15	$ 375	4,380	50%	0.046	$ 56	5.31
LB9	E	1		LED		HADCO	1.30	1.10	1.05	0.90	$ 700	100	1.15	$ 375	4,380	50%	0.046	$ 56	5.31
LB12	E	1		LED		HADCO	1.10	1.05	1.35	1.00	$ 700	100	1.15	$ 375	4,380	50%	0.046	$ 56	5.31
LB13	E	1		LED		HADCO	3.95	0.90	2.55	0.55	$ 700	100	1.15	$ 375	4,380	50%	0.046	$ 56	5.31
LB16	F	1		LED		AMERICAN ELECTRICAL	0.90	0.70	0.75	0.65	$ 1,200	100	1.15	$ 875	4,380	50%	0.046	$ 56	12.38
LB17	F	1		LED		AMERICAN ELECTRICAL	0.95	0.65	0.70	0.60	$ 1,200	100	1.15	$ 875	4,380	50%	0.046	$ 56	12.38
LB19	F	1		LED		AMERICAN ELECTRICAL	0.80	0.70	0.80	0.70	$ 1,200	100	1.15	$ 875	4,380	50%	0.046	$ 56	12.38
LB21	F	1		LED		AMERICAN ELECTRICAL	0.85	0.65	0.65	0.65	$ 1,200	100	1.15	$ 875	4,380	50%	0.046	$ 56	12.38
LB24	G	1		LED		LUMEC	1.00	0.85	1.00	0.90	$ 1,400	90	1.15	$ 1,075	4,380	50%	0.046	$ 56	15.21
LB25	G	1		LED		LUMEC	0.95	0.80	1.05	0.85	$ 1,400	90	1.15	$ 1,075	4,380	50%	0.046	$ 56	15.21
LB28	G	1		LED		LUMEC	1.00	0.85	0.90	0.90	$ 1,400	90	1.15	$ 1,075	4,380	50%	0.046	$ 56	15.21
LB29	G	1		LED		LUMEC	1.00	0.90	1.00	0.95	$ 1,400	90	1.15	$ 1,075	4,380	50%	0.046	$ 56	15.21
LB32	H	1		LED		BETA	1.30	1.20	1.10	1.15	$ 1,928	136	1.15	$ 1,603	4,380	50%	0.046	$ 56	22.68
LB33	H	1		LED		BETA	1.25	n/a	1.60	1.40	$ 1,928	136	1.15	$ 1,603	4,380	50%	0.046	$ 56	22.68
LB36	H	1		LED		BETA	1.30	0.80	1.20	1.05	$ 1,928	136	1.15	$ 1,603	4,380	50%	0.046	$ 56	22.68
LB37	I	1		LED		ELUMEN	1.45	1.15	1.10	1.20	$ 1,438	100	1.15	$ 1,113	4,380	50%	0.046	$ 56	15.75
LB40	I	1		LED		ELUMEN	1.25	1.15	1.20	1.05	$ 1,438	100	1.15	$ 1,113	4,380	50%	0.046	$ 56	15.75
LB41	I	1		LED		ELUMEN	1.00	1.10	1.20	1.10	$ 1,438	100	1.15	$ 1,113	4,380	50%	0.046	$ 56	15.75

Appendix C: 46th Street Pilot Lighting Survey

46th STREET PILOT LIGHTING SURVEY
PRE AND POST INSTALLATION OF LED AND INDUCTION LIGHTS

Pre Survey Conducted:	**Jan. – Feb. 2010**	**102 respondents**
Post Survey Conducted:	**Nov. – Dec. 2011**	**101 respondents**

Population = households within 1 block of 46th Street from 34th to 46th Aves

1. How would you rate the current lighting along 46th Street in terms of:

a. Visibility

	Pre	Post
Poor	25%	5%
Fair	38%	17%
Good	23%	37%
Very Good	8%	38%
No Answer	7%	4%

b. Light Color

Poor	14%	4%
Fair	44%	15%
Good	27%	40%
Very Good	8%	34%
No Answer	8%	8%

c. Appeal of lamps and fixtures

Poor	39%	3%
Fair	27%	8%
Good	18%	27%
Very Good	6%	53%
No Answer	11%	10%

d. Glare

Poor	12%	5%
Fair	30%	15%
Good	27%	32%
Very Good	7%	34%
No Answer	25%	15%

2. What is your current overall impression of roadway and sidewalk light levels on 46th Street?

	Pre	Post
Poor	27%	6%
Fair	41%	14%
Good	22%	39%
Very Good	5%	38%
No Answer	6%	4%

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3. Do you think that the current street lights give off the right amount of light, or are they too bright or too dim?

Right Amount	30%	68%
Too Bright	6%	7%
Too Dim	57%	20%
No Answer	7%	5%

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4. Based on lighting, how safe do you feel walking along 46th Street after dark?

Not at all Safe	10%	7%
Somewhat Unsafe	32%	14%
Moderately Safe	37%	42%
Very Safe	14%	34%
No Answer	8%	4%

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5. Thinking back to fall 2009 / Thinking of the past month…**in a typical week**, how many times did you

   a. Drive your car on 46th Street?

0 to 4	19%	16%
5 to 7	23%	12%
8 to 10	15%	11%
11 to 14	10%	14%
15 to 18	6%	9%
19 to 22	8%	14%
Over 22	11%	18%
No Answer	9%	7%
Mean =	35	17
Median =	10	14

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b. Walk on 46th Street?

	Pre	Post
0	9%	23%
1 to 2	25%	19%
3 to 4	13%	13%
5 to 7	19%	14%
Over 7	22%	20%
No Answer	13%	12%
Mean =	8	5
Median =	4	3

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c. Bike on 46th Street?

0	52%	59%
1 to 2	15%	14%
3 to 4	6%	3%
5 to 7	8%	3%
Over 7	4%	3%
No Answer	16%	18%
Mean =	2	1
Median =	0	0

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d. Ride the LRT?

0	21%	29%
1	26%	18%
2 to 3	11%	12%
4 to 5	8%	8%
6 to 9	9%	3%
Over 9	13%	13%
No Answer	13%	18%
Mean =	4	3
Median =	1	1

6. How did you learn about the 46th Street Pilot lighting project? (Multiple responses allowed)

	Pre	Post
Flyer at my house / LRT station	35%	60%
Neighbor / word of mouth	15%	16%
Public meeting for lighting project	8%	10%
Saw construction in progress	38%	41%
Longfellow Community Council	5%	10%
Standish-Ericsson Neighborhood Association	4%	3%
www.minnehaha-hiawatha.com	--	--
Other_____	5%	12%
I did not know about this project before receiving this letter.	29%	8%