City of Mesa

20 East Main Street
Mesa, Arizona 85211

Street Light Master Plan Report

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1 EXECUTIVE SUMMARY

There are noticeable impacts to a community where LED street lighting is adopted. On the other hand, LED also provides significant opportunities. In preparation of a systemwide street light conversion to LED, the City of Mesa commissioned this report to investigate these impacts and opportunities. The City identified these tasks in the scope of work section in the request for statement of qualifications. Following is a summary of the major findings from these research efforts by Wright Engineering and Tanko Lighting.

- The City of Mesa can reduce light levels lower than IES RP-8 recommendations if they adopt these standards through appropriate procedures. There are neighboring agencies in the Phoenix area that do not reference RP-8 recommendations.

- Dimming street lights throughout the City of Mesa is optional based on criteria specific to 4 distinct lighting zones. The recommendations are supported by studies and reports that warrant dimming based on vehicle and pedestrian volumes and time of day. The proposed dimming criteria will need to be officially adopted by the City Council.

- Smart control nodes have the capability to control, dim, provide diagnostic data, and provide power consumption data. These nodes are necessary to carry out these functions and should be implemented as a City standard on all LED installations.

- SRP adopted a tiered rate structure on May 1, 2019 with 10W increments at lower levels and larger increments at higher levels. The same tiered rates were used in the financial analysis for both SRP and COMEU. The simple payback for converting approximately 35,000 street lights to LED including energy and maintenance savings is 9.14 years in SRP areas and 4.27 years in COMEU areas.

- The City has the option to utilize the tax-exempt municipal lease to spread out the purchase over the useful life of the project. The municipal lease does not count against the City's debt limit and borrowing capacity. Obtaining this type of financing is not difficult since the lenders see this as low risk.

- The conversion timeline to convert approximately 35,000 street lights to LED with 15 crews is about 1.7 years. To complete with 5 crews, it would take approximately 2.1 years. The conversions could be broken out into blocks of 5,000 to 10,000 street lights to provide flexibility and establish more manageable quantities.

2 INTRODUCTION

Light Emitting Diodes known as LEDs are made of semiconductor material that emits light and are referred to as solid state lighting. Over the past decade there has been a considerable increase in all things LED – televisions, automobile headlights, computer monitors and all types of LED lighting. This technology continues to advance producing low cost, energy efficient, and long-lasting LEDs that have significant applications. One of these applications embraced around the world is LED street lighting. Many agencies require public street lighting to provide a level of safety for both vehicles and pedestrians.

LED street lighting installations date back to the early 2000s. These early luminaires were not very effective at lighting roadways; nevertheless, they were still field tested. The cost was high, the testing in its infancy, with no guarantee of success, yet manufacturers and agencies across the country tried their hands at LED. These initial tests were not very effective under today's standards but were necessary to spark the paradigm shift of how street lighting is currently designed and installed. It wasn't until 2008/2009 that significant advancements in the technology warranted change, this was the tipping point. Many manufacturers then gained the confidence to invest significant dollars on research and development to bring LED lighting to the forefront, just a decade later.

The intensity of a light source is measured in lumens. Today, LED light fixtures produce over 130 lumens per watt of power consumed with 160 lumens per watt on the near horizon. The United States Department of Energy is predicting over 200 lumens per watt. As a common comparison, a standard 60W incandescent household lamp produces 15 lumens per watt. For an outdoor comparison, high pressure sodium (HPS) street lights produce approximately 110 lumens per watt.

Many years of research have resulted in LED luminaires that cost the same or just slightly higher than traditional HPS and metal halide (MH) sources, have a fifteen to twenty-year life, and are very efficient. LED prices are continuing to fall, life is increasing, and they are constantly becoming more energy efficient. Agencies around the world are transitioning from legacy HPS and MH sources to LED as their standard for street lighting. Some cities have already converted their entire street light system to LED. The overall purpose of this Street Light Master Plan, or study is to explore the benefits and impacts of an LED standard for public street lighting within the City of Mesa. The Master Plan was broken down into smaller objectives that will be discussed throughout this report and are shown below.

- Evaluate agencies with lower light levels than IES recommendations
- Investigate safety & liability issues when utilizing lower light levels
- Perform pilot test for LED street lighting with dimming & prepare lighting zone map
- Public outreach to solicit citizen input
- SRP/COMEU (the 2 serving utility companies) rate structure analysis
- LED conversion timeline and financial analysis
- Modifications to city code for LED street lighting & dimming

3 LED STREET LIGHTING

Once an agency decides to transition to LED, it is key to develop a standard that is beneficial to the community, the agency, and the surrounding environment. LED technology introduces new parameters that need to be identified and established to develop an effective standard. These parameters include the appearance of the light and luminaire, performance of the system, and maintenance considerations. The parameter that has significant public attention is the appearance of the light, or color temperature.

3.1 Fundamentals of Correlated Color Temperature

Correlated Color Temperature (CCT) is the measure generally used to describe the perceived color of a light source. When LED street lights were first introduced to the market, the prevailing color temperature was 4000 Kelvin (K) and above. This was mainly due to higher color temperature LEDs being more energy efficient. For comparison, moonlight has a CCT of 4100K and is the natural nighttime light that is familiar to everyone. (See Figure 1 for Correlated Color Temperate Chart).

Light sources with a CCT of 4000K are considered white and are significantly different from the 2100K amber color of high pressure sodium (HPS) light. The HPS street light has been the staple of street lighting for over 40 years and is the most common and familiar artificial light source in the nighttime environment. There is a growing trend in the street lighting industry moving away from 4000K LED light towards 3000K, which is more yellow in color and closer to the HPS street lights to which the City of Mesa residents are accustomed. This trend is fueled by public opinion and a press release in June 2016 by the American Medical Association stating that excessive white light at night may be detrimental to health. Since then, various organizations have published responses that do not entirely agree with the AMA. For example, the Illuminating Engineering Society (IES) issued a response on June 28, 2017 that disagrees with portions related to spectral content and CCT of the AMA's release. Due to the varying opinions and disagreements, much more research is still needed to determine if there is a negative correlation of white street lighting to human health.

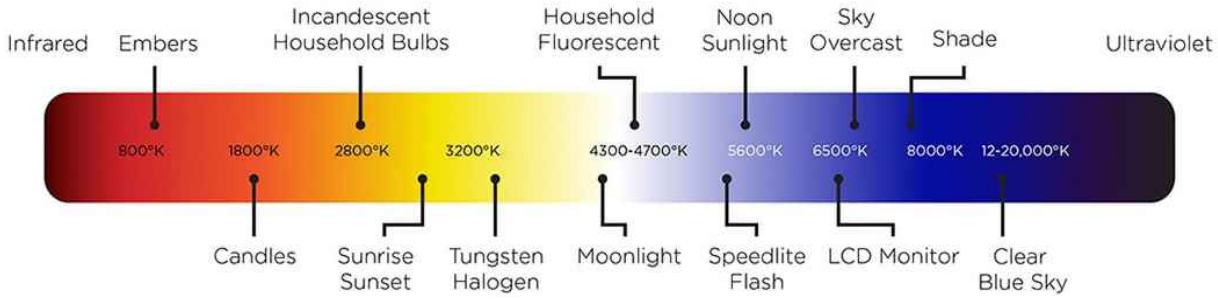


Figure 1 - Correlated Color Temperature Chart

3.2 3000K vs 4000K Street Lights

As LED technology has progressed, the energy efficiency has greatly increased. In addition, the efficiency gap between 3000K and 4000K LED luminaires has become smaller. As recent as 6 - 8 years ago, the lumen output difference between a 4000K and a 3000K LED light fixture was over 25%. Today, most luminaires range from 3% - 10% loss between the 3000K and 4000K option. This significant increase in efficiency for 3000K supports the change that the City of Mesa has already made to 3000K for all roadway lighting. Some jurisdictions have considered and implemented 2700K in recent years. Table 1 below indicates typical industry ranges of lumen loss based on CCT. The table demonstrates the significant difference in loss between 3000K and 2700K sources. Furthermore, some manufacturers do not offer 2700K as a standard option but are heading that direction. As LED technology advances, better efficiencies in 2700K light fixtures will emerge.

Table 1 – Correlated Color Temperature vs Lumen Output

	Correlated Color Temperature (CCT)		
	2700K	3000K	4000K
Lumen output normalized at 4000K	75% - 85%	89% - 97%	100%

3.3 Color Rendering

The Color Rendering Index (CRI) is a measurement of how well colors can be discerned under a specific light type. A value of 100 provides ideal color rendition and is based on an object under natural light or an incandescent light source. The CRI for standard HPS is 25 which is rather low. The CRI for both 3000K and 4000K LED luminaires from most manufacturers is 70 and is also the current City standard. This means that the color of objects, such as cars or the clothing pedestrians are wearing, can be discerned equally well with the 3000K and 4000K LED luminaires. Figure 2 compares the same area with a CRI of 25 vs a CRI of 70.

The photograph on the left is illuminated with HPS lighting and represents a CRI of 25. The photograph on the right represents an LED source with a CRI of 70. Note the shrubbery and grass appear to be brown in the photograph to the left.

Figure 2 – CRI Comparison

Photograph courtesy of GE Lighting

3.4 Blue LED Technology

Almost all LED street lighting is powered by blue LEDs. The blue color with its shorter wavelength is required to produce white light with a CRI that typically ranges between 70 and 85. The efficacy, or lumens per watt, is the most efficient with blue LEDs of all the colors. To achieve a white color, these LEDs are coated with phosphors that also affects the color temperature. These are known as Phosphor Coated, or Phosphor Converted (PC) LEDs. Almost all LEDs used for roadway and outdoor lighting are PC LEDs which inherently means a notable amount of blue light is present. This blue light contributes to sky glow since blue light is the predominant wavelength scattered by air molecules. However, the City of Mesa uses only full cutoff luminaires for street lighting. This means all light produced by the light fixture is aimed in a downward direction which significantly reduces light pollution into the night sky.

There is also concern that blue light may have a negative impact on human health and the environment. Due to these concerns of blue light in outdoor lighting, some products have been developed to reduce the amount of blue light content. One method to reduce blue light emissions is filtering the LED to significantly or completely remove the blue content. This approach is very effective in removing the blue wavelength from the source, but with the cost of 30% - 40% lumen loss and a CCT of under 2000K which appears yellow. This approach also diminishes the benefits of higher light output and better color than traditional HPS.

3.5 City Comparisons

The primary function of street lighting is to provide illumination on roadway surfaces to help provide a safe environment for vehicles, bicycles, and pedestrians. Each roadway classification (Local, Collector, Arterial) corresponds to a recommended value for lighting intensity measured in footcandles and the uniformity ratio which indicates how even the lighting is along the roadway. These recommendations are found in the IES RP-8 publication. The City's standards are based on the values from Table 2: Illuminance Method – Recommended Values from the IES publication RP-8-00 Reaffirmed 2005. The official City values are based on the R2 & R3 column with high, medium, or low pedestrian conflict and are referenced in Chapter 9 of the City of Mesa Engineering Standards. These values are the basis for design of all standard public street lighting within the City of Mesa.

It is important to consider what other municipalities in the Phoenix metropolitan area are doing when it comes to street and pedestrian lighting within the public right of way. Four municipalities of varying size, geographic location, and approach were selected to analyze their standards for LED roadway and pedestrian lighting. These cities included Phoenix, Chandler, Gilbert, and Scottsdale. Below is a short summary of street lighting for each corresponding city.

3.5.1 Phoenix

The City of Phoenix officially adopted LED street lighting in March 2013 when they released their updated Streetlighting Layout Guidelines requiring LED street lighting. These requirements were focused on the GE Evolve fixture with a CCT of 4000K. In 2016, during the award process for the systemwide replacement of over 90,000 HPS street lights, the City decided to go with 2,700K for the new LED replacements. This decision was

prompted by complaints from residents over the 4000K lights in Phoenix Parks. The City will complete converting all 90,000+ street lights to LED sometime in 2019.

Photometric calculations are not required to determine street light spacing. Street light layout is only based on a spacing criterion specific to each roadway type (arterial, collector, local) and is not based on IES RP-8 recommendations. This criterion is published in the City of Phoenix Street Light Design Guidelines. The City of Phoenix occasionally allows reduced lighting on locals and collectors with prior approval in low density developments. The City standard LED fixture is used for both cobrahead and shoebox replacements painted grey and dark bronze respectively. This provides ease of maintenance as it requires only one type of fixture to stock.

3.5.2 Chandler

In January of 2014, the City of Chandler required all new street lighting to be LED. They published these new requirements in their Streetlight Design Technical Design Manual #6. In Appendix A, the illumination levels the City has adopted are below IES recommendations and have been since 1984. However, the uniformity ratios are consistent with IES recommendation. Included in the LED specifications, the CCT was specified to be between 4000K and 5000K. By July of 2015, this range was updated and limited to only 4000K and has not changed since. In speaking with Chandler staff, they were not aware of any current or pending lawsuits related to any type of lighting issues within the City.

3.5.3 Gilbert

The Town of Gilbert recently updated their street light standards in 2018 to utilize only 3000K LED street lighting. Street light placement is based on a spacing chart that provides a range of acceptable spacing dependent on street classification. The spacing on the chart was determined by typical calculations based on IES RP-8 recommendations for illumination, however their standards specifically do not have any reference or mention to IES RP-8 standards nor do they vary based on pedestrian conflict levels. Street light layout based on a spacing range provides flexibility to the designer and review staff. By removing reference to IES RP-8 from their illumination standards, the Town has reduced their liability for designs or installations that may not meet IES RP-8 recommendations.

3.5.4 Scottsdale

The City of Scottsdale has adopted the basic IES RP-8 recommended light levels for roadway lighting in high pedestrian urban activity areas based on the corresponding roadway types for collector and arterial only. These recommendations only apply to roadways with continuous lighting. Areas north and east of the Central Arizona Project (CAP) Canal within Scottsdale are more environmentally sensitive and limit street lighting to intersections only and in some areas no lighting at all. Thus, the City is not actively replacing existing HPS street lighting with LED. This is due to the delicate nature and low impact expectations of the community regarding lighting in environmentally sensitive land areas and neighborhoods where HPS exist.

3.5.5 Tucson and Flagstaff

Two additional cities in Arizona outside the Phoenix Metro area (with observatories nearby) were also analyzed. Tucson and Flagstaff both have operational observatories nearby and have taken measures to help protect the dark skies near these facilities. Both agencies have lighting codes and ordinances that define lighting zones or special areas within each City. The distance from the observatories and the land use defines the zones which have corresponding lighting restrictions. The closer to the observatories, the higher the restrictions.

Furthermore, both agencies have adopted street light spacing criterion used to design varying classes of roadways. Flagstaff spaces their street lights farther apart (between 250' and 400') and does not meet IES recommended light levels. Known as the World's First International Dark Sky City, Flagstaff continues to regulate street lighting and private lighting to maintain this title. Since the City has officially adopted these policies as city code, the liability for not meeting a recommended practice is drastically reduced. On the other hand, Tucson spaces their poles closer together appearing to meet IES recommended levels. Design is based on a spacing chart for collector and arterial streets found in the Pima County/City of Tucson Street Light manual. Photometrics are not required if the chart is followed. When Tucson converted their street lights to LED a few years ago, they sized the LED luminaires to meet the same standards as the light source being replaced. This ensured the same light levels on the roadway.

3.6 Concerns with LED

Due to the newness of LED street lighting, it is possible that a significant number of complaints regarding LED street lighting is not related to the CCT, but to the source. LED is inherently more glaring than the traditional HPS and MH to which people are accustomed. During the 70s and 80s when HPS became the norm for replacing outdated and inefficient mercury vapor street lighting (which produced a whiter light), people complained about the new yellow color of HPS. It is routine today that no matter what occurs, change will prompt complaints since people in general are reluctant to change.

In recent years, the efficiency difference between a 3000K LED light fixture and a 4000K LED light fixture has significantly decreased. This reduction lessens the concern whether the system is as efficient as it could be. Additionally, the public tends to prefer the effects of a 3000K source over a 4000K source. As more research is done, there will most likely be a draw towards the 3000K source and possibly 2700K as efficiencies increase.

4 DIMMING

4.1 Introduction

Over the last ten years, LED street lighting technology has made significant improvements becoming the obvious choice for new installations as well as replacements for aging systems. One of these improvements is the ability to dim the intensity of the light output from the luminaire. There are many benefits of dimming an LED luminaire including energy reduction, extended luminaire life, less light trespass, and decreased sky glow. Although some of these benefits may be difficult to quantify, energy reduction can equate to a direct monetary savings. To capture energy savings from a dimmable street light asset, two conditions must be met:

1. The luminaire must have the ability to be dimmed through local or wireless control
2. The power must be metered or a rate in place that considers dimming

The first item is addressed by a wireless control node already adopted by the City of Mesa; Philips City Touch. The second item is currently in evaluation to determine the options and feasibility of a metered rate. This obstacle is faced by agencies across the country and is one of the main causes preventing them from dimming street light assets. The City of Mesa has commissioned this study in preparation of when dimming street lighting will directly correlate to reduced energy cost.

It is clear now why dimming is beneficial. The next step is to determine how the City of Mesa should develop a dimming schedule with appropriate levels and times for specific land uses and roadway classifications throughout the City. The team acknowledged that it is essential that public safety is maintained through whatever dimming policy is adopted. This was accomplished with a threefold approach.

1. A pilot project within the City was conducted to see what in field dimming looked like while providing the public with the opportunity to share their input.
2. Research was done on other studies around the country related to dimming LED street lighting
3. Documents and reports by other agencies were analyzed that directly addressed dimming of street lighting

This report will take a detailed look at each approach and the valuable information each provided.

4.2 Pilot Study

The pilot study provided valuable data by dimming actual sections of roadway for evaluation of real-life conditions. This allowed the team and City residents to experience how various dimmed levels look and feel. The goal in choosing the specific pilot areas was to include each type of roadway classification found throughout the City of Mesa: Residential, Collector, and Arterial. The team identified 3 locations to conduct the pilot testing that included each roadway classification. Factors that contributed to the areas chosen included the current installation of LED street lighting with the control nodes already in place and location. See map of pilot areas in Figure 3.

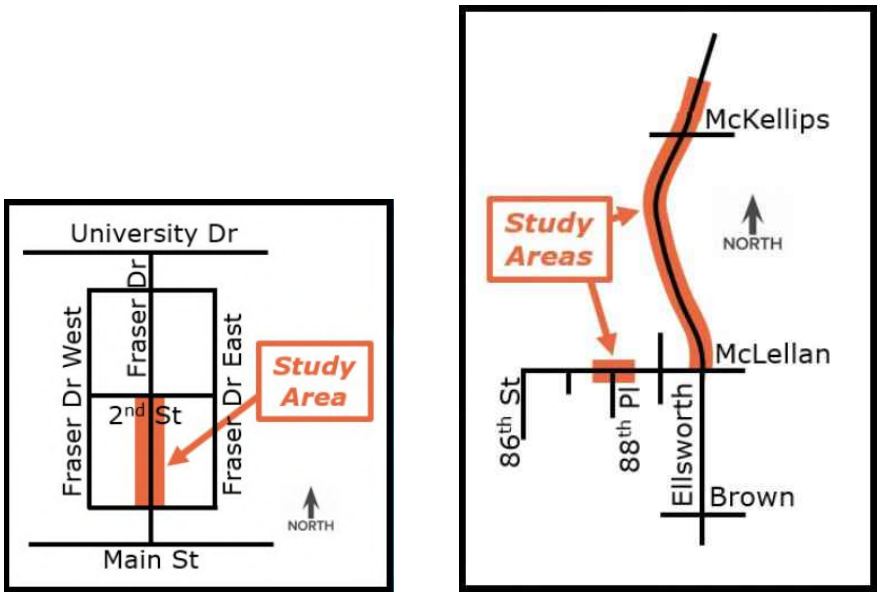


Figure 3 – Map of Dimming Pilot Areas

4.2.1 Pilot Preparation

The first stage of the pilot study was to verify the existing equipment was adequate for the study. This included confirming the LED luminaires met all current City of Mesa lighting standards for each corresponding roadway. Each of these luminaires also needed a control node to allow the team to adjust the light levels throughout the study. A few luminaires and control nodes were installed by Mesa crews to provide an adequate test area of at least 1,000' of continuous roadway for the collector and residential classifications. The arterial test area already had 4,000' of LED street lighting with control nodes in place.

Once the equipment was installed, the team had chosen two dimmed levels and full light level to conduct the study – 25%, 50%, and 100%. Further discussion will be given later in this report on why these levels were chosen. The current method to dim a luminaire with the available control technology is to adjust the power consumption of the luminaire. The correlation between power consumption and light output is not a linear relationship. For example, a light fixture that has been dimmed to 50% light output will consume significantly less than 50% power. Identifying this correlation was necessary to determine the appropriate power settings that will result in the team's target dimmed values. Due to this relationship, the team chose 45% power output as a starting point to determine if the corresponding light output was at least 50%. The 25% power level was not adjusted to account for the nonlinear relationship since this level would represent a very small percentage of dimmed street lighting.

City crews established a grid pattern of points on a straight section of each roadway classification located at each quarter point in all lanes spaced with eleven equal columns between poles. This was done for two cycles of luminaire spacing.

4.2.2 Pilot Measurements

The team measured horizontal illumination at grade for the 3 lighting scenarios (100%, 45%, and 25%) to determine the correlation of power output vs footcandles on the ground. The power levels used in these measurements with the corresponding light output is found in Table 2 below.

Table 2 – Dimmed Light Level vs Power Level

Roadway	Light Output at Corresponding Power Level		
	100% Power	45% Power	25% Power
Ellsworth Road	100%	62%	35%
McLellan Road	100%	59%	33%
Fraser Drive	100%	56%	33%
Average	**100%**	**59%**	**34%**

These results confirmed that the 45% power level was a conservative value that would result in a minimum of 50% light output. Even with a margin of error and the variations between luminaires and applications, the team determined that a 45% power level will result in at least 50% or higher light output with the various luminaires in the study area. These levels were then used during the public input portion of the pilot study. For consistency, whenever dimmed levels are discussed in this report, it refers to dimmed power level.

4.2.3 Public Input

Approximately 2,400 notifications were mailed to residents around the 3 pilot areas directing them to the study areas and asking for input in the form of a survey. A website was created – www.mesastreetlights.com and signage was installed in each pilot area directing participants to the website. The pilot study was conducted over a 4-week period in which each week the light levels were set to a different level. The participants were asked to fill out an online survey each week to evaluate their experience with each corresponding light level. See Table 3 for study dates and light levels.

Table 3 – Pilot Test Dates and Dimmed Levels

Pilot Test Dates in 2018				
Dates	April 23 through April 29	April 30 through May 6	May 7 through May 13	May 14 through May 20
Dimmed Power Levels	100%	45%	100%	25%

The survey questions were formulated to determine each participant's experience passing through the pilot area grouped by class (motorists, cyclists, or pedestrian). Participants were asked questions related to light levels and how it impacted their activities. These questions and

results can be found in **Appendix A**. The average number of participants for each week in their corresponding areas are shown in Table 4.

Table 4 – Average Number of Participants

	Week 1 100% Level	Week 2 45% Level	Week 3 100% Level	Week 4 25% Level	Average
Fraser Drive	3	5	2	3	**3**
McLellan	8	3	2	5	**5**
Ellsworth Road	61	49	46	47	**51**

Although the number of participants was statistically insignificant (2% participation assuming 1 person per mailing), the survey results still provide valuable insight to participants' experience in each specific area. For example, in the Fraser area in all classes, the participants did not express concern that the lighting was too bright in any of the 4 weeks. On the contrary, the participants in the Ellsworth area had a significant majority in almost all cases and classes that the light levels were too bright.

The Ellsworth Road pilot area falls within Desert Uplands which is a special foothills region within the City of Mesa that borders Tonto National Forest and has reduced lighting requirements for certain roadways. Furthermore, Ellsworth Road has recently had street lighting installed within the last few years that the local community is not accustomed to. This information was helpful in determining the appropriate light levels for each corresponding zone that will be discussed later in this section.

4.2.4 Ellsworth Light Shield

A frequent comment by respondents was that the lighting was too bright and the spill lighting onto adjacent properties was substantial. The team looked at ways to mitigate these concerns in addition to dimming the luminaire. Although the luminaire is considered full cutoff, it was acknowledged that installing additional shielding would reduce spill and the observation of the luminaire light source from adjacent properties.

An external light shield specific to the luminaires on Ellsworth and McKellips Road within the pilot area was proposed to provide additional shielding to the adjacent properties but still meet minimum light levels for the street. This shield was fabricated and tested in a photometric laboratory to create a photometric report with corresponding computer ies file. This file was used to model the light output on Ellsworth Road to confirm that the impact of the existing design was minimal and still within Mesa design criteria.

This confirmation led to the fabrication of additional shields that covered the section of roadway north of McKellips. A before and after in field photometric measurement was conducted in March 2019 to determine the effectiveness of the shield in reducing spill light onto adjacent properties. The results indicate an approximate 50% reduction in spill light 100' from the

roadway's edge. Furthermore, at the Right of Way line (12' behind the sidewalk) the light levels dropped between 40% and 50%. See **Appendix B** for light shield diagram and infield results.

4.2.5 Conclusion

The general survey results did confirm that a strong majority of participants did not have any concerns with the visual performance of LED street lighting at any of the levels evaluated in this pilot. The pilot study provided the team real life experience and feedback from citizens within the local community. It is also important to see what other communities are doing with dimming. Research was done to investigate who is dimming and what studies have been performed.

4.3 Seattle Dimming Study

The Seattle LED Adaptive Lighting Study provides valuable information that was found to be the most relevant research related to the City of Mesa's objectives. This study was commissioned by the Northwest Energy Efficiency Alliance (NEEA) in partnership with the City of Seattle. The study was led by Clanton & Associates and the Virginia Tech Transportation Institute (VTTI). Both organizations have extensive lighting experience and have conducted noteworthy research around the county. They are both esteemed as top lighting experts within the industry.

The Seattle study mainly focused on two key elements. The first was to study the effectiveness that LED light offers the motorist in detection of objects compared to traditional HPS. The second was an adaptive lighting evaluation that was done at three levels: 100%, 50% and 25% of full light output.

A pilot test was conducted over a three-night period with 332 participants surveyed. Some of these participants took part in a driving test to determine detection distance of objects under various conditions such as wet/dry pavement, color of objects, color temperature of light and different light levels while others were surveyed as pedestrians. The test site consisted of 6 areas along a 70' wide collector street (approximately 4,000' in length) with 4 different fixture types: LED 3500K, LED 4100K, LED 5000K, and HPS.

Participants were able to experience the 6 different areas in a test vehicle and as pedestrians. Individual surveys were taken from all test groups that included detection distance of objects of various colors under different color temperatures and various light levels. These survey results are part of a comprehensive report that focuses on the fundamental considerations when dimming a street light system. Below are the key results that are most relevant to the City of Mesa's project objectives.

1. **Contrast of objects illuminated under broad spectrum is better** – Contrast is what helps a motorist detect objects ahead. Other studies also support that broad-spectrum lighting (white light) provides better object detection at greater distances than narrow spectrum sources such as High Pressure Sodium (HPS). Simply converting to LED will provide better visual performance than the legacy HPS throughout the City of Mesa.
2. **Dimming lighting does not appear to change contrast of objects** – It was concluded that dimmed light levels does not notably affect object visibility. Conversely higher light levels did not increase the visibility of an object.

3. **Visibility is linked to contrast which is the primary indication of visibility** – contrast of an object is the most important element in visibility. This is contrary to the belief that more uniformity is better. High Uniformity is good for pedestrians but not necessarily better for detection in vehicles.
4. **Testing showed no reduction in detection distance at 50% light output on dry roads** – As participants were driven along each section, they were asked to push a button when a certain object was visible. This was done under different dimmed light levels with the LED sources. It was concluded that dimming broad spectrum LED lighting did not significantly affect the detection distance compared to full light output.
5. **25% output may be justified at low vehicle/ped volumes** – the research team acknowledges that a 25% light output dimmed level may be justified in situations with low vehicle and pedestrian volumes.

The results of this study indicate that dimming a street light system under the proper conditions does not adversely affect the ability for a driver to detect objects. Furthermore, the use of broad-spectrum LED street lighting increases object visibility by creating more contrast.

4.4 City of San Jose, California

The City of San Jose, California updated their street light standards in 2016 to address LED light sources and the ability to dim these street light assets. This section will focus on the adaptive street lighting design guide section found in the updated standards. The standard acknowledges that vehicle and pedestrian volumes decrease at certain times and allows for modified light output to match the conditions. Their approach was to analyze traffic volumes for various street classifications to identify the hourly periods during the night that fell below 10% of peak hourly traffic volumes. This resulted in an adaptive lighting schedule that was consistent for all roadways throughout the City, see Table 5.

Table 5 – San Jose Adaptive Lighting Schedule

	Adaptive Level*	Start	End
Weekday	50%	12:00AM (midnight)	5:00AM
Weekend	50%	1:00AM	6:00AM

* Percent of designed lumen output at normal operation

The team contacted the San Jose street light department in September of 2018 to get feedback on how the implementation was going. Below is a summary of the status at the time of the call.

- 62,000 Street Lights within San Jose (40% converted to LED)
- Approximately 90% of LED fixtures include controls capable of dimming
- City is currently dimming all LED since the end of 2015
- City dims from midnight to 5AM weekdays and weekends
- City has not received negative feedback from community
- No negative feedback from emergency crews or police
- Developers supply nodes on new installations
- At the time, not receiving power cost reduction from utility
- City considers dimming a success

The City expects to convert the remaining fixtures to LED and will continue dimming all lighting throughout the City. They are also working with the utility provider through testing and analysis in hopes that the control nodes can be used for utility grade metering in order to capture the energy savings from dimming. For now, the benefit is to the environment and community.

4.5 FHWA Dimming Report

4.5.1 Report Overview

Various reports on dimming street lighting were examined for relevance to the City of Mesa's objectives. The report sponsored by the Federal Highway Administration Office of Safety – *Design Criteria for Adaptive Roadway Lighting* FHWA-HRT-14-051 published in 2014 with it's companion report *Guidelines for the Implementation of Reduced Lighting on Roadways* FHWA-HRT-14-050 were used as the primary sources in this section. The FHWA publishes roadway design requirements that agencies are mandated by law to follow and is considered the authority when implementing design policies. The organization performing the research and preparing the report was Virginia Tech Transportation Institute. This organization has performed numerous studies that have influenced policies and design standards across the country and is considered one of the top lighting research laboratories in North America.

The Design Criteria report focuses on Adaptive lighting and develops application guidelines for the following issues:

- Optimal times and conditions for reducing lighting.
- Appropriate lighting levels for various roads and road features.
- Appropriate approaches for reducing lighting.
- Energy savings and reduction in greenhouse gases that may result from reducing lighting.
- Potential legal issues related to reducing lighting, including the development of such issues since the release of the original report.

The information contained in this report is directly related to the City of Mesa's goal in dimming street lighting. The comprehensive report details nighttime to daytime crash ratios based on various conditions with corresponding light levels. The result is a set of recommended design criteria based on the same methodology found in the European Commission Internationale de l'Eclairage (CIE) *Lighting of Roads for Motor and Pedestrian Traffic CIE 115:2010*.

Three classes are identified with corresponding design level selection criteria that consider speed, use, traffic volume and pedestrian/cyclist interaction. The three classes with examples are:

1. Roadways (H-Class) – Freeways and limited access roadways
2. Streets (S-Class) – Roads where pedestrians and cyclist are generally present
3. Residential/Pedestrian (P-Class) – Primarily pedestrian areas

The selection criteria are based on parameters such as speed, volume, pedestrian interaction, and ambient luminance. As these parameters change throughout the night, the selection criteria are adjusted which in turn reduces the light level recommended for the street. See Table 6 below for Table 12 Design Criteria for Streets (S-Class) from the *FHWA-HRT-14-050* publication. The S-Class criteria will be used for all roadway classifications in the City of Mesa.

Table 6 – Design Criteria for Streets (S-Class)

Parameter	Options	Criteria	Weighting Value
Speed	High	> 45 mi/h (70 km/h)	1
	Moderate	35–45 mi/h (55–70 km/h)	0.5
	Low	< 35 mi/h (55 km/h)	0
Traffic Volume	High	> 15,000 ADT	1
	Moderate	5,000–15,000 ADT	0
	Low	< 5,000 ADT	-1
Median	No	No median present	1
	Yes (or one-way)	Must be glare blocking	0
Intersection/ Interchange Density	High	> 5 per mi (1.6 km)	1
	Moderate	1–5 per mi (1.6 km)	0
	Low	< 1 per mi (1.6 km)	-1
Ambient Luminance	High	LZ3 and LZ4	1
	Moderate	LZ2	0
	Low	LZ1	-1
Guidance	Good	> 100 mcd/m^2 lx	0
	Poor	< 100 mcd/m^2 lx	0.5
Pedestrian/Bicycle Interaction	High	> 100 pedestrians per h	2
	Moderate	10–100 pedestrians per h	1
	Low	< 10 pedestrians per h	0
Parked Vehicles	Yes	Parked vehicles present	1
	No	Parked vehicles not present	0

The selection criteria provide weighting values for corresponding parameters that change throughout the night. This report will focus on Pedestrian Interaction and Traffic Volume parameters. For information purposes, the base value for this class starts at 6. The weighting values are totaled and then subtracted from the base value to determine the street class found in Table 8. This report is not utilizing this feature and will only discuss changing from one class to another.

4.5.2 Pedestrian Interaction

The FHWA report acknowledges and corresponds with the IES policy that a roadway classification can be reclassified based on the current conditions. The IES defines high pedestrian volume as over 100 pedestrians per hour, medium is between 10 and 100 per hour, and low is less than 10 per hour. Streets are typically designed for the worst-case scenario

pedestrian conflict level and are over lighted for most of the night. In areas where a low pedestrian volume already exists, it is assumed that the late nighttime pedestrian volume will approach zero. In evaluating the pedestrian interaction parameter, it was determined that decreasing the weighting value by 1 during low nighttime activity levels was appropriate for the City of Mesa. This reduced a high classification to moderate, a moderate to low, and a low to very low.

4.5.3 Traffic Volumes

The FHWA report also addresses how hourly traffic volumes affect light level design criteria for streets. Table 8 found in the *FHWA-HRT-14-050* is shown in Table 7 below. As hourly traffic volume changes from high to moderate or moderate to low, the weighting value drops by 1. When comparing volumes in the criteria, each drop in the weighting value has an approximate decrease in volume of 50%. This condition was used to establish a weighting value decrease of 1 for low peak nighttime hours with a reduction of 50% or more in hourly traffic volumes.

Table 7 – Hourly Traffic Volume Weighting

Parameter	Options	Criteria	Weighting Value
Traffic Volume	High	> 1,500 vehicles hourly per lane	1
	Moderate	750–1,500 vehicles hourly per lane	0
	Low	< 750 vehicles hourly per lane	-1

With significant reductions in pedestrian and vehicle volumes during low activity in the late hours of the night, it was determined that an overall weighting value decrease of 2 was appropriate for the conditions. The FHWA supports a decrease of no more than 2 lighting classes for streets when determining appropriate light levels. Table 13 from the *FHWA-HRT-14-050* is shown in Table 8 below. This table indicates the average luminance based on street class. When a street class is decreased by two classes, the result is an average luminance decrease of 50% or more. For example, an S2 going down to an S4 has an average luminance decrease of 56%. All other conditions equal a 50% decrease when changing two classes.

Table 8 – Street Class vs Light Levels

Class	Average Luminance (cd/m^2)	Max Uniformity Ratio (avg/min)	Max Uniformity Ratio (max/min)	Veiling Luminance Ratio
S1	1.2	3	5	0.3
S2	0.9	3.5	6	0.4
S3	0.6	4	6	0.4
S4	0.4	6	8	0.4
S5	0.3	6	10	0.4

When determining the appropriate level for City of Mesa streets, this criterion was used to identify dimming at 50% light level as the basis. This value agrees with the Adaptive lighting

study completed in Seattle and will be recommended as the baseline dimming level throughout the City of Mesa during low activity periods. Based on the findings from the Seattle study that a 25% level may be justified in low pedestrian/vehicle volumes, the 25% dimmed level was also chosen to analyze during the pilot study.

4.6 Lighting Zones

The next step is to determine the low activity periods for specific roadway classifications and locations throughout the City. To determine which roadways are to be dimmed at which time, it is necessary to classify all public roadways into distinct lighting zones. These lighting zones would have time of day dimming criteria that addresses the specific needs of each area. Four lighting zones (LZ) were created to encompass all public streets throughout the City:

LZ4: Downtown

High Pedestrian Activity/Downtown Areas/Regional Commercial – Areas with a high level of nighttime vehicular and pedestrian activity. Light levels meet RP-8 recommendations for all roadway classifications. After curfew, lighting may be reduced in some areas as activity levels decline.

LZ3: Standard

Ordinary Roadways (includes most City streets) – Areas with low to medium levels of nighttime vehicular and pedestrian activity. Light levels meet RP-8 recommendations for all roadway classifications. After curfew, lighting may be reduced in some areas as activity levels decline.

LZ2: Reduced

Special Variances for lower levels – Areas with low levels of pedestrian activity and special areas that have requested a reduced light level (as approved per development agreement). Light levels meet RP-8 recommendations for collector and arterial roadway classifications. Lower light levels on residential streets. After curfew, lighting may be reduced as activity levels decline.

LZ1: Rural

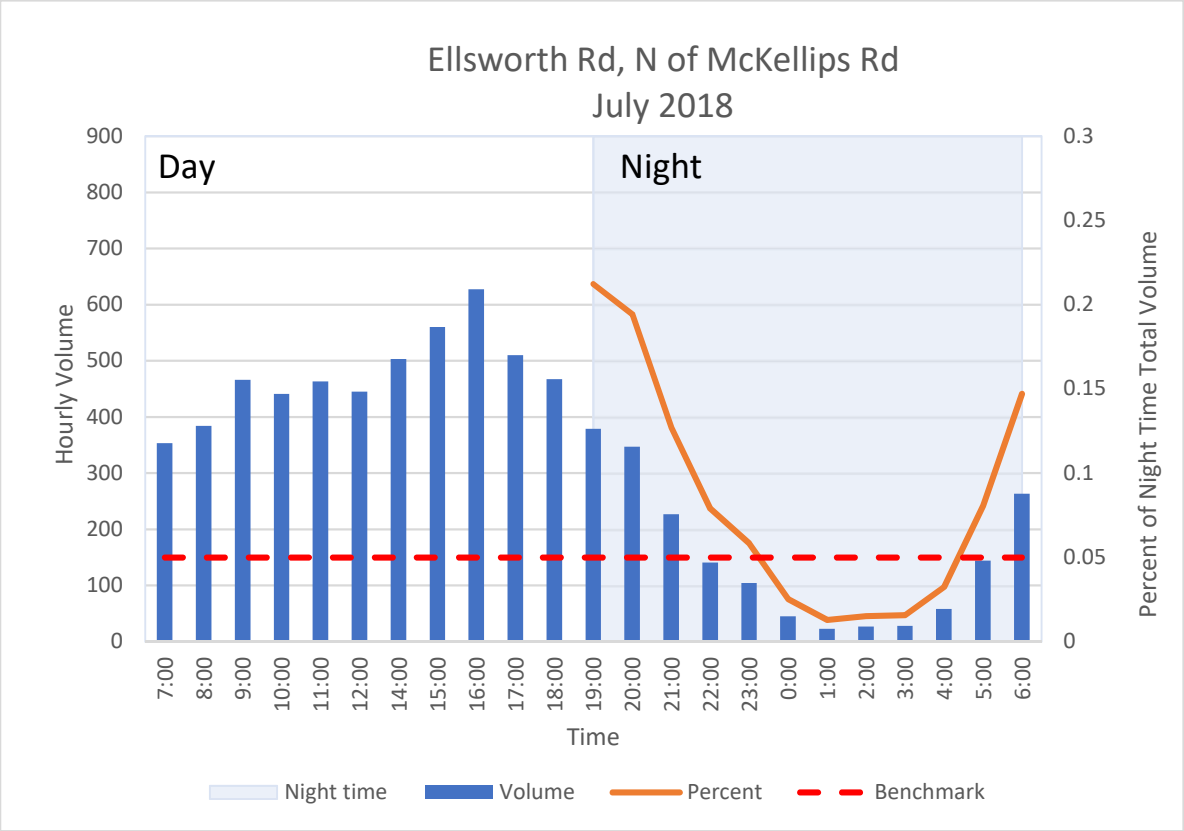
Outlying Residential and low density 2.5 DU per acre or less – Areas in the outlying districts within the City of Mesa limits that include Desert Uplands, Lehi area, and zoning with 2.5 DU per acre or less. Light levels meet RP-8 recommendations for arterial roadway classification. Lower light levels on collector and residential streets. After curfew, lighting may be reduced as activity levels decline.

The lighting zone map shows the lighting zones throughout the City of Mesa, see **Appendix C**. These locations will adjust as City staff reviews and fine tunes area specific needs over time. Once the lighting zones were determined and mapped, the next step was to determine the dimming scenarios for each lighting zone with each corresponding street classification.

Hourly traffic volumes were used to determine these values. Hourly traffic volumes were compiled for five or more arterials and collectors for each lighting zone. Each was graphed to

compare the day and night traffic volumes with an hourly analysis of nighttime traffic volume. An example of an LZ1 arterial street (Ellsworth South of McKellips) is shown in Figure 4 below.

Figure 4 – Hourly Traffic Volume Analysis



The nighttime analysis indicates hourly percentage of the overall nighttime traffic throughout one night. The nighttime hours were determined to be 7:00 pm through 7:00 am. A threshold was chosen by the team to determine the appropriate dimming time for each lighting zone, see Table 9 below. Dimming will generally be done within the hours that the hourly nighttime traffic volume percentage is at or below the threshold.

Table 9 – Lighting Zone Nighttime Volume Threshold

Lighting Zone	Hourly % of overall nighttime volume
LZ4: Downtown	3%
LZ3: Standard	4%
LZ2: Reduced	5%
LZ1: Rural	5%

Traffic volumes from multiple areas within each lighting zone were analyzed to determine an appropriate dimming schedule for each corresponding lighting zone, see **Appendix D**. The threshold percentages in Table 9 were the baselines used to determine the dimming schedule in each lighting zone. The team acknowledges that hourly traffic volumes in all locations will not fit within these guidelines. However, dimming schedules were chosen to accommodate the

majority of the sample areas analyzed. See Table 10 for proposed dimming schedules for each lighting zone and roadway classification.

Table 10 – Proposed Dimming Table

LZ4: Downtown			
Description: *High Pedestrian Activity, Downtown Areas, Regional Commercial*		Area (Including but not limited to): *Downtown, Fiesta Mall, Superstition Springs Mall, Stapley & US60*	
Roadway Classification	Designed Level	Dimming (Percent Power Consumption)	
		Time of Day	Dimmed Level
Local	IES RP-8* Recommendations	11pm - 5am	45%
Collector	IES RP-8* Recommendations	11pm - 5am	45%
Arterial	IES RP-8* Recommendations	12pm - 4am	45%

LZ3: Standard			
Description: *Standard Roadways - Majority of Public streets*		Area (Including but not limited to): *All other streets not included in other zones*	
Roadway Classification	Designed Level	Dimming (Percent Power Consumption)	
		Time of Day	Dimmed Level
Local	IES RP-8* Recommendations	11pm - 5am	45%
Collector	IES RP-8* Recommendations	11pm - 5am	45%
Arterial	IES RP-8* Recommendations	11pm - 5am	45%

LZ2: Reduced			
Description: *Reduced and Special Variances by developer agreement*		Area (Including but not limited to): *Eastmark, Morrison Ranch, PPGN*	
Roadway Classification	Designed Level	Dimming (Percent Power Consumption)	
		Time of Day	Dimmed Level
Local	Varies per development agreement	10pm - 5am	45%
Collector	IES RP-8* Recommendations	10pm - 5am	45%
Arterial	IES RP-8* Recommendations	11pm - 5am	45%

LZ1: Rural			
Description: *Rural Residential and Low Density 2.5 DUA or less*		Area (Including but not limited to): *Desert Uplands, Lehi*	
Roadway Classification	Designed Level	Dimming (Percent Power Consumption)	
		Time of Day	Dimmed Level
Local	Desert Uplands Standards (Reduced)	No Dimming	N/A
Collector	Desert Uplands Standards (0.37 FC, 6:1)	10pm - 5am	45%
Arterial	IES RP-8* Recommendations	10pm - 5am	25%

* IES RP-8 Illuminance table

The proposed dimming schedule in Table 10 is a starting point for the City of Mesa to adopt as City code. The following excerpt is a recommendation of what could be added to Chapter 9 of the City of Mesa Engineering and Design Standards.

Proposed Addition:

> ## *Section 920 – Adaptive Lighting*
>
> *920.1 Where and when determined appropriate by City of Mesa Transportation Department street lights may be dimmed. The City of Mesa is divided into four distinct lighting zones based on roadway types, adjacent land uses and traffic volume data. Figure 9.1 shows the lighting zone map. Table 9.2 shows the dimmed lighting levels and time of day that may be applied to each lighting zone.*

Note: The reference to Figure 9.1 corresponds to Appendix C and the reference to Table 9.2 corresponds to Table 10 in this report.

As dimming schedules are implemented throughout the City, it is recommended the City of Mesa reevaluate the table based on conditions of the time such as increased hourly volumes or new lighting technologies and controls.

5 SMART STREET LIGHT CONTROLS

5.1 Introduction

Smart city technology has risen to the forefront in recent years as a prevalent way for municipalities to try to reduce energy consumption and costs. However, in many states, a key roadblock has been a lack of incentive and, most importantly, a lack of recognition of streetlight control nodes as a means to meter lights by the state utilities commission (Arizona Corporation Commission). Many manufacturers of streetlight control nodes have aspired to and succeeded in creating utility-grade meter controls, but recognition by the state utilities commission remains a challenge.

Rhode Island has been a leader in this regard, where both the utility and the Department of Energy Resources (DOER) not only recognize controls but also provide key incentives to encourage municipalities to install them. Tanko Lighting has seen a push for similar recognition in other states and anticipates that in the next two to three years, controls will be widely accepted throughout the United States.

In their work with the City, Tanko Lighting has determined four smart city technologies that could benefit the City of Mesa.

1. Fixture Dimming and Monitoring
2. Solar Powered Fixtures
3. Environmental Sensors & Security Cameras
4. Installing 3rd Party Equipment

5.2 Fixture Dimming and Monitoring

Dimming is a priority when considering smart city technology and would come standard with any option selected. Dimming allows the city to dim the fixtures remotely or by setting dimming schedules for either a select number of fixtures or the entire system itself. In practice, this results in cities being able to lower the energy consumption of the fixtures during non-peak hours when pedestrian and automobile traffic is at a minimum, allowing municipalities to save on their monthly electric bills.

Another advantage to smart city technology is the monitoring capabilities it provides. The system monitors its own health, meaning that if a failure occurs the Central Monitoring System (CMS) is notified immediately. This eliminates the need for the outage to be reported, as well as reduces the time it takes to repair it as there will be shorter response times to outages. It also eliminates staff costs both to drive through and find outages as well as the need to field calls to locate the outage.

Street lighting fixture controls do not add a significant amount of time to the project, as the design can be done simultaneously with the fixture lighting design, and installation of control nodes require the same amount of time as a traditional photocell installation. A small amount of additional time is needed on site in order to enter node specific information during installation. This is typically a unique node identification number or barcode that can be scanned or recorded at the time of installation. This information is then used by the control company's commissioning team to set up the management system. Some additional time at the end of the project should be allowed for commissioning and troubleshooting any issues that arise with the control system. Note that because the control nodes can operate as a traditional photocell, the lighting fixtures themselves can function normally without the control system being fully operational.

5.3 City of Mesa Control Nodes

The City of Mesa has installed a few hundred Philips City Touch control nodes in various part of the City for testing. The three pilot areas discussed in the prior section all utilized these control nodes for dimming and electric usage metering. The City of Mesa Electric Utility (COMEU) installed utility meters on a few street light poles to monitor the power usage at each pole individually. This data was used to compare against the power usage data reported by the control node on the luminaire. The control nodes were placed on five 39W GE Evolve LED luminaires located on Fraser Street. Below are readings taken from the CityTouch control node and the COMEU meter at one location over a three-day period, see Table 11 below.

Table 11 – CityTouch vs COMEU Meter

Date	Total kWh		Difference*
	CityTouch	COMEU Meter	
April 10, 2018	0.462	0.443	4.29%
April 11, 2018	0.462	0.443	4.29%
April 12, 2018	0.461	0.441	4.54%

* Percentage is difference of control node compared to utility meter

By regulations, a utility grade meter is to have an accuracy that is within 2% of power usage. This table indicates that the control node and utility meter have a 4% discrepancy. This can be due to many factors and would require additional testing in a controlled environment to determine the control node accuracy as compared to utility metering.

5.4 SRP Control Node Testing

Salt River Project (SRP) conducted an evaluation of lighting control nodes from two manufacturers. DimOnOff Lite nodes and the Cimcon iSLC-3100-7P-S nodes were the two control node types that SRP tested on their test board at their East Valley facility. Both types were installed on 4 fixtures each that were also individually monitored by SRP's standard power meter. The purpose of the exercise was to compare the power usage reported by the control nodes with the electric usage reported by the standard SRP meter. This test was conducted over a ten-week period to gather data. The information shown below in Table 12 is an excerpt of data supplied by SRP staff.

Table 12 – DimOnOff & Cimcon vs SRP Meter

DimOnOff			
Date	Total kWh		Difference*
July 14 - Oct 4, 2017	DimOnOff	SRP Meter	
Fixture 1	52.116	51.667	0.87%
Fixture 2	32.342	31.471	2.77%
Fixture 3	88.621	90.286	-1.84%
Fixture 4	32.152	35.132	-8.48%
Cimcon			
Date	Total kWh		Difference*
	Cimcon	SRP Meter	
February 4, 2018	0.5495	0.552	-0.45%

* Percentage is difference of control node compared to utility meter

This data shows a larger discrepancy between the 4 fixtures that could be due to many factors. For one, all 4 of these fixtures were different manufacturer models with different lumen outputs and power consumption. However, an average of the 4 fixtures is -1.67% which falls within the desired range of ±2%. In the end, SRP decided to test the DimOnOff node at a somewhat larger

scale at their PERA facility in Tempe, Arizona. They purchased 50 units and a gateway that will be installed sometime in 2019 for testing. One of the deciding factors in choosing the DimOnOff node for further testing was the computer interface for asset identification was very similar to the asset system of record that SRP already uses.

5.5 Solar-Powered Fixtures

Most smart city applications offer the possibility of solar-powered fixtures. While municipality-wide use has been limited, several municipalities across the country are using solar-powered fixtures for off-street applications such as parking lots and public facilities. The City of Mesa has an ideal climate to utilize this technology and as the technology surrounding these solar-powered fixtures continues to improve, they could provide a valuable element of cost-savings to the City when used in the appropriate areas. The City has installed a limited number of solar light fixtures in appropriate areas such as pedestrian pathways and bus stops. Lumen output and battery life continue to be an issue for solar installations making it only feasible for certain applications.

5.6 Environmental Sensors & Security Cameras

Sensors can be employed as part of a streetlight network that will allow detection of such aspects as available parking, air quality, weather conditions, traffic issues, and a number of other issues that could be of interest to the City. Much of the software that tracks these elements is developed through third-party providers so its application can be customized to the City's needs and specifications.

Security cameras are another common smart city installation. The key question regarding cameras is how frequently to transmit data, and in what manner to transfer the data. The data from the cameras can be sent from the streetlight via fiber cable or using smart city technology. Transmitting data via fiber allows you to send the largest amount of data, including high-resolution recordings, to a central database. However, fiber is expensive and comes with a higher installation cost. Smart city technology has a more limited bandwidth, meaning the recordings will not have the same resolution. In theory, smart city technology could provide enough bandwidth to compete with fiber. To date they have not yet been able to produce the same quality recordings using their products. Note that while fiber is generally faster and more reliable than wireless, maintenance on fiber can also be costly if the fiber gets damaged as it requires significant underground work.

5.7 Third-Party Communications Device Installations

It is mutually beneficial to the city and wireless companies to provide reliable data networks throughout the municipality. With the continuing increase in demand for cellular data nationwide, cell carriers are being forced to find creative ways to meet these demands. One method is the installation of small wireless communications equipment using existing streetlight infrastructure. The city does have limited control on the process and requirements that cellular companies will need to abide by in order to install small cell sites on city-owned streetlight infrastructure. These

requirements are defined in the recent FCC 18-133 ruling adopted on September 26, 2018 related to small cell sites.

There are two primary options for communication devices that wireless companies are implementing on existing poles. The first are small cell sites, which are limited in strength, requiring many devices to reach desired network capability. In addition, small cell sites generally only support a single carrier. The other option is a distributed antenna system (DAS) that can support multiple carriers and are much more powerful, requiring far fewer sites to be installed.

Wireless companies often prefer small cell sites because the system's specifications do not need to accommodate other wireless carriers. Utilizing a DAS option may delay implementation because considerations need to be made for multiple carriers. For municipalities, a more universal DAS system reduces the number of unsightly devices required on streetlight infrastructure and frees up space for other pole attachments the city may require.

Jurisdictions have some control over the requirements and processes that communications companies will need to take in order to install devices on city-owned street light poles. Typically, public works departments require a permitting and administrative process which may include encroachment permits, electrical building permits, and public notices. Tanko Lighting's suggestion is to facilitate and streamline the process by developing clear requirements for wireless communication devices and installations, as maximizing the network capabilities greatly benefits the community as well as provides an opportunity for the City to rent out pole space to wireless companies. The FCC18-133 ruling adopted on September 26, 2018 places restrictions on the municipalities for location, review time, and fees associated with new small cell sites. The recurring fees per location is now limited to $270 per year per Small Wireless Facility, see FCC 18-133 Section 79(b).

A few important considerations for the design and implementation of small wireless equipment include minimum clearance requirements between communications devices and power lines as well as the ability of the pole to bear the additional load of devices and associated equipment. In addition, a backhaul solution will need to be determined. A fiber network may be utilized; however, a wireless solution may be more cost-effective if an existing fiber network is not available at the site. It is in the City's interest to create protocol and requirements regarding items such as the use of city infrastructure, pole structure analysis, and size limitations for cell equipment.

With regards to billing, utility companies may either require a metering device to measure the power consumed by the communication devices or bill via a monthly flat rate. "Jurisdictions should charge rental rates that are reasonable and reflect the regulated rates typically charged between pole owners and utilities within the right of way." (Lockwood, Jim.)

5.8 Recommendations

Smart city and lighting controls technology is still in the early stages of development and will continue to experience rapid growth as well as a decrease in price in the future. It is also important to note that smart city applications can be installed after the initial lighting conversion if fixtures are ordered with 7-pin photocell receptacles, which is already a City standard. The benefit to installing controls and smart city applications simultaneously with the LED fixture conversion is the savings in installation cost. If smart city or controls are desired after the LED conversion, installation contractors will need to return to the site with a bucket truck which creates a higher cost than if they were to install desired controls during the initial installation. It is possible that the increase in labor costs may be balanced by the decreased cost in technology as smart cities and controls continue to develop.

6 FINANCIAL ANALYSIS

This report provides several financial analyses to demonstrate multiple scenarios on how to manage the streetlights in the City of Mesa. The City has requested an analysis for both utilities that supply power to their streetlights and three options of LED wattage buckets for billing from each utility. The two utilities are the City of Mesa Electric Utility (COMEU) and Salt River Project Power & Water (SRP). The purpose of this report is to demonstrate both the advantages and disadvantages of each option and the potential project costs and savings associated with each.

Financial analysis documents were created to model the project costs, savings, and cash flow for a full conversion of the City of Mesa's streetlights to LEDs. In order to create these documents, Tanko Lighting analyzed and incorporated streetlight inventories, utility rate structure documents, and City utility bills. Using the current billing structure and incorporating estimated maintenance costs, the existing system costs were calculated and extrapolated for 20 years. Energy and maintenance costs for a new LED system were calculated forward for 20 years to then compare to the existing system. The new LED system was designed with the City's current replacement wattage chart on a watt for watt basis. Costs for the project implementation were determined through averaging quotes for the fixtures and installation as well as applying management and design fees for the project. In addition, photocell costs and taxes were applied to the total project cost.

Financial Analysis Assumptions List:

1. Utility Inflation Rate: 1%
2. Federal Inflation Rate: 4%
3. High Pressure Sodium Fixture Failure Rate: 14%
4. LED Fixture Failure Rate: 5%
5. Photocell Failure Rate: 2%
6. Current market cost of installation and material for non-warranty replacements of LED luminaires: $325
7. Current market cost of installation and material for existing system luminaires: $175

8. Current SRP Published Price Plan E-56: $0.0626/kWh for SRP analysis
9. Used $1.98 flat per luminaire rate for both existing and new system luminaires for SRP analysis
    a. This number was averaged from the city's utility bills.
10. Used $0.09/kWh for COMEU analysis per the City's estimate of the average billed rate

Assumptions 1, 3, and 5 in the above list are based on Tanko Lighting's experience in the field of streetlighting. Utilities across the country submit annual requests for rate increases through the various public utility commissions, in Arizona it is known as the Arizona Corporation Commission. Generally, a request that is a 5% to 8% increase in rates is made but only a fraction is granted. By assuming a low utility inflation rate of 1%, Tanko Lighting has provided a conservative value to keep annual increases in savings low. As a result, when SRP requests an increase in energy costs, the potential savings to the city will increase due to the accompanying lowered rate via the LED tariff.

Tanko Lighting partnered with the City of Phoenix's current maintenance contractor, Roadway Electric, to obtain access to fifteen years' worth of high-pressure sodium streetlight failure data. In conducting the calculations, Tanko Lighting found an 18.2% annual failure rate for City of Phoenix street lighting. This result supported the assumptions in items 3 and 5 above. Tanko Lighting used the 14% failure rate based on feedback from the City of Mesa maintenance group.

The Federal Reserve estimates an annual 2% inflation rate to allow entities to make accurate long-term estimates on finances. Tanko Lighting has opted to be more conservative and project a 4% inflation rate to allow for a true worst-case scenario.

Generally, Tanko Lighting uses a 1% annual failure rate of LED fixtures which is based on Tanko Lighting's experience of more than 250,000 LED fixture replacements nationwide. In addition, General Electric (GE) published a report found in **Appendix E**, which references the installation of 10,319 LED fixtures in the City of Hamilton, Ontario. Since the installation in 2015, only 18 fixtures have failed. This represents only a .00017% failure rate when the expected anticipated failure rate was .02%. As with any assumption, Tanko Lighting opts for a conservative approach and recommends a higher annual failure rate of 1%. Because the rated lifetimes of the fixtures are just over 20 years, the City of Mesa requested that the financial analyses increase the annual LED fixture failure rate to 5%, so that over 20 years, 100% of fixtures would be replaced in the analyses.

The financial analysis summary for City of Mesa Electric Utility (COMEU), in Table 13 below, demonstrates the savings and payback associated with converting the 2,771 cobra head streetlights under COMEU to LED technology. The analysis used the same rate structure SRP adopted on May 1, 2019 and shows just over a 4-year pay back for the project on energy and maintenance savings with a 20-year savings of over $5.6M.

Table 13 – COMEU Tiered Billing Buckets

Annual Costs + Savings			
	Existing	New	Savings
Annual kWh	2,467,719	1,046,985	1,420,733
Annual Energy	$222,095	$36,512	$185,583
Annual Maintenance	$91,749	$33,252	$58,497
Annual CO2 Emissions (lbs)	1,293,085	548,620	744,464

20-Year Costs + Savings			
	Existing	New	Savings
20-Year Energy	$4,890,304	$803,953	$4,086,351
20-Year Maintenance	$2,732,108	$1,204,885	$1,527,222
20-Year Energy + Maintenance	$7,622,412	$2,008,838	$5,613,573
Loan Payments	$0	$0	$0
Rebate Incentive	$0	$0	$0
Grand Total	$7,622,412	$2,008,838	$5,613,573

Final Project Costs	
Total Retrofit Cost	$1,042,042
Total Rebate Incentive	$0
Net Project Cost	$1,042,042
Sales Tax % Applied	8.05%

Simple Payback (Years)	
	Net Project Cost
Energy Savings Only	5.61
Energy & Maintenance Savings Only	4.27

Note: Material prices increase approximately 5% per year. Prices in this analysis are based on current estimated material costs.

The majority of Mesa's street lights are powered by SRP with a total of 32,184 lights not yet converted to LED. Table 14 below provides a summary of the savings associated with converting these lights to LED under the new billing structure. With the new billing structure, the 20-year project savings is estimated at $30.7M with a project payback of 9.14 years when factoring energy and maintenance savings. Although the new rate structure is more favorable for LED, the facilities charge per pole nearly doubled extending the expected payback period.

Table 14 – SRP Tiered Billing Buckets

Annual Costs + Savings			
	Existing	New	Savings
Annual kWh	29,134,040	12,162,357	16,971,683
Annual Energy	$2,588,483	$1,733,661	$854,822
Annual Maintenance	$868,968	$386,208	$482,760
Annual CO2 Emissions (lbs)	15,266,237	6,373,075	8,893,162

20-Year Costs + Savings			
	Existing	New	Savings
20-Year Energy	$56,995,812	$38,173,492	$18,822,320
20-Year Maintenance	$25,876,197	$13,994,238	$11,881,960
20-Year Energy + Maint.	$82,872,010	$52,167,730	$30,704,280
Loan Payments	$0	$0	$0
Rebate Incentive	$0	$0	$0
Grand Total	$82,872,010	$52,167,730	$30,704,280

Final Project Costs	
Total Retrofit Cost	$12,230,626
Total Rebate Incentive	$0
Net Project Cost	$12,230,626
Sales Tax % Applied	8.05%

Simple Payback (Years)	
	Net Project Cost
Energy Savings Only	14.31
Energy & Maintenance Savings Only	9.14

Note: Material prices increase approximately 5% per year. Prices in this analysis are based on current estimated material costs.

These financial analyses demonstrate that converting SRP and COMEU lighting is extremely favorable to the City even when considering the conservative estimates used. The City would benefit from significant savings over the next 20 years and beyond.

6.1 Utility Rate Code Analysis

During the final stages of this report, SRP published their new LED rates effective May 1, 2019, see Table 15 below for City of Mesa commonly used fixtures. The table demonstrates what the monthly kilowatt hours billed would be for each commonly used GE fixtures in the City. For COMEU, the analysis was completed with the same tiered rate structure for consistency.

Table 15 – Monthly Kilowatt Hours

SRP May 2019 LED Billing Tiers			
#	LED Wattage (GE Fixture)	Tier Name	kWh Billing Rate
3	22	LED30	11
4	39	LED40	14
9	84	LED90	32
11	111	LED125	45
12	120	LED125	45
13	175	LED200	72
15	251	LED300	108

*kWh calculated based on 11.5 hours per night x 365 days / 12 months

7 FINANCING OPTIONS

While there are several options to fund a project such as a streetlight conversion, one of the more common ways to fund a capital project of this nature is through a tax-exempt municipal lease. This type of agreement acts as an installment purchase agreement and allows a municipality to spread the cost of the purchase over the length of the useful life of the project.

The guaranteed savings from the streetlight conversion creates a low risk for the financial institutions, allowing them to offer lower interest rates than a traditional loan. This is due to the streetlights themselves being viewed as a stable and predictable revenue stream. Other energy efficiency projects generally do not qualify for municipal lease purchases, as human interaction renders the energy savings less predictable.

Another benefit to a municipal lease purchase is that the loan does not count against the city's borrowing capacity. The loan itself is counted as off-bill debt, allowing the city to shoulder the project without the debt showing on their balance sheet. In addition, the financial savings from the utility bills can be counted towards the city's revenue for the following year.

From Tanko Lighting's experience this is the most common way to fund a streetlight conversion and, for the above-mentioned reasons, would recommend it to the City of Mesa. To address financing for the City of Mesa's specific streetlight conversion project, Tanko Lighting reached out to multiple lending institutions to gauge interest. Without a finalized start date, only two proposals were received for the project. These loan options are represented in Figure 5 below.

	GE Financing	Graybar Financial
Amount Financed:	$13,272,668.00	$13,272,668.00
Term:	Thirteen (13) Years	Fifteen (15) Years
Payment Frequency:	Annual	Quarterly
Equivalent Annual Payment Amount:	$1,370,739.47	$1,169,735.68
Fixed Interest Rate:	4.50%	3.86%
Total Interest Paid:	$4,546,945.11	$4,273,367.20
Net Retrofit Cost Including Interest:	**$17,819,613.11**	**$17,546,035.20**

Figure 5 – Financing Options

In comparing the two choices, Graybar Financial provides the best option due to its smaller overall cost and the longer term to pay back the loan. The city can also expect a loan term between 10 and 15 years and an interest rate of 3.5% - 4.5% for the project.

8 CONVERSION TIMELINE

Tanko Lighting has converted over 100,000 fixtures nationwide using this experience as well as some of the knowledge acquired from bidding the City of Phoenix conversion to determine a realistic timeframe for the conversion should the City of Mesa decide to move forward with converting their streetlights to LED. All calculations are based on a total of 34,955 Non-LED streetlight fixtures in the City of Mesa

To determine the total time to convert the City's fixtures, the project was divided into distinct phases. These phases are audit and design, procurement of the fixtures, installation, and closeout procedures. The unique climate of Mesa was factored into all of the estimates regarding this project.

The audit of the existing lighting system and the design of the new LED system can happen concurrently. Based on the ability of the auditors and the layout of the City, it was determined

that an auditor can note information on 125 fixtures a day and take around 47 working days. The majority of time in this phase will be used taking the data recorded and confirming its accuracy against the City's utility-billing inventory as well as clearing up any ownership disputes. It is estimated this entire phase will take 167 working days.

For the procurement phase a flat 70 working days was used which aligns with typical lead times. The installation of the fixtures will vary depending on the number of installation crews used in the conversion and the rate at which they install the fixtures. Local installers were contacted to determine how many crews could be available for the City's conversion. The highest number received was 15 crews. The rate determined in the City of Phoenix's estimate of 45 fixtures/crew/day was used in this analysis.

The last phase includes all closeout procedures including commissioning and rate change submissions to the utility. The results of the analysis are shown in Figure 6 below.

Client's Inputs	
Total Lights	**34,955**
Installation Rate (lights/day)	**45**

Project Timelines			
Project Phases (working days)	**Mesa Timeline with 5 Crews**	**Mesa Timeline with 10 Crews**	**Mesa Timeline with 15 Crews**
Total Audit and Design Time	167	167	167
Fixture Procurement Time	70	70	70
Installation	155	78	52
Closeout Procedures	136	136	136
Total Project Time in Days	**528**	**450**	**424**
Total Project Time in Years	**2.1**	**1.8**	**1.7**

Figure 6 – Mesa Conversion Timeline

The above table estimates the conversion of the City's streetlighting fixtures to LED will take between 20 and 25 months. Tanko Lighting has provided the City with a project timeline calculation tool to better assist in determining the duration of the project if any variables should change.

Throughout the country, municipal street light standards vary from no lighting at all to strictly adhering to IES recommended practices. Some agencies require continuous lighting that meet a footcandle and uniformity requirement while others only require lighting at intersections and conflict zones. Conflict zones are areas where the paths of vehicles and pedestrians cross. Each municipality determines what is the appropriate standard for their geographic area and surrounding environment.

9 CITY DOCUMENT REVIEW

With the constant advancements in technology it is essential to evaluate current standards, procedures, and policies related to the street light system. The City Code, Engineering & Design Standards Manual and Standard Technical Manual are all used to ensure a cohesive and well-defined street light system is designed, installed and maintained throughout the City of Mesa.

Periodically it is necessary to review these documents to ensure consistency across all the documents. The review also verifies the staff's desire and intent is conveyed accurately in these documents. Wright Engineering conducted a document review to provide any necessary recommendations for changes related to LED street lighting with the associated dimming and any new or current technologies the City is currently using. The following documents and sections were reviewed as part of this study. Recommended changes to these documents are found in Appendix F. Only pages containing comments were included in the Appendix.

- Mesa Code Section 4 Chapter 4 Mesa Lighting and Electrical Code
- Mesa Code Section 9 Chapter 6 Subdivision Regulations
- Mesa Code Section 9 Chapter 8 Off-Site Improvement Regulations
- Engineering & Design Standards Chapter 9 Public Street Lighting Requirements
- 2019 Street Light Technical Manual Supplement to Mesa Standard Details

10 SUMMARY

There has been a significant increase in LED technology over the past decade. This has produced street light luminaires that illuminate roadways with half the energy and more precise lighting control. This provides a significant cost savings and reduces unwanted spill light that is characteristic to traditional HPS and MH sources. Furthermore, ongoing maintenance for LED fixtures is drastically reduced, over legacy street lights, providing even more cost savings. These are the main reasons why LED has become the industry standard across the country for roadway lighting. The City of Mesa has wisely adopted LED as their new standard for all public street lighting. In addition to the operations and maintenance cost savings, LED street lighting will provide the City with roadways that are more uniformly illuminated, have better color rendition, and have less spill light.

There are noticeable impacts to a community where LED street lighting is adopted but LED also provides significant opportunities. In preparation of a systemwide street light conversion to LED, the City of Mesa commissioned this report to investigate these impacts and opportunities. The City identified these tasks in the scope of work section in the request for statement of qualifications. Following is a summary of the findings from these research efforts by Wright Engineering and Tanko Lighting.

10.1 IES RP-8 Recommendations

Other agencies within the Phoenix metropolitan area have varying degrees of street light requirements. The City of Phoenix does not reference IES RP-8 in their standards following spacing only guidelines and has adopted 2700K LED systemwide. The City will be fully

converted to LED by the end of 2019. On the other hand, the City of Chandler references IES RP-8 and requires 4000K LED systemwide. The City has not undergone a Citywide conversion.

Outside the Phoenix area, the City of Flagstaff does not follow IES recommendation for light levels and has adopted a significantly reduced approach to street lighting. This scenario is found across the country where agencies have reduced or no street light requirements. The liability these agencies encounter is very minimal as long as the City adopted codes and ordinances do not conflict with the standard they follow. In other words, if an agency does not require street lighting, then the liability for not having street lighting is very small.

10.2 Dimming LED Street Lighting

The results from the dimming pilot study, the research conducted of the FHWA adaptive lighting reports, and the research conducted of the Seattle dimming study all support the recommendation to dim LED street lights systemwide throughout the City of Mesa. The recommended dimming chart is found on Table 10 that corresponds to four lighting zones throughout the City of Mesa.

10.3 Smart Technologies and Control Nodes

Street lights are remotely controllable by wireless smart control nodes placed on each luminaire. These nodes have the capability to control, dim, provide diagnostic data, and provide power consumption data. These nodes are recommended to be implemented as a City standard. Furthermore, each street light has the potential to become a platform for third party communications. The possibilities are many and should be explored over time as the City goes into the information age.

10.4 Utility Rate Structures

During the final stages of this report, SRP published their updated LED tiered rates on May 1, 2019. The simple payback for converting approximately 35,000 street lights to LED including energy and maintenance savings is 9.14 years in SRP areas and 4.27 years in COMEU areas.

10.5 Financing the LED Conversion

To finance the project, it is recommended to utilize the tax-exempt municipal lease to spread out the purchase over the useful life of the project. Another benefit to the municipal lease is that it does not count against the City's debt limit and borrowing capacity. Obtaining this type of financing is not difficult since the lenders see this as low risk while streetlights themselves are viewed as a stable and predictable revenue stream.

10.6 Conversion Timeline

The conversion timeline to convert approximately 35,000 street lights to LED will depend on the number of crews the City of Mesa desires. With 15 crews, the conversion would take about 1.7 years to complete where with 5 crews it would take approximately 2.1 years. The difference is not as significant as one would imagine since a large amount of time is dedicated to tasks needed prior to any construction activities are even started.

10.7 Conclusion

The LED street light revolution has seen significant action across the country over the last few years resulting in large scale conversions of HPS to LED luminaires. Technology advances that reduce cost and increase efficiency are key factors in convincing agencies to adopt LED street lighting. Municipalities have already adopted or are in the process of adopting LED as their new street light standard. LED street lighting can now be found in nearly every major municipality across the country. It is estimated that as of 2015, approximately 20% of currently installed street and area lighting is LED (US Department of Energy 2016 Solid-State Lighting R&D plan). This number is steadily increasing due to the many conversion projects seen across the country in addition to new LED installations.

LED technology is here to stay and is consistently improving. Legacy HPS and MH fixtures are slowly being phased out of production. Due to the rapid change in this industry, the City of Mesa will need to regularly evaluate LED technology and update luminaire specifications. Staying current with technology and industry standards will ensure the City's success in maintaining and operating an efficient and safe street light system for years to come.

Appendix A – Survey Questions

Ellsworth Road, McLellan to North of McKellips	Week 1 Apr 23-29 Level A - 100%		Week 2 Apr 30-May 6 Level B - 50%		Week 3 May 7-13 Level C - 100%		Week 4 May 14-20 Level D - 25%	
Number of Total Responses:	**61**		**49**		**46**		**47**	
	Qty	**%**	**Qty**	**%**	**Qty**	**%**	**Qty**	**%**
DRIVING THROUGH AREA:	**47**	**77.05%**	**39**	**79.59%**	**40**	**86.96%**	**42**	**89.36%**
Q7: How would you describe light levels?								
Appropriate to be able to see objects and drive safely	5	10.64%	7	17.95%	4	10.00%	15	35.71%
Needed higher levels of light to be able to see objects/signage	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Lower levels of light would be adequate to safely see objects/signage	42	89.36%	31	79.49%	36	90.00%	26	61.90%
Q8: What was your perception of the area?								
Light levels were appropriate	5	10.64%	9	23.08%	6	15.00%	21	50.00%
Light levels were too high	42	89.36%	29	74.36%	34	85.00%	20	47.62%
Light levels were too low	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q9: Did you experience glare from the street lights?								
Did not experience glare	15	31.91%	10	25.64%	11	27.50%	20	47.62%
Experienced some glare	19	40.43%	18	46.15%	16	40.00%	15	35.71%
Experienced excessive glare	11	23.40%	8	20.51%	11	27.50%	5	11.90%
Other	2	4.26%	2	5.13%	2	5.00%	1	2.38%
Q10: How did light levels compare to last week's levels?								
Can't compare - not in area last week	17	36.17%	10	25.64%	7	17.50%	7	16.67%
This week is comparable to last week	15	31.91%	6	15.38%	15	37.50%	5	11.90%
This week is slightly higher than last week	4	8.51%	1	2.56%	2	5.00%	2	4.76%
This week is slightly lower than last week	8	17.02%	20	51.28%	11	27.50%	24	57.14%
This week is much higher than last week	2	4.26%	0	0.00%	3	7.50%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	2	5.00%	3	7.14%
Q11: What is your preference for which lighting levels provided better experience?								
Last week's level	3	6.38%	2	5.13%	4	10.00%	1	2.38%
This week's level	7	14.89%	16	41.03%	5	12.50%	20	47.62%
Both provided a good experience	2	4.26%	0	0.00%	3	7.50%	2	4.76%
Neither provided a good experience	19	40.43%	13	33.33%	22	55.00%	11	26.19%
No opinion	15	31.91%	5	12.82%	5	12.50%	6	14.29%
WALK, CYCLE, JOG or OTHER PEDESTRIAN ACTIVITY:	**14**	**22.95%**	**8**	**16.33%**	**9**	**19.57%**	**9**	**19.15%**
Q13: How would you describe light levels?								
Appropriate to be able to see objects and discern ped/cycle paths	2	14.29%	1	12.50%	0	0.00%	2	22.22%
Needed higher levels of light to be able to safely walk/cycle	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Lower levels of light would be adequate to safely walk/cycle	12	85.71%	5	62.50%	9	100.00%	7	77.78%
Q14: How safe did you feel in the area during your activity with level of light?								
Light levels were too low	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Very safe - light levels were appropriate	5	35.71%	2	25.00%	2	22.22%	4	44.44%
Light levels were too high	9	64.29%	4	50.00%	7	77.78%	5	55.56%

Q15: Did you experience issues in your ability to discern colors?								
Yes	2	14.29%	0	0.00%	3	33.33%	1	11.11%
No	12	85.71%	6	75.00%	6	66.67%	8	88.89%
Other								
Q16: How did light levels compare to last week's levels?								
Can't compare - not in area last week	2	14.29%	0	0.00%	2	22.22%	1	11.11%
This week is comparable to last week	5	35.71%	2	25.00%	4	44.44%	2	22.22%
This week is slightly higher than last week	0	0.00%	1	12.50%	0	0.00%	0	0.00%
This week is slightly lower than last week	3	21.43%	1	12.50%	2	22.22%	5	55.56%
This week is much higher than last week	3	21.43%	1	12.50%	1	11.11%	0	0.00%
This week is much lower than last week	0	0.00%	1	12.50%	0	0.00%	1	11.11%
Q17: What is your preference for which lighting levels provided better experience?								
Last week's level	1	7.14%	1	12.50%	0	0.00%	0	0.00%
This week's level	4	28.57%	2	25.00%	2	22.22%	4	44.44%
Both provided a good experience	1	7.14%	0	0.00%	0	0.00%	0	0.00%
Neither provided a good experience	5	35.71%	2	25.00%	5	55.56%	4	44.44%
No opinion	3	21.43%	1	12.50%	2	22.22%	1	11.11%
RESIDENT WHO LIVES NEARBY:	**56**	**91.80%**	**44**	**89.80%**	**44**	**95.65%**	**41**	**87.23%**
Q19: How would you describe light levels?								
Appropriate for the type of road	4	7.14%	6	13.64%	4	9.09%	14	34.15%
Needed higher levels of light for vehicles and peds to navigate safely	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Need lower levels of light to minimize light I see from my residence	51	91.07%	37	84.09%	40	90.91%	27	65.85%
Q20: How did level of light impact activities at your residence?								
Light levels were appropriate, activities were not impacted	9	16.07%	13	29.55%	8	18.18%	19	46.34%
Light levels were too low to feel secure for amount of traffic	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Light levels were too high at our residence	46	82.14%	30	68.18%	36	81.82%	22	53.66%
Q21: Did you experience issues this week based on level of lighting?								
Did not experience issues with level of light	16	28.57%	11	25.00%	11	25.00%	20	48.78%
Light levels negatively impacted my view of surrounding area/landscape	28	50.00%	20	45.45%	26	59.09%	12	29.27%
Light levels impacted our family activities in front/back yards	5	8.93%	4	9.09%	3	6.82%	3	7.32%
Light levels create issues with sleeping/activities inside the home	6	10.71%	8	18.18%	4	9.09%	6	14.63%
Q22: How did light levels compare to last week's levels?								
Can't compare - not in area last week	16	28.57%	11	25.00%	9	20.45%	5	12.20%
This week is comparable to last week	24	42.86%	7	15.91%	14	31.82%	5	12.20%
This week is slightly higher than last week	3	5.36%	3	6.82%	5	11.36%	2	4.88%
This week is slightly lower than last week	9	16.07%	20	45.45%	14	31.82%	27	65.85%
This week is much higher than last week	3	5.36%	1	2.27%	2	4.55%	0	0.00%
This week is much lower than last week	0	0.00%	1	2.27%	0	0.00%	2	4.88%
Q23: What is your preference for which lighting levels provided better experience?								
Last week's level	3	5.36%	2	4.55%	4	9.09%	1	2.44%
This week's level	7	12.50%	14	31.82%	6	13.64%	19	46.34%
Both provided a good experience	1	1.79%	0	0.00%	2	4.55%	2	4.88%
Neither provided a good experience	26	46.43%	18	40.91%	26	59.09%	15	36.59%
No opinion	17	30.36%	7	15.91%	6	13.64%	3	7.32%

Fraser Drive, North of Main Street	Week 1 Apr 23-29 Level A - 100%		Week 2 Apr 30-May 6 Level B - 50%		Week 3 May 7-13 Level C - 100%		Week 4 May 14-20 Level D - 25%	
Number of Total Responses:	**3**		**5**		**2**		**3**	
	Qty	**%**	**Qty**	**%**	**Qty**	**%**	**Qty**	**%**
DRIVING THROUGH AREA:	**2**	**66.67%**	**3**	**60.00%**	**2**	**100.00%**	**3**	**100.00%**
Q7: How would you describe light levels?								
Appropriate to be able to see objects and drive safely	2	100.00%	2	66.67%	2	100.00%	3	100.00%
Needed higher levels of light to be able to see objects/signage	0	0.00%	1	33.33%	0	0.00%	0	0.00%
Lower levels of light would be adequate to safely see objects/signage	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q8: What was your perception of the area?								
Light levels were appropriate	2	100.00%	0	0.00%	2	100.00%	2	66.67%
Light levels were too high	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Light levels were too low	0	0.00%	3	100.00%	0	0.00%	1	33.33%
Q9: Did you experience glare from the street lights?								
Did not experience glare	2	100.00%	3	100.00%	1	50.00%	3	100.00%
Experienced some glare	0	0.00%	0	0.00%	1	50.00%	0	0.00%
Experienced excessive glare	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Other	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q10: How did light levels compare to last week's levels?								
Can't compare - not in area last week	1	50.00%	2	66.67%	0	0.00%	1	33.33%
This week is comparable to last week	1	50.00%	0	0.00%	0	0.00%	1	33.33%
This week is slightly higher than last week	0	0.00%	0	0.00%	2	100.00%	0	0.00%
This week is slightly lower than last week	0	0.00%	1	33.33%	0	0.00%	0	0.00%
This week is much higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	0	0.00%	1	33.33%
Q11: What is your preference for which lighting levels provided better experience?								
Last week's level	1	50.00%	1	33.33%	0	0.00%	1	33.33%
This week's level	0	0.00%	0	0.00%	1	50.00%	0	0.00%
Both provided a good experience	1	50.00%	0	0.00%	1	50.00%	1	33.33%
Neither provided a good experience	0	0.00%	0	0.00%	0	0.00%	0	0.00%
No opinion	0	0.00%	2	66.67%	0	0.00%	1	33.33%
WALK, CYCLE, JOG or OTHER PEDESTRIAN ACTIVITY:	**1**	**33.33%**	**2**	**40.00%**	**0**	**0.00%**	**1**	**33.33%**
Q13: How would you describe light levels?								
Appropriate to be able to see objects and discern ped/cycle paths	0	0.00%	2	100.00%	0	0.00%	0	0.00%
Needed higher levels of light to be able to safely walk/cycle	1	100.00%	0	0.00%	0	0.00%	1	100.00%
Lower levels of light would be adequate to safely walk/cycle	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q14: How safe did you feel in the area during your activity with level of light?								
Light levels were too low	1	100.00%	2	100.00%	0	0.00%	0	0.00%
Very safe - light levels were appropriate	0	0.00%	0	0.00%	0	0.00%	1	100.00%
Light levels were too high	0	0.00%	0	0.00%	0	0.00%	0	0.00%

Q15: Did you experience issues in your ability to discern colors?								
Yes	1	100.00%	0	0.00%	0	0.00%	1	100.00%
No	0	0.00%	2	100.00%	0	0.00%	0	0.00%
Other								
Q16: How did light levels compare to last week's levels?								
Can't compare - not in area last week	1	100.00%	0	0.00%	0	0.00%	0	0.00%
This week is comparable to last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is slightly higher than last week	0	0.00%	1	50.00%	0	0.00%	0	0.00%
This week is slightly lower than last week	0	0.00%	1	50.00%	0	0.00%	1	100.00%
This week is much higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q17: What is your preference for which lighting levels provided better experience?								
Last week's level	0	0.00%	2	100.00%	0	0.00%	1	100.00%
This week's level	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Both provided a good experience	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Neither provided a good experience	1	100.00%	0	0.00%	0	0.00%	0	0.00%
No opinion	0	0.00%	0	0.00%	0	0.00%	0	0.00%
RESIDENT WHO LIVES NEARBY:	**3**	**100.00%**	**4**	**80.00%**	**0**	**0.00%**	**2**	**66.67%**
Q19: How would you describe light levels?								
Appropriate for the type of road	2	66.67%	1	25.00%	0	0.00%	0	0.00%
Needed higher levels of light for vehicles and peds to navigate safely	0	0.00%	3	75.00%	0	0.00%	1	50.00%
Need lower levels of light to minimize light I see from my residence	0	0.00%	0	0.00%	0	0.00%	1	50.00%
Q20: How did level of light impact activities at your residence?								
Light levels were appropriate, activities were not impacted	2	66.67%	3	75.00%	0	0.00%	1	50.00%
Light levels were too low to feel secure for amount of traffic	0	0.00%	1	25.00%	0	0.00%	1	50.00%
Light levels were too high at our residence	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q21: Did you experience issues this week based on level of lighting?								
Did not experience issues with level of light	2	66.67%	4	100.00%	0	0.00%	2	100.00%
Light levels negatively impacted my view of surrounding area/landscape	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Light levels impacted our family activities in front/back yards	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Light levels create issues with sleeping/activities inside the home	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q22: How did light levels compare to last week's levels?								
Can't compare - not in area last week	0	0.00%	1	25.00%	0	0.00%	1	50.00%
This week is comparable to last week	1	33.33%	1	25.00%	0	0.00%	1	50.00%
This week is slightly higher than last week	1	33.33%	0	0.00%	0	0.00%	0	0.00%
This week is slightly lower than last week	0	0.00%	2	50.00%	0	0.00%	0	0.00%
This week is much higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q23: What is your preference for which lighting levels provided better experience?								
Last week's level	1	33.33%	3	75.00%	0	0.00%	2	100.00%
This week's level	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Both provided a good experience	1	33.33%	0	0.00%	0	0.00%	0	0.00%
Neither provided a good experience	0	0.00%	0	0.00%	0	0.00%	0	0.00%
No opinion	0	0.00%	1	25.00%	0	0.00%	0	0.00%

McLellan Road, West of Ellsworth Road	Week 1 Apr 23-29 Level A - 100%		Week 2 Apr 30-May 6 Level B - 50%		Week 3 May 7-13 Level C - 100%		Week 4 May 14-20 Level D - 25%	
Number of Total Responses:	**8**		**3**		**2**		**5**	
	Qty	**%**	**Qty**	**%**	**Qty**	**%**	**Qty**	**%**
DRIVING THROUGH AREA:	**5**	**62.50%**	**2**	**66.67%**	**0**	**0.00%**	**4**	**80.00%**
Q7: How would you describe light levels?								
Appropriate to be able to see objects and drive safely	1	20.00%	0	0.00%	0	0.00%	2	50.00%
Needed higher levels of light to be able to see objects/signage	0	0.00%	0	0.00%	0	0.00%	1	25.00%
Lower levels of light would be adequate to safely see objects/signage	4	80.00%	2	100.00%	0	0.00%	1	25.00%
Q8: What was your perception of the area?								
Light levels were appropriate	2	40.00%	0	0.00%	0	0.00%	3	75.00%
Light levels were too high	3	60.00%	2	100.00%	0	0.00%	0	0.00%
Light levels were too low	0	0.00%	0	0.00%	0	0.00%	1	25.00%
Q9: Did you experience glare from the street lights?								
Did not experience glare	1	20.00%	0	0.00%	0	0.00%	3	75.00%
Experienced some glare	4	80.00%	2	100.00%	0	0.00%	1	25.00%
Experienced excessive glare	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Other	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q10: How did light levels compare to last week's levels?								
Can't compare - not in area last week	3	60.00%	1	50.00%	0	0.00%	1	25.00%
This week is comparable to last week	1	20.00%	1	50.00%	0	0.00%	1	25.00%
This week is slightly higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is slightly lower than last week	1	20.00%	0	0.00%	0	0.00%	2	50.00%
This week is much higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q11: What is your preference for which lighting levels provided better experience?								
Last week's level	1	20.00%	0	0.00%	0	0.00%	0	0.00%
This week's level	0	0.00%	0	0.00%	0	0.00%	3	75.00%
Both provided a good experience	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Neither provided a good experience	1	20.00%	1	50.00%	0	0.00%	1	25.00%
No opinion	3	60.00%	1	50.00%	0	0.00%	0	0.00%
WALK, CYCLE, JOG or OTHER PEDESTRIAN ACTIVITY:	**2**	**25.00%**	**1**	**33.33%**	**1**	**50.00%**	**2**	**40.00%**
Q13: How would you describe light levels?								
Appropriate to be able to see objects and discern ped/cycle paths	0	0.00%	0	0.00%	0	0.00%	1	50.00%
Needed higher levels of light to be able to safely walk/cycle	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Lower levels of light would be adequate to safely walk/cycle	2	100.00%	1	100.00%	1	100.00%	1	50.00%
Q14: How safe did you feel in the area during your activity with level of light?								
Light levels were too low	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Very safe - light levels were appropriate	0	0.00%	0	0.00%	1	100.00%	2	100.00%
Light levels were too high	2	100.00%	1	100.00%	0	0.00%	0	0.00%

Q15: Did you experience issues in your ability to discern colors?								
Yes	0	0.00%	0	0.00%	0	0.00%	0	0.00%
No	2	100.00%	1	100.00%	1	100.00%	2	100.00%
Other								
Q16: How did light levels compare to last week's levels?								
Can't compare - not in area last week	1	50.00%	0	0.00%	0	0.00%	1	50.00%
This week is comparable to last week	0	0.00%	0	0.00%	1	100.00%	0	0.00%
This week is slightly higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is slightly lower than last week	1	50.00%	1	100.00%	0	0.00%	1	50.00%
This week is much higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q17: What is your preference for which lighting levels provided better experience?								
Last week's level	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week's level	1	50.00%	0	0.00%	0	0.00%	1	50.00%
Both provided a good experience	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Neither provided a good experience	0	0.00%	1	100.00%	1	100.00%	0	0.00%
No opinion	1	50.00%	0	0.00%	0	0.00%	1	50.00%
RESIDENT WHO LIVES NEARBY:	**7**	**87.50%**	**2**	**66.67%**	**2**	**100.00%**	**4**	**80.00%**
Q19: How would you describe light levels?								
Appropriate for the type of road	1	14.29%	0	0.00%	0	0.00%	3	75.00%
Needed higher levels of light for vehicles and peds to navigate safely	1	14.29%	0	0.00%	0	0.00%	1	25.00%
Need lower levels of light to minimize light I see from my residence	5	71.43%	2	100.00%	2	100.00%	0	0.00%
Q20: How did level of light impact activities at your residence?								
Light levels were appropriate, activities were not impacted	3	42.86%	0	0.00%	0	0.00%	3	75.00%
Light levels were too low to feel secure for amount of traffic	1	14.29%	0	0.00%	0	0.00%	1	25.00%
Light levels were too high at our residence	3	42.86%	2	100.00%	2	100.00%	0	0.00%
Q21: Did you experience issues this week based on level of lighting?								
Did not experience issues with level of light	3	42.86%	1	50.00%	1	50.00%	3	75.00%
Light levels negatively impacted my view of surrounding area/landscape	0	0.00%	0	0.00%	0	0.00%	1	25.00%
Light levels impacted our family activities in front/back yards	2	28.57%	1	50.00%	0	0.00%	0	0.00%
Light levels create issues with sleeping/activities inside the home	2	28.57%	0	0.00%	1	50.00%	0	0.00%
Q22: How did light levels compare to last week's levels?								
Can't compare - not in area last week	2	28.57%	1	50.00%	0	0.00%	2	50.00%
This week is comparable to last week	3	42.86%	0	0.00%	1	50.00%	1	25.00%
This week is slightly higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is slightly lower than last week	2	28.57%	1	50.00%	1	50.00%	1	25.00%
This week is much higher than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week is much lower than last week	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Q23: What is your preference for which lighting levels provided better experience?								
Last week's level	0	0.00%	0	0.00%	0	0.00%	0	0.00%
This week's level	2	28.57%	0	0.00%	0	0.00%	2	50.00%
Both provided a good experience	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Neither provided a good experience	2	28.57%	1	50.00%	2	100.00%	1	25.00%
No opinion	3	42.86%	1	50.00%	0	0.00%	1	25.00%

Q24 Thank you for participating in our survey!Please provide any additional comments you'd like to share with the study team in the comment box below.Once you click "SUBMIT", you're survey will be submitted and you'll be redirected to our project website.

Answered: 33 Skipped: 39

#	RESPONSES	DATE
1	More people need to know about,this testing and survey.	4/30/2018 5:04 PM
2	this is first week of the survey so not able to compare	4/30/2018 8:05 AM
3	In my opinion it would be appropriate if you asked the question - Did the light levels interfere with your viewing of the night sky?	4/30/2018 6:45 AM
4	Use the lowest level of lighting that is safe for pedestrians. Cars have headlights. The lights have been too bright. Thank you for doing this survey!	4/30/2018 6:32 AM
5	In this uplands area, a lower level of light would be perfectly adequate for safe driving and would be better for the nighttime wildlife.	4/29/2018 10:25 PM
6	Thanks for taking the time to do this investigation	4/29/2018 9:40 PM
7	Look forward to dimmer test lighting	4/29/2018 9:28 PM
8	The bright moonlight impacted the Night sky, which is one of my concerns.	4/29/2018 9:23 PM
9	We are in support of lower light levels as our property backs up to Ellsworth Rd., Before this test the light levels were very intrusive to our home. The lower the levels is best for us. This test level is A, we are hoping B, C, D are even lower than A	4/29/2018 8:26 PM
10	My preference is for the yellow colored lights by the Mountain Bridge area on McKellips. The LED lights are too white.	4/29/2018 5:48 PM
11	Many of the answers were inconclusive because I honestly could not tell the difference when driving. However the lights shine into my bedroom window at night so during winter months and cooler nights I have the option of either closing up my house and all of my blinds in the back of my house or opening my windows to let the nice weather in and the not so nice bright light in my bedroom. If the city of mesa finds it necessary to have street lighting everywhere instead of just the intersections then maybe they should investigate the option of shorter lights to light the street but not overshine into the houses along the street.	4/29/2018 3:46 PM
12	2 pole lights shine on the entire front my property,	4/29/2018 2:52 PM
13	The "yellowish" street lights were bright but softer; the high intensity white LED street lights were a drastic intensity change - too much. This used to be Mesa's only remaining "night sky" area.	4/29/2018 1:42 PM
14	We really did not notice any difference in lighting levels. The high levels of both weeks are an ongoing annoyance.	4/29/2018 11:08 AM
15	This weeks level was better. I could sleep but still had a bright light at night.	4/28/2018 1:40 PM
16	Excessive amount of artificial lighting in the back of our property up to and including intruding into our home.	4/28/2018 12:03 PM
17	The lighting is obtrusive, I moved to this area to get away from the city lights & to be able to see the stars. Myself and folks whom visit my residence, feel the lighting is uncomfortable to sit and relax in the back yard as the glare from the lights cause headaches.	4/28/2018 10:06 AM
18	The level of light is too high and too bright as seen from our back yard Andy living room facing Ellsworth. Would like to see the level much lower	4/27/2018 6:23 PM
19	Lights at Ellsworth & McKellips Roads are way too bright last week and this week.	4/27/2018 2:11 PM

20	Our home backs to Ellsworth; we had the new lighting installed back in June of last year; the city was kind enough to change the new lights out back to the old HPS along our area of Ellsworth from some stock they had stored of the HPS lighting so that helped the direct shining down in our backyards; however, we know going forward that once these HPS lights go out they will be replaced with the newer brighter ones and we do not want the bright lights shining into our backyard. Thank you.	4/27/2018 11:39 AM
21	We liked our Desert Uplands neighborhood much more when we were able to enjoy this Dark Sky area, way before these blue-rich brite-white LED lights were installed along Ellsworth, from McLellan to North McKellips Road. They shine into the backyards & some front yards of homes now being built along Ellsworth Road, which is very bad for human beings, the landscape, and disrupted the area's wildlife !	4/26/2018 1:03 PM
22	Don't like the on Ellsworth between the two sets of lights. color difference	4/26/2018 9:14 AM
23	I have a residence in view of street lights. I am interested in Street lighting that is as low as possible so as to generate the least amount light pollution as possible.	4/26/2018 7:36 AM
24	The lights this week are bright and act like individual spotlights on the street. Driving on the street, it was like this: dark, light, dark, light, etc. They do not produce enough of a diffused light source for the entire street. I recommend lights that are 2700K or equivalent with a fixture cover that helps diffuse the light source better so a softer light spreads out over more street surface area. Bright spot lights are not attractive for the high desert. They make you squint while driving and the focused brightness makes it difficult to see things in the dark that are higher off the ground like street names or building signs. Looking forward to next week's lights. Thank you.	4/25/2018 9:06 PM
25	Thank you for your efforts. This area of Mesa with the surrounding mountains & desert should ultimately reflect peacefulness & serenity & should only be subject to low lighting, being respectful to our beautiful natural environment.	4/25/2018 5:53 PM
26	I haven't been there to notice because I wasn't aware it started, but I will make it my business to travel that route going forward.	4/25/2018 1:18 PM
27	Hello, I think the lights are way too bright and would much prefer them to be much lower. I live in an area where the light bleeds into my back yard from the bright lights along McKellips leading into Ellsworth. In fact, my neighbors and I believe the bright lights attract the motorcyclists to race along McKellips and Ellsworth late at night because they can see so well. It is very noisy, annoying, and frustrating because by the time we'd alert the police, they would be long gone. Otherwise, there is very little traffic along these streets so don't believe it warrants the lights being up so bright. Thanks so much for the opportunity to share our feedback!	4/25/2018 11:50 AM
28	Lighting all of this historic district is needed with the light rail activities we expect , will be higher.	4/25/2018 8:22 AM
29	My backyard is impacted by high, glaring street lights off of Ellsworth. My backyard, Bedrooms are super affected by 3 of the lights. I am grateful that your a testing the levels of lights. Thank you.	4/25/2018 7:41 AM
30	desert uplands .....please respect what remains of it	4/24/2018 4:59 AM
31	I drove both the Ellsworth and McLellan street test. I understood this to be a dimming test which I expected the lighting to be not as intense as last week before this pilot started; I have to admit I think the levels were just as intense as before this test if not a slightly more with spillage than last week...I drove it twice and it seemed to me the spillage went further looking at the test dots than it was last week; glare from lights the same, if not more. I will see what next week brings!	4/23/2018 8:40 PM
32	As we are currently located in Mountain Bridge near the corner of Ellsworth and Mckellips the lights are terribly bright and we feel something should be done to make this a dark sky area which has been done in other areas in Az such as Sedona. The night sky draws people to Az and should be preserved.	4/23/2018 8:37 PM
33	blanford planted another tree behind our yard. we are hoping it will block some of the light. 7th light from the corner of mcKelli & Ellsworth is our hm.	4/23/2018 1:36 PM

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Answered: 29 Skipped: 28

#	RESPONSES	DATE
1	At the time of the night I was there, I was the only vehicle at the intersection of Ellsworth & McKellips Rds and the brighter lights are not needed. The level of traffic does not support these bright lights.	5/7/2018 6:19 PM
2	The light poles are too high and need to have shoe box covers. The whole front of my property is lit up. I live on the corner of McLellan & 88th Place.	5/7/2018 12:16 PM
3	Please dimm these White-Brite Blue-LED Lights as we want to maintain the Desert Uplands Dark Sky like we had in the past and for the people, who will be buying the Mountain Bridge homes going up along Ellsworth from McLelland to past McKellips Rds !	5/7/2018 12:16 PM
4	I could see the road, but felt that it was a little dark and could have used more light.	5/7/2018 12:06 PM
5	The light is overwhelming and uneccessary, PLEASE turn it down.	5/7/2018 10:49 AM
6	My backyard backs to Ellsworth; though the old HPS lighting is behind me; these lights will eventually be replaced with the new lights and that will definitely impact my backyard. When I view from my backyard to the south down Ellsworth the new lights are excessive; the lights need to be dimmer. Again, I back to Ellsworth and these new lights and their intensity concern me.	5/7/2018 9:21 AM
7	Because of the brightness of these lights my eyes were drawn to look up at them and it was unsafe because I was distracted from focusing on the road.	5/7/2018 6:10 AM
8	Many questions needed a Not Applicable option. I skipped those questions but it would have been more accurate to answer N/A	5/6/2018 11:38 PM
9	Difficult to tell lighting difference because last week there was full moon and more lights at the power and brown ballpark were on last week when I was walking and driving.	5/6/2018 10:45 PM
10	Still too much glare and light spilling into my yard. We're on the edge of town...would be nice to be able to see the stars at night more prominently. The street lights are too bright-it takes away from the ambiance of being far removed from the city.	5/6/2018 8:18 PM
11	A lower level of lighting would be compatible with the uplands area, and still be safe for travel.	5/6/2018 3:29 PM
12	For the area that we live in, the amount of light is too bright. The amount of traffic and activities does not warrant this high amount of of light. We specifically moved to this area to be in a rural area with minimal or no lighting.	5/6/2018 12:50 PM
13	Lighting seems excessive for the requirement of either driving or walking without impacting safety. The spacing between light poles seems too close which is also contributing to overall excessive brightness.	5/6/2018 11:12 AM
14	This week was an improvement over last week, however, it is my sincere hope that the lights will have the capacity to be dimmed even more. Thank you.	5/6/2018 10:13 AM
15	led lights cause much glare	5/6/2018 9:27 AM
16	Although, this weeks lighting was preferable to last week, it is still too bright and intrusive.	5/6/2018 8:53 AM
17	The light still intrudes into our backyard and the back of our home.	5/6/2018 7:45 AM
18	The lights were lower this week; but still higher than needed; still puts out excessive glare and spillage. For the Desert Uplands area, the lights need to be dimmer. Thank you.	5/4/2018 9:42 PM
19	Lighting levels seemed to be the same or very close in the past two weeks.	5/4/2018 2:55 PM

20	Just want dimmer lights. We have beautiful views in the area and bright lights take away from it as n the evening	5/3/2018 8:44 PM
21	I travel weekly Monday through Friday North of McKellips and Ellsworth. My recommendation would be that the lighting be the same as the surrounding developments with yellow hues of lighting. The lights that Mountain Bridge has installed are too white and bright for the Arizona desert. When your driving through the surrounding areas of Ellsworth/ Crismon and Brown where it's lower lighting and then approach McKellips it's rather blinding to the eyes. It's like whoa!! Driving through a stadium arena. Quite shocking for the eyes.	5/3/2018 8:34 PM
22	I am JUST north of the LED lighting. We experience Sodium, which is adequate lighting. The test lighting seems both brighter and higher than it needs to be. The Roadway is quite bight. Why is height so high, specially in a Dark Sky area?	5/3/2018 1:41 PM
23	Thank you for your concern & very important efforts. Ultimately, & simply put, whether there was a slight difference between the past two weeks, there are just too many lights & just too bright. Your attention to this is so very important in an effort to protect & preserve the low light community that was established many years ago ~ we all have a duty to preserve nature & the gifts it provides ~ thank you.	5/3/2018 8:34 AM
24	Please get the white lights dimmed down to the same level, or dimmer than the surrounding orange street lights as soon as possible. The light intensity is very intrusive as it currently stands.	5/2/2018 10:50 PM
25	I liked this week's lights better than last week's. Even though this week's lights were still whiter and brighter than I prefer, the light was more diffused than last week. Last week's lights were like bright spot lights on the ground and the bulbs in the fixture had high glare. This week's lights were still spot lights on the ground, but the spots on the ground were more diffused and less defined. I wish the bulb in the light fixture could be more recessed and less bright white without compromising visibility. Looking forward to next week. Thank you.	5/2/2018 10:31 PM
26	The lower the light level the better for residences & drivers.	5/2/2018 7:09 AM
27	This week was too darn bright! I hope to see lower light options to preserve night sky and desertviews. Thanks.	5/2/2018 6:25 AM
28	All of Fraser Feilds could use thede led's. Much truer lihjt will cut crime down	4/30/2018 9:54 PM
29	Low or even lower lighting is better for the surrounding residential areas.	4/30/2018 9:14 PM

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Answered: 24 Skipped: 26

#	RESPONSES	DATE
1	doesn't seem to be much change in my opinion	5/14/2018 7:03 PM
2	I would like the light levels as low as possible for residents, wildlife, star gazing while remaining safe for drivers.	5/14/2018 6:29 PM
3	As I drive Ellsworth road all of the time, I am curious as to why there are so many lights in this area, which is a residential area? South of Main street, on Ellsworth, which is more heavily populated, only has street lights at commercial intersections. I think the number of lights North of Main are excessive and only serves to encourage the continual speeding of vehicles on this road. You could reduce the number of light poles by 75% and still have enough lighting to safely drive through the area.	5/14/2018 4:52 PM
4	The street light commission needs to replace the cool tone LED lights with warm tone lights to match the other two sections that meet up with it. A survey is not needed to see that the lighting along Ellisworth does not match and it looks distracting and poorly planned.	5/14/2018 3:50 PM
5	The debate is the color of the lights. Amber is much kinder to the environment and LEDs come in a variety of colors.	5/14/2018 2:51 PM
6	I feel the way this study was set up was totally ineffective.Asking if the lighting was better this week or last week is like asking if the sun was brighter yesterday or last Wednesday. A more appropriate way would have been to set different levels of light on the North side of Ellsworth Rd. than on the South side so a comparison could be seen between them as you drove or walked .	5/14/2018 1:26 PM
7	Level A, 1st week of test seemed to us the lowest light level, which we are in favor of. We forgot to respond on week 2, which seemed to be a little higher level than week 1. Week 3 which ended yesterday, seemed a little brighter than week 2. Our property backs up to Ellsworth Road.	5/14/2018 11:45 AM
8	My whole front property is lit too high.	5/14/2018 11:37 AM
9	There will be homes constructed soon along Ellsworth Rd between McLellan Dr & North McKellips Rd that won't have a say on this matter or be able to take the survey regarding these bright-white LED Lights that effect the Desert Uplands Dark Sky area and our wildlife - which is so important to our neighborhood and I feel the new owners should be able to have their input too!	5/14/2018 10:50 AM
10	The lights need to be dimmed quite a bit.	5/13/2018 11:48 PM
11	This level of lighting was quite sufficient to be able to walk, ride or bike. If cost savings are decreasing as the lighting is lowered, it could be lower without any negative impact.	5/13/2018 8:42 PM
12	This weeks level of lighting seemed about the same as last weeks level of lighting. Still unacceptable.	5/13/2018 8:01 PM
13	Again, the light intensity, glare and spillage is still too much. We need softer, lower lighting similar to the HPS that will soon be replaced by the new LED technology.	5/13/2018 5:40 PM
14	This weeks lights were a little brighter than last week with a little more glare when looking directly at the light. We preferred last week's lights better (Week B). This week, the light level was brighter and the area of street/ground lit up by each light was larger and wider. but nicely diffused. That said, it wasn't really necessary to light up that large of an area in order to see safely. We hope you are saving the best light test for last. Looking forward to next week.	5/11/2018 9:13 PM
15	We need a lower level of lighting for this uplands area to protect our special wildlife area.	5/11/2018 12:59 PM

16	There is still significant light spillage beyond the sidewalks and into the desert. the road was lighted at least enough, somewhat more light than needed. From our home, we can still see the lights from our back and side yard, and through the windows on the south side of the house. The lights that are 1/4 mile-plus away from our home are still significantly brighter than the HPS lights that are about 300 feet away! City and Sky views are definitely being lost due to the extra light (brightness and color?)	5/11/2018 8:38 AM
17	In comparison to the first week, the levels have come down slightly, but still are too high. We live in a desert and low light area, therefore, these light levels are inappropriate.	5/10/2018 5:56 PM
18	This is Dark Mesa the lights are blinding and need to go. the lights are blinding and destroy the night sky.We don't need it lit up like downtown. If they do stay shield them so they don't blind me.	5/10/2018 2:14 PM
19	The light levels were too high this week. This is the upland desert area and lighting should be lower. Lighting levels look better lower like the levels north of Mckellips on Ellisworth. Thank you for your consideration.	5/10/2018 12:41 PM
20	I know safety is the main goal of our street lighting, but hopefully the second priority can be preserving the desert uplands experience and enjoying the beauty of the night sky.	5/10/2018 11:01 AM
21	I honestly could not tell a difference from week one to week three in terms of dimming. I parked at the intersection of McKellips and Ellsworth were I could see the dimmed lights and the normal levels and could not tell the difference. Very subtle if any. I very much appreciate the City looking at this because I believe the levels should be much lower, please. To save energy consumption, to reduce the spillage, and reduce maintenance costs. Also the lights are so bright...being on the edge of town bordering Usery park the ambiance feels so sterile. Not sure if you could make the lights more of a brown color like the ones lighting McKelllips as you head east from the 202. Those are way better and are less invasive, and you can see just fine at night with your headlights on. Thanks again for studying this and hope you can come up with a compromise of some sort.	5/10/2018 10:15 AM
22	Driving North from McLellan the line of lighting instantly reminded me of nearing a Stadium. Street Lighting should be just "there" subconsiously not noticed when driving.	5/10/2018 9:07 AM
23	Again, my backyard backs to Ellsworth; where I am located the city changed the light behind be back to the HPS lights; however, once that goes out, it will be replaced with the new one; when I look to the south down Ellsworth from my backyard, it is still very bright; really have not seen much change in dimming, i.e. intensity of light change/glare compared to the lighting before the test started. Thank you.	5/10/2018 9:01 AM
24	It was not obvious that the lights had been dimmed from last week. It IS obvious that these new LED lights are much brighter than the old lights that are still in use nearby.	5/8/2018 8:32 AM

Q24 Thank you for participating in our survey!Please provide any additional comments you'd like to share with the study team in the comment box below.Once you click "SUBMIT", you're survey will be submitted and you'll be redirected to our project website.

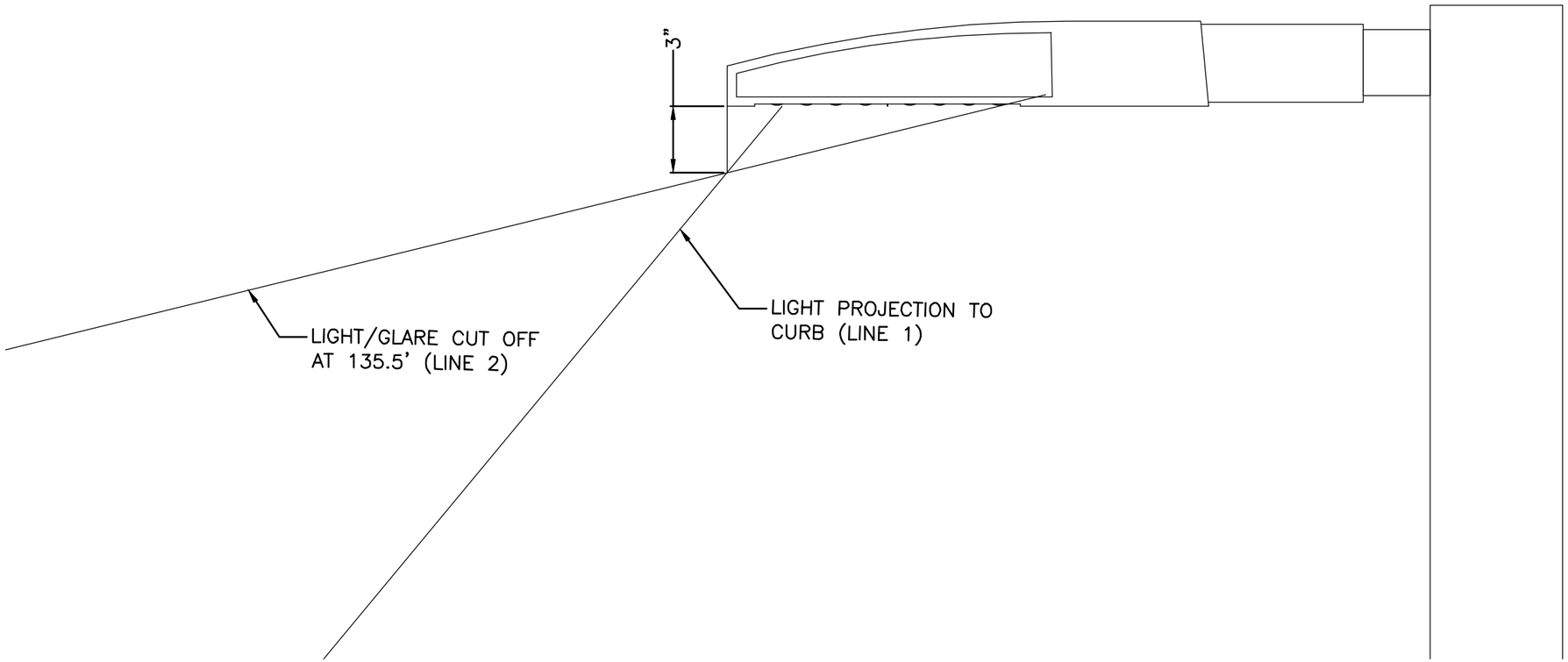
Answered: 28 Skipped: 27

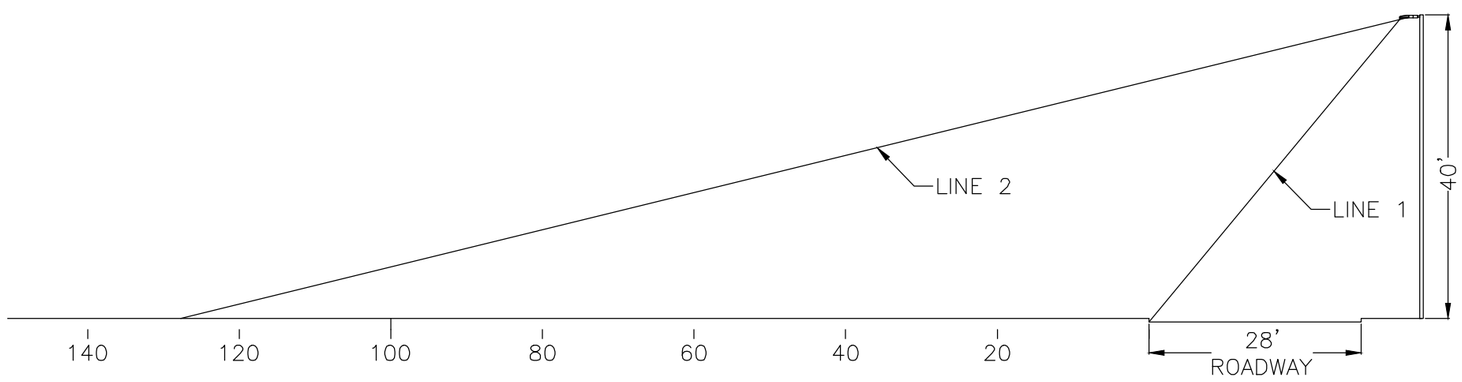
#	RESPONSES	DATE
1	Our property backs up to Ellsworth Rd. We have 6-7 street lights that we can see from inside our home. The lowest level of lighting is best for us. Of the 4 weeks, we have no idea which week had highest level of lighting, but we prefer the lowest level of lighting available.	5/21/2018 4:37 PM
2	If it is possible to lower them, we would appreciate it. I am going to have to buy blackout shades for our bedroom. Also, if you might consider dimming them during the sleep hours or shutting off every other one that would be great. Thank you!	5/21/2018 1:30 PM
3	I found this weeks lighting to be much more pleasing. I noticed much less light spillage off the sidewalks, very little hallowing around the lights while approaching the test area. Also I did not notice any spotlight effects on the road or my windshield while driving through the test area as I had in the past weeks.	5/21/2018 1:05 PM
4	LED's are too intense/bright	5/21/2018 10:29 AM
5	The dimmest they have been but still too much glare; they need to be dimmer please. Could the city use a softer amber color LED or amber lens to give the effect of the softer, warmer effect like the HPS lights that are still being used? A neighbor found this article from last week in the Tucson paper and will attach the link if you are able to open it on your end. The AMA has weighed in on this discussion. Please let me know if you'd like me to send you the link another way...hope this helps! http://tucson.com/news/science/in-switchover-to-led-streetlights-tucson-is-aware-of-sleep/article_5638e2c8-d897-5166-97d9-008fa782ed21.html?utm_medium=social&utm_source=email&utm_campaign=user-share	5/21/2018 10:24 AM
6	There is no data that suggest that higher Kelvin lighting creates a safer lighting environment. Please communicate with other municipalities in Arizona and find out what lighting policies they have enacted in residential areas. We live in a very dark part of the city, and this type of lighting does increase safety, it only creates light pollution. Thank you for doing this survey and test.	5/21/2018 5:06 AM
7	Why are there so many lights? How about every other light post be lit. Driving up Hawes from McDowell, there are no lights and it is fine in a car or on a bike with headlights. Point being, we do not need so many lights. We are polluting our skies with light.	5/20/2018 10:18 PM
8	Tonight, for the first time, the LED lights were not noticeably brighter than the HPS lights. Also, there was not much spillover into the adjacent desert areas which does occur at full brightness.	5/20/2018 8:51 PM
9	The lights are angled so that it glares into my eyes as I drive through the area. In addition the color of the light is too stark, a warmer color light would provide a more pleasing and safer environment.	5/20/2018 8:35 PM
10	The color of the light causes glare and the position shines at the driver instead of straight down the existing amber lights adjacent to the test area are better on the eyes when driving.	5/20/2018 8:30 PM
11	The lights were less annoying this week. The color of the light emitted was a warmer amber color. However, Sunday night the lights seemed to revert to their old brighter level. Please lower the light level.	5/20/2018 8:27 PM
12	This was the dimmest they have been since the start I felt; however, the levels are still high for a Dark Sky area; can the city offer a softer color, more amber LED or lens that would give the effect and light levels of the HPS lights that are still in place along the test corridors? The blue/white lighting of the LED is too excessive; a softer yellow light would be best as we have had with the older HPS lighting. I am sure with advancements in LED technology something with an soft amber light should be available. Flagstaff is/is working on using a amber LED lighting type in their city last I read. Thank you.	5/20/2018 5:28 PM

13	Since we purchased a house in the dessert uplands and low lighting, the street lights installed are too bright. When we first moved in they were amber colored and were fine. Why change them when we live in a low light subdivision. If they no longer make amber LED lights then put amber shields on the lights. The current LED lights are way too bright even on the dimmest setting.	5/20/2018 4:43 PM
14	This week was dimmer, but there was still a glare. It would be beneficial to have a softer/amber color bulb or lens to soften the effect	5/20/2018 11:31 AM
15	I like this weeks lighting level .	5/20/2018 9:42 AM
16	At this level, the color difference between the new (blue) LED lights and the older lights is not as noticeable.	5/20/2018 9:17 AM
17	Lights are bright and do not match the existing yellow lights. I am not happy with the new lights.	5/20/2018 8:04 AM
18	If this is as low as the LED lighting can be adjusted they should be turned off. The exiting (yellowish) lights should be the highest emission & gage for the LED lights.	5/20/2018 6:18 AM
19	This dimmed level is plenty adequate. The light levels appears/feels comparable to the adjacent HPS lights on Ellsworth.	5/19/2018 10:05 PM
20	A lower level of light is needed on the roadways in the uplands area of Mesa.	5/19/2018 9:16 PM
21	The lower the lighting, the better! Driving & safety not compromised by less lighting. I wish we did not have to have the lights on this street at all...but, the lowest level of lighting would suffice. Thank you for allowing us to give our opinions. Much appreciated. ;)	5/19/2018 4:53 PM
22	You DID save the best for last!! Perfect balance between light intensity coming from the bulb and street illumination. The light on the street this week, although "spotty" and less diffused, it was not annoying to drive thru the spots of light like it was on Week A. One occupant of our vehicle said the lights look "modern" this week. What a difference a week makes. I hope you will share the survey results with us. Thank you for allowing the community the opportunity to provide feedback and be included in these kinds of decisions.	5/18/2018 10:13 PM
23	Better this week, but white lighting still creates more glare for me when driving, cycling or walking in the area at night. I would prefer amber LED lighting.	5/18/2018 8:21 PM
24	We need to protect the Desert Uplands Dark Sky communities - especially our wildlife, owls, & natural habitat from these Brite-White Blue LED Street Lights	5/18/2018 1:44 PM
25	Thanks for conducting the survey.	5/17/2018 3:34 PM
26	The new LED lights are bright white and seem much brighter than the older lights with an amber cast. It appears much lower levels of lighting should be used in order to match the level of lighting provided by the older lights. Also, on Ellsworth, there are two lights on each pole in the center of the median so lower levels of light should be possible even when walking. Thank you.	5/16/2018 1:50 PM
27	My house backs up to Ellsworth. Lights are very bright. Negatively affects my ability to sleep. Remits considerably glare into my living room--can no longer sit at my sofa without distraction. Is an eyesore on my view of the landscape. These lights negatively affect my quality of life and property value.	5/15/2018 9:20 AM
28	Week D appears to have the lowest level of lighting that while being safe and adequate for driving/walking still maintained a low-light similar to our sub division and that of Mountain Bridge collective developments. This level D of lighting also allowed us to see the beauty of the sky and stars - the other levels of lighting were too bright to even notice the sky. Hope this level is chosen. Liz and Dan Evans	5/15/2018 6:45 AM

Appendix B – Light Shield

STREET SIDE (FRONT) SHIELD FOR LED MEDIAN STREET LIGHTING





GENERAL NOTES

1. INSTALLING A SHIELD ON THE FRONT EXTERIOR OF THE FIXTURE THAT EXTENDS 3" BELOW THE LED PROJECTION PLANE WILL ONLY BLOCK A SMALL PORTION OF LIGHT COMING FROM THE FRONT ROW OF LEDs AT THE CURB LINE. (LINE 1)

2. ALL LIGHT/GLARE IS BLOCKED AT 135' FROM FRONT OF POLE. (LINE 2)

WRIGHT ENGINEERING PROJECT NO:

18034

DESIGN BY: SLG

DRAWN BY: SLG

CHECKED BY:

WRIGHT engineering corporation
ELECTRICAL ENGINEERING AND DESIGN
165 EAST CHILTON DRIVE • CHANDLER, ARIZONA 85225
PHONE 480.497.5829 • FAX 480.497.5807
www.wrightengineering.us

PROJECT:

MESA LED MASTER PLAN

PRELIMINARY NOT FOR CONSTRUCTION

DRAWING NO:

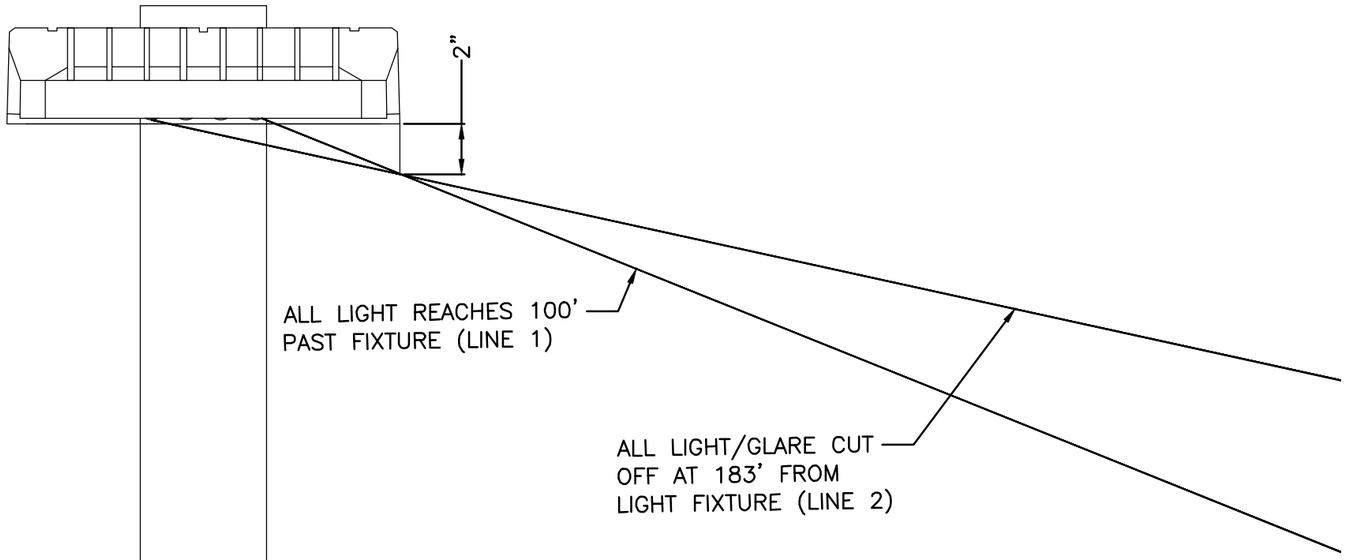
E1

OF

2

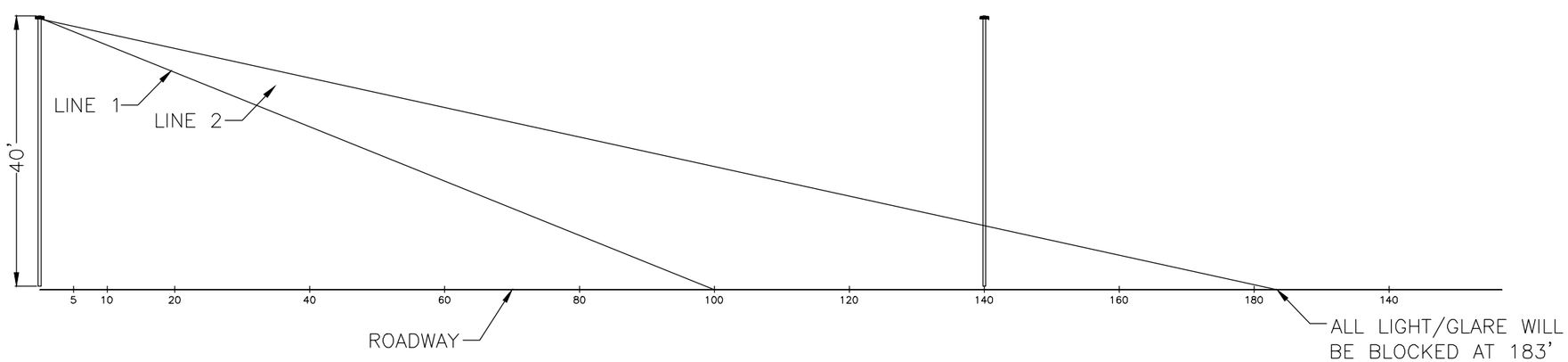
H:\2018\18034-City of Mesa SL Master Plan\Engineering\Galleon Shield.dwg

SIDE SHIELD FOR
LED MEDIAN STREET LIGHTING



GENERAL NOTES

1. INSTALLING A SHIELD ON THE SIDE EXTERIOR OF THE FIXTURE THAT EXTENDS 2" BELOW THE LED PROJECTION PLANE WILL PERMIT ALL LIGHT TO REACH 100' FROM POLE.
2. ALL LIGHT/GLARE WILL BE BLOCKED AT 183'



WRIGHT engineering corporation
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www.wrightengineering.us

WRIGHT ENGINEERING PROJECT NO:
18034

DESIGN BY: SLG
DRAWN BY: SLG
CHECKED BY:

PROJECT:
MESA LED MASTER PLAN

PRELIMINARY
NOT FOR
CONSTRUCTION

DRAWING NO:
E2
OF
2

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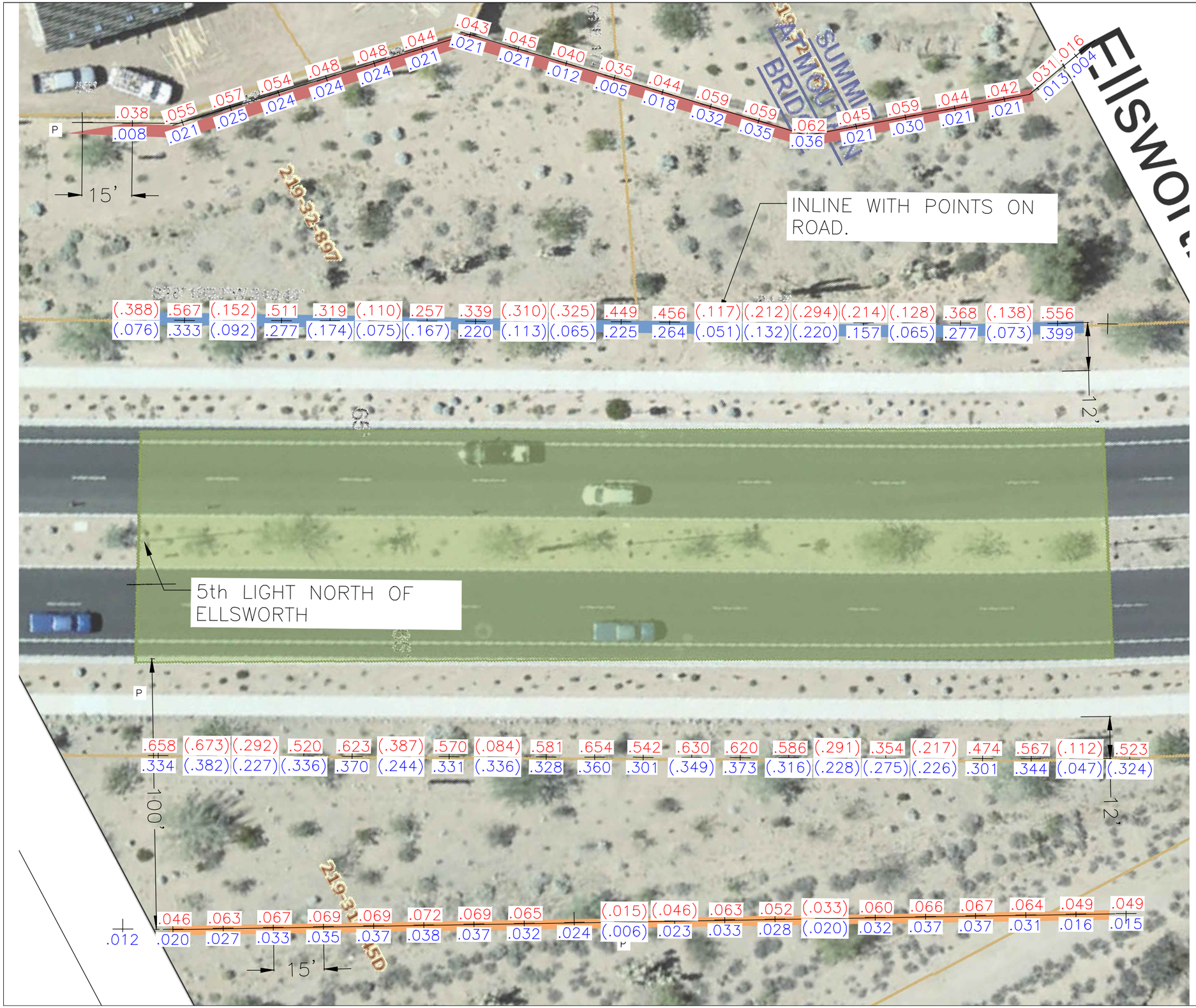


LEGEND

TEXT — BEFORE – HORIZONAL LIGHT LEVEL (FOOTCANDLES) APPROXIMATELY 5 FEET ABOVE GRADE

TEXT — AFTER – HORIZONAL LIGHT LEVEL (FOOTCANDLES) APPROXIMATELY 5 FEET ABOVE GRADE

(TEXT) — TEXT INSIDE PARENTHESES DENOTES MEASUREMENT BEHIND AN OBSTRUCTION

Appendix C – Lighting Zone Map

mesa·az

N

1 0.5 0 1
Miles

THOMAS RD
3600 N

MCDOWELL RD
2800 N

MCKELLIPS RD
2000 N

BROWN RD
1200 N

UNIVERSITY DR
400 N

MAIN ST
0

BROADWAY RD
400 S

SOUTHERN AVE
1200 S

BASELINE RD
2000 S

GUADALUPE RD
2800 S

ELLIOT RD
3600 S

WARNER RD
4400 S

RAY RD
5200 S

WILLIAMS FIELD RD
6000 S

PECOS RD
6800 S

GERMANN RD
7600 S

PRICE RD
2800 W

DOBSON RD
2000 W

ALMA SCHOOL RD
1200 W

COUNTRY CLUB DR
400 W

MESA DR
400 E

STAPLEY DR
1200 E

GILBERT RD
2000 E

LINDSAY RD
2800 E

VAL VISTA DR
3600 E

GREENFIELD RD
4400 E

HIGLEY RD
5200 E

RECKER RD
6000 E

POWER RD
6800 E

SOSSAMAN RD
7600 E

HAWES RD
8400 E

ELLSWORTH RD
9200 E

CRISMON RD
10000 E

SIGNAL BUTTE RD
10800 E

MERIDIAN RD
11600 E

101 202 60 202

Legend

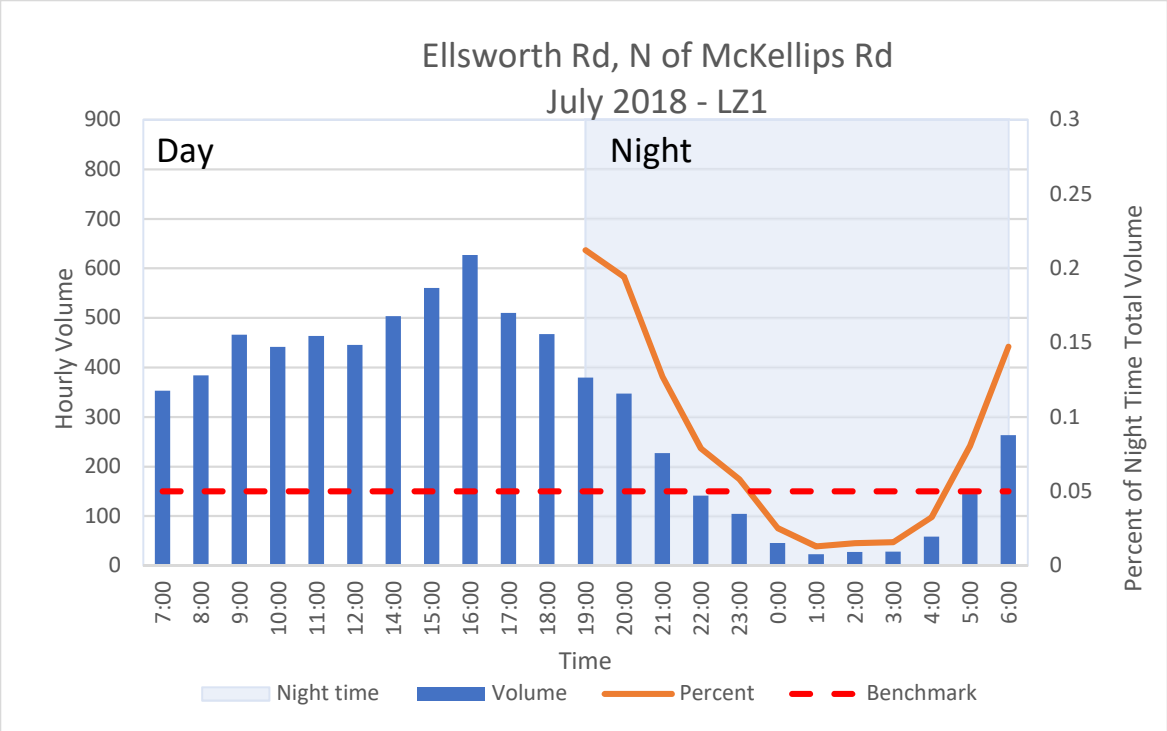
- Lighting Zone 1
- Lighting Zone 2
- Lighting Zone 3
- Lighting Zone 4

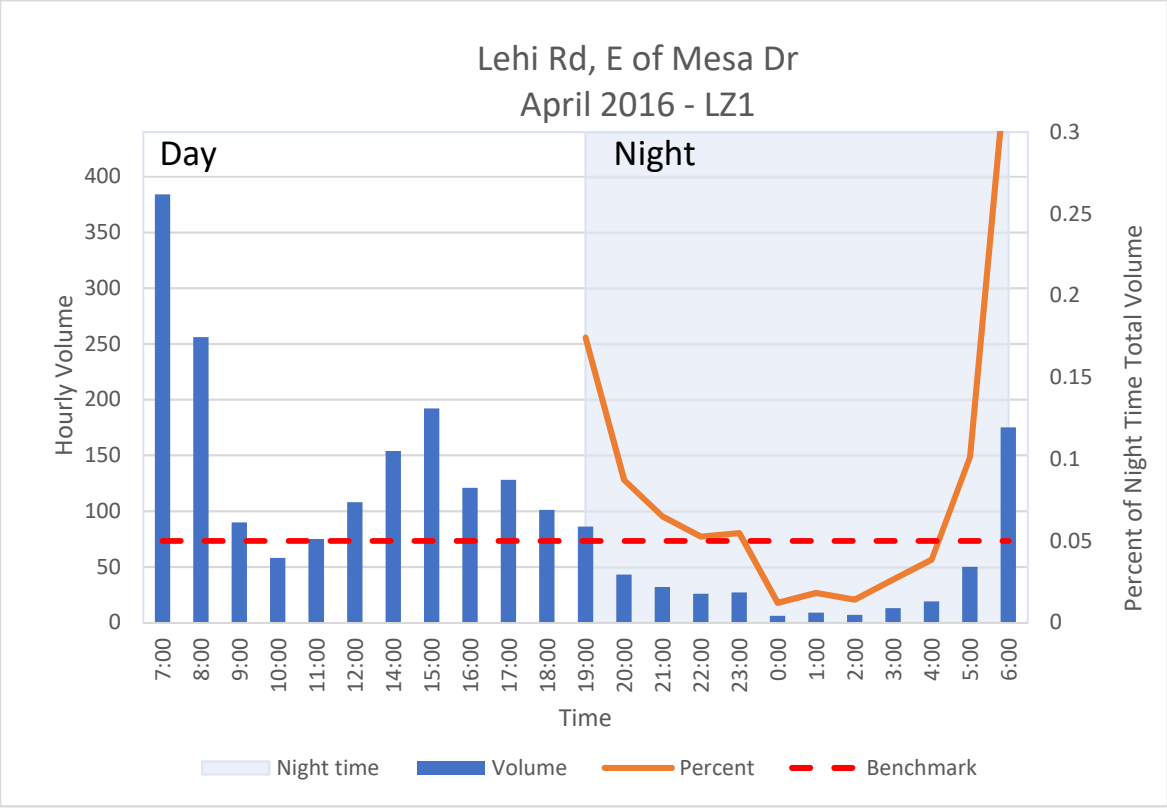
Transportation Department

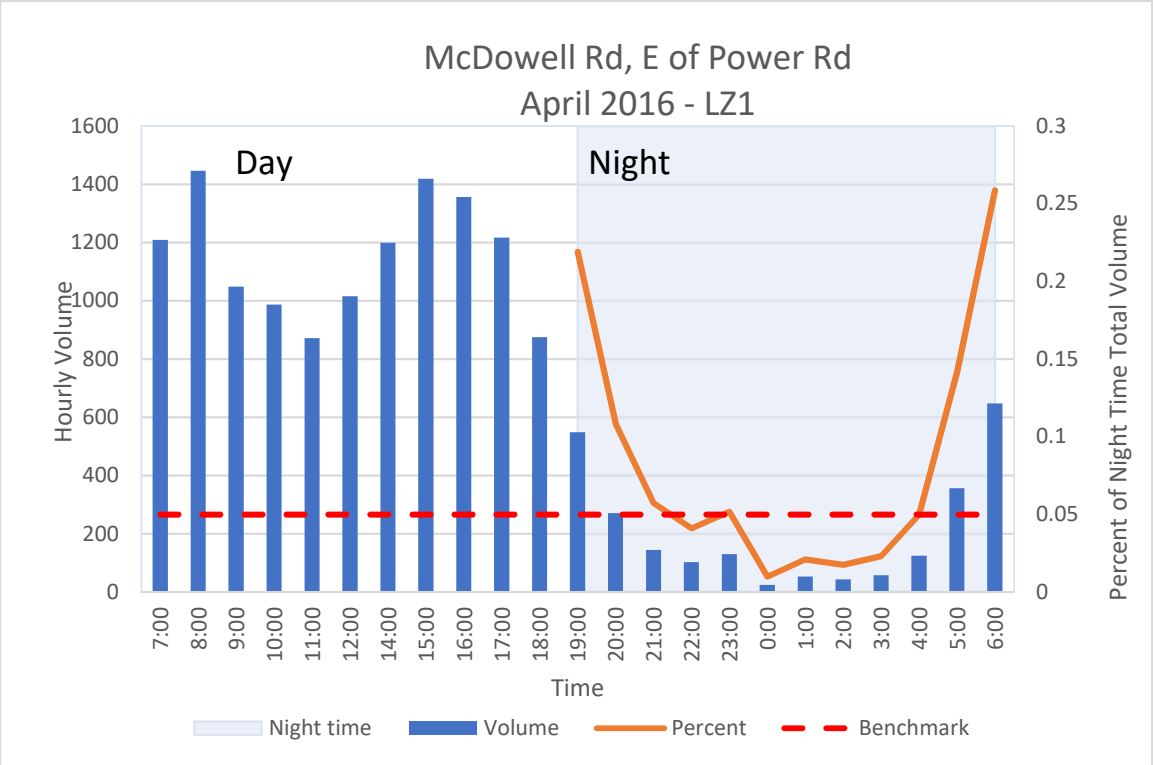
Lighting Zones

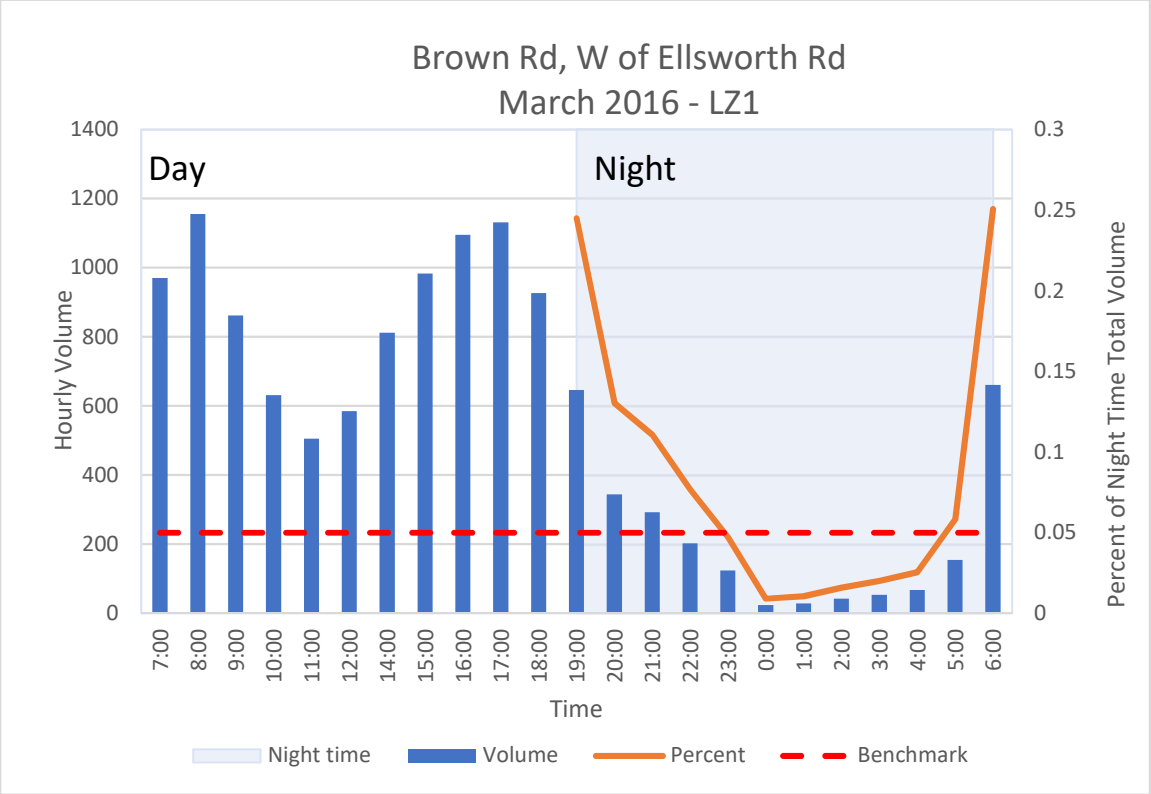
Drawn By: DW	Revised: 6/12/19
Drawn For: Wright Engineering	Filename: LZ.mxd

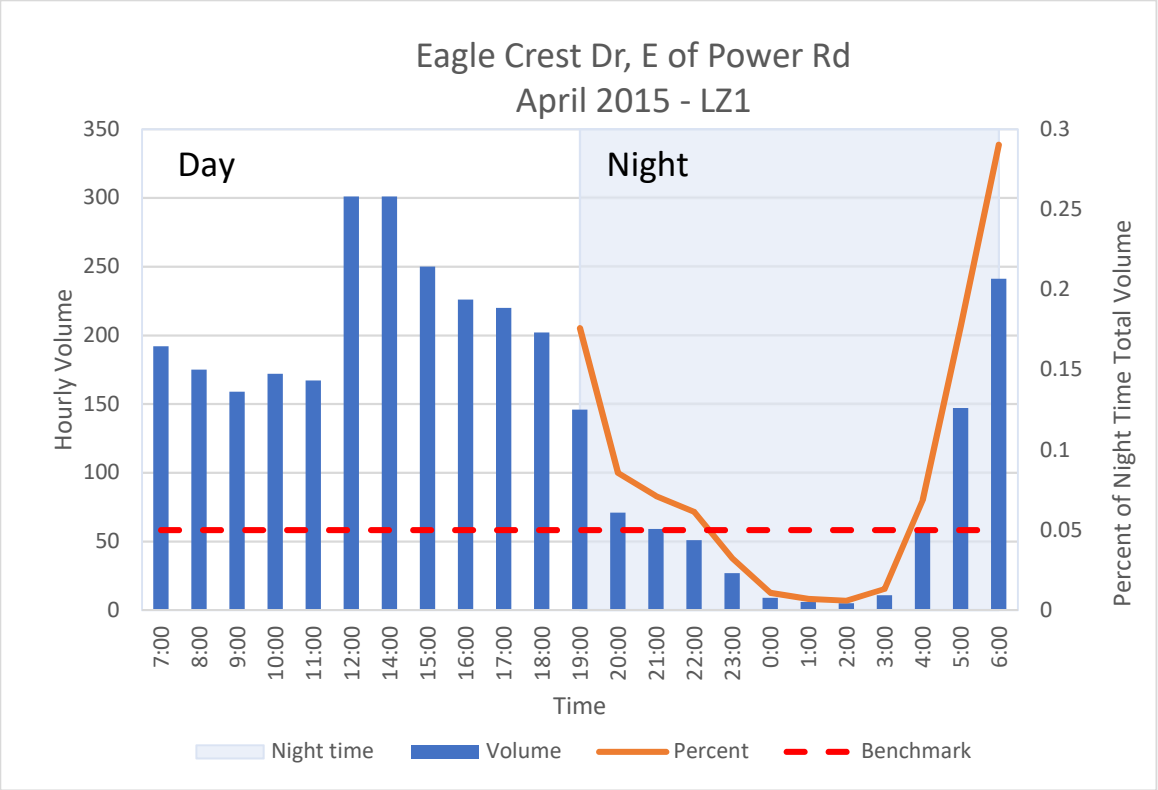
Appendix D – Traffic Volumes

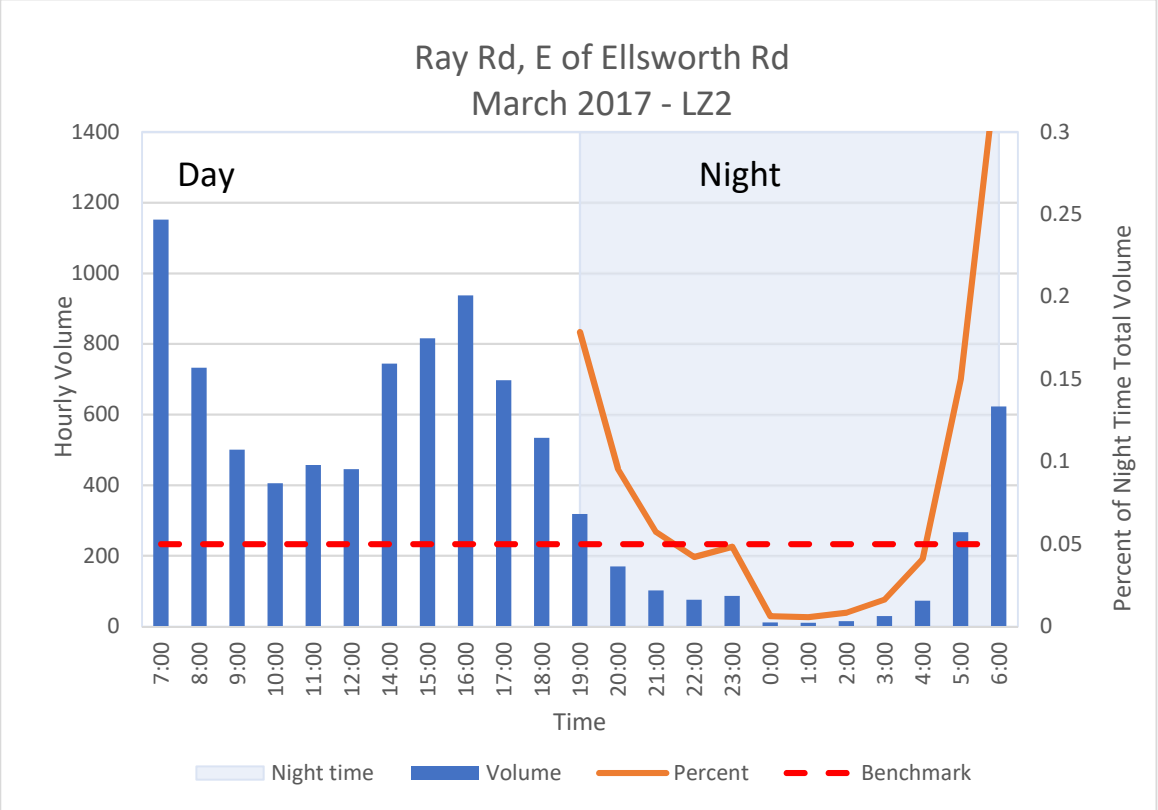


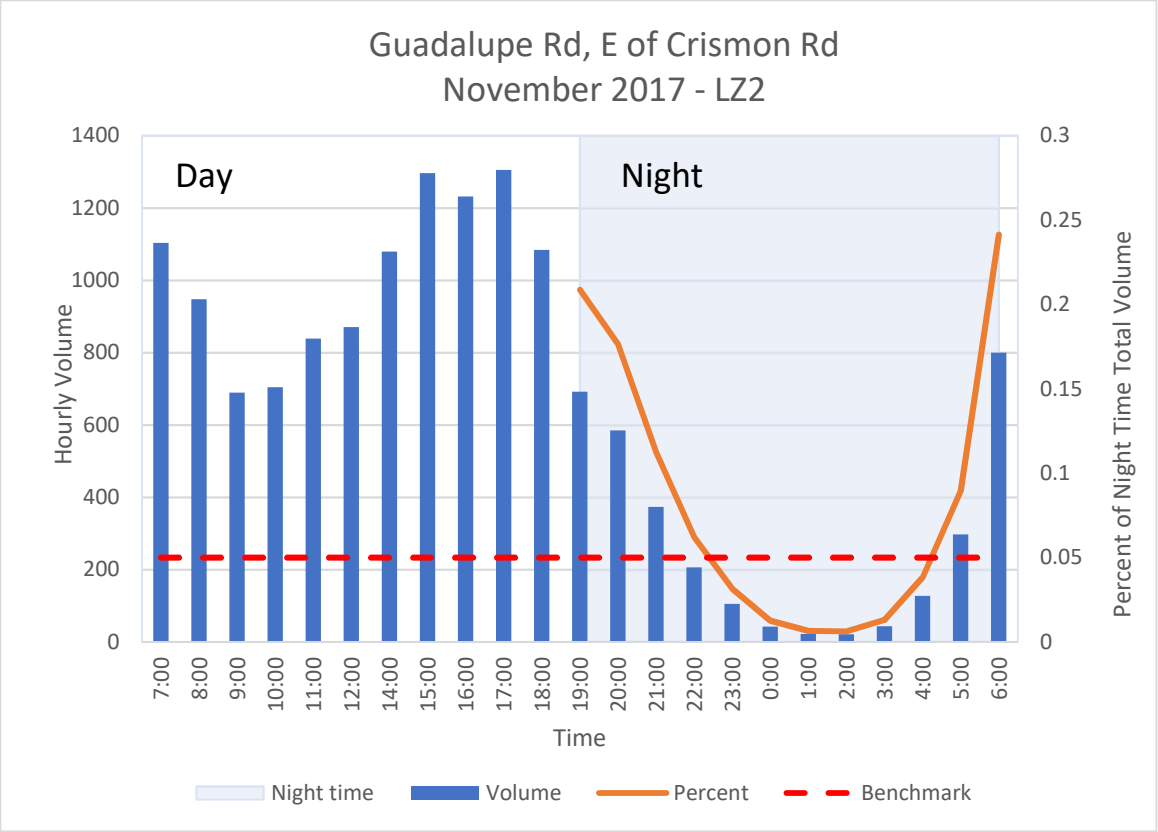


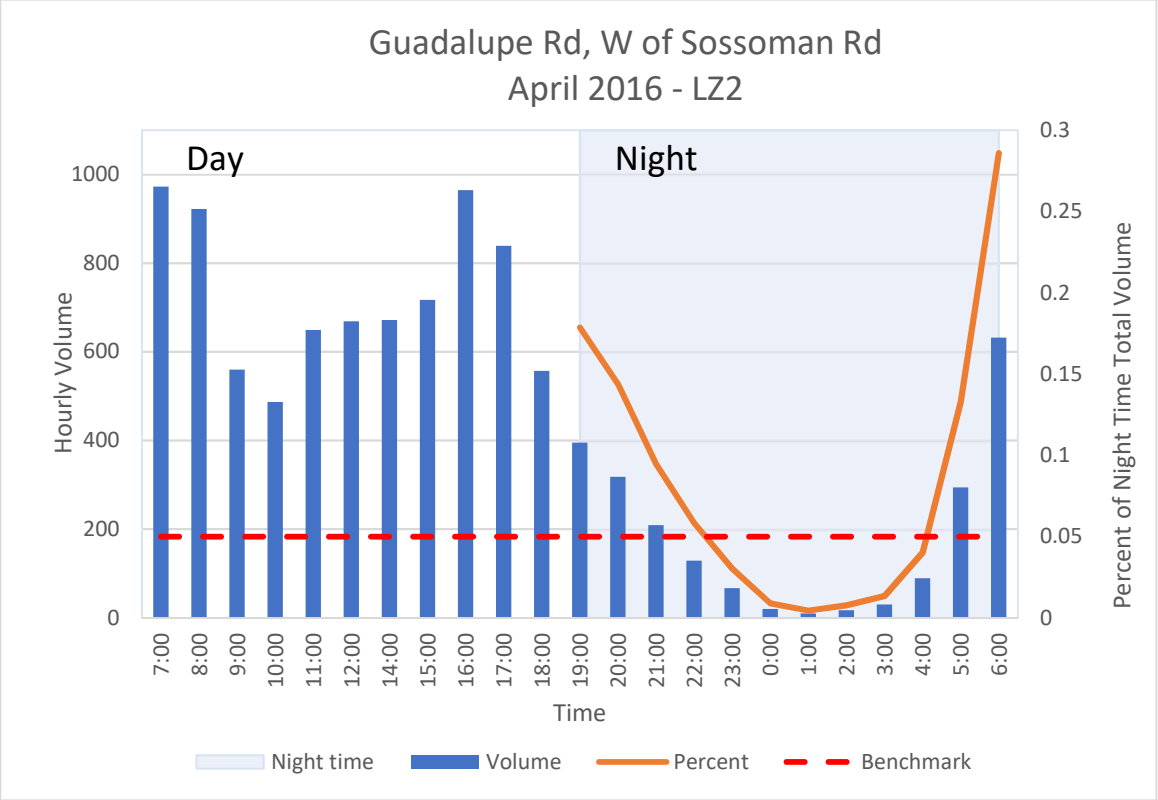

McDowell Rd, E of Power Rd
April 2016 - LZ1
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

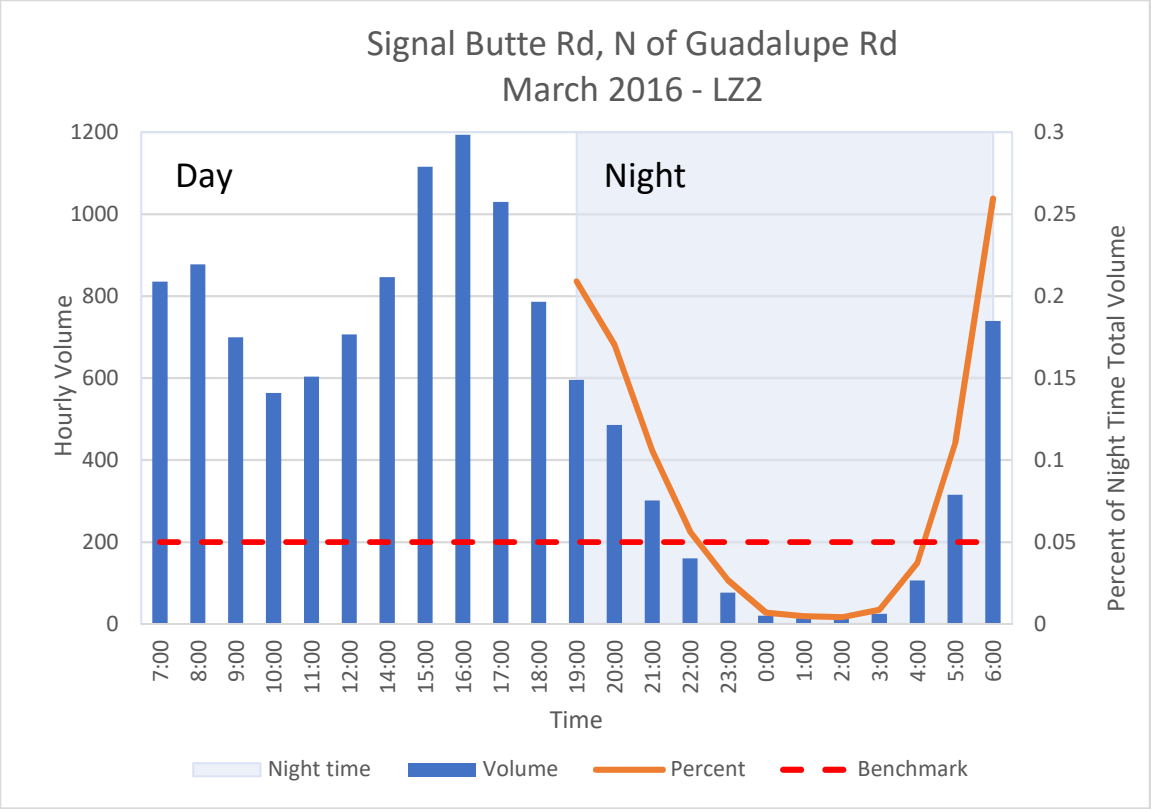

Brown Rd, W of Ellsworth Rd
March 2016 - LZ1
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

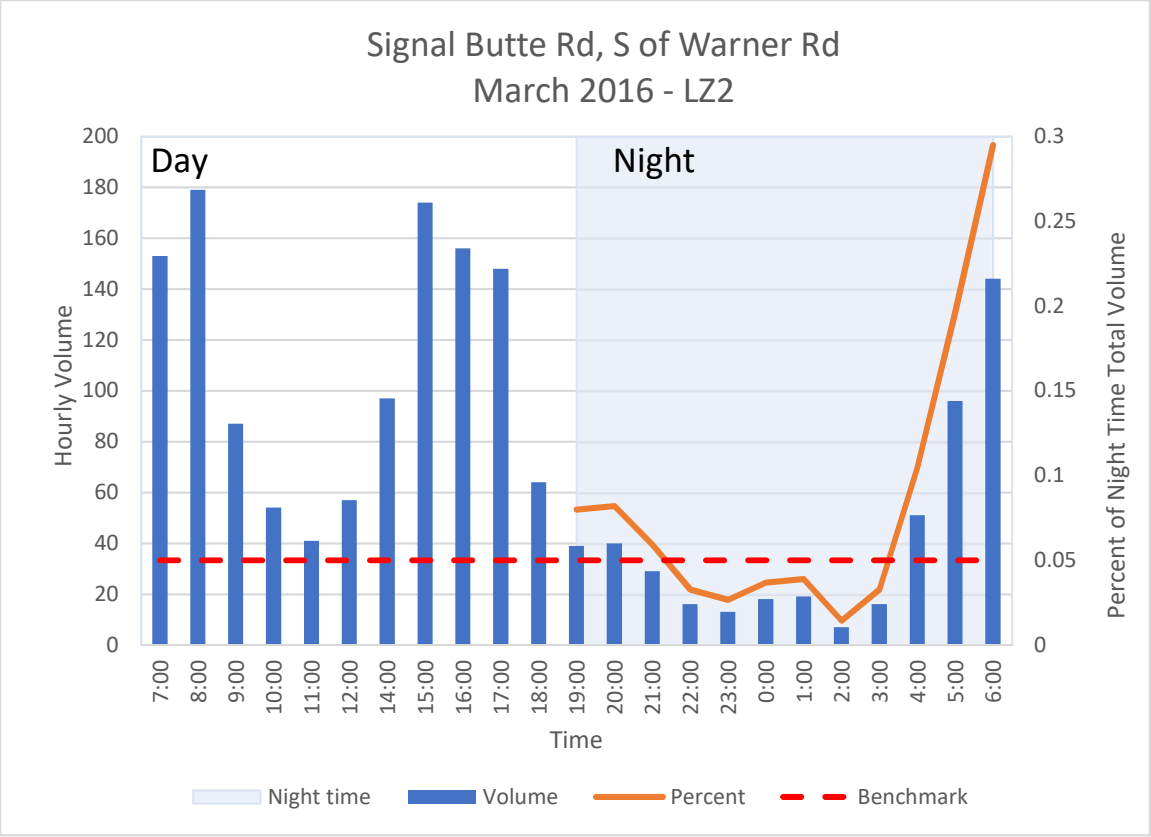

Eagle Crest Dr, E of Power Rd
April 2015 - LZ1
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

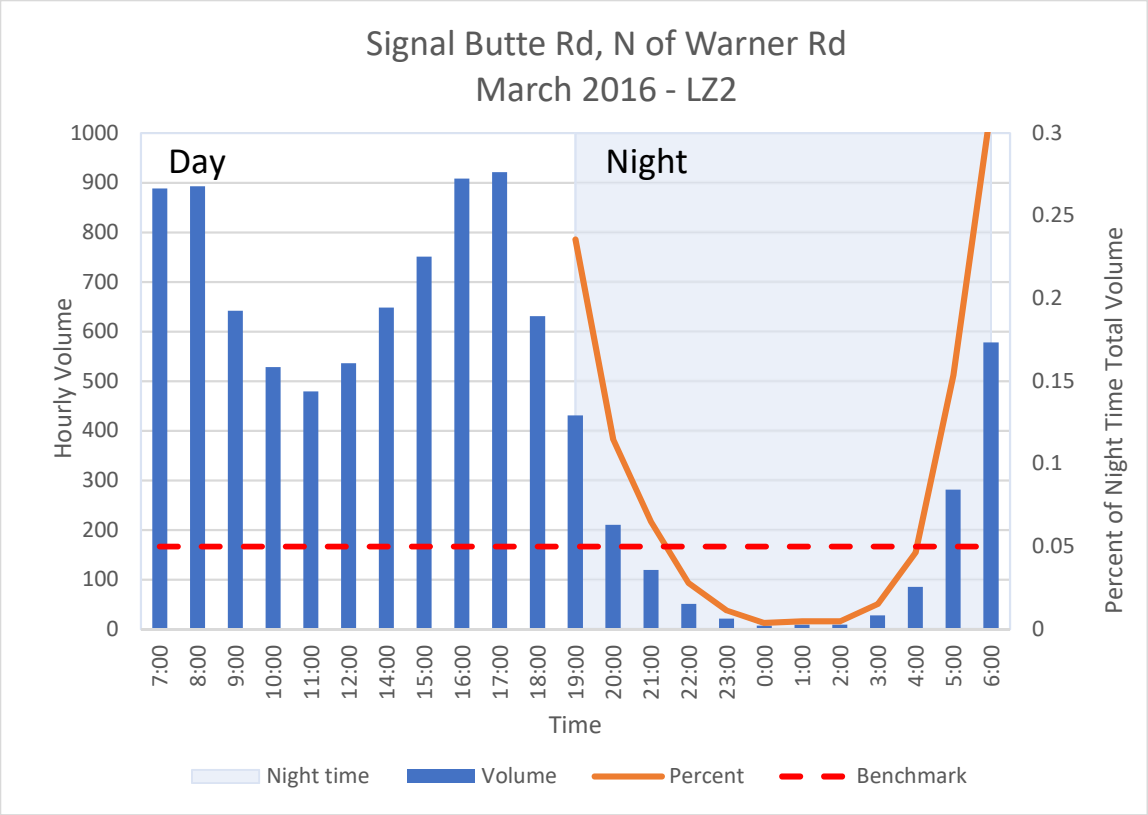

Ray Rd, E of Ellsworth Rd
March 2017 - LZ2
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

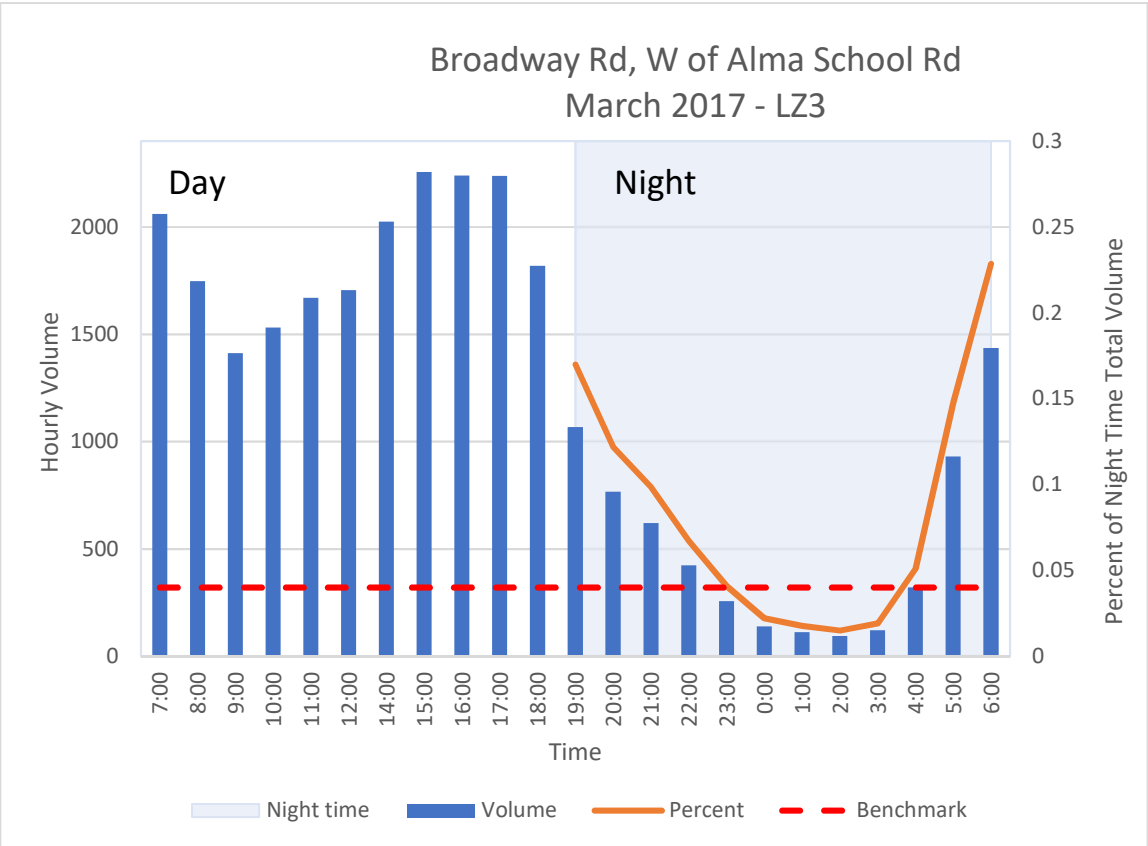

Guadalupe Rd, E of Crismon Rd
November 2017 - LZ2
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

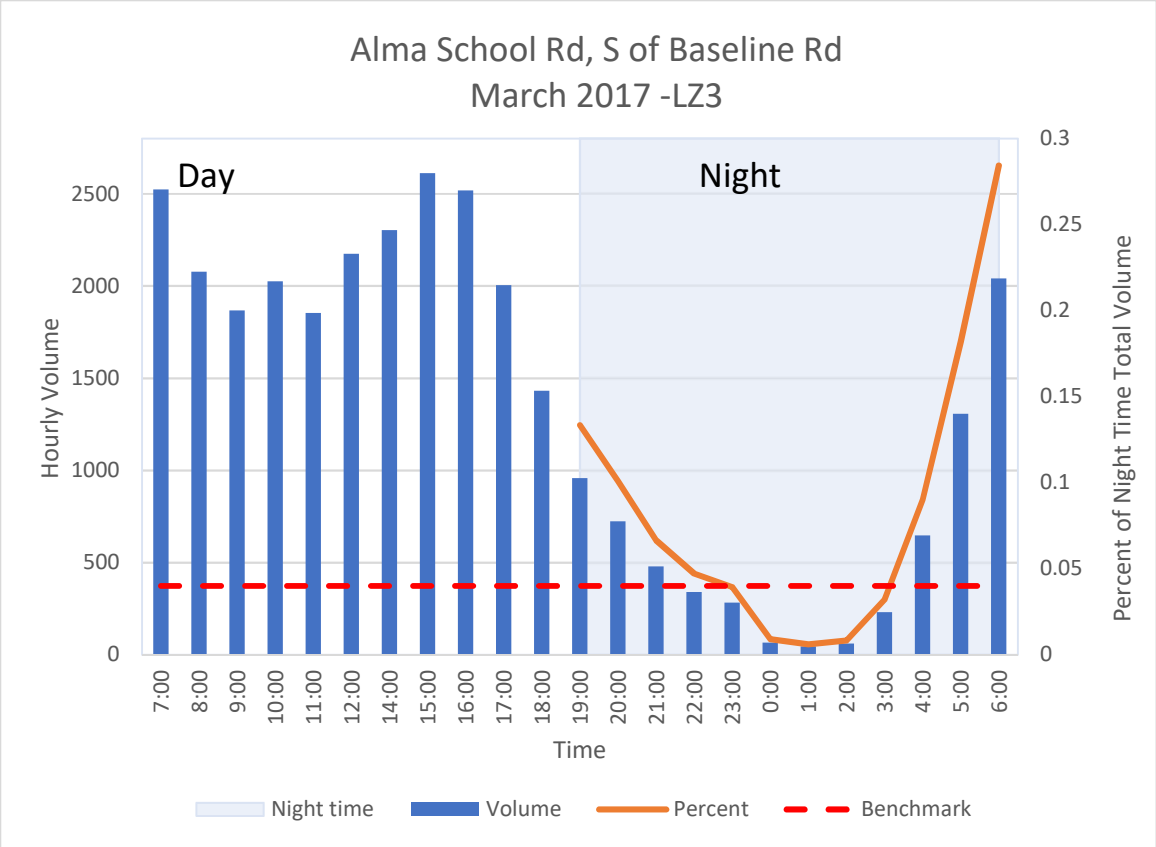

Guadalupe Rd, W of Sossoman Rd
April 2016 - LZ2
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

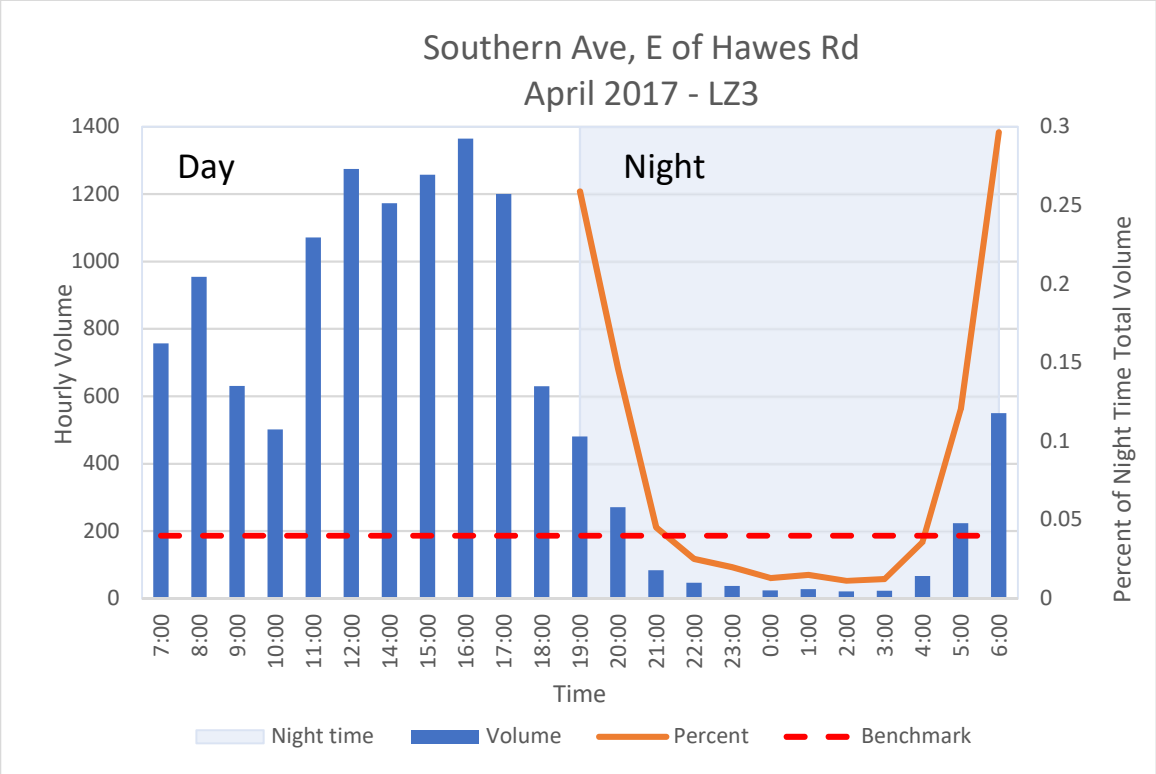

Signal Butte Rd, N of Guadalupe Rd
March 2016 - LZ2
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Signal Butte Rd, S of Warner Rd
March 2016 - LZ2
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Signal Butte Rd, N of Warner Rd
March 2016 - LZ2
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Broadway Rd, W of Alma School Rd
March 2017 - LZ3
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Alma School Rd, S of Baseline Rd
March 2017 -LZ3
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Southern Ave, E of Hawes Rd
April 2017 - LZ3
Day
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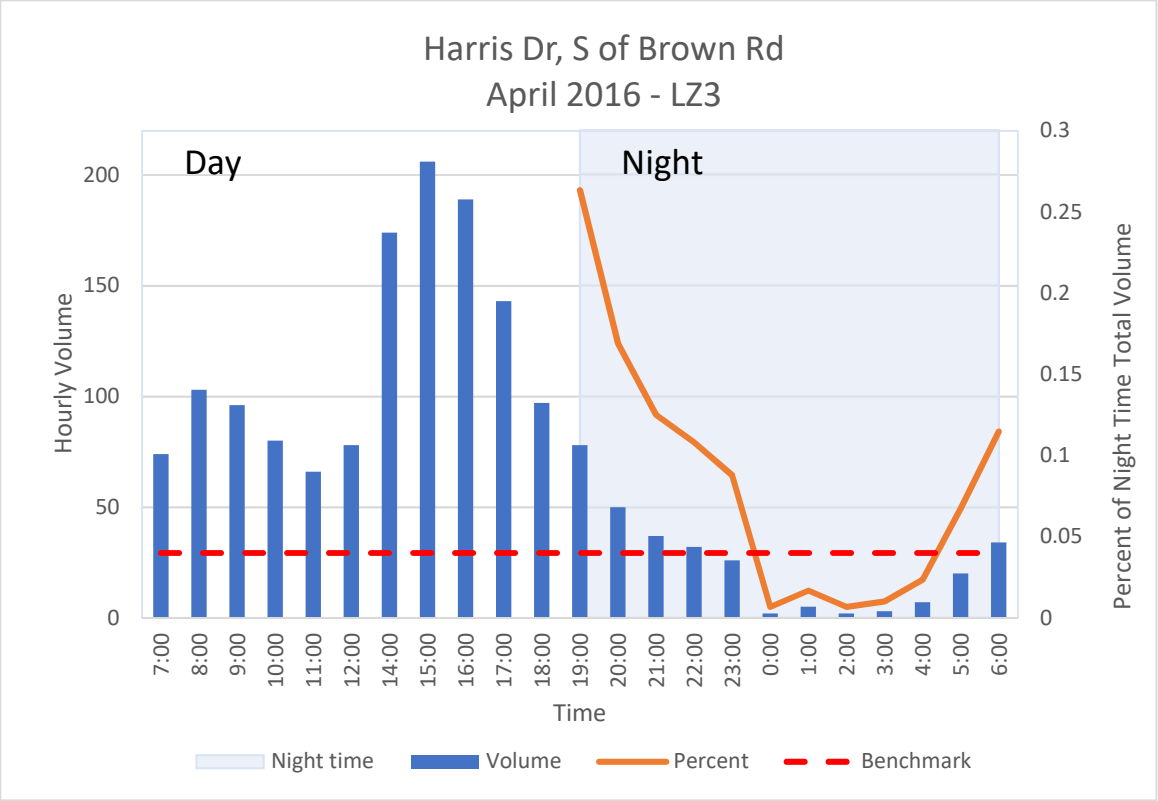
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Harris Dr, S of Brown Rd
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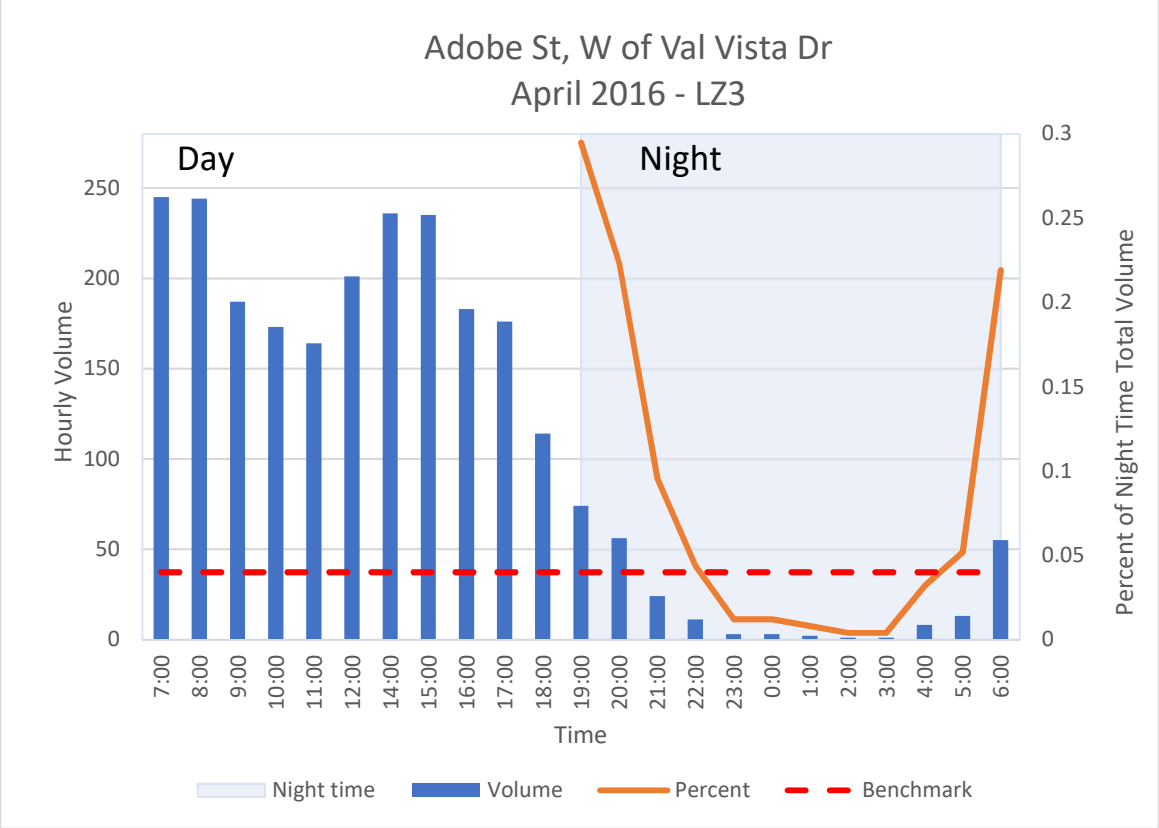
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark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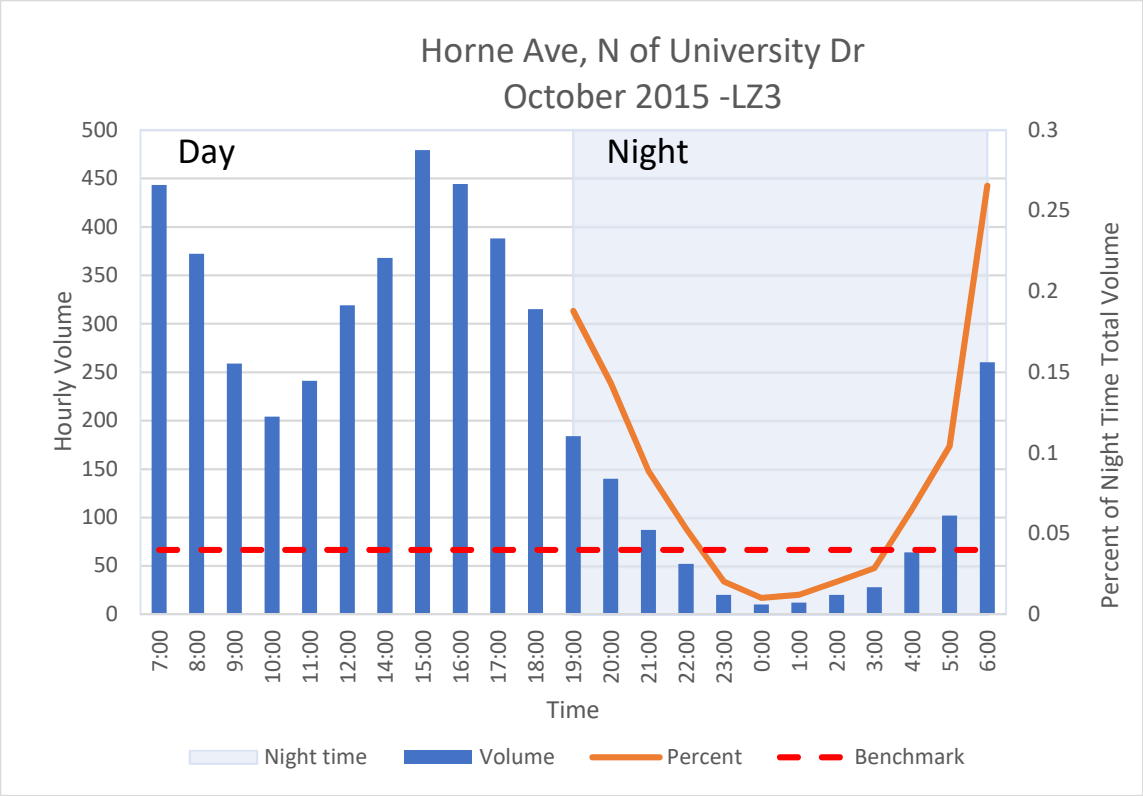
April 2016 - LZ3
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark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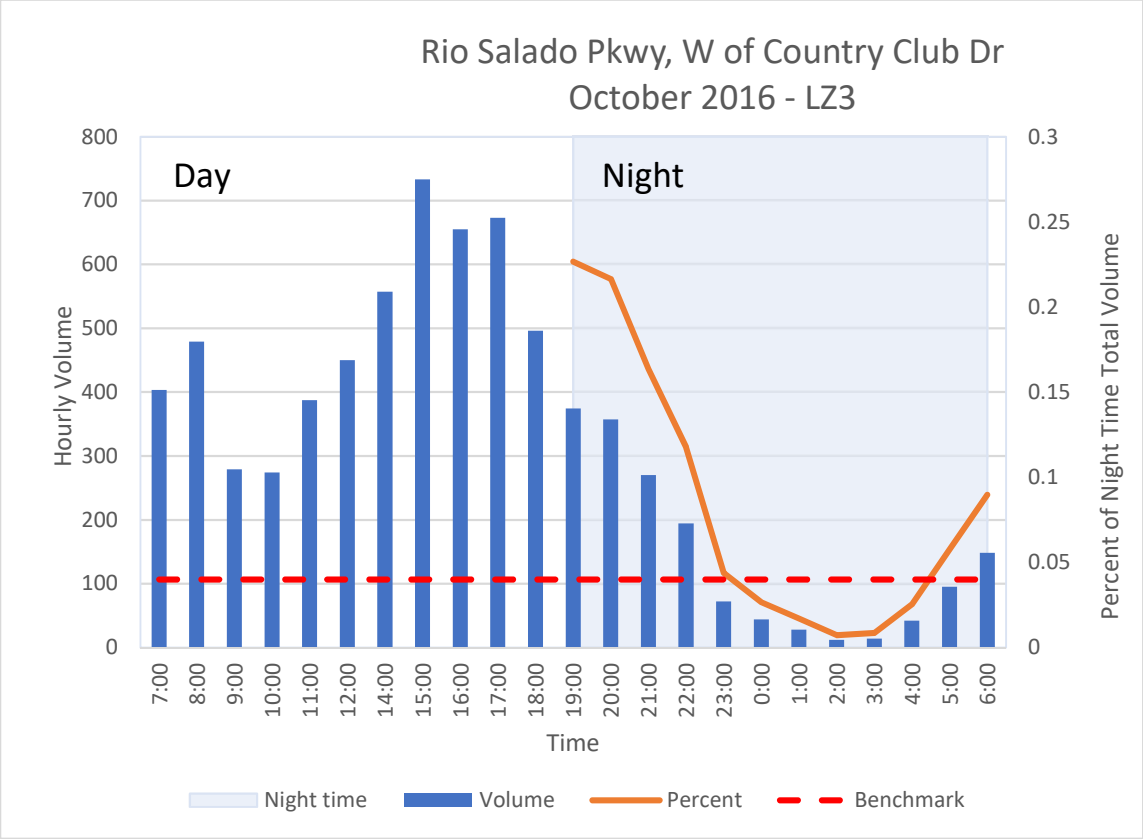
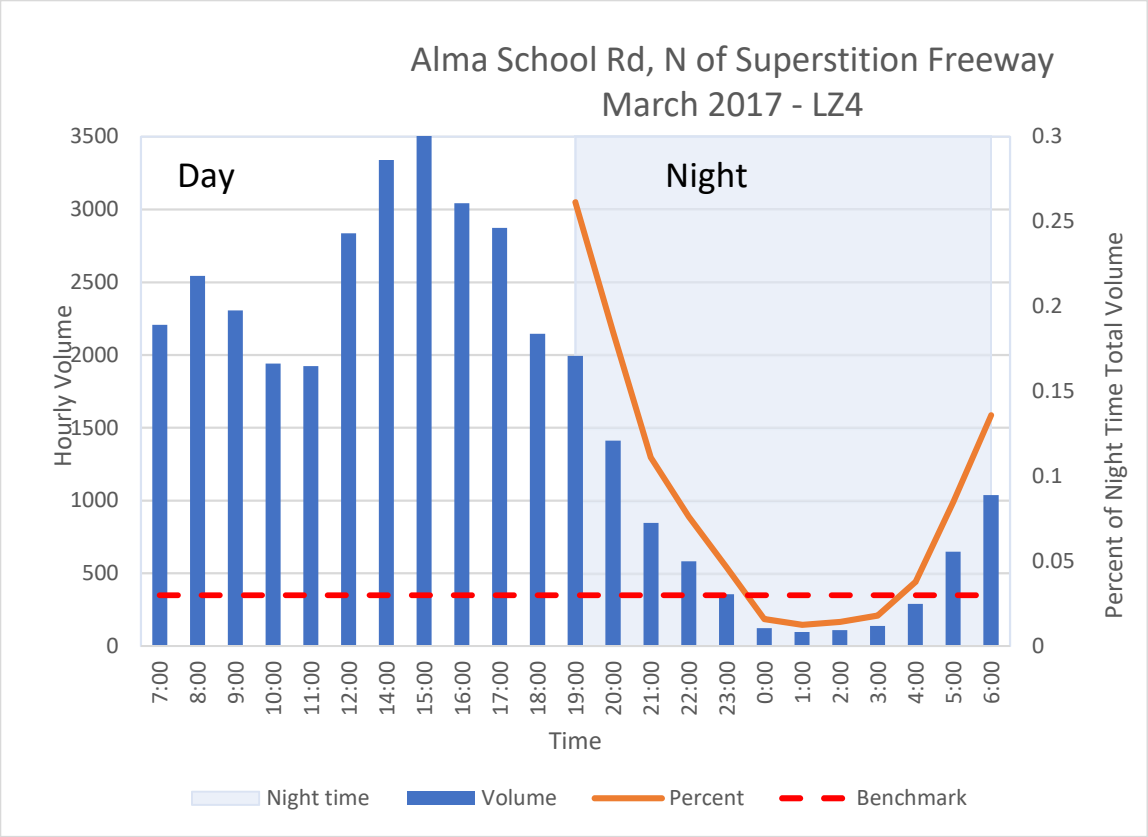
October 2015 -LZ3
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Rio Salado Pkwy, W of Country Club Dr
October 2016 - LZ3
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark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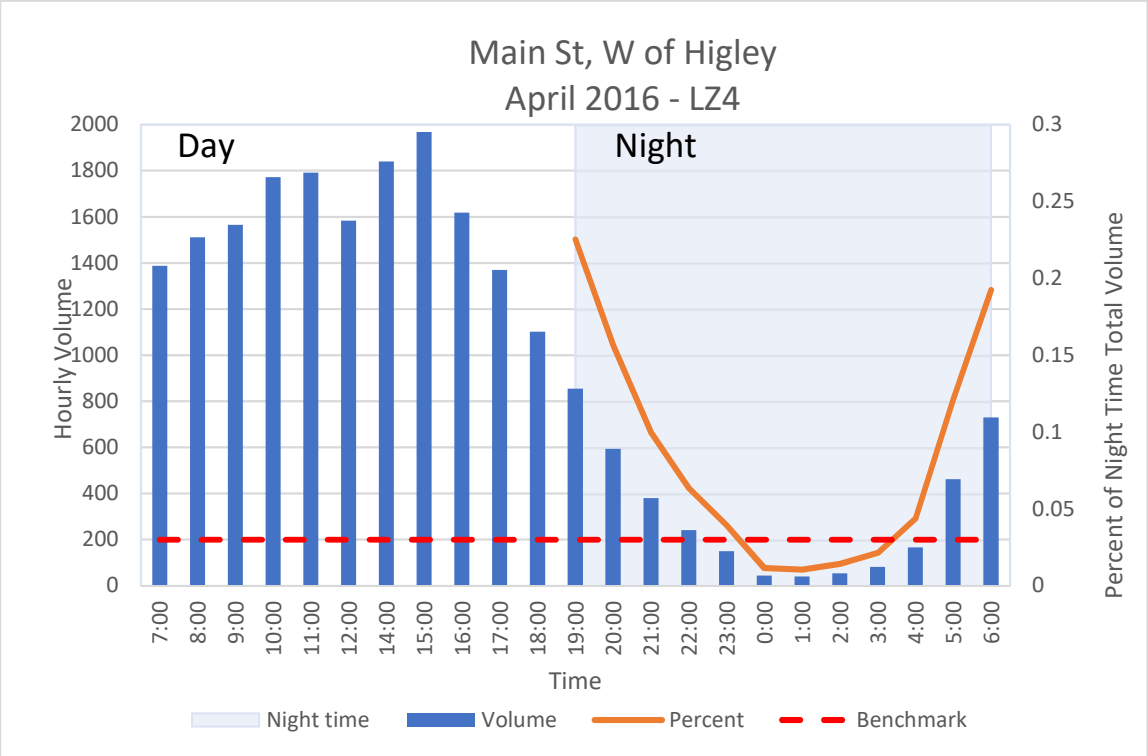
March 2017 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark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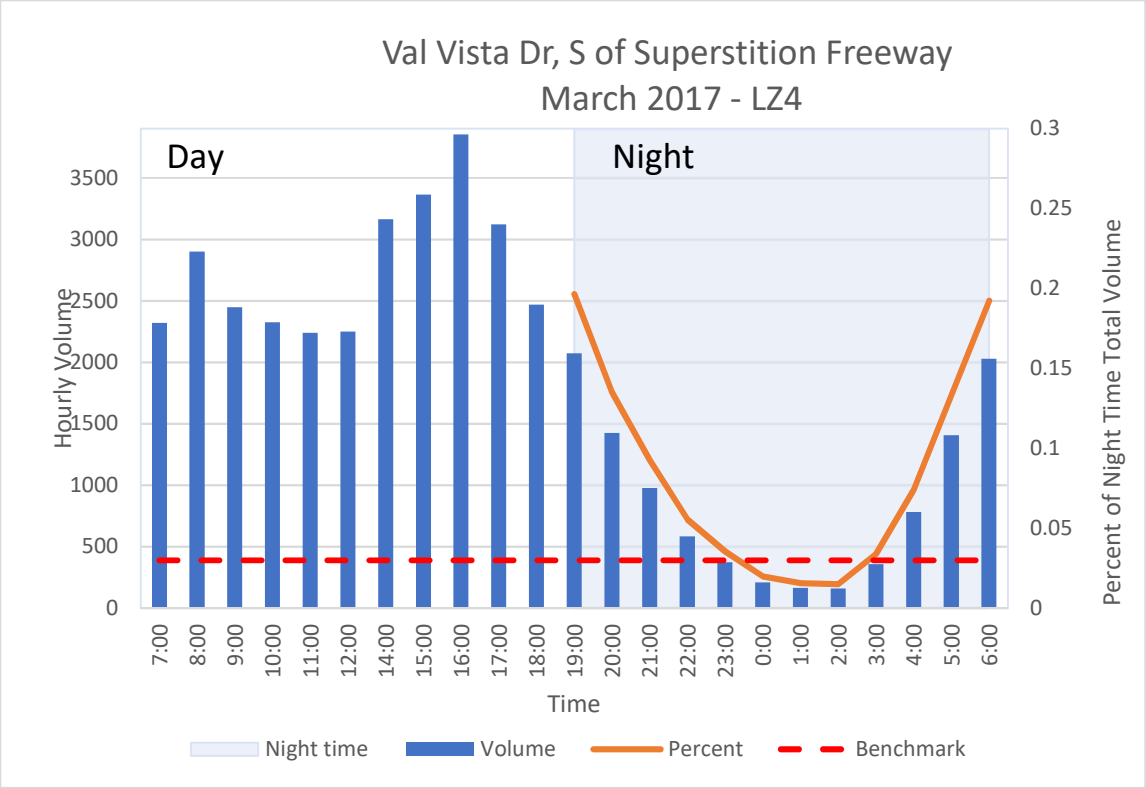
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark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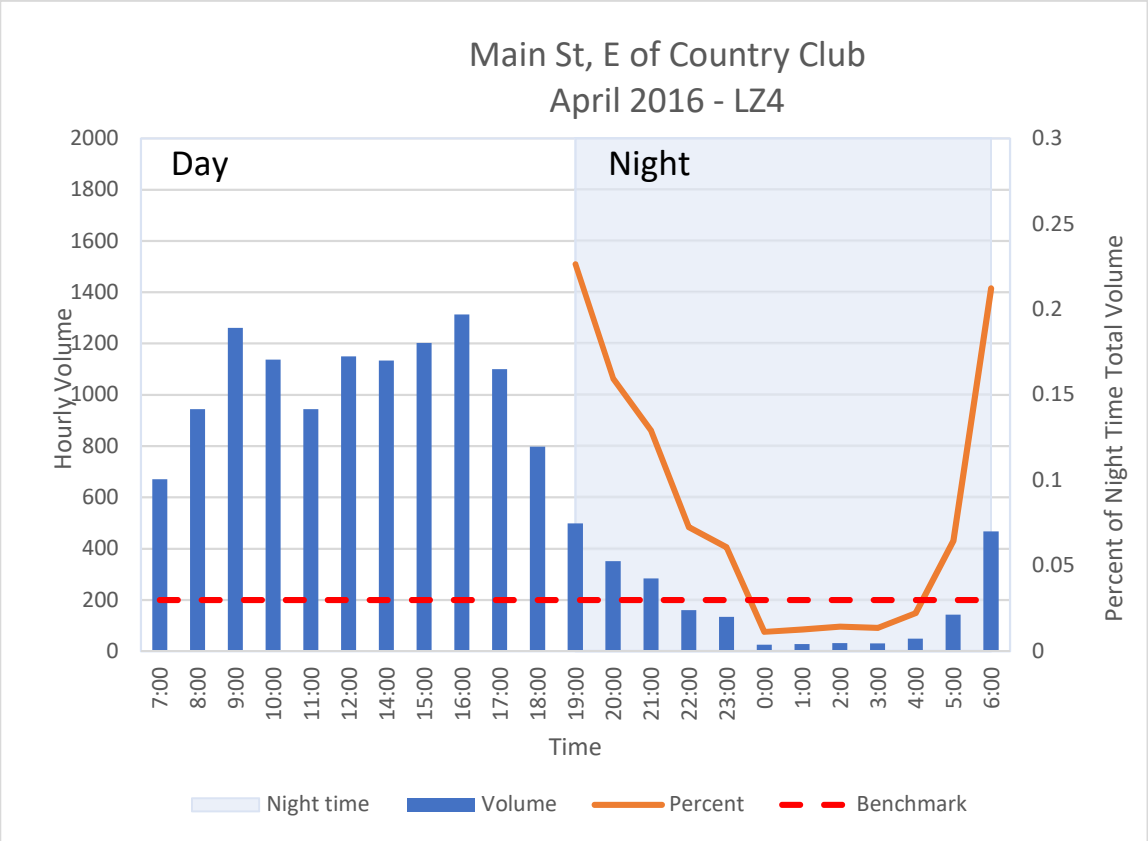
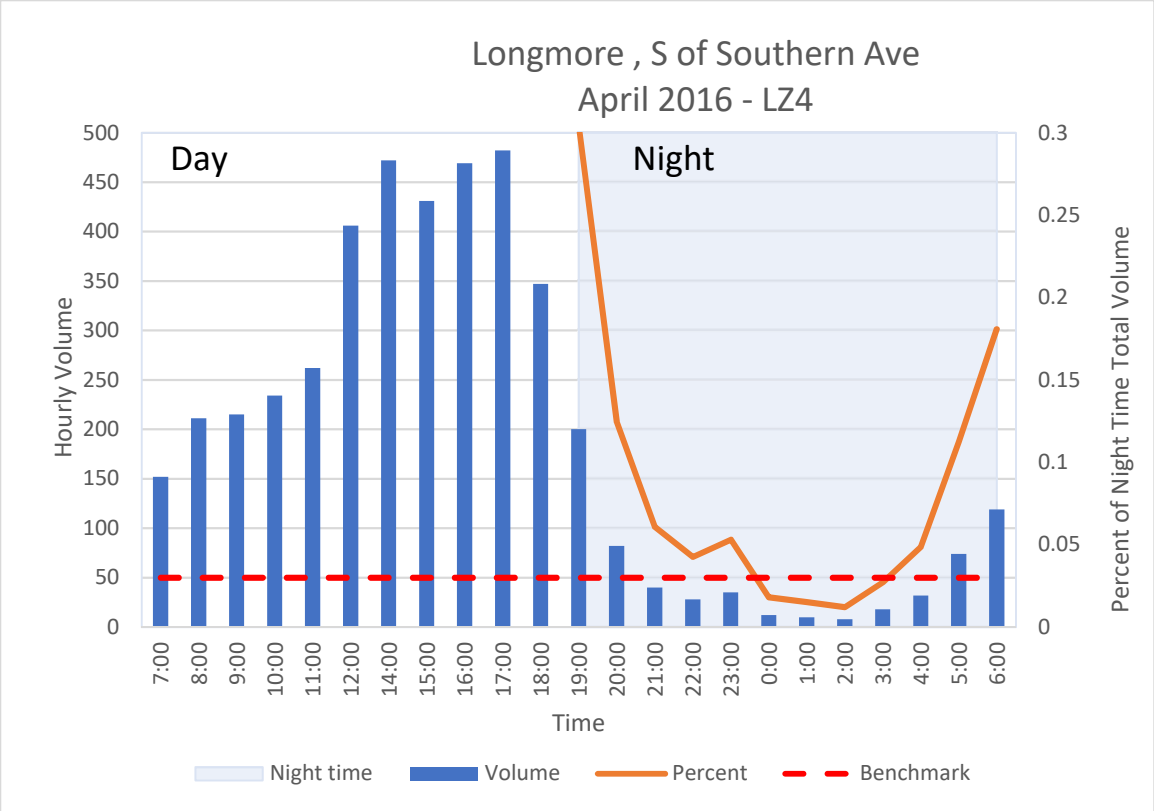
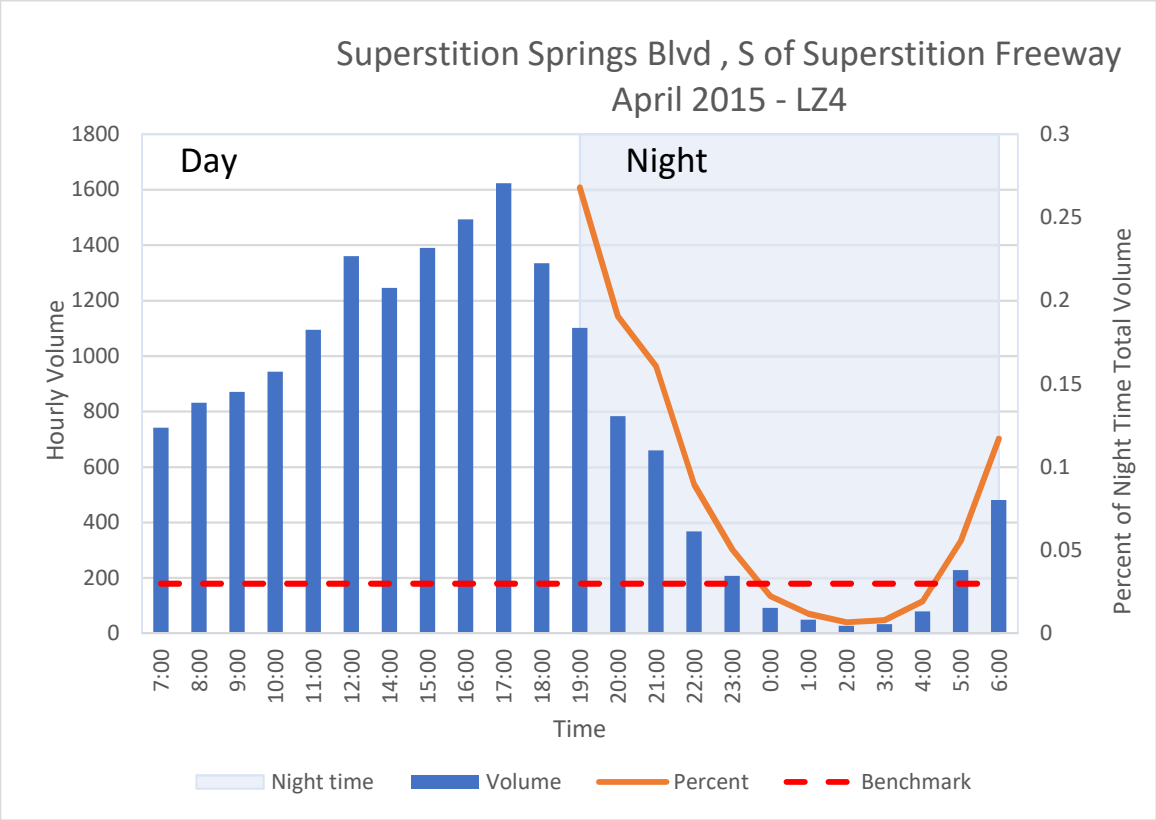
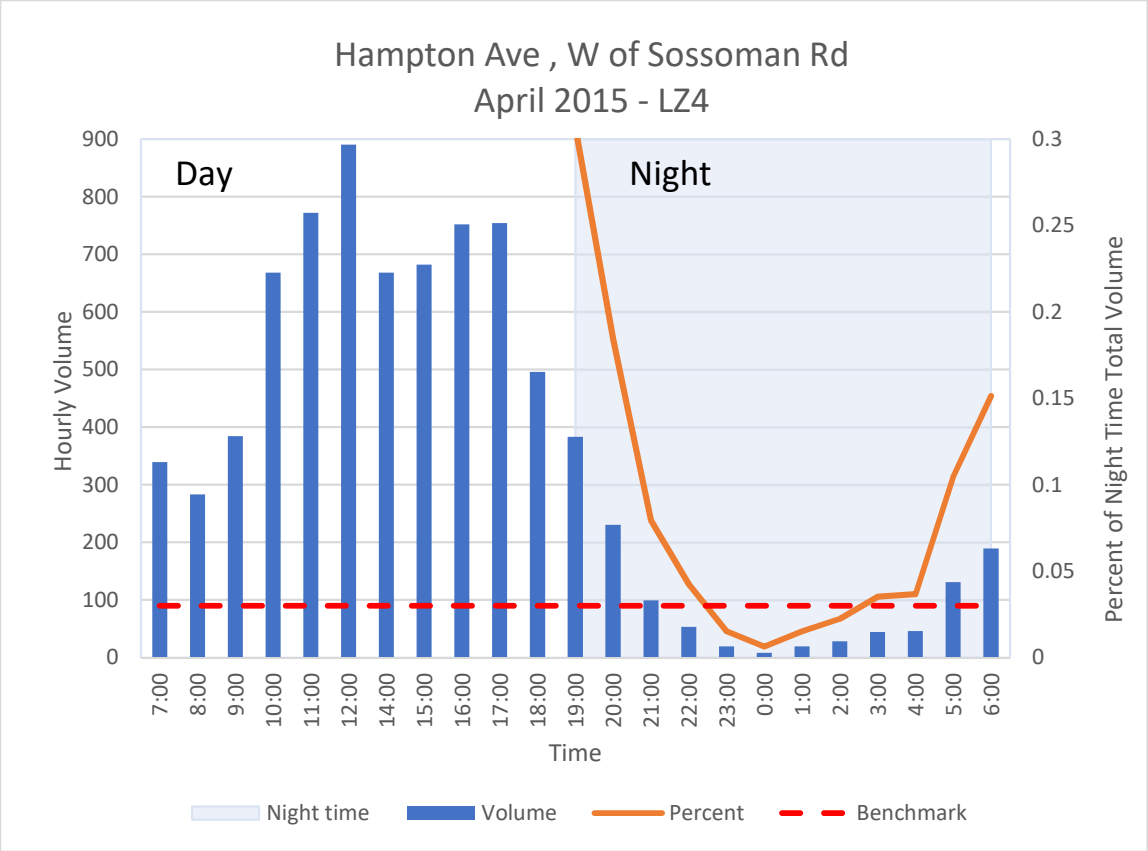
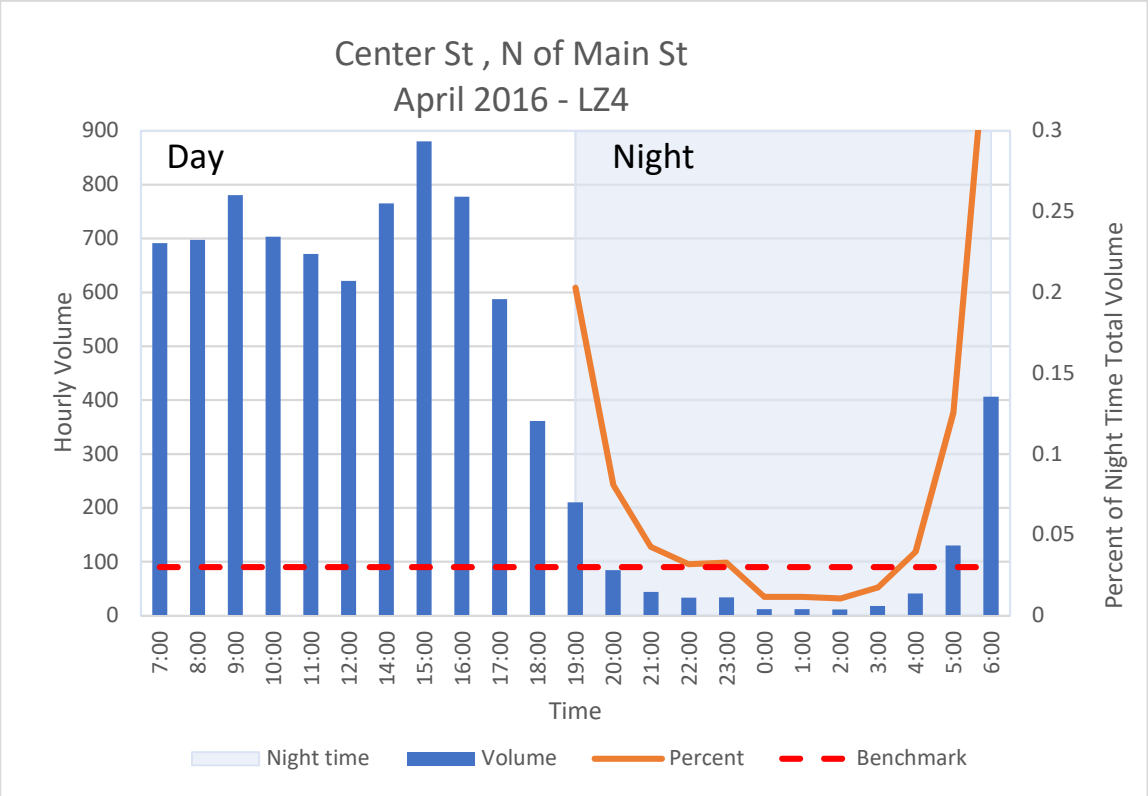
March 2017 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Main St, E of Country Club
April 2016 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Longmore , S of Southern Ave
April 2016 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Superstition Springs Blvd , S of Superstition Freeway
April 2015 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Hampton Ave , W of Sossoman Rd
April 2015 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark


Center St , N of Main St
April 2016 - LZ4
Day
Night
Hourly Volume
Percent of Night Time Total Volume
Time
Night time
Volume
Percent
Benchmark

Appendix E – GE Report

Hamilton

CITY OF HAMILTON
PUBLIC WORKS
Engineering Services

TO:	Chair and Members Public Works Committee
COMMITTEE DATE:	July 7, 2016
SUBJECT/REPORT NO:	Standardization of Street Light LED Luminaires (PW16058) (City Wide)
WARD(S) AFFECTED:	City Wide
PREPARED BY:	Gord McGuire (905) 546-2424, Extension 2439 Mike Field (905) 546-2424, Extension 4576
SUBMITTED BY: **SIGNATURE:**	Gary Moore, P. Eng. Director, Engineering Services Public Works Department

RECOMMENDATION

(a) That the General Electric (GE) Evolve LED Roadway luminaire be approved as single source standard equipment for cobra-head style street lights used for street lighting within the City of Hamilton;

(b) That General Electric Canada be approved as the single source of supply for General Electric (GE) Evolve LED Roadway luminaires, as funded through the capital budget project ID 4041610018;

(c) That the General Manager of Public Works and Finance & Corporate Services, or his designate, be authorized and directed to enter into and sign on behalf of the City of Hamilton, all negotiated agreements and all necessary associated documents with General Electric Canada for General Electric (GE) Evolve LED Roadway luminaires with content acceptable to the General Manager of Public Works, and in a form satisfactory to the City Solicitor;

(d) That the General Manager of Public Works be authorized to direct the Standards and Approved Products Committee to amend Section 3 - Street Lighting of the Approved Products List to be reflective of Recommendation (a) of Report PW16058.

EXECUTIVE SUMMARY

Single sourcing on the GE Evolve LED street light has a variety of benefits to the City and it is already the most widely used LED street light in the City. Continuing the wide-scale use of the GE Evolve LED street light will further enhance the street lighting

program and ensure that the illumination of the municipal right-of-way is completed in an efficient and cost effective manner.

Permitting single sourcing of the GE Evolve LED street light will result in operational efficiencies where by it will streamline and enhance efficiency of existing maintenance practices while providing enhanced service levels.

The GE Evolve is an approved product and exceeds the City's technical and performance specifications. Through past deployment of the GE Evolve LED street light in the City it has proven to be a high performing and reliable light and has been positively accepted by staff, contractors, the public and both Horizon Utilities and Hydro One.

As an output of single sourcing, future deployment of a street lighting adaptive control system would be eased as installing such a system across a wide variety of different street light types could prove to be problematic. Single sourcing on the GE Evolve would ensure that consistency is maintained therefore protecting the successful implementation of an adaptive controls system.

The GE Evolve LED is known to staff and City consultants which reduces engineering time and costs and also enhances the quality of street lighting designs and ultimately the quality of lighting of the public right-of-way.

Through Public Works capital tenders, the 2015 High Wattage LED Incentive Project and other initiatives, the GE Evolve has shown to have a cost advantage over the other approved lights. Further cost reductions could be gained by leveraging and negotiating through a single source arrangement. Single sourcing would also enable the City to purchase direct from General Electric Canada which would further reduce purchase costs by 5-10%.

Alternatives for Consideration - See Page 10

FINANCIAL - STAFFING - LEGAL IMPLICATIONS

Financial: Single sourcing on the GE Evolve will reduce street light purchase costs for both maintenance and capital project by approximately 10-20%. Additional to the above there are other savings, particularly staff time and consultant assignment costs, which would be reduced due to gained efficiency.

Staffing: There are no attributed staffing impacts due to single sourcing.

Legal: N/A

HISTORICAL BACKGROUND

Hamilton owns and operates approximately 45,000 street lights, 40,000 being standard 'cobra-head' street lights and 5,000 decorative. 13,110 street lights are LED and the remaining is high-pressure sodium (HPS) or metal halide (MH). This report addresses only cobra-head street lights and not decorative.

Between 2009 and 2012 staff investigated and researched LED street lighting to obtain a comprehensive understanding and to determine if it was suitable for wide-scale use.

In this period 80 LED street lights were installed across 10 pilot locations. Early piloting identified a variety of issues and barriers however the technology matured quickly where it surpassed the performance of its predecessor.

Leveraging knowledge gained from the pilot installations and by consulting with other Municipalities and professional organizations such as the Illuminating Engineering Society of North America and United States Department of Energy Street Lighting Consortium, staff developed base technical specifications for LED street lights.

In 2012 a Downtown lighting upgrade project was selected to utilize LED street lighting and a request for pre-qualification (C11-59-21) was issued in December of 2012. The Request for Pre-Qualification (RFPQ) contained minimum mandatory requirements and measured performance based attributes. Three LED street lights were approved: the Cooper Lighting Navion, Philips Lumec Roadview and General Electric Evolve.

In Q1 of 2013 the three approved lights were added to the City's Approved Products List through the Public Works Standards and Approved Products Committee and simultaneously the use of HPS and MH street lights were restricted for maintenance thereby standardizing on the use of LED.

In 2014 the City undertook the first large scale LED retrofits where 730 street lights were replaced with LEDs via the 400W HPS to LED Street Light Conversion (ENG14.005) and Sherman Access Conversion Projects. The three approved LED products were equally represented across all project lights. Procurement of the project lights was completed through a Request for Tender (RFT) (C11-51-13) and installations were conducted by the City's street lighting maintenance contractor.

In Q4 of 2014, and in advance of the 2015 High Wattage Street Light Incentive Project (PW14119c), the City reviewed and renewed the 2012 RFPQ and issued another RFPQ (C11-82-14). The second RFPQ was revised slightly by updating the base technical specification based on lessons learned and technological advances that occurred since the first RFPQ. Three additional LED street lights were approved therefore bringing the total to six. The added street lights were the Philip Roadfocus, Cree Canada XSP/LEDway and the LED Roadway Lighting Ltd NXT.

In 2015 10,319 street lights were replaced with LED through the High Wattage Street Light Incentive Project. The project was completed via a supply and install RFT (C15-29-15 SL) in which the successful bidder was required to choose one of the six pre-approved LED street lights. Enersource Power Services Inc., the successful bidder, chose the General Electric Evolve street light which was used exclusively for all 10,319 street light replacements. The justification for the selection of the General Electric Evolve street light was a combination of price, capacity and speed to deliver.

In combination with the above noted projects and from other initiatives (such as Public Works (PW) capital construction and residential sub-division development) the City currently has approximately 13,110 LED street lights. While there were initially six approved street lights the majority are the General Electric Evolve LED street light (approximately 11,360).

As approved in the 2016 capital budget, Public Works (PW) will be retrofitting the remaining street lights across the City to LED. The quantity of targeted lights is approximately 27,000 which will be replaced over a 3-4 year period. To support this project there is a need to procure LED street lights. In addition to the City-wide project, the street lighting maintenance program requires the purchase of new LED street lights and/or parts in order to maintain acceptable service levels.

It is desirable and advantageous to the City to standardize on one street light type/manufacturer for a variety of reasons. The General Electric Evolve street light is the most widely used LED street light in the City and has statistically performed beyond expectations. As such, it is recommended that it be used exclusively for the 2016-2019 LED retrofit project and for all other future LED installations, inclusive of the maintenance program.

POLICY IMPLICATIONS AND LEGISLATED REQUIREMENTS

The City of Hamilton Bylaw #13-317 – Procurement Policy, Policy #14 allows for standardization.

This process aligns with the Public Works Business Plan by ensuring that equipment is maintained and completes its expected lifecycle, and costs are kept to a minimum.

RELEVANT CONSULTATION

These recommendations are the result of consultations with the Procurement Section whom provided input into the report recommendations.

ANALYSIS AND RATIONAL FOR RECOMMENDATION

Single source selection of one type/manufacturer of cobra-head style LED street lights has a variety of benefits to the City. A total of six LED street lights have been approved through two RFPQ processes, three of which are currently included on the Approved Products List. Maintaining a large list of approved LED street lights is problematic and the rationalization of the single source recommendation for the General Electric (GE) Evolve LED street light is categorized below into a) operational efficiencies, b) performance and reliability, c) technical benefits and d) cost and delivery.

a) Operational Efficiencies

There are 13,110 LED street lights installed City-wide. 11,360 are the GE Evolve street light of which 10,319 were installed as part of the 2015 High Wattage Street Light Incentive Project. The remainder of LED street lights are comprised of various other manufacturers.

Limited variation in street light equipment is advantageous from an operational perspective as it streamlines troubleshooting, repair, replacement, general maintenance work resulting in timelier and more efficient response to non-operating street lights, thereby minimizing response times, maximizing service and maintaining Council approved service levels.

Staff and the City's street lighting maintenance contractor has a high level of understanding and comfort (when compared to other installed LED lights) of the

operational characteristics and needs of the GE Evolve street light since it is the most prevalent LED light in the City. This understanding is beneficial as it assists and promotes efficient operational processes and procedures.

An inventory of LED street lights, both complete assemblies and parts, is required to service and replace lights for both planned and reactive maintenance. LED street light parts are not interchangeable from one manufacturer to another and the more variability that exists the greater the variability and quantity of individual inventory items are required. Having limited inventory variability is an efficient methodology for controlling, stocking and managing spare street light assemblies and parts needed for maintenance. A smaller and more defined inventory reduces staff time needed to oversee, simplifies procurement of street lights/part and ultimately lowers costs.

b) Performance and Reliability

General Electric is established as one of the leading manufacturers of LED street lighting in the North American marketplace and the GE Evolve LED street light is recognized as one of the leading street lights in the industry, awarded with the "Best-in-Class designation in the roadway lighting category by the U.S. Department of Energy. It is one of the most widely deployed street lights in North America.

The GE Evolve LED street light exceeds the City's base technical specifications for LED street lights. The stringent base specifications were developed to ensure that the LED street lights met or exceeded constructability and operational standards and that the lights will operate reliably and maintenance free for upwards of 15 years.

Since the installation of 10,319 GE Evolve street lights in 2015, to date only 18 units have failed (an equated failure rate of 0.0017%). The anticipated failure rate was 0.02% and therefore the lights are performing far better than expected.

With the exception of the LED Roadway Ltd NXT street light, the GE Evolve street light is an 'OEM integrated' product (OEM – Original Equipment Manufacturer) in that all of the primary internal components (housing, LED light engine, driver and surge arrestor) are developed and manufactured by the source manufacturer (GE). The other approved LED products are not considered to be integrated as some critical primary components are not of OEM origin (most often the driver). Integration of LED street lights is a beneficial aspect as it ensures that all components are compatible and designed/manufactured to the same performance quality and objectives. OEM Integration provides a higher level of protection of long term reliability and availability of replacement components as the OEM manufacturer maintains control over component updates/revisions to make sure that they are backwards compatible with older street lights.

All of the approved LED street lights have a 10 year operational warranty. OEM integration results in a 'one-finger-to-point-to' model when dealing with failures within and outside of the warranty period. Since the OEM manufacturer is the originator of all internal components, troubleshooting operational issues and managing warranties is more efficient when compared to dealing with similar issues with non OEM integrated street lights. Permitting single sourcing of the GE Evolve street light eases the

complication with managing multiple warranties (across multiple types/manufacturer street lights) resulting in a reduction of staff time and attention. Single sourcing on one product places the City in a preferential position to negotiate custom operational warranties thereby providing additional financial protection against failures.

Allowing single sourcing of one standard street light type will assist with managing the City's energy profile with both Horizon Utilities and Hydro One. For energy billing, the majority of street lights in the City are 'flat-rate', as they are not connected to utility meters. Both Horizon and Hydro one calculate the energy consumption of the flat-rate street lights based on a) assumed operating time and b) energy consumed by the lights. The operating time is a profile regulated by the Ontario Energy Board (OEB) however the City is responsible for tracking the energy that each street light consumes. This information is delivered to the utilities at routine intervals by the City. Energy consumed by each street light type must be provided to and approved by the utilities before it can be used for billing. The City provides specification sheets and additional technical information to the utilities for each different street light type/wattage. Limiting the amount of variation in street light types simplifies this process considerably for both the City and the Utilities and therefore single sourcing on one street light type, such as the GE Evolve, would result in a more streamlined, efficient and potentially accurate billing process. The GE Evolve LED street light energy consumption information has previously been reviewed and accepted by Horizon and Hydro one.

The most important output of street lights is their ability to adequately illuminate sidewalks and roadways. Staff have a high degree of confidence in the ability of the GE Evolve LED street light for meeting the needs of the municipal right-of-way based on previous installations, specifically the 2015 High Wattage Street Light Incentive Project. As previously noted the City has approximately 11,360 GE Evolve LED street lights deployed across the City lighting a wide variety of sidewalk and roadway configurations. Staff is not aware of any areas that are insufficiently lit as a function of the performance of the street lights.

Of the six approved street lights the GE Evolve has the largest number of light output options available and therefore enabling it to accurately illuminate sidewalks and roadways from major arterials to residential locals. The variety of options also results in a noted reduction in light pollution (light trespass and sky-glow) for many applications as the light output can be matched up with the exact needs of the right-of-way better than many of the other approved LED street lights. There have been several instances on PW capital construction projects that the GE Evolve LED street light was the only street light (of the six approved) which could adequately illuminate the right-of-way despite a concerted effort to seek out acceptable alternatives for project specifications. In some cases, other approved LED street lights could light these applications but could only do so at much higher output wattages which would have resulted in higher operating (energy) costs.

Of the six approved LED street lights the GE Evolve is the only one that uses reflective optics technology for distributing light. All other approved lights utilize lensed optics. Reflective options (where light from LEDs is controlled and distributed by a specular

reflector) are shown to produce less disability glare when compared to lensed optics. Reducing disability glare for roadway users is an important consideration for lighting design and can result in a safer lit environment.

The GE Evolve LEDs and reflectors are recessed in the housing of the fixture and sealed in the optic chamber by tempered glass. Excluding the Philips Roadview, the other approved LED street lights have individual lensed LEDs which are not enclosed within an optic chamber and the lenses protrude from the bottom. The exposure of the lenses to the open environment leaves them prone to dirt adhering to the lenses and therefore reducing efficiency. The Illuminating Engineering Society reported at the 2015 Street and Area Lighting Conference that LED street lights with exposed optics present a higher level of 'dirt-depreciation' (when light output is reduced by dirt build up on the lenses) and would require more frequent routine cleaning to remove dirt when compared to LED street lights that have sealed optical chambers, such as the GE Evolve.

LED street lights are unlike HPS and MH street lights in that each manufacturer's street light is design and constructed differently resulting in wide variations in performance and appearance from one to another. Single sourcing on one LED street light type ensures that consistency is maintained across the City. Street lights work together to illuminate the municipal right-of-way and consistency is important to ensure that sidewalks and roadways are adequately illuminated. Performance differences between different types of street lights can sometimes be considerable and if consistency is not maintained along a linear run of street lights, the resultant could be unwanted dark-spots between street lights, glare issues, isolated over-illumination or light trespass. Although not important to illumination, the difference in appearance caused by non-consistent LED light types could be viewed as unsightly by the public. Permitting single sourcing of the GE Evolve LED street light would ensure that consistency is maintained across the City, especially considering that it is the most prevalently deployed LED street light.

Post completion of the 2015 High Wattage Street Light Incentive Project, which replaced 10,319 street lights to the GE Evolve LED, the City received very few complaints from the public. Most complaints were regarding the loss of inadvertent lighting of private property which the majority of the public views as a positive change. In total, Staff received less than 20 complaints, far lower than anticipated. The low complaint rate is a resultant of the GE Evolve's ability to adequately light the municipal right-of-way and demonstrates that the public is overly satisfied with the quality and distribution of light. Allowing single sourcing of the GE Evolve will ensure that public satisfaction is maintained during and after the remainder of the City is converted to LED lighting as part of the 2016-2019 conversion initiative.

c) Technical Benefits

LED street lights are much more complicated than traditional street lights. They are more optically efficient than the old style of lights and have many more distribution shapes, wattages and lumen outputs (the amount of generated light). This creates challenges for designing new or replacement street lighting systems. There is a wide variation of performance for street lights from one manufacturer to the next. This further

compounds the design complications if there are multiple approved LED street lights compared to a limited or single source selection of lights. Lighting design is conducted through a 'trial and error' process which relies heavily on experience and familiarity of LED street light products lines. Staff and the City's roster consultants are most familiar with the GE Evolve LED street light as it is the most used street light in the City. This familiarity enables new lighting designs to be completed in an efficient and timely manner when compared to attempting to conduct a design using less familiar LED street lights. Single sourcing on the GE Evolve will ensure that this familiarity is maintained and that designs are conducted quickly and accurately, which when utilizing roster consultants, equates to lower roster assignment costs.

Operationally familiarity with a specific product line, such as the GE Evolve, has further benefits as performance expectations, modes of failure and general life expectancy will be well known to Staff, the roster consultants and contractors.

LED street lighting technology has and continues to develop, evolve and improve at a rapid pace. Tracking these changes to ensure the most up-to-date street light version is being designed with and installed is currently problematic across the six approved LED street light types. It is difficult for Staff and roster consultants to be aware of the latest revisions due to the quantity of approved lights. Each manufacturer updates their street lights independently of each other meaning that Staff must be constantly refreshing the knowledge base of each and every approved product. Staff and roster consultants are most familiar with the GE Evolve LED street light product line mainly due to its wide-scale use as part of the 2015 High Wattage Street Light Incentive Project. If single sourcing of the GE Evolve is permitted, Staff could continue to improve its understanding of the product line as without single sourcing, equal attention must be given to all approved products – this is a time consuming endeavour which potentially takes staff away from other core duties.

Approximately 200-400 new street lights are installed annually through residential development. Street lighting design and installation is the responsibility of developers with the oversight of City. Developers must adhere to the City's Standard Products List for street lighting equipment, inclusive of LED street lights. Currently, the Standard Products List includes three LED street lights of which developers are free to select one of the three approved lights. Despite this, the GE Evolve LED street light is the most commonly installed light through development. Standardizing on the GE Evolve street light is not expected to have any impact on development and would have similar benefits as it does with Staff and roster consultants. Single sourcing on one street light product will result in a gained familiarity with the developer's electrical consultants which, based on the use of the GE Evolve in developments, likely already exists. Further, standardizing on one product will mean that all new street lights installed through development construction will match lights being installed by City initiatives thereby ensuring consistency for the City's lit environment and for the maintenance program.

Some right-of-way configurations are difficult to illuminate, even with the more advanced optics of LED street lights. The GE Evolve street light optics can be customized through

the design and selection process to better match any challenging needs of the right-of-way. This customization was used for the 2012 Downtown Hamilton Lighting Upgrade Project on James Street North between Main Street East and Hunter Street East. A high level of lighting was required on the sidewalks due to the elevated pedestrian activity in the area. Out of the three approved LED street lights, the GE Evolve was the only light that could adequately illuminate the sidewalks and was subsequently installed. The street lights used in this segment of James Street North were modified by General Electric to provide a higher than standard amount of light towards the back (sidewalk side) of the street lights via customization at the request of the City. Without the customization of these street lights, adequate lighting levels would not have been achieved and would have resulted in substandard lighting levels for sidewalks. Customization of street lights provides the City with added flexibility through the design process to meet required lighting levels in instances that are challenging. The alternative to using customized lights is to relocate or install additional street light poles which are considerably more expensive than simple light replacements.

The next progression in the evolution of street lighting, by leveraging LED technology, is adaptive control systems. Adaptive control systems are installed on street light systems and establish an independent wireless communication network across of street lights contained within the network. The adaptive control system enables the street lights to be remotely and actively controlled (turned on, off and dimmed). It also automatically monitors and reports of any issues or outages of street lights therefore alerting the City immediately as issues are found so that the appropriate action may be taken to resolve the issue. All of the LED street lights installed in the 2015 High Wattage Street Light Incentive Project are 'controls-ready' in that they have internal components that are compatible and easily able to accept an adaptive control system. This feature was included in the 2014 revised base LED street light specifications. This specification will be maintained and carried forward for the street lights to be installed as part of the 2016-2019 wide-scale conversion initiative. Single sourcing on one street light product will be advantageous to the future installation of an adaptive controls system as it would ensure that all street lights are of the same specification. Any variation between products types could potentially cause compatibility issues when an adaptive controls system is installed as the specifications and operating profiles that the adaptive controls system connects to would have inherent variability. Considering that 11,360 GE Evolve LED street lights are already deployed across the City, sole sourcing on it would ensure that the compatibility across the majority of LED street lights would exist in advance of the installation of a future adaptive control system.

d) Cost and Delivery

Most of the six approved LED street lights are priced similarly as they are all competing products in the industry. The GE Evolve LED street light is on the lower end of the cost scale across all six approved products. Evidence of this is via the selection of its use for the 2015 High Wattage Street Light Incentive Project by the awarded contractor. Additionally, the GE Evolve LED street light is the most frequently used street light for both PW capital construction and development construction of which both utilize a low-bid tendering process. Permitting single sourcing of the GE Evolve will place the City in

a more favourable position to negotiation unit pricing for new construction and for supply of lights and parts for the maintenance program. Single sourcing will also allow the City to negotiate direct purchase of street lights with General Electric Canada. Direct purchase will remove the reliance on electrical distributors which typically provide a service mark-up between 5-10%, therefore saving the City added expense. General Electric Canada does permit direct sale to municipalities and only a small proportion of the other approved LED manufacturers allow direct sale. It is the City's intention for the 2016-2019 City-wide LED retrofit to purchase all project luminaires and enabling single sourcing to the GE Evolve coupled with the ability to purchase direct from General Electric Canada will potentially save the City upwards of $800k.

The 2015 High Wattage Street Light Incentive Project operated on a tight completion timeline due to the required eligibility completion date for the Independent Electricity System Operator (IESO) saveONenergy incentive. The installation of 10,319 LED street lights had to be fully completed within a 12 month schedule. The availability and delivery of the LED project lights was a critical component to the success of the project. The selection of the GE Evolve LED street light by the awarded contractor was a combination of pricing and delivery. GE supplied project street lights ahead of the project schedule and averaged 3 weeks delivery per 1000 lights. In Q3 of 2015 GE implemented an SAP (System, Applications and Products) standard to their production and delivery process. Since this system has been implemented, GE has increased its delivery timelines made by the City and its contractors from an average of 3-4 weeks to 1-2 weeks. When comparing the ability to deliver lights to City projects from the approved LED products, GE has completed orders and delivered lights on average two weeks faster. Single sourcing on the GE Evolve will ensure that street lights are supplied in the most time efficient manner as possible to support both PW capital construction projects and the maintenance program. Additionally, GE has shown that it is capable of supplying lights for large scale projects such as what was completed in 2015.

ALTERNATIVES FOR CONSIDERATION

An alternative to the recommendations in this report is to sustain the three approved luminaires on the Standards and Approved Products list. Another option would be to expand the list to include the other three approved LED street lights, bringing the total to six approved LED street lights.

In order to deal with the maintenance requirements of the 11,360 GE Evolve LED street lights Staff could utilize Policy 11 purchasing rules to acquire lights and parts on an as-needed basis.

When purchasing large quantities of LED street lights the City could issue RFT's on an as needed basis.

These options would prove to be time consuming and potentially more expensive in the short and long term.

ALIGNMENT TO THE 2012 – 2015 STRATEGIC PLAN

Strategic Priority #1

A Prosperous & Healthy Community

WE enhance our image, economy and well-being by demonstrating that Hamilton is a great place to live, work, play and learn.

Strategic Objective

1.2 Continue to prioritize capital infrastructure projects to support managed growth and optimize community benefit.
1.5 Support the development and implementation of neighbourhood and City wide strategies that will improve the health and well-being of residents.
1.6 Enhance Overall Sustainability (financial, economic, social and environmental).

Strategic Priority #2

Valued & Sustainable Services

WE deliver high quality services that meet citizen needs and expectations, in a cost effective and responsible manner.

Strategic Objective

2.1 Implement processes to improve services, leverage technology and validate cost effectiveness and efficiencies across the Corporation.
2.3 Enhance customer service satisfaction.

Strategic Priority #3

Leadership & Governance

WE work together to ensure we are a government that is respectful towards each other and that the community has confidence and trust in.

Strategic Objective

3.4 Enhance opportunities for administrative and operational efficiencies.

APPENDICES AND SCHEDULES ATTACHED

None

Appendix F – City Documents Recommended Changes

CHAPTER 4

MESA LIGHTING AND ELECTRICAL CODE

(1685,1736,3571,4637,4790)

4-4-1: LIGHTING CONTROL ORDINANCE (4245,4637,4790)
4-4-2: NATIONAL ELECTRICAL CODE ADOPTED (4245,4637)
4-4-3: PENALTY CLAUSE (4245)

4-4-1: LIGHTING CONTROL ORDINANCE: (4245,4637)

(A) Purpose. This Section is intended to restrict the permitted use of outdoor artificial illuminating devices emitting undesirable rays into the night sky which have a detrimental effect on astronomical observations. (4245)

(B) Conformance with Applicable Regulations. All outdoor artificial illuminating devices shall be designed and installed in conformance with the provisions of this Section and all other Sections of Chapter 4-4. Where provisions of the Arizona State Statutes, or of the Federal laws, or other regulation of the City conflicts with the requirements of this Section, the most restrictive shall govern. (4245)

(C) Conformance with Applicable Standards. ~~All outdoor artificial illuminating devices shall be installed in conformance with recognized standards as approved by the American National Standards Institute (ANSI) and the Illumination Engineering Society of North America (IES)~~. Public street lighting shall be in conformance with the City of Mesa engineering and design standards. (4245,4637)

(D) Definitions. The following definitions shall apply to this chapter. (4245,4637)

OUTDOOR LIGHT FIXTURES: Outdoor artificial illuminating devices, outdoor fixtures, lamps, and other devices, permanent or portable, used for illumination or advertisement. Such devices shall include, but are not limited to, lighting for buildings and structures, recreational areas, parking lots, landscape areas, billboards and other signage, and street lighting. (4245)

FULLY SHIELDED: Those fixtures designed and erected in such a manner that light rays emitted by the fixture, either directly from the lamp or indirectly from the fixture, are only projected below a horizontal plane running through the lowest point on the fixture where light is emitted. (4245)

PARTIALLY SHIELDED: Those fixtures designed and erected in such a manner that the bottom edge of the shield is below the plane of the centerline of the light source (lamp), minimizing the light emitted above the horizontal. (4245)

FILTERED: Outdoor light fixtures whose transmission is less than five percent (5%) total emergent flux at wavelengths less than three thousand nine hundred (3,900) angstroms. Total emergent flux is defined as that between wavelengths of three thousand (3,000) and seven thousand (7,000)-angstrom units. (4245)

AMBIENT LIGHT LEVEL: The measured light level at night when all the lights associated with a facility are off. (4245)

This statement can be interpreted to mean that all outdoor lighting installations have to conform with all IES publications. The IES has several dozen published Recommended Practices (standards) for various types of outdoor lighting: basketball courts, tennis courts, horseshoes, pathways, sidewalks, parking lots, public gathering spaces, tunnels, crosswalks, etc. Each of these published documents are complex and involved. Unless Mesa staff intends to become fully familiar with thousands of pages of IES standards and guidelines, and start enforcing them, then this statement should be removed.

and is not subject to this code.

private

See comment on item (C) above.

4-4-1

INSTALLED: The initial installation of outdoor light fixtures defined herein, provided the date of such installation is on or after September 18, 2004. (4245)

(E) Where Required. All exterior walkways, parks, parking lots, sales areas, or similar facilities which are intended to be occupied by the public during hours of darkness shall be provided with illumination to the minimum level recommended by IES standards for the use intended, during hours of normal occupation. (4245)

(F) Shielding and Filtering. All exterior illuminating devices, except those exempt from this Section, shall be fully or partially shielded and filtered as required in the following table: (4245)

TABLE 4-4-1(F)
REQUIREMENTS FOR SHIELDING AND FILTERING

FIXTURE LAMP TYPE	SHIELDED	FILTERED (4)
Low-Pressure Sodium (1)	Partially	None
High-Pressure Sodium	Partially	None
Metal Halide	Fully	Yes
Fluorescent	Partially (3)	Yes (5)
Quartz (2)	Partially	None
Incandescent Greater than 150W	Partially	None
Incandescent 150W or Less	None	None
Fossil Fuel	None	None
Glass Tubes Filled with Neon, Argon, Krypton	None	None
Other Lamp Types	AS APPROVED BY THE BUILDING SAFETY DIRECTOR	

Footnotes:
(1) This is the preferred lamp type to minimize undesirable light into the night sky, negatively affecting astronomical observations.
(2) For the purposes of this Section, quartz lamps shall not be considered as an incandescent light source.
(3) Outdoor advertising signs of the type constructed of translucent materials and wholly illuminated from within do not require shielding.
(4) Glass, acrylic, or translucent enclosures shall be deemed to satisfy filter requirements.
(5) Warm White and Natural Lamps are recommended to minimize detrimental effects.

(4245,4637)

(G) Visibility. No fixture, with a lamp size greater than 150W incandescent, shall be designed or erected where the lamp is directly visible to a person standing at the property line. (4245)

(H) Light Spillage. The light level at any property line, measured thirty-six inches (36") above ground level, shall be not more than 0.5 footcandles (5 Lux) above ambient light level, except for property lines adjacent to residential use property, the light level shall be not more than 0.3 footcandles (3 Lux) above ambient light level. Where the property is adjacent to a public street, the property line may be considered to be the centerline of the street. (4245)

10. Streetlights. Streetlights shall be installed along all streets within the subdivision and along all perimeter streets developed in conjunction with the subdivision. Streetlights shall be installed by the subdivider in accordance with plans approved by the Engineering Department and in conformance with City standards. For a single parcel development with less than one hundred fifty feet (150') of street frontage, the City Engineer may waive the required streetlight installation. If installation is waived, prior to the issuance of a building permit, the subdivider shall pay an amount determined by the City based on the street frontage to pay for the future installation of streetlights by the City or others. (2474/Reso. 6188)

11. Traffi (a) Adaptive Lighting. Public street lights may be dimmed in accordance with City standards at times of reduced night traffic. shall be modified in conjunction with the development in accordance with designs approved by the Development Services Department, where required in accordance with the Mesa Transportation Division. The Transportation Division may defer the installation of required traffic control devices. (4570)

    When the installation of required traffic control devices is deferred, the owner/developer shall pay the City a payment in-lieu of causing the actual design, installation, and/or construction of the devices. This in-lieu payment shall be based upon a cost estimate prepared by a professionally registered civil engineer and approved by the City of Mesa. The in-lieu payment cost estimate shall include all design costs, labor and materials costs, plus twenty percent (20%) for future contingency costs. All in-lieu payments shall be remitted to the City of Mesa as a condition of and in conjunction with the issuance of any on-site construction permits and/or off-site rights-of-way permits associated with the development project. (4570)

12. Street Name Signs. Street name signs shall be placed in all street intersections. The subdivider shall install signposts meeting City standards at locations designated by the City Engineer. The signposts shall be in place prior to the completion of street paving. Prior to the issuance of a City permit for street paving, the subdivider shall pay to the City an amount per street name sign location as determined by the City Engineer to pay for the fabrication and installation of sign plates by the City. (2474,4570/Reso. 6188)

13. Survey Monuments. Survey monuments conforming to City standards shall be installed at all corners, angle points, and points of curves and at all street intersections for streets within and around the perimeter of the subdivision and at such other locations as may be required by the City Engineer. After all improvements have been installed, the subdivider's registered land surveyor shall check the location of the monuments and mark the brass cap. (2474,4570/Reso. 6188)

14. Lot Corners. Iron pipe or round reinforced steel bars not less than one-half inch (1/2") in diameter shall be set at all corners, angle points, and points of curve for each lot within the subdivision prior to the recording of the plat, except that the City Engineer may approve a temporary delay where topographic conditions make it necessary. (2474,4570/Reso. 6188)

15. Parkway Landscaping. Parkway areas along arterial streets and other streets, as deemed necessary by the City Engineer, shall be landscaped in accordance with approved plans and standards set by the City Engineer. In PADs, a statement shall be contained in both the deed restrictions and the owners' association by-laws that all landscaping, including that within the public right-of-way adjacent to the site, shall remain the responsibility of the owners' association to maintain in perpetuity. (2474,4570/Reso. 6188)

(C) Collector Street - Public. Where no lot/home access is provided along a collector street, and the area served by the collector is not so large as to require a wider street, the collector street may be as follows: eighty feet (80') right-of-way, thirty-four-foot (34') face-of-curb to face-of-curb, no on-street parking, and five-foot (5') sidewalks detached a minimum of four feet (4'). At intersections with major streets and adjacent to school sites, parks, or activity centers, the face-of-curb width shall be increased to forty-six feet (46'). (4233)

collector streets in Desert Uplands do not comply with City normal standards. See next item.

(D) Streetlights. (2474/Reso. 6188,4233)

1. The "shoebox" fully shielded streetlight fixture with a square pole shall be the standard fixture and pole in the Desert Uplands Area (see Figure 31). (2474/Reso. 6188,4233)

2. Streetlights on major streets ~~and collector streets~~ shall comply with City standard illumination and spacing requirements, except as specified in Subsection (D)3, (D)6 and (D)7 of this Section. Streetlights may be installed in median islands where available or adjacent to sidewalks where medians do not exist. Mounting height shall be thirty-five feet (35') to forty feet (40'). (2474,4513,4233,4766/Reso. 6188)

3. On collector streets as permitted under Subsection (C) of this Section, street lighting shall use poles with a thirty-foot (30') or thirty-five foot (35') maximum mounting height and an average 0.37 footcandle light level with a six-to-one (6:1) average-to-minimum ratio. Lighting along the forty-six-foot- (46') wide sections of these streets adjacent to school sites, parks, or activity centers shall comply with City standard illumination and spacing requirements for collector streets. (4233)

This is not very far. Consider changing to 250'

4. Streetlights on local streets shall be placed at all intersections and at the end of cul-de-sacs that are more than two hundred feet (200') long except as specified in Subsection (D)6 and Subsection (D)7. On straight sections of roadway, four hundred-foot (400') spacing between lights may be used. However, other factors must also be evaluated; e.g., horizontal and vertical alignment. Topographical conditions may require additional lighting. Mounting height on local streets shall be twenty-five feet (25') with a seventy (70) ~~watt lamp~~. (2474,4513,4570,4766/Reso. 6188,4233)

watt HPS lamp or LED luminaire of 3,300 nominal lumens.

5. Pull boxes shall be a maximum of two hundred feet (200') apart. (2474/Reso. 6188)

6. For the area north of McDowell Road and east of Hawes Road and west of Usery Mountain Regional Park along public streets, no lighting on the public street shall be required. The developer shall provide an area light with a light pole no less than eight (8) feet in height and no greater than sixteen (16) feet in height with a seventy (70) ~~watt fixture~~. The type of area light fixture and pole shall meet all applicable City standards. The area light shall be installed at each entrance to a multi-unit subdivision. The area light shall be owned, operated and maintained by the owners of the property, where the area light is installed. The area light shall be installed outside of the City right-of-way or public utilities and facilities easement and shall be installed adjacent to the edge of the driveway approach. (4513)

watt HPS luminaire or LED luminaire of 3,300 nominal lumens.

7. Streetlighting on public collector and local streets located in the area north of McLellan Road, west of Ellsworth Road/92nd Street alignment, south of McKellips Road and east of a north/south line one-quarter mile west of Hawes Road, and for the area north of McKellips Road, west of Ellsworth Road/92nd Street alignment, south of Hermosa Vista Drive, and east of Hawes Road, shall be provided at locations specified below to the light level required by City standards as set forth in 9-6-4(D)10 and City of Mesa Engineering and Design Standards:

   (a) At all public street intersections and all locations where private driveways intersect a public street. (4766)

   (b) At all marked and unmarked pedestrian crosswalks. (4766)

   (c) At all pedestrian crossing points adjacent to parks or other activity centers. (4766)

   (d) At all pedestrian, bike, equestrian, or joint use pathway crossings where pathway lighting is provided. (4766)

Section 903 - City Code

903.1 Title 9, Public Ways & Property contains information regarding the construction of public street lighting in association with private land development. Chapter 6 of Title 9 pertains to land subdivision projects, while Chapter 8 deals with individual lot or parcel development (non-subdivision) projects.

903.2 Title 4, Building Regulations contains information regarding light pollution and light trespass. Chapter 4, Mesa Lighting and Electrical Code deals primarily with private lighting and does not apply to the lighting of public streets.

This says that Title 4 chapter 4 does not apply, but then 905.3 and 906.1 reference Title 4, Chapter 4.

Section 904 - City Policy

904.1 All private land development projects, as formalized by the City Code are required to provide street lighting that meets City of Mesa standards, for all public streets within, adjacent or affected by the proposed project

Section 905 - Arizona State Statutes

905.1 Title 49 – The Environment, Chapter 7 – Light Pollution contains requirements for shielding of outdoor light fixtures as well as the prohibition of mercury vapor light fixtures. The provisions of this Title apply to both public and private lighting systems.

905.2 In accordance with ARS Title 49, the City of Mesa requires the use of full cutoff light fixtures on the public street lighting system and prohibits the use of Mercury Vapor (MV) lamps.

905.3 Title 4, Chapter 4 of the Mesa City Code pertaining to Mesa Lighting and Electrical Code supersedes the requirements of the Title 49 in accordance with Article49-1106.

Mesa street lighting does not follow NEC. The "Mesa Electric Code" references NEC.

Section 906 - Public Street Lighting System Design

906.1 **General Information:** In addition to the M.A.G. Uniform Standards, Mesa's amendments to M.A.G, and Mesa's Streetlight Technical Manual; Mesa has also established the Mesa Electric Code. For additional information please see Title 4, Chapter 4 of the Mesa City Code.

906.2 **Design Criteria:** It is the City of Mesa's intention to provide illumination of the public street transportation system in accordance with the "American National Standard Practice for Roadway Lighting" (RP-8-00) as published by American National Standards Institute (ANSI) and the Illuminating Engineering Society of North America (IESNA).

906.3 Copies of RP-8-00 are available by contacting the Illuminating Engineering Society of North America at 120 Wall Street, New York, New York 10005 or at http://www.iesna.org.

906.4 **Design Method:** While the RP-8-00 Standard Practice contains three different design criteria methodologies for designing roadway lighting, designs in the City of Mesa are to utilize the "Illuminance Criteria" method.

906.5 **Minimum Values:** Tables 2 & 9, of RP-8-00 provide the minimum recommended values that are to be met by all public street lighting designs within the City of Mesa.

908.3 All luminaires installed on the public street lighting system must be from one of the following approved manufacturers:

GE (General Electric) Lighting Systems, Inc.

Philips Lighting, or

City of Mesa approved equal.

908.4 All luminaires installed are to be

908.4.1 Classified as a "full – cutoff";

908.4.2 Housings are to be fitted with tool-less entry for mounting of driver and terminal buss. Luminaire shall mount to a horizontal 2.375" tenon with no more than 4 bolts. Cooling shall be done with heat sinks.

908.4.3 Driver shall be 120-277 60 HZ input with surge protection per ANSI C136.2-2015. Driver shall be replaceable and have plug connections. Drivers for light emitting diode (LED) shall be capable of 0-10V dimming.

908.4.4 Fixture shall have ANSI C136.331 seven (7) pin receptacle.

908.5 Mesa Standard Details M-70 series and the Streetlight Technical Manual have additional specifications, such as the IES Distribution, Type, Housing Color, etc., which all luminaires installed in the City of Mesa street lighting system must comply with. Use of non-standard IES distribution may be allowed with approval from the City. The Streetlight Technical Manual is available at https://www.mesaaz.gov/residents/transportation. Details found in the Streetlight Technical Manual have an "SL" prefix.

908.6 **Optics:** Fixture shall utilize ~~high bright~~ light emitting diodes (LEDs) with a CCT (Correlated Color Temperature) of 3000k or lower. Luminaire shall meet IESNA full cutoff classification (BUG rating of U0) and have IESNA Type II, Type III, or TYPE IV distribution.

908.7 **Poles:** Street light poles to be installed on a local or collector street are to be either a P-104 or P-106 per Mesa Standard Detail SL-73.01 Series unless otherwise approved in accordance with 908.7.1.

908.7.1 **Non-Standard Poles:** The use of non-standard, specialty materials within City of Mesa rights-of-way or easements or for infrastructure to be owned, operated or maintained by the City of Mesa is typically not allowed. "Specialty materials" are defined as items, such as streetlight poles, streetlight fixtures and street name signs which are not on the City of Mesa's approved products lists or otherwise not fully in accordance with the City of Mesa's standard details and specifications.

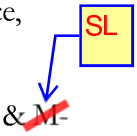
Any desired specialty items must be discussed with the City during the planning and zoning phases of a project and shall not be proposed in plans submitted for review without prior discussion or notice. The City will typically require execution of a development agreement with the developer during the project planning stage to set forth the requirements for the installation and maintenance of specialty items and, when specialty items are desired, the developer shall allot

time for this activity. The City is not under any obligation to approve non-standard, specialty items.

For proposed specialty items, detailed shop drawings, including product data sheets, must be provided to the City for review, included and shown in the permit drawings, and must be approved by the City of Mesa (including approval by the City of Mesa departments that own, operate or maintain such items) during the plan review process. Approval must be obtained prior to permit issuance. If the use of specialty materials is approved, the associated shop drawings shall remain a part of the approved building permit plan set that is used for construction. The permittee shall ensure that the materials delivered and installed in the field are in full and complete compliance with the shop drawings in the approved plan set.

The requirements of this section do not apply to capital improvement projects contracted for and administered by the City of Mesa (i.e., where the City is the contracting agency).

908.8 Street light poles to be installed on a four (4) lane collector or major street are to be a P-206, when the light pole is adjacent to or within a residential neighborhood. A P-207 may be used when in office, retail, commercial or industrial zoning districts. See Mesa Standard Detail SL-73.02 Series.



908.9 **Pole Foundations:** Street light pole foundations shall be per Mesa Standard Details SL-76.01 & ~~M~~-76.02.

908.10 Where a proposed pole foundation will be in conflict with an existing City of Mesa natural gas main, the gas main shall be sleeved and encased per City of Mesa Natural Gas Detail GD-3.6 (Contact City of Mesa Gas Engineering for a copy of this detail). Where the existing gas main cannot be encased per GD-3.6, an offset or spread foundation must be designed or the utility must be relocated.

908.11 **Conduits:** Conduits shall run in a direct line from pole to pole or pull box to pull box.

908.12 **Material:** Unless otherwise approved, conduits that are part of the public street lighting system shall be schedule 40, rigid PVC, UL approved for use with 90° C wire above and below ground.

908.13 **Location:** Conduits shall be dimension on the plan with a minimum of one foot (1') from edge of sidewalk or two feet (2') from the curb in median islands.

908.14 **Minimum Depth:** Minimum depth from the top of curb or street pavement finish grade is to be twenty-four inches (24") unless otherwise approved.

908.15 **Rigid Steel Conduit:** Areas where twenty-four inches (24") cover is not possible, galvanized rigid steel conduit (G.R.S.) may be installed. G.R.S. conduit shall be double wrapped with 20-mil tape to six inches (6") past the threaded metal coupling. Compression couplings are not allowed. Prior approval is required for any design proposing to use G.R.S. conduit.

908.16 **Sizes:** Acceptable sizes of conduit on the public street lighting system are: one and one-half inch (1 ½") or two-inch (2") in diameter as described below.

908.16.1 Conduits on major streets are required to be two-inch (2") diameter, except that a one-inch and one-half inch (1 ½") diameter conduit shall be used between the circuit pull box and the street light pole.

908.16.2 Conduits on collector or local streets shall be one and one-half inch (1 ½") or larger if required by the conductor size. Conduit on collector or local streets shall be one and one-half inch (1 1/2") from pull box to streetlight pole and one and one-half inch (1 1/2") or larger from pull box to pull box.

908.16.3 A two-inch (2") in diameter conduit shall be installed from the street light control cabinet to the pull & junction box located at the point of service connection.

908.16.4 Conduits containing photo control wiring shall be one and one-half inch (1 ½") minimum.

908.17 The conduit from the point of service connection to the electric utility's facilities shall be per the specifications of the electric utility.

908.18 A two-piece expansion joint coupling shall be installed in all conduits at intervals not to exceed one hundred feet (100').

908.19 Conduit stubs that are twenty-feet (20') or longer are required to be terminated with a sweep into a temporary pull box.

Section 909 - Circuits, Wire & Conductors

909.1 The public street lighting system is composed of the following circuits:

909.2 **Supply Circuit:** The circuit, which is from the electric utilities facilities to the approved point of service, is known as the supply circuit.

909.3 **Power Circuit:** The power circuit, which is the circuit from the point of service to the streetlight control cabinet.

909.4 **Street Light Circuit:** The street lighting circuits, which are from the streetlight control cabinet to the street light poles & luminaires.

909.5 The maximum numbers of street light circuits from a lighting control cabinet is two (2) and are usually designated as circuits "A" and "B". Note that the typical total load of a single circuit shall not exceed 24 amps.

909.6 Where a control cabinet is utilized the street light circuit shall be 240 volt.

909.7 Where a control cabinet is not utilized the street light circuit shall be 120 volt. Note that the electric service shall still be 120/240 volt.

909.8 **Photo Control Circuit:** The photo control circuits shall be 120 volts, which are from streetlight control cabinets to the photoelectric controls.

909.9 The photo control circuit wiring is to run continuously, without splices, from the photocell to the lighting control cabinet.

Is this the new policy? The construction note used on plans states to run the 14/3 tray cable unspliced from LCC to hand hole, and then run THHN conductors from hand hole to photocell.

909.10 **Wire:** All wire used in the public street lighting system shall be stranded copper. Aluminum wire is prohibited.

909.11 **Insulation:** All wire to be used shall have insulation as follows:

909.12 All conductors in the power circuit shall be XHHW/XHHW-2. Insulation color shall be black (power), and white (neutral). It is also acceptable to use black insulation for the neutral wire, when each end of the conductor is marked with white tape, six-inches (6") in length. Exception: power conductors from pole hand hole in luminaire may be THHN/THWN insulation and cannot be color coded with tape.

in conduit runs,

909.13 Bond wire for streetlight circuits shall be #8 seven strand bare and green #6 XHHW for foundation ground.

909.14 Photo control circuit shall be three (3) No. 14 XHHW-2 (RRCP 14/3) conductors contained in a TC (CPE Jacket) type control cable with a sunlight-resistant CPE jacket. Individual insulation colors shall be black (power to photocell), red (power from photocell) and white (neutral).

909.15 **Gauge:** All wire sizes shall be as follows:

909.16 **Power Circuit:** The wire to be used in the power circuit (i.e., from the point of service to the streetlight control cabinet) shall be:

909.16.1 Minimum gauge (AWG): No. 2 XHHW/XHHW-2

909.16.2 Maximum gauge (AWG): No. 2/0 XHHW/XHHW-2

909.17 **Street Light Circuit:** The wire to be used as a conductor in the street light circuits shall be based on the Voltage Drop Calculations. The minimum and maximum gauges are:

909.17.1 Minimum gauge (AWG); No. 8 XHHW/XHHW-2

909.17.2 Maximum gauge (AWG); No. 2/0 XHHW/XHHW-2

909.18 **Photo Control Circuit:** The wire to be used in the photo control circuit shall be three (3) no. 14 XHHW-2 conductors contained in a TC type control cable with a sunlight-resistant CPE jacket.

909.19 **Street Light Pole:** The wire to be used as a conductor in the street light pole (i.e., hand hole to the luminaire) shall be No. 12 (AWG).

909.20 **Ground (Bond):** All wires intended to be used; as a ground (bond) shall be seven (7) strand copper, minimum gauge is No 8 (AWG).

Section 910 - Point Of Service (POS)

910.1 The design engineer shall contact the appropriate electric utility company to establish a "point of service". It is the responsibility of the designer to coordinate the proposed project design with the utility company's approved point of delivery (P.O.D.). Placement of point of service pull box shall be per M-75.03 and M-75.04 of the Mesa Standard Details and Specifications.

SL-76.02 and SL-77.11

910.2 When the proposed development is within the City of Mesa Electric Service area, the design engineer shall provide with the construction documents submittal, a "Point of Service form" sometimes referred to as a "meter spot form" identifying the approved point of service.

910.3 Point of Service forms shall include the stationing identification for the point of service delivery.

910.4 Point of Service forms shall also identify all lots or tracts of the proposed projects within the vicinity of the point of service.

Section 911 - Power Supply

911.1 When the public street lighting improvement plans are approved and CAD drawings and PDF reproducibles are received and processed, the City of Mesa Transportation Department will submit a copy of the approved design to the public utility supplying electricity to the proposed development. This will allow that agency to initiate the final power design for the public street lighting system.

Section 912 - Voltage Drop

912.1 Voltage drop calculations are required to be submitted with the construction documents.

912.2 The voltage drop between the electric utility point of delivery pull box and the lighting control cabinet shall not exceed one percent (1%), assuming 240 volts at the pull box and a maximum 48 amp load at the lighting control cabinet.

912.3 The voltage drop between the lighting control cabinet and the end of each lighting circuit shall not exceed three percent(3%) for HPS and five percent (5%) for LED circuits.

Section 913 - Photometrics

913.1 The photometric results of the lighting analysis shall be shown on plan sheets that utilize the civil engineering base sheets for the proposed public street improvements. The X and/or Y coordinates shall match the stationing on the civil engineering improvement plans.

Section 914 - Location

914.1 The public street light system shall be designed for, and installed in the public street right-of-way. If existing conditions are such that the street light system cannot be located within the right-of-way, Public Utilities and Facilities Easements (PUFE) shall be dedicated, or cause to be dedicated for the public facilities.

914.2 **Local Streets:** Streetlights are typically installed on the south or west side of the public street.

914.3 **Collector Streets:** Streetlights are typically installed on the south or west side of the public street.

914.4 **Major Streets:** Streetlights are typically installed on both sides of the major streets with staggered ~~spacing, or may be located in center raised median.~~
spacing. Streetlights can only be located in median with prior approval of Transportation Department.

914.5 **Lot Lines:** Streetlights in residential areas should be installed on the intersecting lot lines.

This is not very far. Consider changing to 250'

917.4 **Location:** Approved streetlights (meaning City approval of the applicable building permit or right-of-way permit) shall be installed behind back of curb (e.g., adjacent to sidewalks). Mounting height shall be thirty-five feet (35') to forty feet (40') unless otherwise noted in City Code 9-6-5 (D).

917.5 **Pull Boxes:** Pull boxes shall be a maximum of ~~two hundred ten feet (210')~~ apart.

917.6 **Other Requirements**: Other requirements relating to streetlights within the Desert Uplands Area shall comply with City Code 9-6-5(D).

Section 918 - Public Street Lighting Components

918.1 **Poles:** All proposed or existing poles on the public street light system are required to be identified by stationing. Design plans shall show the station number for both proposed and future poles as well as any existing poles.

918.2 All poles on the public street light system are required to be identified by a public street address number. The Street Light Engineering Technician will provide addresses during the plan review process.

918.3 **Lighting Control Cabinets:** The lighting control cabinet and pad shall be in accordance with Mesa Standard Detail SL-~~75.01~~ series ~~and M-75.02 series.~~

SL-77.01

918.4 All control cabinets on the public street light system are required to be identified by stationing. Design plans shall show the station number for both proposed cabinets as well as any existing cabinets within the vicinity of the project.

918.5 All control cabinets on the public street light system are required to be identified by a public street address number. Street Light Engineering Technician will provide addresses during the plan review process.

918.6 Electrical service to the lighting control cabinet shall be 100 amps 120/240 volt single phase.

918.7 The engineer shall assure that the available fault current at the lighting control cabinet shall not exceed 10,000 amps.

918.8 The electric control panel for the lighting control cabinet will be furnished and installed by the City of Mesa Transportation Department.

918.9 Separate lighting control cabinets are typically required when streetlights are going to be installed on both sides of a public street.

918.10 It is the responsibility of the developer and the design team to assure that the locations of the lighting control cabinets coincide with the point of power delivery as established by the electric utility.

918.11 **Pull Boxes:** The distance between pull boxes (which also includes the hand holes on poles) shall not exceed ~~two hundred feet (200')~~.

918.12 Standard location of pull boxes is adjacent to the public sidewalk when possible.

This is not very far. Consider changing to 250'

918.13 A pull box shall be installed in any horizontal conduit run that has a change in direction greater than forty-five degrees (45°).

918.14 A pull box shall be installed whenever a conduit run branches to a conduit r cting public street.

SL-75.02

918.15 A pull box shall be installed whenever a conduit crosses a public street. The pull box shall be installed in order to create the shortest conduit run possible crossing the public street.

SL-75.03

918.16 Pull boxes are to be installed per Mesa Standard Detail ~~SL-74.01 & M-74.02.1~~. Pull boxes shall be offset from the light pole ~~a minimum of~~ five feet (5') (center to center).

918.17 Pull boxes to be installed on slopes shall be in conformance with Mesa Standard Detail ~~M-74.02.2~~.

918.18 A pull box shall be installed at each streetlight pole ~~where the conduit to be installed is one and one half inches (1.5") or greater~~.

918.19 A No. 3.5 pull box shall be used on local or collector streets one and one half inches (1.5") conduit is used.

where

918.20 No. 5 pull boxes shall be used with a two inches (2") conduits.

918.21 Point of Service (P.O.S.) boxes shall be No. 5 pull boxes.

918.22 **Photo Cell:** The photocell for the photo control circuit is typically installed on the first street light pole on each circuit from the lighting control cabinet.

Section 919 - Improvement Plans - Public Street Lighting

919.1 **Basis:** Public street lighting plans shall be based on the civil engineering improvement plan base sheets and shall show all existing and/or proposed off-site public improvements (i.e., public street widening, right-turn decelerations for both public street intersections or private property, driveways, sidewalk ramps, public and private utilities, etc.). For those projects in which separate civil engineering design is not required (i.e., existing public street improvements), the street light plans shall be developed per the standards for Construction Documents as discussed in Section 1, General Requirements.

919.2 **General Notes:** Public street lighting shall include the City of Mesa general notes for public street lighting.

SL-73.01.01

919.3 **Construction Notes:** Construction notes for public street lighting shall refer to the Mesa Standard Detail number as well as the specific specification number (e.g., ~~SL-73.01.03~~, P-106 pole).

919.4 **Stationing:** Stationing of public street light equipment or facilities shall be based on the same stationing as the civil engineering design or where civil engineering design is not required for the proposed project, stationing shall be based on a known survey monument on a public street centerline.

919.5 **Future Street Light Locations:** Where future street lighting (i.e., future widening of the opposite side of the street) is utilized by a lighting analysis in order to meet the required lighting levels for the

proposed project, the proposed future street light locations shall be shown on the street light design sheets.

919.6 **Addressing Street Light Facilities:** The City of Mesa requires that street lights & control cabinets be addressed. Address for new facilities will be provided during the plan review process. New facilities shall have addresses enclosed within parentheses ( ) while existing addresses are to be enclosed in brackets [ ]. Addresses for existing facilities can be found on the approved street lighting plans for those facilities.

919.7 **Quantities List:** The quantities list on the street light plans for the public street lighting system shall show only the number of street lighting poles and lighting control cabinets, unless otherwise directed.

919.8 **Reproducibles:** Reproducible PDF and CAD drawings of the street light design sheets are required to be submitted upon approval of the public street light design.

919.9 **Incorporation Into Civil Design:** When the street light design is in conjunction with other public works infrastructure improvements, the street light design sheets are to be incorporated into the civil engineering design set, the design sheets and the PDF and CAD drawings shall be sequentially numbered. The street light engineer shall coordinate with the project's civil engineer.

919.10 **Construction Details:** The City of Mesa standard details for the public street lighting system are to be referenced in construction note callouts. The standard details shall not be included as details on the plans except where the project will receive federal funds for the construction of the public streetlights.

919.11 Details will be required for aspects of the public street lighting system (such as poles, luminaires, and/or pole foundations) that are not covered by Mesa's standard details. Variations from the City of Mesa Standard Details must first be approved by the City of Mesa Transportation Department.

See attachment for Adaptive Lighting section.

Section 920 – Adaptive Lighting

920.1 Where and when determined appropriate by City of Mesa Transportation Department street lights may be dimmed. The City of Mesa is divided into four distinct lighting zones based on roadway types, adjacent land uses and traffic volume data. Figure 9.1 shows the lighting zone map. Table 9.2 shows the dimmed lighting levels and time of day that may be applied to each lighting zone.

HOUSING

1. LED FIXTURE SHALL HAVE A 10 YEAR WARRANTY ON LED MODULES, DRIVERS, AND FINISH.
2. HOUSING SHALL BE PRIMARILY CONSTRUCTED OF ALUMINUM WITH POWDER COAT GRAY FINISH. ALL MOUNTING HARDWARE SHALL BE NON-CORROSIVE OR SUITABLE PROTECTED METAL.
3. THE HOUSING SHALL BE ABLE TO WITHSTAND 1000 HOUR SALT SPRAY TEST ASTM 117.
4. LUMINAIRE SHALL MOUNT TO A HORIZONTAL 2.375" O.D. TENON WITH NO MORE THAN 4 BOLTS, WITH NO REARRANGEMENT OF PARTS OR SEPARATE PARTS NEEDED TO INSTALL AND HAVE STEP TYPE LEVELING.
5. WEIGHT SHALL NOT EXCEED 28 LBS. WITH AN EPA OF LESS THAN 1.2 SQ FT.
6. COOLING SHALL BE DONE WITH HEAT SINKS. NO FANS, PUMPS, OR LIQUIDS SHALL BE USED.

FIELD

OPTICS

1. LUMINAIRE SHALL MEET THE IESNA FULL CUTOFF CLASSIFICATIONS (BUG RATING OF U0) AND HAVE IESNA TYPE II, TYPE III OR TYPE IV DISTRIBUTION.
2. LUMINAIRE SHALL HAVE AN OPTION FOR A FIELD INSTALLABLE HOUSE SIDE SHIELD FROM THE MANUFACTURER.
3. CORRELATED COLOR TEMPERATURE (CCT) SHALL BE ±3000K ±300K. COLOR RENDERING INDEX (CRI) OF 70 OR GREATER.
4. LUMEN MAINTENANCE AT 50,000 HRS AND 25°C BASED ON TM-21 TESTING SHALL BE 92% OR GREATER.
5. LUMINAIRE IES FILES MUST BE GENERATED IN ACCORDANCE WITH IESNA STANDARD LM-79-08 FOR ABSOLUTE PHOTOMETRY, BY NVLAP ACCREDITED LAB.

TERMINAL BOARD

1. THE TERMINAL SCREWS SHALL BE OF CAPTIVE TYPE AND EACH SCREW SHALL BE EQUIPPED WITH WIRE GRIPS WHICH WILL AUTOMATICALLY BE RAISED AND LOWERED AS THE TERMINAL SCREW IS OPERATED.
2. THE TERMINALS SHALL BE CAPABLE OF ACCEPTING #8 TO #14 AWG CONDUCTORS.
3. THE TERMINAL BOARD SHALL HAVE THREE TERMINALS; ONE OF THESE TERMINALS SHALL BE FOR THE SYSTEM GROUND AND SHALL BE CONNECTED TO THE LUMINAIRE HOUSING.
4. ALL LUMINAIRES SHALL HAVE PHOTOCELL RECEPTACLE. THREE ADDITIONAL TERMINALS SHALL BE PROVIDED FOR EXCLUSIVE PHOTOCELL OPERATION.
5. ALL UNITS ARE TO BE PREWIRED TO A SINGLE TERMINAL BOARD REQUIRING ONLY CUSTOMER CONNECTIONS TO CLEARLY IDENTIFIED TERMINALS.

DRIVER

1. DRIVER & LED MODULES SHALL BE REPLACEABLE AS SEPARATE UNITS, & HAVE PLUG CONNECTIONS.
2. LED DRIVER SHALL ACCEPT 120V THRU 277 60HZ INPUT, AND SHALL HAVE POWER FACTOR OF 0.90 MINIMUM.
3. LED DRIVER SHALL BE CAPABLE OF 0-10V DIMMING. DIMMING LEADS SHALL BE WIRED TO PINS 4 AND 5 OF PHOTOCELL RECEPTACLE.
4. POWER SUPPLIES SHALL MEET APPLICABLE FCC GUIDELINES FOR INTERFERENCE, WITH TOTAL HARMONIC DISTORTION LESS THAN 20%.
5. LUMINAIRE SHALL HAVE SURGE PROTECTION DEVICE (SPD) TO WITHSTAND HIGH REPETITION NOISE TRANSIENTS AS RESULT OF UTILITY LINE SWITCHING, NEARBY LIGHTING STRIKES, AND OTHER INTERFERENCE. THE SPD SHALL PROTECT FROM DAMAGE AND FAILURE FOR COMMON AND DIFFERENTIAL MODE TRANSIENT PEAK CURRENT UP TO 10KA (MINIMUM). SPD CONFORMS TO UL 1449. SPD PERFORMANCE HAS BEEN TESTED PER PROCEDURES IN ANSI/ IEEE C62.41:2002 CATEGORY C HIGH EXPOSURE AND ANSI C136.2 10KV BIL. THE SPD SHALL FAIL IN SUCH A WAY AS THE LUMINAIRE WILL NO LONGER OPERATE. THE SPD SHALL BE FIELD REPLACEABLE.

~~GENRAL~~ GENERAL

1. UNIT SHALL BE UL1598 TESTED AND HAVE APPROVED REPORT SHOWING FIXTURE CAPABLE OF OPERATING IN AMBIENT TEMPERATURES OF -7°C TO 50°C.
2. LUMINAIRE HOUSING SHALL BE OR ETL LISTED FOR WET LOCATIONS. OPTICS/OPTICAL ENCLOSURE SHALL IP65 RATED.
3. LUMINAIRE SHALL HAVE BEEN TESTED FOR L70 LUMEN DEPRECIATION, EFFICACY AND CCT PER IESNA STANDARD LM-80-08.
4. ELECTRONIC IES FILES MUST BE READILY AVAILABLE FOR DOWNLOAD ON MANUFACTURER WEBSITE.
5. LUMINAIRE SHALL HAVE A 7-PIN LOCKING PHOTOCELL RECEPTACLE MEETING ANSI C136.41-2013. PROVIDE A 30 AMP LOW PROFILE SHORTING CAP FOR LUMINAIRES THAT DO NOT REQUIRE PHOTOCELL, PER APPROVED PRODUCTS LIST.
6. LUMINAIRE SHALL HAVE A MINIMUM EFFICACY OF 102 LUMENS PER WATT AT 3000K.
7. LUMINAIRE SHALL HAVE LUMEN OUTPUTS AT CCT OF 3000 KELVIN AS SHOWN IN THE TABLE BELOW.

TYPE	NOMINAL LUMENS	TOLERANCE
~~3~~KL	3300	±15%
~~5~~KL	5300	±15%
~~9~~KL	9100	±10%
~~13~~KL	13000	±10%
~~16~~KL	16500	±10%
~~21~~KL	21000	±10%
~~27~~KL	27000	±10%

Delete K for simplicity

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LED LUMINAIRE

SHEET NO. SL-71.01

Incorporate LED luminaire label specifications on to this sheet. See the "Mesa LED Labels" PDF and CAD file that was provided.

Match the nominal lumens shown on SL-71.01

DATA TABLE

LED LUMENS	LAMP TYPE	FIXTURE WATTAGE	FIXTURE VOLTAGE	I.E.S. DIST. TYPE	P.C. RECPT.	COLOR
3,300	LED	25	120x27V.	II	7 PIN	GRAY
3,300	LED	25	120x27V.	II	7 PIN	BRONZE
5,300	LED	40	120x27V.	II	7 PIN	GRAY
5,300	LED	40	120x27V.	II	7 PIN	BRONZE
9,100	LED	90	120x27V.	II	7 PIN	GRAY
9,100	LED	90	120x27V.	II	7 PIN	BRONZE
13,000	LED	125	120x27V.	II	7 PIN	GRAY
13,000	LED	125	120x27V.	II	7 PIN	BRONZE
13,000	LED	125	120x27V.	III	7 PIN	GRAY
13,000	LED	125	120x27V.	III	7 PIN	BRONZE
16,500	LED	132	120x27V.	III	7 PIN	GRAY
16,500	LED	132	120x27V.	III	7 PIN	BRONZE
21,000	LED	193	120x27V.	III	7 PIN	GRAY
21,000	LED	193	120x27V.	III	7 PIN	BRONZE
27,000	LED	280	120x27V.	III	7 PIN	GRAY
27,000	LED	280	120x27V.	III	7 PIN	BRONZE
9,100	LED	90	120x27V.	III	7 PIN	CREOLE
16,500	LED	132	120x27V.	III	7 PIN	CREOLE

LED LUMINAIRE DATA TABLE

SHEET NO. SL-71.02

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TIME DELAY PHOTO ELECTRIC CONTROL REQUIREMENTS

PC-101	PC-101 IS 105 - 135 VOLTS, 50/60HZ AC (120V NOMINAL)
PC-102	PC-102 IS 200 - 300 VOLTS, 50/60HZ AC

PHYSICAL

SIZE	SEE DRAWING
WEIGHT	APPROXIMATELY 7 OZ. GROSS
CHASSIS	MOLDED PHENOLIC WITH 3 POLE TWISTLOCK PLUG WITH CROSS LINKED POLYETHYLENE GASKET.
HOUSING	U.V. STABILIZED POLYPROPYLENE WITH ACRYLIC WINDOW WITH ULTRAVIOLET INHIBITOR.
COLOR CODE	PC-101 IS GRAY PC-102 IS MAROON

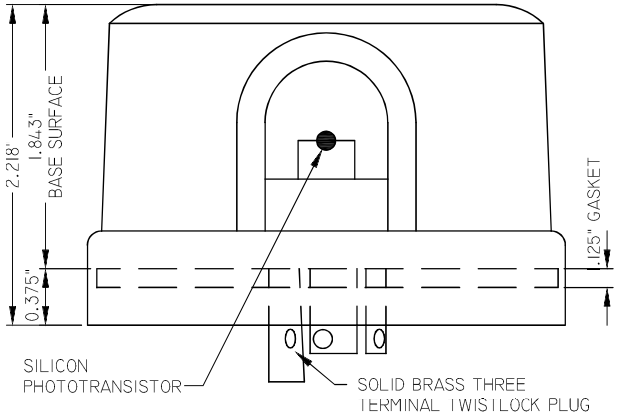
ELECTRICAL

SUPPLY VOLTAGE	PC-101 IS 105 - 135 VOLTS, 50/60HZ AC (120V NOMINAL) PC-102 IS 200 - 300 VOLTS, 50/60HZ AC
RATINGS LOAD	1000 WATTS / 1800VA MAX. SPST, N.C. (1000 WATTS TUNGSTEN) (1800VA MERCURY VAPOR, HIGH PRESSURE SODIUM)
INRUSH CURRENT	130 AMPERES AT 120 VOLTS 65 AMPERES AT 240 VOLTS
OPERATING LEVELS	TURN ON AVERAGE 1 FC ±0.25 FC TURN OFF BY 2.25 FC OFF TO ON RATIO: 1.5:1
CONTROL POWER	3.2 WATTS, MAXIMUM (2.75 AVERAGE) AT 240 VAC.
DIELECTRICAL STRENGTH	5 KV MINIMUM BETWEEN ANY CURRENT CARRYING PART AND METAL MOUNTING SURFACE.
SURGE SUPRESSOR	~~300~~ JOULE MOV / 13000 AMPS
PHOTOCELL	SILICON PHOTOTRANSISTOR
TIME DELAY	OFF CYCLE ONLY, 3 TO 30 SECONDS

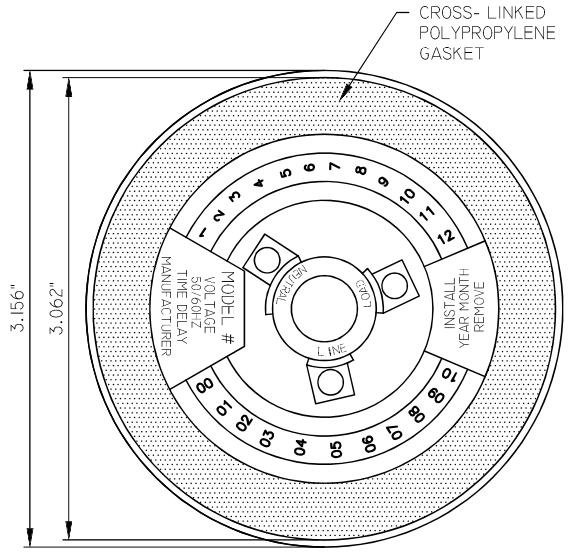
ENVIRONMENTAL

AMBIENT TEMPERATURE RANGE	-40 TO 70 DEGREES C
MOISTURE RESISTANCE	100% RELATIVE HUMIDITY
WARRANTY	~~5~~ 10 YEARS FROM DATE OF MANUFACTURING

MINIMUMUM 510



NORTH SIDE VIEW



BOTTOM VIEW

NOT TO SCALE

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TIME DELAY PHOTO ELECTRONIC CONTROL

SHEET NO. SL-72

LED LUMINAIRE LABEL SPECIFICATIONS

1. LUMINAIRE SHALL HAVE AN EXTERNAL LABEL FOR FIELD IDENTIFICATION.
   a. LABEL SHALL MEET THE PHYSICAL REQUIREMENTS, DIMENSIONS, AND FONT SIZE PER ANSI C136.15 (2015): LARGE 3" MARKER TYPE.
   b. TOP ROW OF LABEL SHALL INDICATE LUMINAIRE WATTAGE ROUNDED TO NEAREST 10 WATTS PER ANSI C136.15 (2015).
   c. BOTTOM ROW OF LABEL SHALL INDICATE LUMEN DESIGNATION TYPE PER FIRST COLUMN OF TABLE ON SL-71.01.
   d. SEE EXAMPLE LABELS BELOW FOR INFORMATION TO BE SHOWN ON LABEL: