

City and County of Denver

Street Lighting Design Guidelines & Details



Department of Public Works
Engineering Division

September 2019

Developed by:



The City and County of Denver Public Works Department

CLANTON & ASSOCIATES



LIGHTING DESIGN AND ENGINEERING

Clanton & Associates, Inc.

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List of Abbreviations

A – Amps
ANCI – American National Standards Institute
AP – Access Point
B – Backlight
BID – Business Improvement District
BUG – Backlight, Uplight, and Glare
C – Celsius
CCD – City & County of Denver
CFR – Code of Federal Regulations
CCT – Correlated Color Temperature
cd/m² – Candela per Square Meter
CMS – Central Management System
CRI – Color Rendering Index
D – Depth
EMI – Electromagnetic Interference
FC – Footcandles
FTP – File Transfer Portal
G – Glare
GPS – Global Positioning System
H – Height
HID – High Intensity Discharge
HPS – High Pressure Sodium
Hz – Hertz
IRMS – Current Root Mean Square
IEEE – Institute of Electrical and Electronics Engineers
IES – Illuminating Engineering Society
IP – Ingress Protection
J – Joules
K – Kelvin
LDD – Luminaire Dirt Depreciation
LED – Light Emitting Diode
LLD – Luminaire Lumen Depreciation
LLF – Light Loss Factor
MH – Metal Halide
NEC – National Electric Code
NESC – National Electric Safety Code
NIC – Network Interface Controller
PF – Power Factor
RFI – Radio Frequency Interference
RMS – Root Mean Square
ROW – Right of Way
SLV – Streetlight Vision Luminaire
THD – Total Harmonic Distortion
U – Uplight
UV – Ultraviolet
V – Volts
VAC – Volts Alternating Current
VDC – Volts Direct Current
VRMS – Volts Root Means Square
W – Watts

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Chapter

1



1 Background and Purpose

This document establishes guidelines for all lights installed in the public ROW.

The *City and County of Denver Street Lighting Design Guidelines* have been developed to establish a standard for the application of lighting within the public right-of-way. This document is intended to help Designers, Contractors, Plan Reviewers, and other users verify that ROW lighting plans meet the City and County of Denver's (CCD's) Technical Plan Review Criteria along with the specifications and standards of the Owner of the lighting system. It is critical that all users of this guideline determine who will own the lighting system before the lighting design occurs. Refer to Appendix B for more information on who could own the lighting system.

These *Street Lighting Design Guidelines* are comprised of the following chapters:

- Chapter 2 Street Light General Guidance Equipment Ownership establishes the primary design and payment difference between Xcel Energy owned lights, City and County of Denver (CCD) owned lights, or District owned lights.
- Chapter 3 Fundamentals of Lighting Design establishes important factors in lighting design along with describing how to set up lighting design software calculations.
- Chapter 4 Luminaire Specification lists the key requirements when selecting a CCD, District owned, or Xcel Energy owned light.
- Chapter 5 Lighting Applications describe the typical process when determining and establishing lighting levels, along with examples of typical lighting applications.
- Chapter 6 Adaptive Street Lighting describes how a City owned control system would determine dynamic lighting levels with adaptive dimming.
- Chapter 7 Infrastructure lists new infrastructure requirements for all new light standards.

The Streetlight Design Guide relies on roadway lighting design guidelines issued by the Illuminating Engineering Society (IES). This Streetlight Design Guide reference IES's *American National Standard Practice for Roadway Lighting* (Recommended Practice 8 [RP] Affirmed in 2018). RP-8 is the nationally recognized industry recommendation for roadway lighting.

CCD reserves the right to approve deviations from these guidelines as long as deviations meet the general intent of these guidelines.

1.1 Typical Street Light Installations

CCD will allow four different street lighting deployments to be installed in CCD public right-of-way (ROW). All lighting within the public ROW requires that above grade and in-grade infrastructure be

installed. Above grade infrastructure includes but is not limited to the light standard (pole), mast arm, luminaire, photocell or control node, control system AP, transformer or secondary service pedestal, and the lighting control center and meter when required by the Project. The in-grade infrastructure includes, but is not limited to the foundation, splice box(es), conduit and wiring. Each of these infrastructure items will be selected and sized per the Project.

The infrastructure is required to ensure the lighting system is equipped to the best of CCD's ability for future smart city equipment and future Type 3 small cell replacements. Type 3 small cells involve the removal of existing streetlights and replacement with a new combination small cell and streetlight pole. These Type 3 installations are expecting to replace the majority of existing streetlights in CCD as cellular network providers begin to support and install 5G cellular towers in CCD. Refer to the *City and County of Denver Small Cell Infrastructure Design Guidelines* for more information about small cell equipment allowed in CCD public ROW.

The type of streetlight installation listed below only applies to new streetlight installations when an entire corridor within the City is being redesigned. These installations do not apply to one-for-one LED replacement unless all the streetlights associated with a single feeder are being replaced with new infrastructure. These installations do not apply to pedestrian lighting or other non-streetlight installations.

- **Streetlight Type I** – Xcel Energy Owned Standard Streetlight Only
One streetlight electrical splice box, street lighting foundation (12" bolt circle) with galvanized streetlight standard, straight mast arm and LED cobra head luminaire. Light standards should include a handhole at the bottom of the pole and at the top of the pole opposite the mast arm.
- **Streetlight Type II** – City / District Owned Standard Streetlight Only
One streetlight electrical splice box, street lighting foundation (12" bolt circle) with galvanized streetlight standard, straight mast arm and LED cobra head luminaire. Light standards should include a handhole at the bottom of the pole and at the top of the pole opposite the mast arm.
- **Streetlight Type III** – City Owned Standard Streetlight with Small Cell Capability
Three small cell splice boxes, small cell foundation (24" bolt circle with 12" adaptor plate), galvanized small cell light standard, straight mast arm and LED cobra head luminaire. Refer to the *City and County of Denver Small Cell Infrastructure Design Guidelines* for more information about allowable small cell equipment sizes.
- **Streetlight Type IV** – City Owned Type 3 Small Cell/ Streetlight Combination Pole.
Three small cell splice boxes, small cell foundation (24" bolt circle), small cell equipment cabinet, small cell pole, antenna, straight mast arm and LED cobra head luminaire. Small cell standards should include six handholes along the standard with gasketed handholes for cable runs. Refer to the *City and County of Denver Small Cell Infrastructure Design Guidelines* for more information about allowable small cell equipment sizes.

Chapter

2



2 Streetlight General Guidance

When beginning a lighting and electrical design within CCD one of the most important questions to ask is “Who will own and maintain the lighting and electrical equipment.” For most lighting within the public ROW, the answer will typically be either CCD or Xcel Energy. Ownership establishes the primary design and payment difference between Xcel Energy owned lights, CCD owned lights, Developer owned lights, or District owned lights.

Refer to Chapter 2 for information about designing and maintained lighting within the public ROW.

Important Street Lighting Design Questions

The following is a list of questions to ask when beginning a lighting design.

- **Who will own the equipment?**

All lighting levels within these guidelines shall be met no matter who owns the equipment. See Appendix B for the Ownership Construction Path flowchart.

If CCD owns the equipment, then all equipment requirements established in these guidelines must be met. It is important to note that CCD has substantially different electrical design requirements than Xcel Energy, and is required to meet the National Electric Code (NEC).

If Xcel Energy owns and maintains the equipment, then a Xcel Energy approved luminaire and infrastructure equipment should be selected to meet the lighting levels established in these guidelines. The equipment shall be per Xcel Energy’s standards and the National Electric Safety Code (NEC). Consult the current version of Xcel Energy’s *Outdoor Lighting Manual* for more information.

If a private party or District owns and maintains the equipment, then the equipment should be selected to meet the intent of these guidelines and meet the standards of the private party.

- **What type of project is this?**

The project design team and the City Engineering Review should ensure that all lighting within the public right of way meet the intent of the lighting equipment specifications and target lighting levels listed in these guidelines.

- **City Managed Capital Project:** These projects include new street lighting, traffic signal mounted streetlights, or pedestrian lights. The selected lighting equipment shall meet all requirements established in this guideline including: type of infrastructure installed, luminaire specifications, control specifications, and appropriate target level per the Lighting Application.

- **Outside Agency Project:** Other agencies, such as Xcel Energy, that are installing lighting within the public right-of-way shall meet the intent of the lighting specifications listed in Section 4 and the infrastructure requirements listed in Section 1.1. The project lighting design shall meet the target illuminance levels per the appropriate Lighting Application in Section 5.3.
- **Private Development Project:** The Developer and City Engineering Reviewer shall ensure that all lighting equipment installed for the project meets the lighting specifications listed in Section 4. The project target illuminance levels shall be selected per the appropriate Lighting Application in Section 5.3.
- **Privately Installed Lights:** The owner of the private lighting shall ensure that all new lighting installations meet the lighting specifications listed in Section 4 and the maximum BUG ratings (backlight, uplight, and glare) listed per the appropriate Lighting Application in Section 5.3. If the private lighting illuminates the public right-of-way, the target lighting levels should be selected from Section 5.3.

■ **Will there be federal funds involved in the construction of the project?**

If federal funds are used as a portion of the Project’s funding source, then an electrical engineer shall be consulted in the design of the electrical lighting system. The electrical engineer must be licensed in the State of Colorado and shall stamp the plans prior to Construction. This shall be true whether the City, Xcel Energy, or a private party owns the lighting infrastructure.

If City or District funds are used for the construction of the Project (no federal funds are used), then an electrical engineer shall be consulted if the City or District will own the equipment; the electrical engineer shall be responsible for stamping the plans. If Xcel Energy will own and maintain the equipment, then an Xcel Energy electrical engineer will typically design the electrical system.

Refer to Appendix B Ownership Construction Path flowchart for more information on the design process when federal funds are or are not involved in a project.

■ **What are the lighting styles adjacent to this Project?**

All new streetlight standards should have 3000K CCT LED cobra head luminaires, with a straight mast arm and tapered, round non-painted galvanized steel light standard unless the following conditions apply:

- If the Project is immediately adjacent to light standards painted federal green, black, or other special color, then this style may be utilized for the new Project.
- If the Project is within a Historic District or Business Improvement District (BID) the new luminaires and light standards should match the pre-approved lighting characteristics. Contact the local district or BID for more information about what style of light to install.
- If the lighting is for a special application, not listed in this guideline, that requires a deviation. For example, 4000K CCT LED luminaires should be installed in roadway tunnels to improve daytime adaptation and motorist visibility.

■ **What is the adjacent space use?**

Adjacent land use should be considered prior to beginning the lighting design. The luminaires’ characteristics of light (ie: Backlight-Uplight-Glare rating) may vary depending on whether the luminaire will be installed next to a residential property or in a downtown environment. Refer to the Lighting Applications for more information.

■ **What should be shown on the lighting plans?**

A list of the technical plan review criteria is provided in Appendix A. This list includes technical criteria to be listed in the project plans and specifications. Deviations from the technical plan review criteria should be approved by the CCD Project Manager.

Chapter

3



3 Fundamentals of Lighting Design

This chapter of the Guide provides technical background information relevant to these guidelines, how to determine classifications, and steps in performing light level calculations.

Refer to Chapter 3 for information about lighting design considerations and how to set up lighting software calculations.

3.1 Factors in Lighting Design

Effective lighting design depends on the control and consideration of six factors: illuminance, luminance, uniformity, glare, contrast, and adaptation. All factors must be adequately addressed to increase visibility.

Visibility

The ability for motorists and pedestrians to see and detect objects and other pedestrians at night, depends on task visibility. Object visibility may include obstacles in the roadway, street signs, or identifying pedestrians in a crosswalk. The visibility of an object is dependent on the size, brightness, vertical luminance, and contrast of all the objects in an area. Increasing the amount of light (brightness and luminance) that falls on an object increases the task visibility. However, the object brightness must be balanced with its surroundings to prevent light source glare.

Wayfinding

Wayfinding refers to the visual guidance provided by the lighting, such as a light at the corner of an intersection or lighting a sign. The lighting system may also provide wayfinding by establishing consistent patterns and visual cues. For instance, bollards and pedestrian poles often signify pedestrian walkways or plazas, while roadway light standards imply a roadway.

Illuminance

Illuminance is the primary lighting metric used for non-roadway applications such as crosswalks, walkways, and bike paths. Illuminance is the amount of light reaching a surface, expressed in units of footcandles (fc). Horizontal illuminance refers to the amount of light falling on a horizontal surface, such as pavement. Vertical illuminance is to the amount of light falling on a vertical surface, such as a person, which is critical for drivers to be able to see pedestrians in a crosswalk.

This metric should only be used for pedestrian areas, curved roadways, or for vertical illuminance requirements, as it does not address surface brightness which a person sees. Another metric, luminance, is used to determine the surface brightness.

Luminance

Luminance is reflected light, or the brightness of a surface or an object in an individual's field of view. It is measured in units of candela per square meter (cd/m^2). This metric is important because, unlike illuminance, luminance best describes what a person sees.

In roadway lighting, pavement luminance refers to how bright the pavement appears to motorists. When the pavement is under-lighted, it is harder to see pavement markings and small objects on the road. Higher pavement luminance provides the driver with visual information on the roadway boundaries, and conflict areas such as crosswalks and intersections. More reflective, lighter colored surfaces, such as concrete, reflect more light than darker, less reflective surfaces, such as asphalt; less light is required for more reflective surfaces, like concrete, to provide the same luminance level.

Uniformity

Lighting uniformity is defined as the evenness of light. Our eyes are continually adapting to the brightest object in our field of view. Any object lighted to even 1/10 the brightest level of the immediate surroundings appears noticeably darker. Uniformity that meets the lighting criteria allows the pavement and sidewalk to be evenly lighted. However, too uniform surfaces (1:1 average to minimum) may minimize surface contrast of an object, which can cause some objects to blend into the background, making them harder to detect. A balance is required between uniformity and contrast.

Contrast

Contrast is the difference between the luminance values of two adjacent surfaces. High contrast is necessary for good visibility. However, if the contrast becomes excessively high, the brighter surface can become a source of glare.

Surface or object contrast provides motorists the most information for guidance. When contrast is diminished, such as flat daylight on snow packed roads, or when objects on the road have the same luminance as the pavement background, then navigation becomes difficult. It is important to keep strong object contrast for all tasks.

Glare

Direct glare is caused by excessive light entering the eye from a bright light source. A system designed solely on lighting levels tends to aim more light at higher angles to increase pole spacing, thus producing more glare potential. With direct glare, the eye has a harder time seeing contrast and details. Direct glare can be minimized with careful equipment selection and placement.

Adaptation

Adaptation refers to the eye's ability to quickly adjust between changes in luminance; but when luminances are decreased, the eye's ability to adjust takes longer. The time required for adaptation increases with age due to normal structural and chemical changes in the eye.

Light Trespass / Light Pollution

Light trespass is often referred to as nuisance glare or the "light shining in my window" effect. Not only does light trespass cause neighbor annoyance, but it also increases light pollution. Refer to IES RP-33 for a complete discussion on minimizing light trespass and light pollution.

Uncontrolled light sources are usually the cause of light trespass. However, even a shielded luminaire may cause light trespass due to the location, height, orientation, and aiming of the luminaire. If the location is not opportune and cannot be changed, additional shielding may be required. The luminaire head should be leveled and plumb with the foundation, rather than aimed upward or downward.

Over lighting areas will increase reflected light which will result in poor adaptation between the brightly lighted area and adjacent non-lighted areas. Over lighting should be avoided as it increases light trespass and light pollution.

Light pollution, or sky glow, is caused by light aimed directly up into the sky, by light emitted directly at the near-horizontal angles, and by light reflected off the ground or objects. Direct light, rather than reflected light, is the most significant cause of light pollution. Acorn style pedestrian lights, floodlights, wall packs, and other luminaires with uplight components are major contributors to sky glow. Over lighting, even with luminaires that produce little to no uplight, reflects unnecessary light back into the atmosphere and adds to sky glow. Figure 3-1 shows a view of Denver and the results of uncontrolled light pollution.

To minimize light pollution, do not over light areas and use luminaires with little to no uplight, which will be noted by a U0 rating. Dimming lights during periods of lower traffic and pedestrian volumes, when snow cover increases pavement reflectance, and during curfew hours, will also reduce light pollution and light trespass. To minimize light trespass, use low glare (G) and minimal backlight (B), Refer section 3.4 for more specifics.

Figure 3-1: City of Denver light pollution from Mt. Evans Observatory
©University of Denver – Astronomy Department



3.2 Non-Visual Effects of Light

The following paragraphs about non-visual effects of light at night on humans and the ecosystem is taken from IES RP-33-14 *Lighting for Exterior Environments*. Please refer to IES RP-33 for more information.

“While much more research is required to fully understand the interaction between electric light sources and animals and plants, the likely overall negative impact is not in doubt. The examples cited here are intended as representative of ongoing research. When development is considered in environmentally sensitive areas, the use and application of nighttime lighting should be carefully reviewed. At the most basic level, the way to do this is to remove unnecessary lights, turn off lights except when needed, reduce the amount of light, block light from entering sensitive areas, and direct light only where it is needed. For example, as a rule of thumb, the equivalent of full moonlight (0.01 fc average) should be considered adequate unless there are specific requirements for higher levels of illumination in these sensitive areas.

IES TM-18-08 indicates that exposure to optical radiation affects human physiology and behavior, both directly (acute effects including melatonin suppression, elevated cortisol production, increased core temperature) and indirectly (resetting the internal circadian body clock). There is no confirmation that typical exposure to exterior lighting after sunset lead to cancer or other life-threatening conditions. Some of the uncertainty about the research in this area arises from the differences in spectral sensitivity between the visual and non-visual responses to optical radiation. The position of the IES is that typical exposures to exterior lighting after sunset have not been shown to lead to cancer or other life-threatening conditions.

Electric lighting has impacts on animal communities, from insects to large predators. It disrupts normal breeding, predation and predator avoidance, migration, feeding, communication, and social interactions – in short, every aspect of animal life. Almost all small rodents and carnivores, 80% of marsupials, and 20% of primates are nocturnal. Lighting in sensitive areas should minimize the duration, direct the light only where needed, reduce intensity as much as possible (no more than full moonlight as a guideline), and consider how the spectral power distribution affects the sensitive species.

Plants have evolved a wide range of photoreceptors that perceive and respond to light signals in the ultraviolet, blue, red, and near-infrared regions of the electromagnetic spectrum. Plants that are sensitive to photo-periodicity in their flowering, bud dormancy, or leaf senescence in response to day length may be adversely affected by prolonged light. They need sunlight during the day

and darkness at night to sustain a healthful life. Landscape lighting that is left on continuously at night is seldom necessary, and should be avoided.”

3.3 Correlated Color Temperature (CCT)

The correlated color temperature (CCT) rating is a metric that describes how "warm" or "cool" a light source appears to be. Light sources with a CCT rating below 3200K are usually considered "warm" and more closely match firelight while those with a CCT at or above 4000K are usually considered "cool" in appearance. Anything in between 3200K and 4000K is considered "neutral." See Figure 3-2 for an example of "warm" and "cool" color temperatures.

Figure 3-2: Correlated Color Temperature Diagram

Temperature*	Source
1700 K	Match flame, low pressure sodium lamps (LPS)
1850 K	Candle flame, sunset/sunrise
2400 K	Standard incandescent lamps
2700 K	Soft white compact fluorescent and LED lamps
3000 K	Warm white compact fluorescent and LED lamps
3200 K	Studio lamps, photofloods, etc.
4100 – 4150 K	Moonlight
5000 K	Horizon daylight
5500 – 6000 K	Vertical daylight, electronic flash
6500 – 9500 K	LCD or CRT screen

All streetlights should have a correlated color temperature (CCT) of 3000K or less.

*These temperatures are merely characteristic; considerable variation may be present.

3.4 BUG Ratings

The luminaire BUG (Backlight-Uplight-Glare) rating system, as defined in IES TM-15-11, provides a numerical rating of the luminaire light distribution as it applies to light trespass, uplight, and glare. BUG ratings are defined by the zonal lumen output within the distribution angles of the luminaire. In general, a higher BUG rating means that more light is emitted at each angle. The selected luminaire must not exceed the BUG rating requirements listed in the Lighting Applications.

Figure 3-3: BUG Rating Diagram

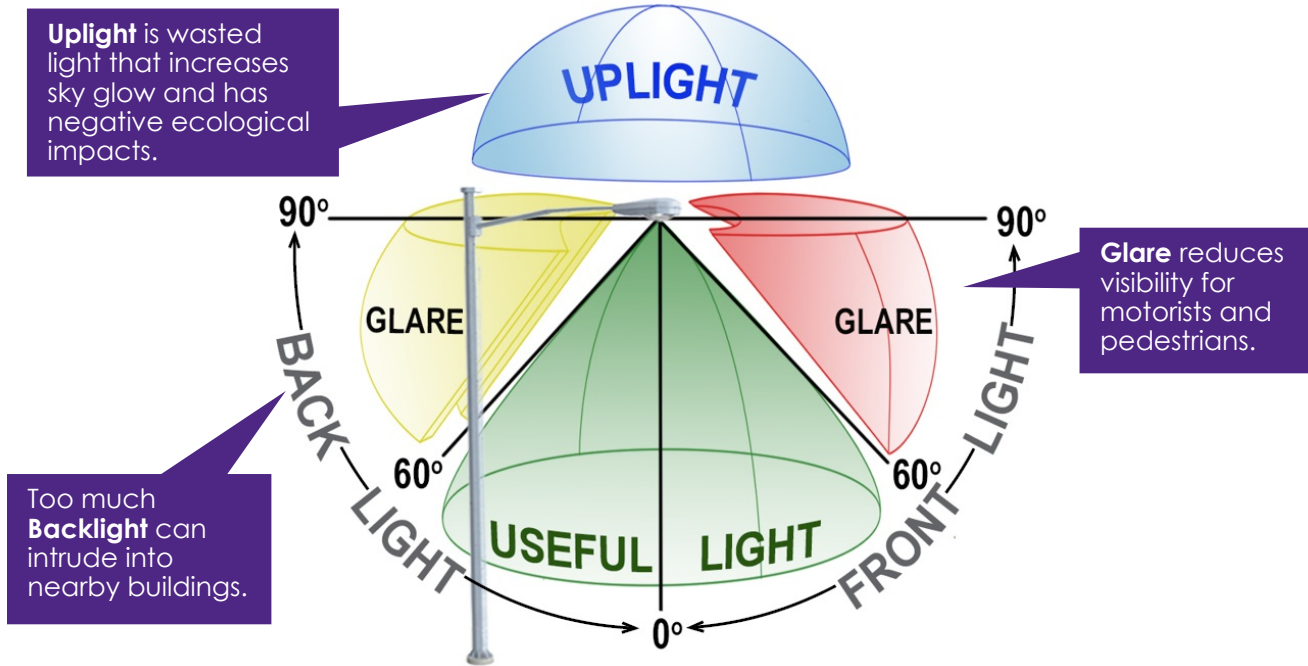
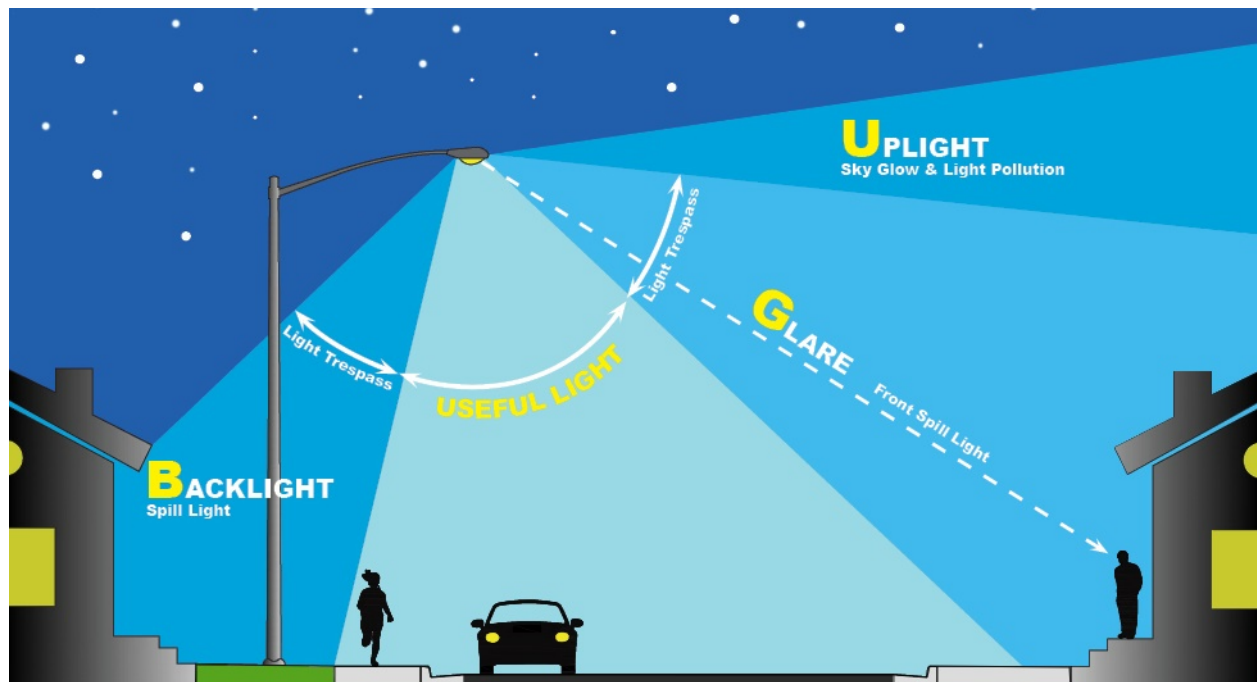


Figure 3-4: BUG Ratings Applied to a Streetscape



Backlight (B) is the amount of light behind the luminaire. Backlight can result in unwanted light trespass onto adjacent surroundings, or it may provide beneficial lighting for sidewalks behind the amenity zone. The quantity of backlight should be carefully considered in these instances.

Uplight (U) is the amount of light in the upper 90 degrees of the luminaire. Low angle uplight (from 80° to 100°) is the largest cause of sky glow and adversely affects astronomy, smog levels, and the view of the night sky. Higher angle uplight, angles greater than 100 degrees, is generally wasted light.

Glare (G), as described in 3.1, can be annoying or disabling. While high angles of front light allow the light to be thrown further, any angle above 63° can cause disability glare and therefore should be minimized. Luminaires that have a glare rating greater than G3 have the greatest potential for disability glare. Luminaires with lower glare ratings (G2 or lower) are preferred.

3.5 Lighting Layouts

An opposite lighting layout is recommended when designing a new streetlight installation in order to minimize neutral contrast occurrences. Neutral, vertical contrast occurs when an object is both positively contrasted (light strikes the front of the surface) and negatively contrasted (light strikes the back of the surface, causing a silhouette). The equal levels of positive and negative contrast result in uniform lighting of the object, making it difficult to distinguish from background surfaces. A depiction of an opposite arrangement with neutral, vertical contrast is shown in Figure 3-5 and Figure 3-6.

Many existing light layouts have a staggered arrangement. This lighting arrangement results in a higher quantity of roadway sections with neutral, vertical contrast. It is discouraged to use a staggered arrangement if possible.

Figure 3-5: Opposite Pole Arrangement

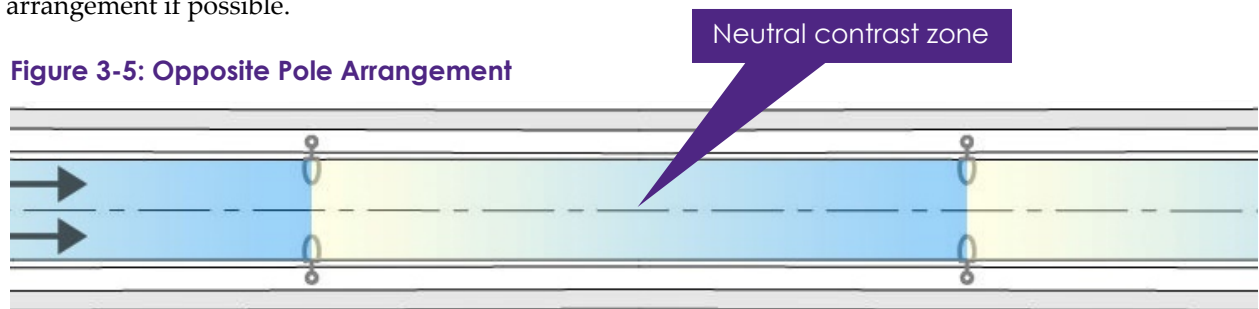
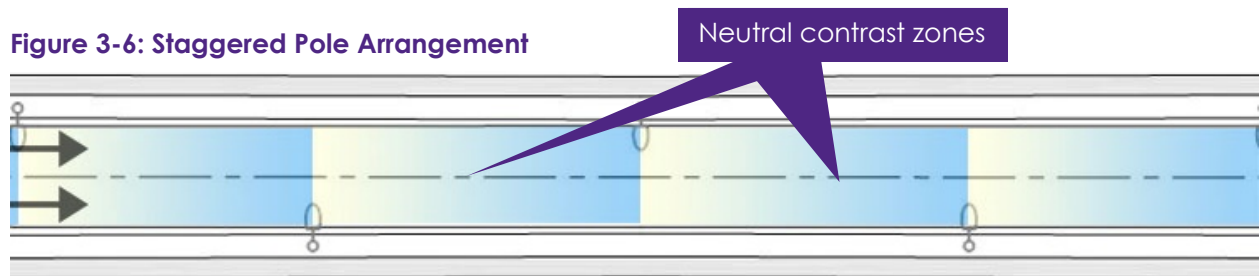


Figure 3-6: Staggered Pole Arrangement



Horizontal Curves

Streets that have a radius of 2,000 feet (600 meters) or less (measured from the center point to the curb face), can be calculated using the horizontal illuminance goals for straight streets. Streets that have a radius greater than 2,000 feet rounded to the nearest 100 feet, should be designed using luminance goals.

- Sharper radius curves (less than 2,000 feet, rounded to the nearest 100 feet) warrant closer spacing of luminaires to provide higher pavement illuminance.
- Poles should be located behind curb, guard rail or other natural barriers and, whenever possible, four feet behind the face of curb or six feet behind the edge of the shoulder.
- Place poles on inside of curve where feasible, there is some evidence that poles are more likely to be struck if placed on the outside of curves.
- Aim luminaires with mast arm perpendicular to the centerline of the street

Slopes

Streets with a grade less than six percent should be designed using luminance criteria. Streets that have a six percent grade or greater can be calculated using illuminance. Steeper grades often require closer spaced luminaires to provide higher pavement illuminances. Orient the luminaire and mast arm so that the luminaire is plumb to the streetlight foundation centerline and level (no tilt).

3.6 Lighting Calculations

The following sections document the parameters and considerations when calculating lighting levels.

Street Classifications

The following street and roadway definitions are per IES RP-8-18:

Intersections:

The traffic conflict area in which two or more streets join or cross at the same grade. The outside edge of pedestrian crosswalks defines intersection limits. If there are no pedestrian crosswalks, then the stop bars define the intersection. If there are no stop bars, then the intersection is defined by the radius return of each intersection leg. Intersection limits may also include the area encompassing channelized areas in which traffic is directed into definite paths by islands with raised curbing.

Freeway:

A divided highway with full control of access, often with great visual complexity and high traffic volumes. This common roadway is often found in major metropolitan areas in or near the central core and will operate at or near design capacity through some of the early morning, or late evening hours of darkness.

Expressway:

A divided highway with partial control of access.

Major (Arterial):

The part of the roadway system that serves as the principal network for through-traffic flow. The routes connect areas of principal traffic generation and important rural roadways entering and leaving the city. These routes are often known as "arterials". These routes primarily serve through traffic and secondarily provide access to abutting property.

Collector:

Roadways servicing traffic between major and local streets. These are streets used mainly for traffic movements within residential, commercial, and industrial areas. They do not handle long, through trips. Collector streets may be used for truck or bus movements and give direct service for abutting properties.

Local:

Local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property. They make up a large percentage of the total street system but carry a small proportion of vehicular traffic.

Pedestrian Activity Level Classifications

The following are pedestrian classification definitions per IES RP-8-18. The pedestrian counts should be taken during darkness hours when the typical peak number of pedestrians will be present. The lighting designer should determine what the typical peak hours are for each street. Common applications for each pedestrian activity level are listed next to the high, medium, or low pedestrian activity levels (ie: High – Event Center). These classifications are based on IES pedestrian activity level and are intended only to provide a quick reference. The pedestrian activity and adjacent land use should be considered for each area.

High (Event Center):

Areas with significant numbers (over 100 pedestrians an hour) of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, theaters, concert halls, stadiums, and transit terminals.

Medium (Retail/Office/Transit Station):

Areas where less numbers (10 to 100 pedestrians an hour) of pedestrians utilize the streets at night. Typical areas are downtown office areas, streets with libraries, apartments, neighborhood shopping, industrial, parks, and streets with transit lines.

Low (Residential):

Areas with very low volumes (10 or fewer pedestrians per hour) of night pedestrian usage. A low pedestrian classification can occur in any street classifications but may be typified by suburban streets with single family dwellings, very low density residential developments, and rural or semi-rural areas.

Determining Pedestrian Activity Levels

IES pedestrian volumes represent the total number of pedestrians walking in both directions in a typical block or 660 foot section. Pedestrian counts and traffic studies take precedence over other references. There are two options for determining pedestrian counts:

1. Take one (1) hour of pedestrian counts during the first or last hour of darkness on some selected days to establish the estimated pedestrian traffic count. One or two representative blocks, or a single block of unusual characteristics can be counted – such as a discharge from a major event.
2. Factor two (2) hour (such as 4-6PM) pedestrian counts crossing at intersections by 0.5 (to account for a one hour time period) and divide the count based upon the intersecting streets.
 - a. Matching street classes: Divide the count equally between the two streets.
 - b. Major/Local street: Allocate 80 percent of the total count to the major street and 20 percent to the local street.
 - c. Major/Collector street: Allocate 60 percent of the total count to the major street and 40 to the collector street.
 - d. Collector/Local street: Allocate 60 percent of the total count to the collector street and 40 percent to the local street.

Light Loss Factors

A light loss factor should be applied to every luminaire considered, to ensure that the maintained light levels will meet the target criteria. Table 3-1 lists typical light loss factors for LEDs and legacy products found throughout CCD.

Figure 3-7: High Pedestrian Activity Classification

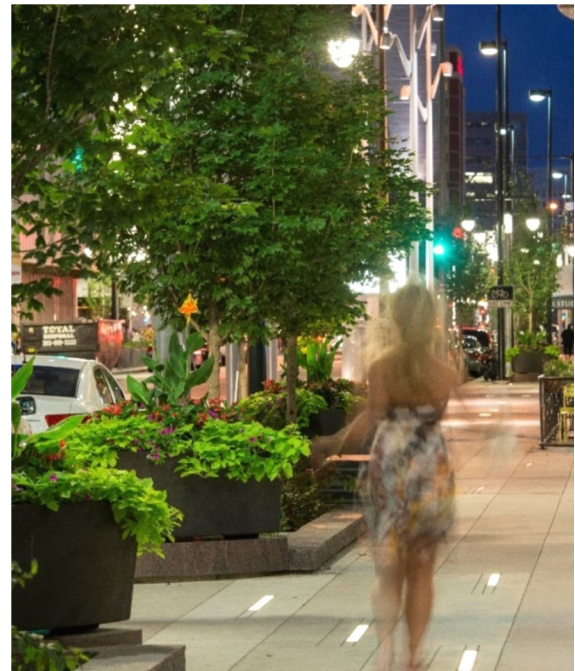


Figure 3-8: Pedestrians in Downtown Denver



Table 3-1: Typical Light Loss Factors

Light Source	Luminaire Dirt Depreciation (LDD)	Luminaire Lumen Depreciation (LLD)	Total Light Loss Factor (LLF)
LED	0.9	0.9 ¹	0.81 ²
HPS	0.9	0.9	0.81
MH	0.9	0.7	0.63

HPS: High Pressure Sodium

MH: Metal Halide

Roadway Calculation Process for Continuous Straight Streets

1. Determine the appropriate lighting level, per the Lighting Application(s), based on the street classification, pedestrian activity level, and intersection type.
2. Select a luminaire that meets the Lighting Application BUG ratings.
3. Calculate the roadway, intersection, crosswalk, bike lane, and sidewalk lighting levels with lighting software calculations. Appropriate light loss factors shall be used for each luminaire. When possible an opposite pole arrangement or single sided pole arrangement should be used over a staggered pole arrangement.
4. Maintain clearance from other elements in the public ROW: driveways (10 feet commercial and 5 feet residential), fire hydrants (5 feet), and trees (centered between trees, a minimum of 25 feet from the tree trunk). Place lights near property lines wherever practical and avoid locations in front of doorways, windows, and lines of egress.

Pedestrian Area Calculation Process

1. Determine the design parameters of the pedestrian area, including: connected sidewalk, detached sidewalk, bike pathway, or plaza.
2. Determine pedestrian activity level based on the Project location and how many people will likely be using the area.
3. Select a luminaire that meets the Lighting Application BUG ratings and preferred luminaire aesthetic.
4. Calculate the lighting levels with lighting software calculations. Appropriate light loss factors shall be used for each luminaire. Pedestrian lights should be a located a minimum of 30 feet from an adjacent streetlight.
5. Maintain clearance from other elements in the public ROW: driveways (10 feet commercial and 5 feet residential), fire hydrants (5 feet), and trees (centered between trees, a minimum of 25 feet from the tree trunk).

Crosswalk Calculation Process

Crosswalks require a lighting layout that will provide adequate vertical lighting to see pedestrians within the crosswalk. The general rule of thumb is locating a luminaire half to one pole height away from the crosswalk. This will provide vertical illumination and high contrast on the pedestrian. If the luminaire is located directly above the crosswalk, the pedestrian would not be visible, since only the top of the pedestrian is lighted, and the body will remain in silhouette.

1. Determine the design parameters of the crosswalk, including: obstacles that would obscure approaching pedestrians, traffic signals, flashing beacons, etc.
2. Determine the target lighting level based upon the street classification, intersection type, and level of pedestrian activity.
3. Select a luminaire that meets the Lighting Application BUG ratings.
4. Set up a horizontal illuminance calculation grid for the entire crosswalk.
5. Set up a vertical illuminance grid (5 feet above grade) spanning all lanes within a single direction of travel, facing oncoming traffic. The vertical grid points shall be spaced 2ft apart and shall be located in the center of the crosswalk.

¹ Use 0.9 or LM value provided by the Manufacturer at 60,000 hours, if L70 is greater than 100,000 hours

² If using an LM value provided by the Manufacturer, the Total LLF is equal to 0.9 x LM60,000hr

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Chapter

4



Refer to Chapter 4 for general information on luminaire and equipment specifications.

4 Luminaire Specification

All streetlights shall meet the characteristics listed in Section 4.2. The luminaire BUG ratings shall be per the Lighting Application detailed in Chapter 5. See Section 1.1 for ROW infrastructure information.

4.1 Finishes

For all new streetlight installations in CCD, the equipment color shall be selected from the list of available colors below. Should it be determined that a unique or non-standard color is appropriate based on character of adjacent infrastructure, the Designer shall propose appropriate colors for approval by CCD in writing. The Public Works Department reserves the right to modify proposed finishes prior to approval.

- **Galvanized or Light Gray (RAL 7038)** – Default finish to be used in new-build corridors, or in downtown or heavily urbanized locations where there are trends of galvanized light standards or gray streetlight heads.

If the adjacent infrastructure is painted, then the new installation may be painted to match.

Federal Green (RAL 6012) – Default finish to be used when matching adjacent streetlight or installations.

- **Black (RAL 9017)**
- **Dark Gray (RAL 7039)**
- **Light Gray (RAL 7047)**
- **Per the Historic District allowed finish**
- **Per the Special District allowed finish**
 - **Cherry Creek North BID: Matthews Paint – MP18249 “Dark Metallic Gray”**
 - **Downtown Denver BID: Diamond Vogel – Cadaver Gray**
 - **University of Denver: Maroon (Pantone PMS 202 C; Hex color: #8B2332; RGB: 139, 35, 50; CMYK: 29, 96, 76, 29)**

Poles located in Historic Districts or Special Districts that are not owned by Xcel Energy may offer additional opportunities to coordinate with adjacent predominant infrastructure finish. CCD is prepared to approve color codes whenever appropriate to match adjacent District infrastructure.

4.2 Key Equipment Characteristics

Correlated Color Temperature (CCT)	3000K Maximum	Note: Xcel Energy owned equipment must be selected from the current version of the <i>Xcel Energy Outdoor Lighting Manual</i>
Color Rendering Index (CRI)	≥70	
IP rating	IP65 or greater	
Voltage	120/277 at 50/60 Hz	
Operation and Storage Temperature	-40°C to +40°C	
Rated Life (Minimum)	70,000 hours minimum at 55°C, per IES TM-21	
Surge Protection	Luminaire shall meet the "Elevated" (10kV/10kA) requirements per IEEE/ANSI C62.41.2. Surge protection shall be integral to the LED power supply	
Luminaire Identification	Luminaire shall have an external label per ANSI C136.15, and an interior label per ANSI C136.22	
Warranty	10-years on luminaire and components. Earliest warranty period allowed shall start on the date of shipment.	
Photocontrol or Control Node	Individual multi-contact 7-pin twist lock receptacle per ANSI C136.41, or wireless luminaire control system per CCD's control requirements. (Optional) ANSI C136.58 4-pin twist lock receptacle and shorting cap.	Xcel Energy does not offer a 4-pin receptacle
Dimming	Pre-wired for 0-10V dimming through the 7-pin receptacle.	
Power Factor (PF)	Minimum of 0.9 at full input power.	
Total Harmonic Distortion (THD)	Maximum of 20 percent at full input power.	
Off State Power Consumption	Luminaire, including driver and controls, shall consume no more than 4 watts in the off-state	
Electromagnetic interference	Shall comply with Federal Communications Commission (FCC) 47 Code of Federal Regulations (CFR) part 15 non-consumer radio frequency interference and/or electromagnetic interference standards	
Light Standard Style	Round, tapered, galvanized steel or aluminum	
Mast Arm	Straight, galvanized steel (1-foot, 6-foot, or 10-foot)	
Foundation	Per Section 1.1	

Chapter

5



5 Lighting Applications

This chapter of the Guide is to be used for all installations of public street lighting, pedestrian lights within the ROW, traffic signal mounted lights, and modifications to existing street lighting installations that affect pole types or locations, excluding minor work by maintenance staff.

Refer to Chapter 5 when installing lighting within the public ROW (Traffic signal mounted lights, streetlights, or pedestrian lights).

For all new installations, lighting design shall follow the values set forth in the Illuminating Engineering Society (IES) *American National Standard Practice for Roadway Lighting and Parking Facility Lighting* (RP-8). Refer to Appendix B on information that should be included in all CCD lighting plan sets.

5.1 Lighting Design Process

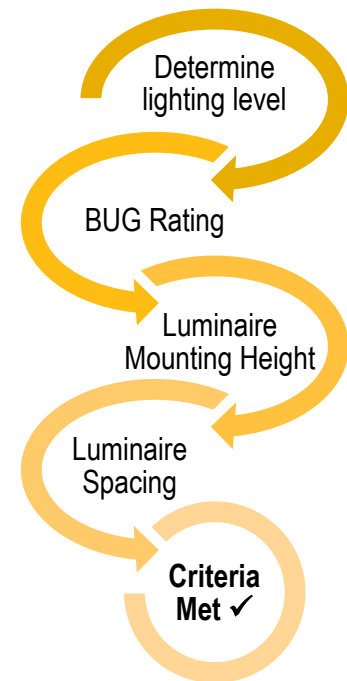
Performing a lighting design for installations of streetlights and pedestrian lights is an iterative process. This occurs because the lighting design is altered (spacing, arrangement, mounting height) until the target goals for the specific street in question is met.

A simulated model is often created to perform the luminance (straight streets) or illuminance (intersections and non-straight streets, along with sidewalks and other pedestrian areas) calculations while allowing easy modification of the streetlight parameters. The selected luminaire should be in compliance with the BUG ratings, efficacy, and other luminaire requirements specified in the typical lighting applications.

Care should be taken, when selecting a luminaire, to illuminate the surrounding sidewalks and public spaces without causing light trespass. Light trespass occurs when unwanted light spills onto surrounding properties and through residential windows. Instructions on setting up the lighting design calculations can be found in Chapter 3.

5.2 Basis of Design

The following pages describe the lighting level and luminaire characteristics for the majority of installations within the public ROW.



5.3 Typical Lighting Applications

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TRAFFIC SIGNAL MOUNTED STREETLIGHTS/ INTERSECTIONS

All traffic signal mounted streetlights shall meet the lighting requirements listed below. Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-1: Intersection Target Lighting Levels

Functional Classification	Average Illuminance (fc) by Pedestrian Classification			Avg:Min Illuminance
	High (Event Center)	Medium (Retail / Office)	Low (Residential)	
Arterial/Arterial	3.2	2.4	1.7	3
Arterial/Collector	2.7	2.0	1.4	3
Arterial/Local	2.4	1.9	1.2	3
Collector/Collector	2.2	1.7	1.1	4
Collector/Local	2.0	1.5	0.9	4
Local/Local (>30mph)	1.7 ³	1.3	0.7	6
Local/Local (<30mph)	n/a	n/a	n/a	n/a

The same luminaires are to be used throughout the intersection. The intersection design should ensure that the crosswalks are sufficiently lighted to light the vertical surface (body) of pedestrians in the crosswalk. This may require that additional streetlights be located before the intersection as shown in the Figures below.

The recommended streetlight layout for an intersection is dependent on whether the street classification calls for continuous or non-continuous lighting. The following lighting applications provide additional information about lighting for each street classification.

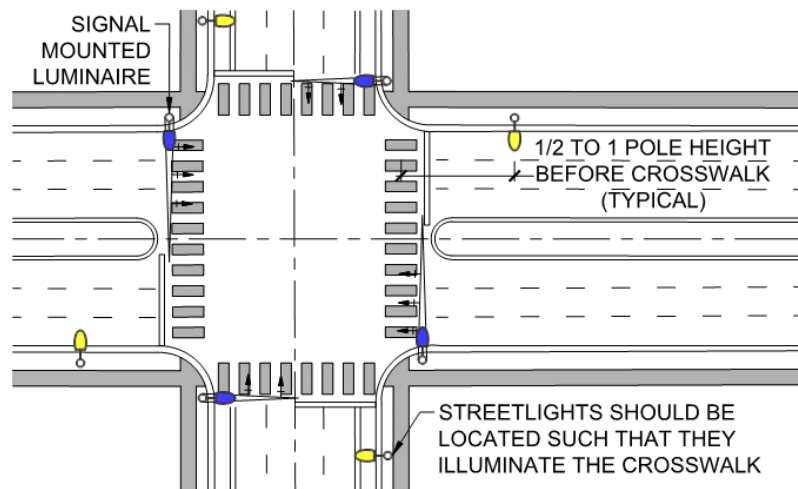
Signalized, large intersections

Typical of arterial roadways with arterial or collector cross streets.

For a signalized intersection, with continuous lighting, the typical streetlight arrangement is interrupted by placing a streetlight on the signal pole. See the appropriate Lighting Application for more information.

Another streetlight should be located before the crosswalk, installed half to one pole height in front of the crosswalk. This is called out as “1/2 to 1 pole height before crosswalk”. See the Crosswalk section for more information.

Figure 5-1: Signalized, Large Intersection



³ A high pedestrian classification on a local road is unlikely and requires City Engineer’s approval.

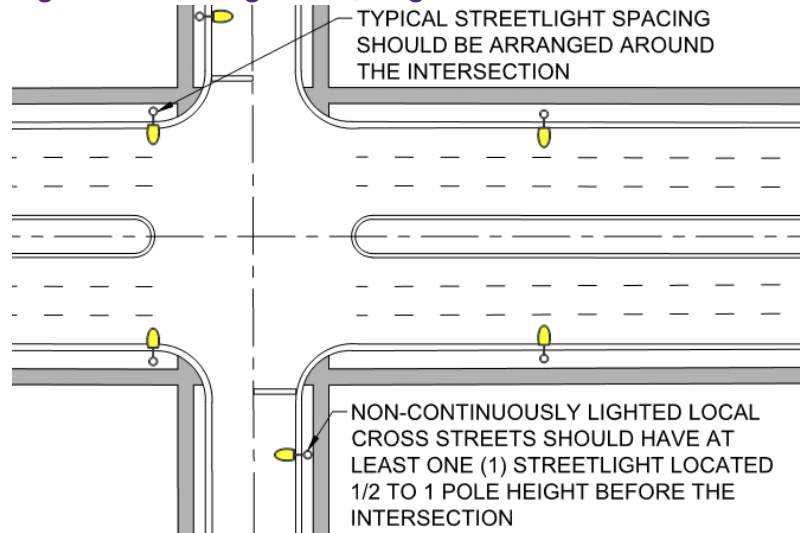
Non-signalized, large intersection

Typical of principal collector streets or arterial streets with local streets intersecting them.

The larger street sections should be continuously lighted through the intersection. The typical streetlight arrangement is carried through the intersection (see Figure 5-2). The streetlights should be located half to one pole height before the crosswalk, if it exists.

The local (or 2-lane) cross street should have at least one light located before the stop bar

Figure 5-2: Non-Signalized, Large Intersection

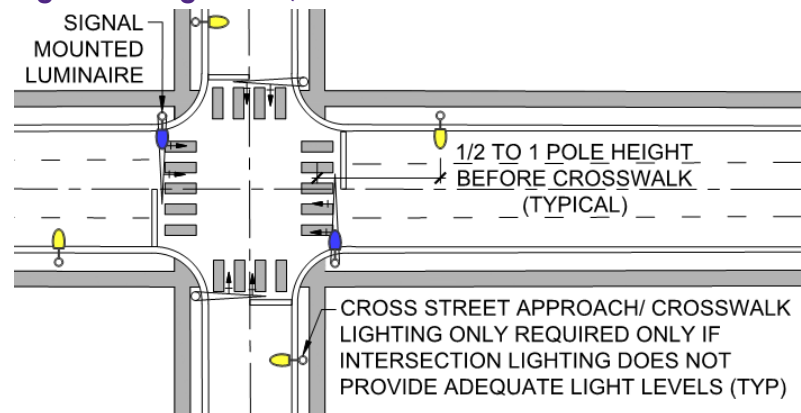


Signalized, small intersection

Typical of collector and local intersections with low pedestrian classification, may include up to 2-lanes of travel and a turn lane.

Streetlights should be located half to one pole height before the crosswalk, along streets with 36' or greater cross sections. This will light the people within the crosswalk, (see Figure 5-3). An additional streetlight located along local, non-continuously lighted cross streets may be included to better illuminate the crosswalk and intersection.

Figure 5-3: Signalized, Small Intersection

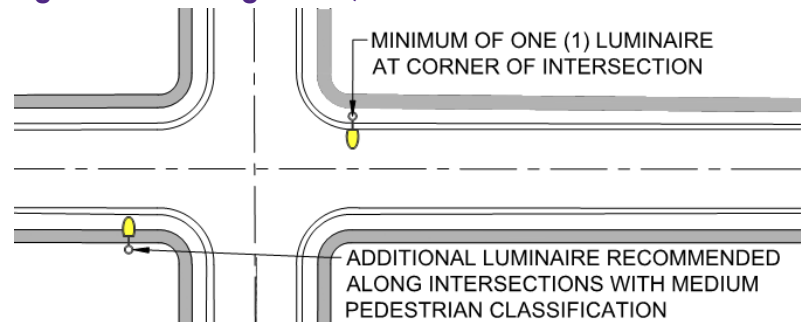


Non-signalized, small intersection

Typical of local intersections within residential areas with 2-lanes of traffic along cross streets.

At least one luminaire is to be placed at each intersection, as shown in Figure 5-4. Refer to the **Local Street** section for more information.

Figure 5-4: Non-Signalized, Small Intersection



CROSSWALKS

Mid-block crossings and denoted crosswalks shall always be lighted. Crosswalks can be denoted by striping, signage, flashing beacons, etc. Crosswalks are important parts of the streetscape and an appropriate lighting design will improve the visibility of pedestrians in the crosswalk.

Crosswalk lighting is typically provided by either streetlights or pedestrian lights; light columns may also be considered if low glare (G2) luminaires are selected and the vertical illuminance levels are met. The lighting should be installed between the vehicle and the crosswalk (ie: half to one pole height before the crosswalk) to ensure that the body of the pedestrian is adequately lighted. If streetlights are installed above or immediately adjacent to the crosswalk, only the top of the pedestrian’s head will be lighted making it difficult for motorists to see the pedestrian. In unique applications when the light cannot be located before the crosswalk, locating the light behind the crosswalk to silhouette the pedestrian may be considered.

Figure 5-6: Poorly Lighted Crosswalk



Figure 5-5: Well Lighted Crosswalk



The vertical and horizontal lighting levels listed in Table 5-2 shall be met when lighting a crosswalk. Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-2: Crosswalk Target Lighting Levels

Functional Classification	Average Vertical and Horizontal Illuminance (fc) by Pedestrian Classification						Avg:Min Illuminance
	High (Event Center)		Medium (Retail / Office)		Low (Residential)		
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	
Arterial/Arterial	3.2	1.6	2.4	1.2	1.7	1.0	3
Arterial/Collector	2.7	1.3	2.0	1.0	1.4	1.0	3
Arterial/Local	2.4	1.2	1.9	1.0	1.2	1.0	3
Collector/Collector	2.2	1.1	1.7	1.0	1.1	1.0	4
Collector/Local	2.0	1.0	1.5	1.0	0.9	1.0	4
Local/Local (>30mph)	1.7 ⁴	1.0	1.3	1.0	0.7	1.0	6
Local/Local (<30mph)	n/a	1.0	n/a	1.0	n/a	1.0	n/a
Mid-block Crossing	3.7	1.8	2.8	1.4	1.8	1.0	4

When setting up the crosswalk calculation the horizontal calculation grid shall span the entire crosswalk at ground level. The vertical calculation grid shall be located 5 feet above finished grade, facing the

⁴ A high pedestrian classification on a local road is unlikely and requires City Engineer’s approval.

direction of oncoming traffic. The vertical calculation grid shall span all lanes of traffic traveling in a single direction. Refer to Section 3.6 *Crosswalk Calculation Process* for more information.

Figure 5-7: Streetlight Placement with Respect to Crosswalk

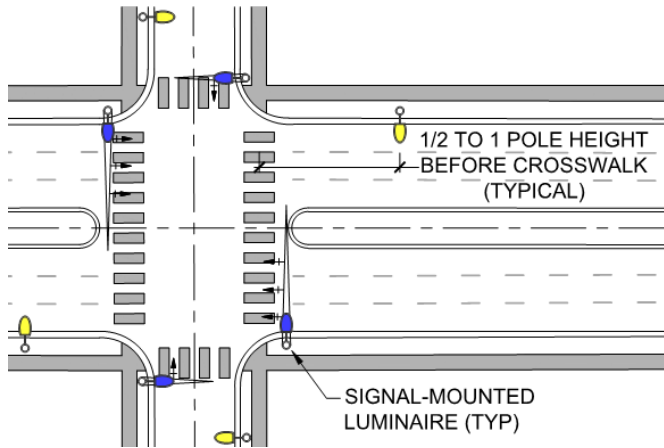
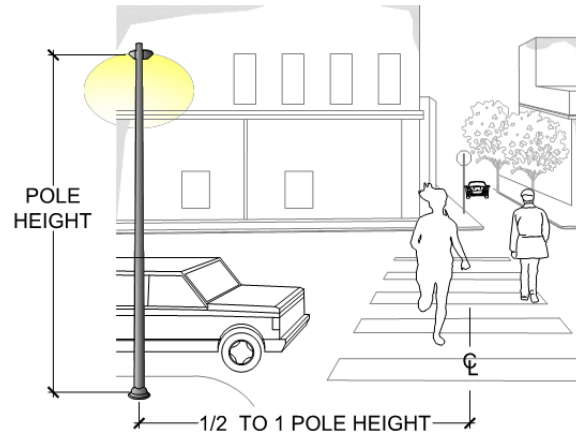


Figure 5-8: Streetlight Located Before Crosswalk



ARTERIAL STREETS

Six or Four Lane Arterial

The figures and tables below provide direction on the appropriate luminaire selection and typical lighting layout when designing a six-lane arterial. The criteria listed in Table 5-3 should be met for each design unless the City approves an alternative lighting level. Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-3: Arterial Target Lighting Levels

Pedestrian Activity	Roadway			Sidewalks / Adjacent multi-use path Average Illuminance (fc)
	Max. BUG Rating	Average Luminance (cd/m ²)	Luminance Avg:Min Ratio	
High (Event Center)	B3-U0-G3	1.2	3	0.9 ⁵
Medium (Retail / Office)	B3-U0-G3	0.9	3	0.5
Low (Residential)	B3-U0-G2	0.6	4	0.4

Street lighting is intended to light the roadway, intersections, crosswalks, on-street parking, bike lanes, and sidewalks. Additional luminaires such as pedestrian lights, bollards, step lights, wall mounted lights and landscape lights may supplement street lighting at under lighted areas within the ROW or be incorporated for aesthetic purposes.

The following figures provide common arterial lighting layouts with signalized intersections. These figures are intended as a starting point on a project. Each project will vary depending on design conditions and specific project requirements. Lights shall be located to avoid driveways and utility conflicts.

Figure 5-9: Typical Six-Lane Arterial Median Mounted Lighting Layout

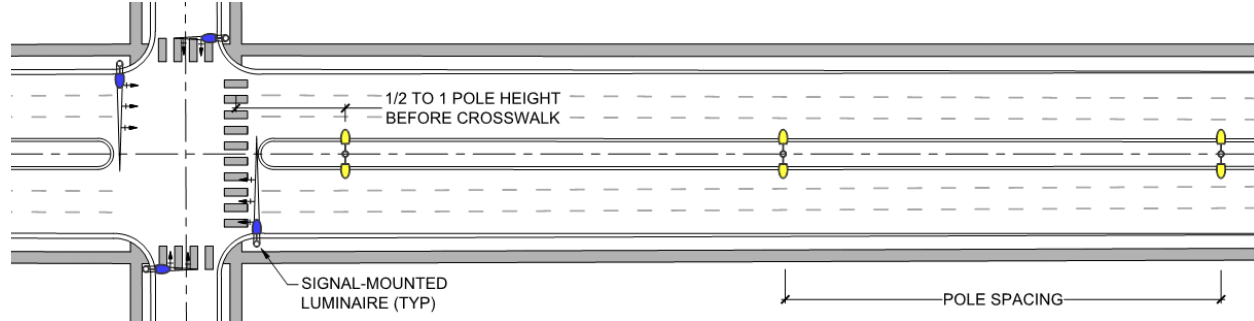
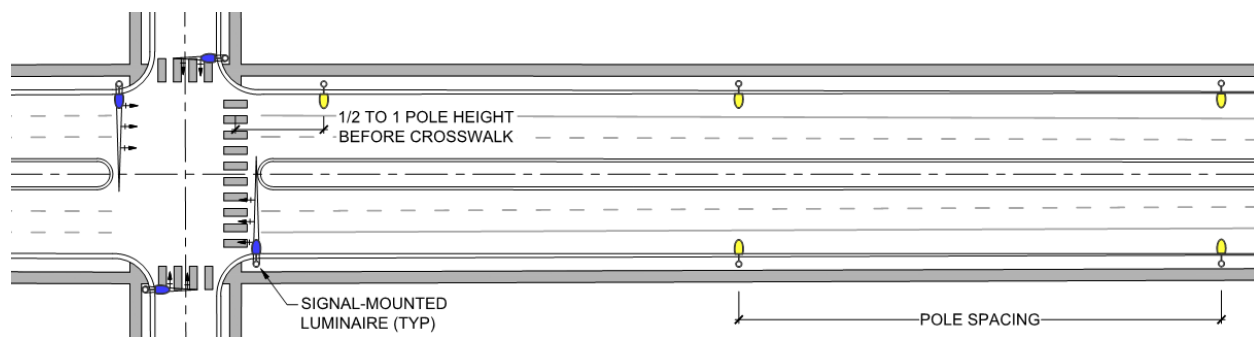


Figure 5-10: Typical Four-Lane Arterial Opposite Lighting Layout



⁵ Additional pedestrian lighting is warranted in high pedestrian activity zones

Streetlights should be located to align with other objects in the public ROW whenever possible, this includes centering the lights within the median or amenity zone.

Figure 5-11: Typical Six-Lane Arterial Median Mounted Street Cross Section

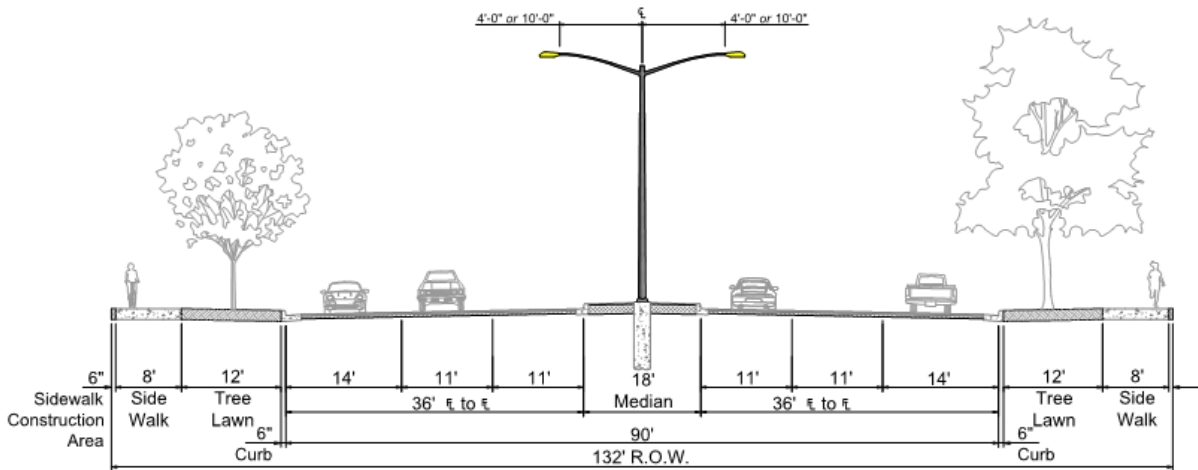


Figure 5-12: Typical Four-Lane Arterial Opposite Street Cross Section

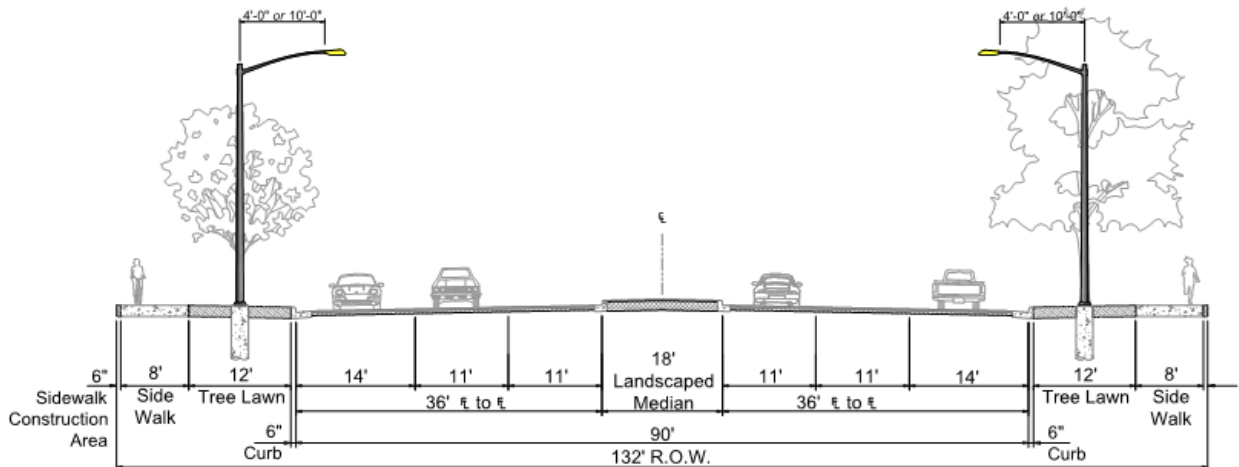


Table 5-4 provides common lighting characteristics for arterial roadways as a starting point for designers to use. These rules of thumb will vary depending on the unique characteristics of each project such as: roadway width, location of driveways, fences or walls, parking, bike lanes, locations within Special Districts, inclusion of pedestrian lighting or other lighting, locations near residential properties or wildlife refuge. The lighting design should be modified accordingly to address unique project characteristics. Alternative lighting strategies may be considered to appropriately light the street.

Table 5-4: Arterial Rules of Thumb

Pedestrian Activity	Typical Pole Spacing (ft)	Typical Pole Height (ft)	Typical Photometric Distribution
High (Event Center)	150-200	30-40	Type III Medium
Medium (Retail / Office)	200-250	30-40	Type III Medium
Low (Residential)	200-250	30-40	Type III Medium

COLLECTOR STREETS

The figures and tables below provide direction on the appropriate luminaire selection and typical lighting layout when designing a collector street. The criteria listed in Table 5-5 should be met for each design unless the City approved an alternative lighting level. Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-5: Collector Target Lighting Levels

Pedestrian Activity	Max. BUG Rating	Roadway		Sidewalks / Adjacent multi-use path Average Illuminance (fc)
		Average Luminance (cd/m ²)	Luminance Avg:Min Ratio	
High (Event Center)	B3-U0-G3	0.8	3	0.9
Medium (Retail / Office)	B2-U0-G2	0.6	4	0.5
Low (Residential)	B1-U0-G2	0.4	4	0.4

Street lighting is intended to light the roadway, intersections, crosswalks, on-street parking, bike lanes, and sidewalks. Alternative luminaires such as pedestrian lights may replace street lighting to meet neighborhood design aesthetics if the selected luminaire meets the target lighting levels and BUG ratings. Other luminaires such as bollards, step lights, wall mounted lights and landscape lights may supplement street lighting or pedestrian lighting when the ROW is under lighted or incorporated for aesthetic purposes.

The following figures provide common collector lighting layouts with signalized intersections. These figures are intended as a starting point on a project. Each project will vary depending on design conditions and specific project requirements. Lights shall be located to avoid driveways and utility conflicts.

When luminaires are installed on both sides of the street the light standards should be placed in an opposite arrangement whenever possible. When luminaires are placed on a single side of the street care should be taken to ensure that both sides of the street are adequately lighted. Both lighting designs will be considered appropriate as long as the roadway and both sidewalks are appropriately lighted.

Figure 5-13: Typical Collector Lighting Layout with Smaller Cross Section (Single Sided)

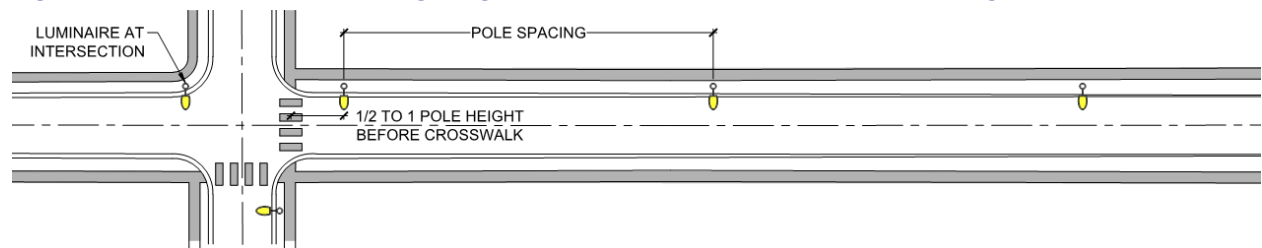


Figure 5-14: Typical Collector Lighting Layout with Wider Cross Section

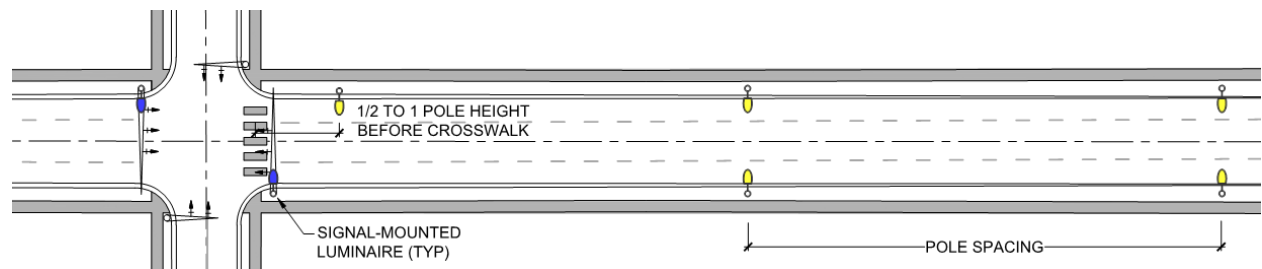


Figure 5-15: Typical Single Sided Collector Street Cross Section

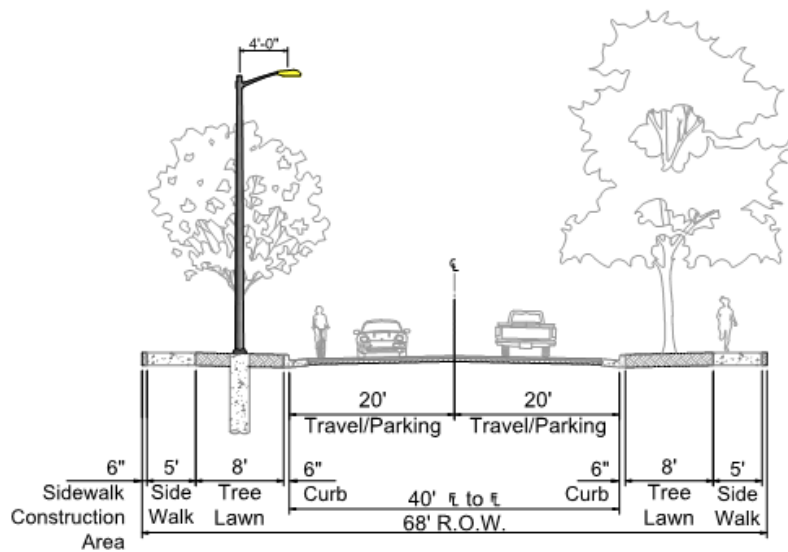


Table 5-6 below provides common lighting characteristics for collector roadways as a starting point for designers to use. These rules of thumb will vary depending on the unique characteristics of each project such as: roadway width, on street parking, bike lanes, locations within Special Districts, inclusion of pedestrian lighting or other lighting, driveways, fences or walls, residential front entries. The lighting design should be modified accordingly to address unique project characteristics. Alternative lighting strategies may be considered to appropriately light the street.

Table 5-6: Collector Rule of Thumb

Pedestrian Activity	Typical Pole Spacing (ft)	Typical Pole Height (ft)	Typical Photometric Distribution
High (Event Center)	150-250	25-30	Type II Medium
Medium (Retail / Office)	150-250	25-30	Type II Medium
Low (Residential)	150-250	25-30	Type II Medium

RESIDENTIAL AND LOCAL STREETS

The figures and tables below provide direction on the appropriate luminaire selection and typical lighting layout when designing a local or residential street. The criteria listed in Table 5-7 should be met for each design unless the City approved an alternative lighting level. Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-7: Residential and Local Streets Target Lighting Levels

Pedestrian Activity	Max. BUG Rating	Roadway		Sidewalks / Adjacent multi-use path Average Illuminance (fc)
		Average Luminance (cd/m ²)	Luminance Avg:Min Ratio	
Medium (Retail / Transit Station)	B2-U0-G2	0.5	6	0.5
Low (Residential) > 30 mph	B1-U0-G1	0.3	6	0.4
Low (Residential) ≤ 30 mph	B1-U0-G1	N/A (Lighting is provided for wayfinding and pedestrians' comfort)		

When the roadway speed is greater than 30 mph, lighting is needed to improve motorist visibility. It is recommended that lights be located before an intersection or crosswalk to provide the best visibility. Street lighting is intended to provide lighting for the roadway, intersections, parking, and sidewalks. Additional luminaires such as bollards, step lights, wall mounted lights and landscape lights may supplement street lighting for under lighted areas within the ROW or be incorporated for aesthetic purposes. Pedestrian lights may be used as an alternative to street lighting if the pedestrian light meets the BUG ratings and lighting criteria.

When the roadway speed is equal to or less than 30 mph, street lighting for visibility of the roadway is not necessary since headlights light an object in the roadway up to one stopping sight distance away. A stopping sight distance is the distance a driver needs to safely stop after identifying an object in the roadway, when traveling at design speeds. Along these roadways, lighting is primarily intended for pedestrian comfort when walking along the street, and to help identify approaching conflict points for motorists. Lights should be located at each intersection and along the mid-block when possible. If the length of the block is over 600 feet, an additional streetlight may be warranted to increase pedestrian comfort. Alternative light sources, such as pedestrian lights, bollards, step lights, wall mounted lights and landscape lights may replace streetlights if they provide adequate wayfinding and meet the BUG ratings.

Figure 5-16: Typical Local Lighting Layout (> 30 mph)

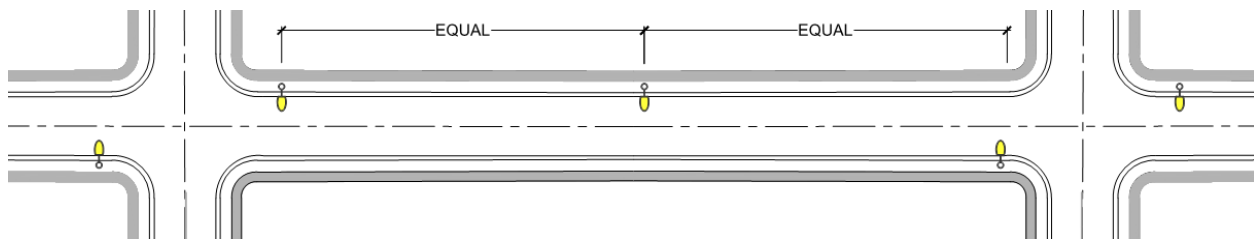


Figure 5-17: Typical Local Lighting Layout (≤ 30 mph)

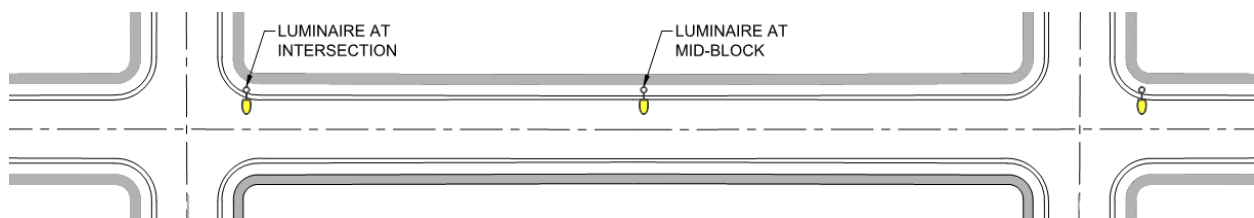


Figure 5-18: Typical Local Street Cross Section

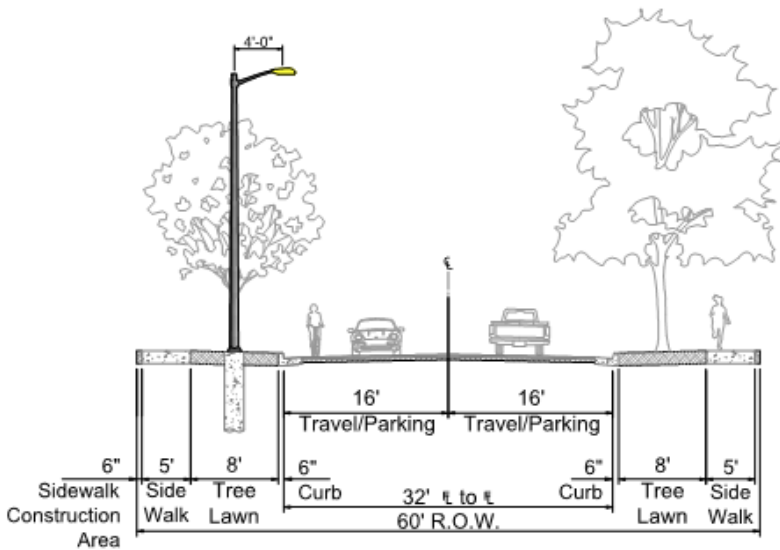


Table 5-8 below provides common lighting characteristics for local roadways, as a starting point for designers to use. These rules of thumb will vary depending on the unique characteristics of each project such as: roadway width, on street parking, bike lanes, locations within Special Districts, inclusion of pedestrian lighting or other lighting, driveways, fences or walls, residential front entries. The lighting design should be modified accordingly to address unique project characteristics. Alternative lighting strategies may be considered to appropriately light the street.

Table 5-8: Residential and Local Streets Rules of Thumb

Pedestrian Activity	Typical Pole Spacing (ft)	Typical Pole Height (ft)	Typical Photometric Distribution
Medium (Retail / Transit Station)	150 - 250	20 - 30	Type II Medium
Low (Residential) > 30 mph	150 - 300	20 - 30	Type II Medium
Low (Residential) ≤ 30 mph	Intersections and Midblock	20 - 30	Type II Medium

BIKEWAY AND MULTI-USE PATH LIGHTING

When bike lanes are located within the roadway, the bikeway should be lighted to the same criteria as the adjacent roadway. The street lighting system is often adequate for illuminating the bike lanes. A streetlight should be located before the conflict point (where bikeways merge or switch lanes with traffic), such that vertical light falls on a bicyclist within the bikeway-roadway conflict points.

Multi-use pathways in the Downtown environment may be continuously lighted to improve visibility along highly traveled routes. The City may decide to provide non-continuous lighting along other pathways. At a minimum, all conflict points where a bicyclist or pedestrian may change direction (such as where multiple pathways merge together) should have at least one pedestrian light or streetlight to illuminate the adjacent pathway. Additional lights may be installed at the conflict point to create a sense of space. If bollards, step lights, wall mounted lights, or tunnel lights are installed, then multiple lights of this type should be installed to provide adequate lighting at the conflict point.

Below are minimum considerations for bikeway or multi-use path lighting:

- Conflict points within the pathway, along with any merge and diverge points.
 - Bike lanes within the roadway should be lighted to the same luminance level as the adjacent roadway target lighting level.
 - Conflict points along both non-continuously and continuously lighted multi-use pathway should be lighted to the target lighting level listed below for the appropriate pedestrian activity classification.
- Conflict points where multi-use path abut the roadway should be lighted to the target illuminance level per the appropriate roadway classification listed in the previous sections.
- Road crossings should be lighted per the appropriate crosswalk target lighting level. Refer to the crosswalk section for more information.
- Pedestrian tunnels should be lighted during the day and night for bicyclist adaptation.

Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-9: Bikeway and Multi-use Path Target Lighting Level

Pedestrian Activity	Maximum BUG Rating*	Horizontal Illuminance (Avg. fc)	Vertical Illuminance (Avg. fc)	Uniformity Ratio (Avg:Min)
High (Event Center)	B4-U3*-G3	0.9	0.5	4
Medium (Retail / Office/ Transit Station)	B3-U2*-G2	0.5	0.2	4
Low (Residential)	B2-U1*-G1	0.4	0.1	4
Bike lanes within the roadway	Should be lighted per the target lighting level listed for the roadway classification listed in the previous sections			

* Streetlights must have U0 uplight rating. The uplight ratings listed in the table are only applicable for pedestrian lighting systems.

Pedestrian tunnels should be lighted during the day and night to help bicyclists and other pedestrians traveling at higher than walking speeds adapt to the darker tunnel interior. Under bridge pedestrian walkways greater than 100 feet in length should consider keeping lights on during both the daytime and nighttime hours. Long tunnels (100 feet or more) should consider installing adaptive lighting (additional luminaires) at the entrances to the tunnel to allow bicyclists to adapt from the bright daylight to the dark interior of the tunnel. Adaptive lighting shall be dimmed at night and increased during the daytime.

Oftentimes streetlights, pedestrian lights, bollards, wall mounted lights, tunnel lights, or step lights will be used to light different sections of a pathway. The type and style of lighting should be coordinated with the City prior to the completion of the final lighting design. The luminaire's glare should be considered for any installation.

If a multi-use path is adjacent to, or crosses over a waterway, care must be given to minimize or prevent any lighting from reaching or reflecting in the waterway. No light shall be directed or reflected into environmentally sensitive waterways, such that the calculated lighting level does not exceed 0.01 fc (the intensity of moonlight).

PEDESTRIAN LIGHTING

In some cases, sidewalk or pedestrian light levels can be achieved with the adjacent roadway lighting system. In other cases, especially in high pedestrian activity areas, additional pedestrian lighting is necessary to illuminate the sidewalk, plaza, pedestrian bridge, or other pedestrian area. Table 5-10 outlines the recommended average illuminance levels for pedestrian areas. Refer to Section 3.2 for guidance on determining the pedestrian activity classification.

The pedestrian lighting may be able to adequately light one-lane or two-lane streets, adjacent multi-use paths, and adjacent single row parking spaces without installing additional streetlights.

When lighting a pedestrian bridge, plaza, or sidewalk adjacent to a wall, alternative lighting sources should be considered; this may include bollards, wall mounted lights or step lights. The resulting glare should be considered for any luminaire that is installed.

Lighting levels will be considered as meeting the criteria if the calculated values are within ten percent (10%) of the criteria or do not exceed the criteria by more than one and a half times (1.5x).

Table 5-10: Pedestrian Area Target Lighting Level

Pedestrian Activity	Maximum BUG Rating	Horizontal Illuminance (Avg. fc)	Vertical Illuminance (Avg. fc)	Uniformity Ratio (Avg:Min)
High (Event Center)	B4-U3-G3	0.9	0.5	4
Medium (Retail / Office/ Transit Station)	B3-U2-G2	0.5	0.2	4
Low (Residential)	B2-U1-G1	0.4	0.1	4

The average illuminance on the sidewalks shall be determined using the calculation process as described in Section 3.6. If the streetlights cannot meet the recommended average illuminance on the sidewalk, then additional pedestrian lights should be considered for the project.

Pedestrian lighting is typically mounted at fourteen feet or lower and spaced sixty to ninety feet apart, depending on the application. Bollards, wall mounted lights, and step lights are often spaced fifteen to thirty feet apart depending on the application.

Lights owned by the City, District, or Private development must be connected to a meter. Lights owned by Xcel Energy must be selected from Xcel’s approved LED lighting catalogue; contact Xcel Energy for more information.

When a light is located adjacent to a waterway, care must be given to minimize light spilling or reflecting into the water way. No light shall be directed or reflected into environmentally sensitive waterways; the calculated lighting level shall not exceed 0.01 fc (the intensity of moonlight).

The images below are examples of pedestrian lights currently installed throughout Denver.



ABUTTING WILDLIFE REFUGE

Due to the environmental sensitive nature of the Rocky Mountain Arsenal National Wildlife Refuge, and other wildlife refuges, care must be taken to minimize any lighting impact to the wildlife refuge. The following paragraphs about non-visual effects of light at night on humans and the ecosystem is taken from IES RP-33-14 *Lighting for Exterior Environments*. Please refer to IES RP-33 for more information.

“While much more research is required to fully understand the interaction between electric light sources and animals and plants, the likely overall negative impact is not in doubt. The examples cited here are intended as representative of ongoing research. When development is considered in environmentally sensitive areas, the use and application of nighttime lighting should be carefully reviewed. At the most basic level, the way to do this is to remove unnecessary lights, turn off lights except when needed, reduce the amount of light, block light from entering sensitive areas, and direct light only where it is needed. For example, as a rule of thumb, the equivalent of full moonlight (0.01 fc average) should be considered adequate unless there are specific requirements for higher levels of illumination in these sensitive areas.

Electric lighting has impacts on animal communities, from insects to large predators. It disrupts normal breeding, predation and predator avoidance, migration, feeding, and communication, and social interactions – in short, every aspect of animal life. Almost all small rodents and carnivores, 80% of marsupials, and 20% of primates are nocturnal. Lighting in sensitive areas should minimize the duration, direct the light only where needed, reduce intensity as much as possible (no more than full moonlight as a guideline), and consider how the spectral power distribution affects the sensitive species. In addition, electric lighting has been shown to disrupt numerous natural behavioral patterns including:

- Foraging behavior and increased predation
- Biological clocks, which could affect mating success, group-mediated anti-predator vigilance, and other light-stimulated behaviors
- Dispersal movements and wildlife corridor use
- Breeding behavior in birds – nest site selection, increased predation, timing of breeding
- Possible support for invasive species (mostly insects)
- Alteration of territorial behavior
- Delays and changes in migratory behavior
- Reduced populations of nocturnal insects, which has a cascade effect on their predators, and possibly on pollination

Plants have evolved a wide range of photoreceptors that perceive and respond to light signals in the ultraviolet, blue, red, and near-infrared regions of the electromagnetic spectrum. Some of the many processes sensitive to light are:

- Seed germination
- Stem elongation
- Leaf expansion
- Flower development
- Fruit development
- Bud dormancy (when leaves stop growing)
- Leaf senescence
- Leaf drop

Plants that are sensitive to photo-periodicity in their flowering, bud dormancy, or leaf senescence in response to day length may be adversely affected by prolonged light. They need sunlight during the day and darkness at night to sustain a healthful life. Landscape lighting that is left on continuously at night is seldom necessary, and should be avoided.”

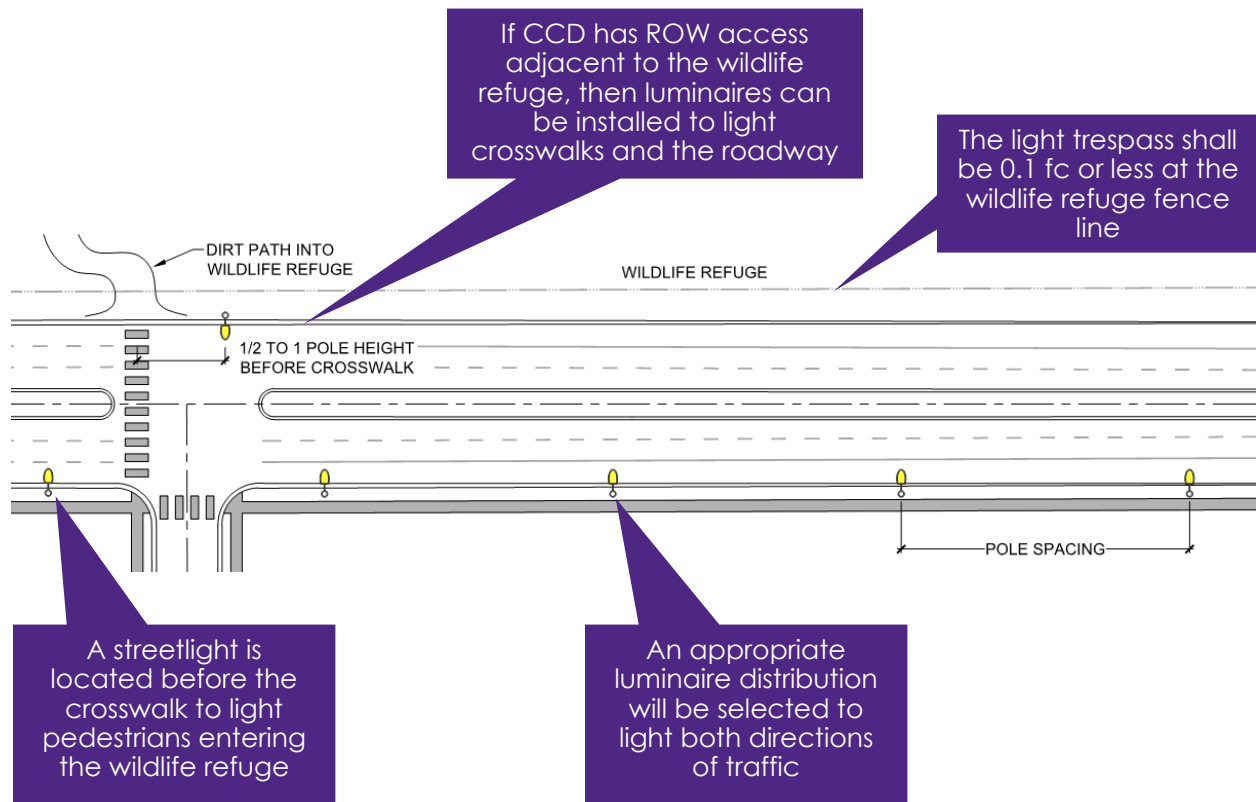
To ensure that the natural habitat of the wildlife refuge is being protected, the light trespass from adjacent streetlights shall have a maximum light level of 0.1 fc vertical at the fence line of the wildlife refuge. The light trespass shall be measured at 5 feet above finished grade with an illuminance meter pointed towards the closest light source.

When designing the lighting along roadways adjacent to the wildlife refuge, care must be taken when selecting an appropriate roadway luminaire. The luminaire should adequately light the street per the appropriate lighting application. Additional luminaires such as pedestrian lights and bollards may be located along the sidewalk or bike path to provide additional lighting. The glare and upright rating on all selected luminaires shall meet the lighting application requirements to minimize impact to the animals.

The following figure provides an example of a potential lighting layout for an arterial roadway adjacent to a wildlife refuge. The figure shows continuous lighting on the side of the roadway opposite the wildlife refuge; continuous lighting ensures that the roadway will meet the arterial lighting level requirements. The selected roadway luminaire distribution should be carefully considered to ensure that both sides of the street, for single sided arrangements, will be lighted while meeting the light trespass requirements.

In a single sided roadway lighting configuration, the side of the roadway adjacent to the streetlights will have a light level greater than the opposite side of the street. For this situation where a roadway is abutting a wildlife refuge the difference in luminance values will be considered appropriate if the average luminance and uniformity level of all lanes of traffic meet the roadway classification lighting level. The streetlight spacing will be tighter than normal to meet these requirements.

Figure 5-19: Typical Abutting Wildlife Refuge Lighting Layout



ONE-FOR-ONE LUMINAIRE REPLACEMENT

One-for-one luminaire replacement guidelines should only be used when streetlights within the existing CCD's right of way are replaced with new LED luminaires. The goal of a replacement is to provide equivalent or better lighting levels for a given stretch of roadway when luminaires are replaced.

If new lighting locations are proposed for the LED replacement, then the new luminaires and locations shall meet the requirements established per the appropriate Lighting Application.

If the streetlights will not be relocated, then the existing HID streetlights will be replaced with 3000K LED luminaires per the CCD's luminaire specification. The new LED luminaire(s) should meet the maximum BUG ratings and replacement wattage listed in Table 5-11. Per Xcel Energy's standards, all the lights connected to a single feeder (circuit) are required to be converted to LED at the same time.

Care should be taken, when selecting a luminaire, to illuminate the surrounding sidewalks and public spaces while minimizing backlight or offensive glare for adjacent residential neighborhoods. Table 5-11 below provides LED replacement equivalents based upon lumen output range and maximum wattage for the following existing conditions:

- Continuously lighted streets
- Non-continuously lighted streets
- Intersections
- Mid-block crosswalks

Replacing the existing lighting with the designated LED lumen output packages will deliver an equivalent luminance. Care should be taken to select an appropriate LED replacement based on calculation results instead of simply selecting the maximum allowable wattage. Installing the maximum wattage may result in over lighting the street. A calculation of the typical roadway design should be performed to determine what the appropriate LED wattage and lumen output is for the one-for-one replacement.

The one-for-one replacement should either provide the equivalent lighting levels as the existing lighting system; or if the lighting levels are intended to be increased then the new lights should meet the target lighting criteria for the roadway type listed in the previous sections. Care should be taken to prevent over lighting the roadway.

Table 5-11: One-for-One Luminaire Replacement

Street Classification	Existing Luminaire Type	Typical LED Replacement Lumen Output Range	Minimum Luminaire Efficacy	Maximum LED Replacement Wattage	Maximum BUG Rating
Arterial	400W HPS	15,000 – 30,000 ⁶	85	235	B3-U0-G3
	400W MH	15,000 – 20,000 ⁶	85	235	B3-U0-G3
	250W HPS	10,000 – 15,000	85	175	B3-U0-G2
	250W MH	10,000 – 15,000	85	175	B3-U0-G2
Collector	250W HPS	4,000 – 10,000	85	115	B2-U0-G2
	250W MH	4,000 – 10,000	85	115	B2-U0-G2
Local	100W HPS	3,500 – 5,500	85	65	B1-U0-G1

HPS (High Pressure Sodium)

MH (Metal Halide)

LED luminaires shall replace the existing luminaires in a like-for-like manor. For example, curvilinear HPS luminaires without a mast arm shall be replaced with an LED cobra head with a 1-foot straight mast arm.

⁶ Greater lumen output might be warranted for special applications with the City's approval.

PROJECTS ADJACENT TO EXISTING LEGACY LIGHT SOURCES

In recent years LED luminaires have become widely used throughout the outdoor lighted environment. Due to this, many projects in the public ROW are installing LED luminaires immediately adjacent to an existing legacy light sources such as: high pressure sodium (HPS), low pressure sodium (LPS), metal halide (MH), fluorescent, and induction light sources.

Installing LED luminaires adjacent to legacy light sources, such as HPS luminaires, is not a concern. Motorists and pedestrians may note that it is easier to see objects under the white LED light sources. The human eye is capable of quickly adapting to variations in lighting systems as long as spaces are not over lighted and the new system meets the glare ratings established per the Lighting Application.

When LEDs are installed along a stretch of roadway, calculations should be performed to ensure that the roadway and adjacent area meet the target lighting levels listed in the previous Lighting Applications. LEDs have improved optically distribution than legacy light sources which allows them to appropriately illuminate the entire project area without over lighting the space. The target lighting level will only apply to the section of roadway, crosswalk, intersection, bike path, and/or sidewalk that is within CCD ROW. Similar to every other roadway within CCD, glare and light trespass should be carefully considered to minimize impact to adjacent neighborhoods.

In the past, roadways were commonly lighted with HPS cobra heads or HPS curvilinear luminaires. HPS luminaires have a 2200K CCT which appears yellow to the human eye than new LED luminaires with a 3000K CCT, refer to Section 3.3 for more information. The human eye is more sensitive to blue wavelengths of light, which can be found in white light source but are not common in HPS light sources. For this reason, roadways lighted with LED luminaires will appear brighter than those lighted with HPS luminaires even if they are lighted to the same level. LEDs also improve the color rendering of objects within the roadway, which makes it easier for motorists to identify pedestrians, bicyclists, or potential objects within the roadway.

White light sources such as MH lamps, fluorescent lamps, and induction lamps provide a correlated color temperature (CCT) that is similar to new LED luminaires (refer to Section 3.3 for more information on CCT). The public has a difficult time distinguishing between these various light sources. The project design may request that the new LED luminaire style match the existing legacy light source styles.

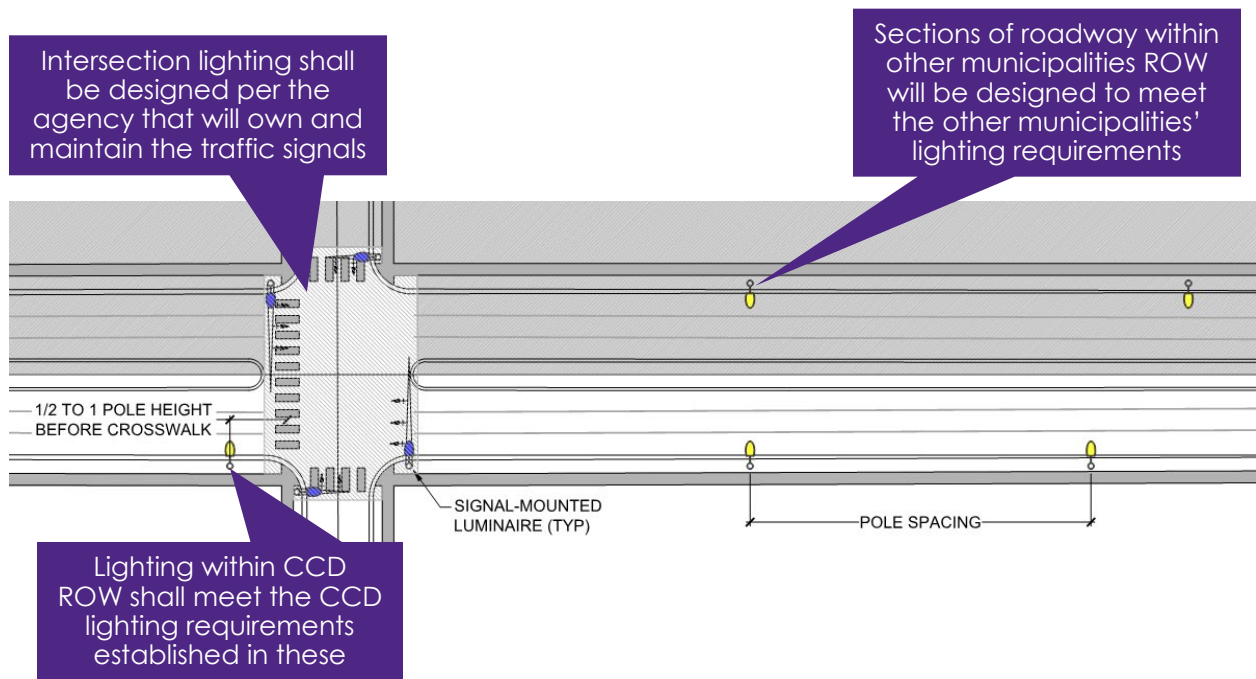
ABUTTING OTHER MUNICIPALITIES/ CROSS-JURISDICTIONAL COORDINATION

When lighting a section of roadway that crosses between two municipalities or agencies, only the section or roadway within the CCD ROW must meet the requirements established in these guidelines.

The roadway lighting within CCD ROW shall be selected per the appropriate lighting application listed in these guidelines. The target lighting level will only apply to the section of roadway, crosswalk, intersection, bike path, and/or sidewalk that is within CCD ROW. Similar to every other roadway within CCD, glare and light trespass should be carefully considered to minimize impact to adjacent neighborhoods.

Intersections that bisect multiple agencies will be owned and maintained by one of the adjacent agencies. When the traffic signal is owned by CCD the intersection shall be lighted the target lighting level listed in the Section *Traffic Signal Mounted Streetlights/ Intersections* of these guidelines. Whether the traffic signal is owned by CCD or not, streetlights within CCD should be located in such a way to appropriately light the crosswalks within the intersection. Calculations for areas within CCD ROW may also include adjacent, existing luminaires to remain that are located in other municipalities.

Figure 5-20: Example of Roadway Abutting Other Municipalities



HISTORIC DISTRICTS/ BUSINESS IMPROVEMENT DISTRICTS

Historic Districts, Special Districts, or Business Improvement Districts (BIDs) may have special guidelines. CCD must give approval for all special luminaires prior to installation. Refer to the individual district guidelines to determine the appropriate luminaire aesthetic for installation within these areas.

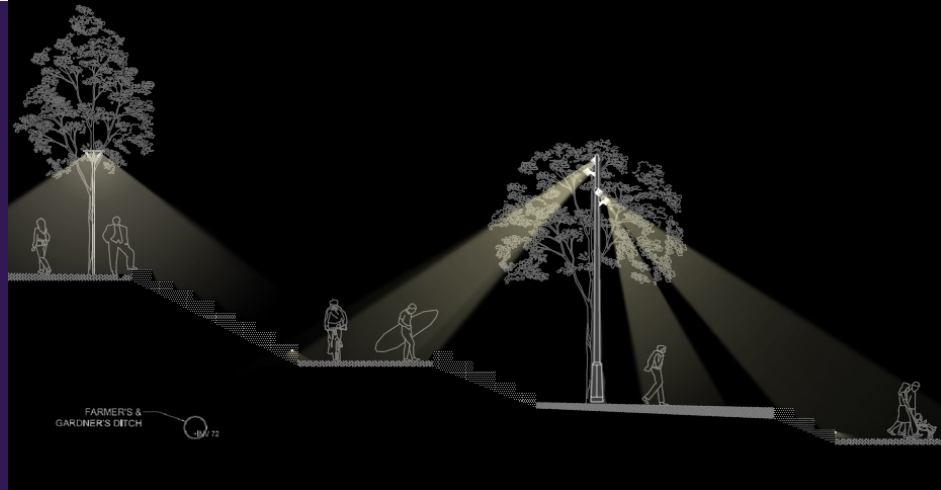
Alternative luminaire options such as pedestrian lights, bollards, light columns, wall mounted lights, step lights, and landscape lighting may be requested by the Historic District or BID for aesthetic purposes. These luminaires may be used to supplement or replace streetlights as long as the lighting application target lighting levels are met. Selected luminaires shall meet the BUG ratings listed per the lighting application, in these guidelines, unless CCD Public Works Department approves a deviation from these guidelines.

The following luminaire and light standard paint colors have been selected by the Special Districts listed below. The noted paint colors should be used when designing projects within the noted Special District.

- Cherry Creek North BID: Matthews Paint – MP18249 “Gaspire Gray”
- Denver University: Maroon, Pantone – PMS 202 C
- Downtown Denver BID: Diamond Vogel CB1402 -100

Chapter

6



Refer to Chapter 6 when modifying luminaire light output to match the conditions present at a particular time (adaptive lighting).

6 Adaptive Street Lighting

Roadway lighting levels are typically designed for peak traffic conditions that may exist on a given stretch of street. Typical lighting controls have included a simple “on/ off” photocell or timeclock. However, with advances in adaptive street lighting, the City can leverage additional considerations for lighting control including traffic volumes, the presence of pedestrians, weather, special events, neighborhood or abutting use type, and presence of ambient luminance. Adaptive lighting not only offers the opportunity to reduce energy consumption, but also minimizes light trespass and light pollution.

The key benefits of streetlight controls over photocells

1. Energy savings through adaptive dimming schedules
2. Elimination of “day-burners”
3. Increased efficiency of asset management (knowing when lights are out and planning timely replacement and reduced maintenance trips)
4. Extended the life of LEDs through constant light output and other dimming strategies
5. Streetlight energy consumption readings
6. Increased customer satisfaction and Quality of Service through ability to adapt lighting to needs and preference of citizens
7. Societal benefits such as:
 - a. Fewer “Out” luminaires:
 - i. Fewer customer complaints
 - ii. Reduced traffic accidents from burned out lights
 - b. Reduced greenhouse gases due to energy savings

The purpose of this chapter of the *Street Lighting Design Guide* is to provide guidance on the City recommended adaptive lighting control system, and how street lighting levels should be modified based on site specific conditions. This adaptive lighting approach is drawn from the Illuminating Engineering Society of North America’s (IES) *American National Standard Practice for Roadway Lighting* (RP-8-2018). Refer to RP-8 for additional information on adaptive lighting practices.

6.1 Application of Adaptive Lighting

For all street classifications, the lighting levels may be decreased at night when fewer pedestrians are present. Since the roadway lighting levels are designed for peak traffic counts, when the majority of pedestrians are present, less roadway lighting is necessary during later nighttime hours when fewer vehicles and pedestrians are present. See Chapter 3.6 for more information on determining pedestrian activity levels. The varying pedestrian area classifications can be applied to Table 6-1 to determine the lighting level criteria applicable for different times of night.

Table 6-1: Target Street Lighting Levels

Street Classification	Pedestrian Area Classification	Roadway		Sidewalks
		Average Luminance (cd/m ²)	Luminance Avg:Min Ratio	Average Illuminance (fc)
Arterial	High (Event Center)	1.2	3	0.9
	Medium (Retail / Office)	0.9	3	0.5
	Low (Residential)	0.6	4	0.4
Collector	High (Event Center)	0.8	3	0.9
	Medium (Retail / Office)	0.6	4	0.5
	Low (Residential)	0.4	4	0.4
Local	High (Event Center)	0.6	6	0.9
	Medium (Retail / Office)	0.5	6	0.5
	Low (Residential)	0.3	6	0.4

Lighting controls enable the luminaire light output to be increased or decreased as needed, which saves energy. Simple lighting controls such as astronomical time clocks or electronic photocells signal the lights to turn on at dusk and off at dawn. More sophisticated lighting controls can turn the lights on and off, increase or decrease light levels, monitor energy usage, provide asset location and description, and send maintenance requests to appropriate personnel when the luminaire malfunctions. CCD requires specific hardware to be provided with each streetlight installation to ensure adaptive lighting capabilities can be provided, as described in the following sections.

If adaptive lighting controls are not included on a project, each installed luminaire shall have the following capabilities to allow adaptive controls to be installed at a later date:

- ANSI 7-pin receptacle
- 0-10V dimmable driver factory wired to the 7-pin receptacle
- (Optional) ANSI 4-pin receptacle located on the underside of the luminaire

The ANSI 7-pin receptacle shall be located at a standard location on top of the luminaire so that a long-life LED photocell can receive enough daylight to turn the lights on or off. Alternatively, a shorting cap will be installed if the lights are fed from a photocell-controlled lighting control center.

Figure 6-1: 7-pin Photocell Receptacle



6.2 Streetlight Control System Selection

When street lighting is to be owned by CCD, a luminaire control node is required. While a photocell is the default control, CCD Public Works Department requires that the Itron Streetlight Vision (SLV) luminaire control system be installed on all new streetlight projects.

The Itron SLV system was selected by CCD Public Works since this system has also been selected by Xcel Energy for deployment in Xcel Energy service areas for electric and gas meter reading and distribution automation. Xcel Energy is testing Itron’s network for streetlight control in Denver and Minneapolis.

CCD recognizes the opportunity to share resources and control monitoring capabilities and reporting between both agencies. CCD will have the option of operating its own SLV network with independent security ID and coordinating with Xcel Energy to leverage Xcel Energy’s growing network. The Itron SLV system has the capabilities to provide access and control to multiple users on role and permission-based structure.

6.3 Streetlight Control System Installation

Adaptive lighting hardware shall be included in all new streetlight installations owned by CCD, and should be strongly considered for deployment in a programmatic approach to all existing City streetlights owned by Xcel Energy or others.

To allow for adaptive street lighting, all new lighting fixtures must include an ANSI 7-pin wired to the luminaire 0-10V dimmable driver. The 7-pin receptacle provides for the capability for a wireless control system to be installed as easily as a photocell, providing the City with maximum future-forward flexibility for control system usage. To allow for additional and rapidly developing smart lighting functionality, an optional ANSI 4-pin receptacle should also be installed on the bottom of the luminaire.

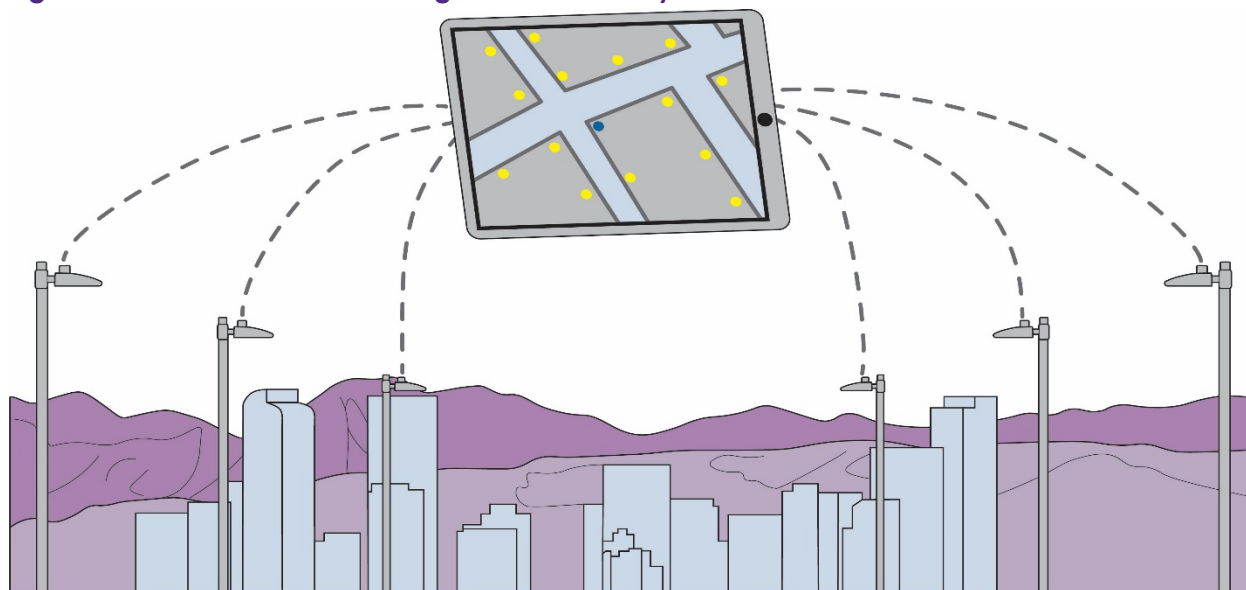
The control node sends small packets of luminaire data back to an Itron Access Point (AP) with either cellular or fiber backhaul. City project managers shall confirm with Itron that a nearby AP can be used for device communication. If a new AP is necessary to provide communication for the new control nodes, then the Project shall coordinate with Itron to determine the best location for a new AP.

The Itron APs, located throughout CCD, communicate to a cloud-based Central Management System (CMS) as shown in Figure Figure 6-2. Users with the appropriate permissions will be able to access the lighting system that corresponds to their assigned role through an internet browser. CCD project managers should coordinate with CCD Public Works for more information on access to the Itron system user interface.

The following, minimum features, are required with every control node installation in the City:

- ITRON/ Silversprings Network Interface Controller (NIC)
- Real time luminaire positions (latitude and longitude)
- Adaptive lighting scheduling and control
- Luminaire operating hours and calculated time until end of life
- Immediate power failure reporting (last gasp/ disconnect or power)
- Real time energy use

Figure 6-2: Luminaire Asset Management Control System

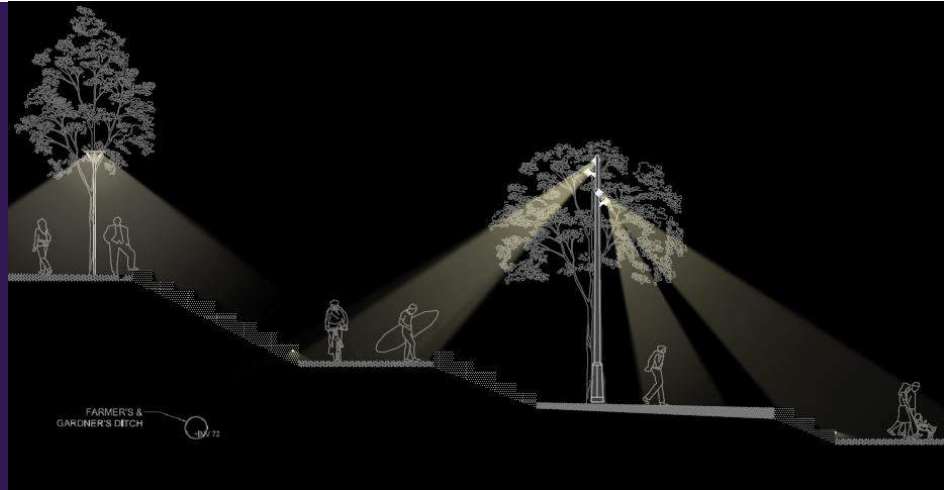


For reference, the following control node specifications are provided to ensure the final selected control node meets minimum City requirements:

Table 6-2: City Owned Control System Technical Specifications

Control Technical Specifications	
Metering Accuracy	1%
Metering Range	90-320 VAC, 8A RMS (50/60 Hz)
Operation and Storage Temperature	-40°C to +70°C
Voltage	105-305 VAC (50/60 Hz)
Load Current	10 Amps maximum
Rated Load	1800VA 3 x 400W
Maximum Power Consumption	4-Watts
Photocell On Setting	1.5 fc
Switching Ratio (Off:On)	1.5 : 1
Housing	UV Stabilized Polycarbonate
IP Rating	IP65 or greater
Control Node Dimensions	4.55"H x 3.5" Dia. maximum
Control Node weight	300g maximum
Warranty	5 years on hardware and software
Surge Protection	Minimum of 10kV/10kA
Standards	EN ISO 9001:2008 EMC EN55015, EN61547 EN61000-3-2, EN61000-3-3 UL773, CSA C22.2
Security	Full PKI, AES-128 and -256, and embedded firewall

A



A GLOSSARY AND REFERENCES

A.1 Glossary

Following are general definitions used in lighting design and this Guide. Unless otherwise noted, these definitions come from IES.

Bikeway – Any road, street, path, or way that is specifically designated as being open to bicycle travel, regardless of whether such facilities are designed for the exclusive use of bicycles or are to be shared with other transportation modes.

BUG (Backlight, Uplight, Glare) Rating – The quantity of light within various beam angles.

Backlight – the percent lamp lumens or the luminaire lumens distributed behind a luminaire between zero degrees vertical (nadir) and 90 degrees vertical.

Uplight – the percent lamp lumens or the luminaire lumens distributed above a luminaire between 90 and 180 degrees vertical.

Glare – the percent lamp lumens or the luminaire lumens distributed between 60 and 90 degrees vertically in front of the luminaire.

Candela (see luminous intensity), (cd) – The unit of luminous intensity.

Continuous Lighting – When uniform light levels are provided by luminaires spaced an equal distance apart along a roadway.

Correlated Color Temperature (CCT) – The absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source.

Crosswalk – Any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by lines on the surface, which may be supplemented by contrasting pavement texture, style, signs, or beacons.

Dimming Protocol – The control standards that vary the luminaire intensity through mechanical means.

0-10V Dimming- A unidirectional analog lighting control protocol. The 0-10V control applies a voltage between 0 and 10 volts DC to vary intensity levels. Although no light might be output when the voltage is at 0, power is still supplied to the luminaire. A switching device or separate relay is required to turn the luminaires off.

Digital Addressable Lighting Interface (DALI) – A two-way digital control protocol that can individually address each luminaire or control luminaire groups.

Digital Multiplex Signal (DMX) – A unidirectional digital control system that can individually address each luminaire or luminaire groups through channels. DMX controls are commonly used when color changing luminaires are desired.

Disability Glare - Also frequently called veiling luminance, it is a luminance superimposed on the retinal image that reduces its contrast. It is this veiling effect produced by bright sources or areas in the visual field that results in decreased visual performance and visibility.

Discomfort Glare - Glare that produces discomfort but does not necessarily diminish visual performance.

Driver (LED Driver) – A device composed of a power source and light emitting diode (LED) control circuitry designed to operate an LED light source.

Footcandle (fc) – A unit of illuminance. One footcandle is one lumen per square foot (lm/ft²).

Glare – The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance or visibility.

Illuminance (footcandle, fc) - The incident light falling on a surface such as roadway pavement. The source of light may include the roadway luminaires, automobile headlights and other nearby lighting equipment. Total illuminance at a point is a combination of all light sources that contribute. Units in footcandles (fc).

Initial Illuminance (footcandle, fc) - The amount of horizontal illuminance on the pavement area at the time the lighting system is installed, when light sources are new, and the luminaires are clean; units in footcandles (fc).

Light Loss Factor (LLF) - A depreciation factor that describes the drop in light output over the life of the system. The total LLF is determined by a combination of factors, such as lumen depreciation and luminaire dirt depreciation.

Light Standard: A pole, the supporting member for a luminaire.

Lumen (lm) – The luminous flux emitted within a unit solid angle by a point source (one steradian) having a uniform luminous intensity of one candela (cd). See luminous flux.

Luminaire - A complete lighting device consisting of the light source, lens, reflector, refractor, housing and such support as is integral with the housing. If the driver is located within the housing, it is considered Integral and therefore part of the luminaire. The pole, posts, and bracket or mast arm are not considered to be part of the luminaire.

Luminaire Efficacy – Efficacy is the lumen output of the luminaire divided by the total luminaire power input expressed in lumens per watt. It is a measure of how energy efficient luminaires are compared to alternative luminaires.

Luminaire Lumens – The amount of light delivered by the luminaire.

Luminance (candelas per square meter, cd/m²) - The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction; i.e., the apparent brightness of a surface.

Luminous Flux (lumen, lm) - A unit of measure of the quantity of light. One lumen is the amount of light that falls on an area of one square meter, every point of which is one meter from a source of one candela. A light source of one candela emits a total of 12.57 lumens. Light sources are rated in terms of luminous flux.

Luminous Intensity (candela, cd) - The candela is the basic unit of light quantity. The candela is historically related to the light emitted by a candle flame and was once known as candlepower. The candela can be thought of as the number of photons per second emitted by the light source. (A photon is a subatomic particle with zero mass that carries the energy of light and all other forms of electromagnetic energy.)

Maintained Illuminance (footcandle, fc) - The average level of horizontal illuminance on the roadway pavement when the illuminating source is at its lowest output and when the luminaires are in their dirtiest condition; expressed in footcandles for the pavement area. This is calculated by multiplying the initial illuminance by a light loss factor.

Median – The portion of a divided roadway physically separating the traveled ways for traffic in opposite directions.

Mesopic Vision – Vision with fully adapted eyes at luminance conditions between those of photopic and scotopic vision. The range of adaptation is between 3.4 and 0.034 cd/m².

Mounting Height (MH) – the vertical distance between the roadway surface and the center of the apparent light source of the luminaire.

Nadir – Nadir is the lowest point on a sphere directly straight down.

Non-continuous Lighting – When lighting is provided at key locations to improve visibility and wayfinding.

Pedestrian Walkway – A public walk for pedestrian traffic, not necessarily within the right-of-way of a vehicular traffic roadway. Included are pedestrian overpasses, pedestrian tunnels, and walkways giving access through parks or block interiors.

Pedestrian Conflict Areas – Location with pedestrian-vehicle interaction. Three classifications of pedestrian night activity levels and the types of land use with which they are typically associated are given below:

High – Areas with significant numbers (over 100 pedestrians an hour) of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, near theaters, concert halls, stadiums, and transit terminals.

Medium – Areas where less numbers (10 to 100 pedestrians an hour) of pedestrians utilize the streets at night. Typical are downtown office areas, blocks with libraries, neighborhood shopping, parks, and streets with transit lines.

Low – Areas with very low volumes (10 or fewer pedestrians per hour) of night pedestrian usage. A low pedestrian classification can occur in any street classifications but may be typified by suburban streets with single family dwellings, very low density residential developments, and rural or semi-rural areas.

Photopic – Photopic vision is our day vision. It is color vision provided by cones in the eye, generally associated with adaptation to a luminance of at least 3.4 cd/m².

Scotopic – Scotopic vision is our night vision when lighting is not present. It is black and white vision provided by rods in the eye, and generally associated with adaptation to a luminance equal to or less than 0.034 cd/m².

Shoulder – A paved portion of the roadway adjacent to the edge stripe.

Sidewalk – A paved or otherwise improved area for pedestrian use, located within public street right-of-way, which also contain roadways for vehicular traffic.

Small Target Visibility (STV) – a weighted average of the values of target Visibility Level over a grid of points on an area of roadway for one direction of traffic flow. STV values are typically both positive and negative over an area on the roadway. A value of 1.0 or below (positive or negative) indicates that the target is below threshold for a standard observer who is allowed a fixation of 0.2 seconds.

Spacing –The distance between successive luminaires, measured along the center line of the installation (roadway, pathway, bridge, etc).

Street Classification – The street classifications are based on varying levels of access and traffic volumes as noted below:

Major – Principal roadway network for through-traffic flow. The routes connect areas of principal traffic generation and important roadways entering and leaving the city. These routes are often classified as “arterials”, “thoroughfares”, or “preferentials”.

Collector – Roadways servicing traffic between major and local streets. These are streets primarily used for traffic movements within residential, commercial, and industrial areas. Collector streets may be used for truck or bus movements and give direct service for abutting properties.

Local – Local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property. They make up a large percentage of the total street system but carry a small percentage of vehicular traffic.

Uniformity Ratio - Maximum uniformity ratios are used to judge the evenness of the light on the road or sidewalk surface. The most significant uniformity ratios are average to minimum and maximum to minimum.

Veiling Luminance Ratio - Describes how bright the light source is compared to the roadway surface. It is important in roadway lighting since light source brightness can inhibit one's ability to see details on the pavement.

Visibility – The quality or state of being perceivable by the eye. Visibility may be defined in terms of the distance at which an object can be just perceived by the eye or it may be defined in terms of the contrast or size of a standard test object, observed under standardized view-conditions, having the same threshold as the given object.

A.2 References

AASHTO, *Roadway Lighting Design Guide*, American Association of State Highway and Transportation Officials, Washington DC, 2005.

FHWA, *Lighting Handbook*, Federal Highway Administration, Washington DC, 2012.

The IES Lighting Handbook, Tenth Edition, The Illuminating Engineering Society, New York, 2011.

IES Design Guide 19-08 Roundabout Lighting. The Illuminating Engineering Society, New York, 2008.

IES Recommended Practice 8-14 Roadway Lighting. The Illuminating Engineering Society, New York, 2014.

IES Recommended Practice 22-11 Tunnel Lighting. The Illuminating Engineering Society, New York, 2011.

IES Recommended Practice 33-11 Lighting for Exterior Environments. The Illuminating Engineering Society, New York, 2011.

IES Technical Memoranda 12-12 Spectral Effects of Lighting on Visual Performance at Mesopic Lighting Levels. The Illuminating Engineering Society, New York, 2012.

IES Technical Memoranda 15-11 Luminaire Classification System for Outdoor Luminaires. The Illuminating Engineering Society, New York, 2011.

IES Technical Memoranda 21-11 Projecting Long Term Lumen Maintenance of LED Light Sources. The Illuminating Engineering Society, New York, 2011.

IES Lighting Measurements Testing and Calculation Grids 79-08 Electrical and Photometric Measurements of Solid-State Lighting Products. The Illuminating Engineering Society, New York, 2008.

B

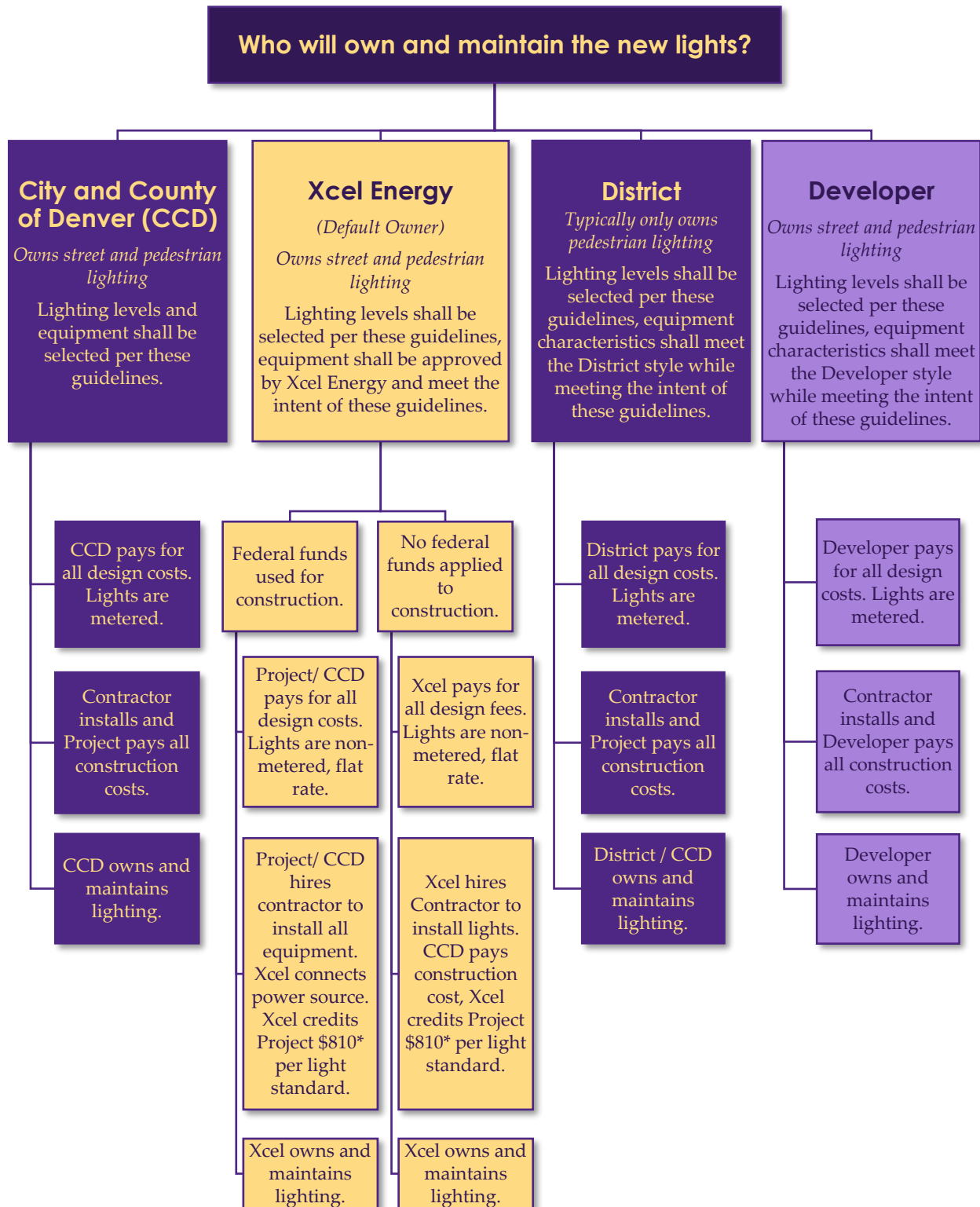


B Ownership Construction Path and Technical Plan Review Criteria

B.1 Ownership Construction Path

When beginning a lighting and electrical design within CCD, one of the most important questions to ask is “Who will own and maintain the lighting and electrical equipment?” For the majority of lighting within the public ROW, the answer will typically be either CCD or Xcel Energy. If a developer installs lights within the public ROW, ownership of the street lighting must be carefully vetted and agreed to at the outset of any project so that the correct application of these Guidelines is made.

Figure B.2-1: Ownership Construction Path



*Or current price per the franchise agreement.

B.2 Technical Plan Review Criteria

When the City and County of Denver performs technical and/or regulatory plan review for street lighting design submitted for installation in the public rights-of-way in Denver, the following Technical Plan Review Criteria should be applied.

Table B.2-1: Light Standard Equipment

Light Standard Item Description	Typical Item Description (Alternative items are allowed)
Luminaire Type	LED cobra head (typical of streetlights) Decorative lights: pedestrian lights, wall mounted lights, step lights, bollards, light columns, etc. will vary per project
Correlated Color Temperature (CCT)	3000K or less (unless special permission is granted)
Color Rendering Index (CRI)	70 or greater, listed in specification
IP Rating	IP65 or greater, listed in specification
Luminaire BUG Rating	Refer to maximum rating listed per Lighting Application
Luminaire Lumen Output	Varies per luminaire
Luminaire Wattage	Varies per luminaire
Operating Temperature	-40°C to +40°C, listed in specification
Voltage	120, 277, or 120-277V (often referred to as universal voltage)
Surge Protection	"Elevated" 10kV/10kA, listed in specification
Minimum Rated Life	These items are to be listed in the specification 70,000 hours for streetlights 50,000 hours for decorative light sources: pedestrian lights, wall mounted lights, step lights, bollards, light columns, etc.
Warranty	10-years, listed in specification
7-pin receptacle	Yes
4-pin receptacle	Optional
Photocell or control node	1) Photocell located on streetlight, or shorting cap on streetlight with photocell on lighting control center. 2) Itron SLV control node on streetlight
Luminaire Finish	Light Gray or RAL 7038, unless painted to match an existing pole finish.
Mast Arm	Straight; 1-foot, 6-foot, or 10-foot) Straight, 1-foot mast arms shall be used when replacing an existing HPS curvilinear flush mount luminaire
Light Standard Style	Round, tapered, galvanized steel or aluminum
Light Standard Height	Per Lighting Application
Light Standard Finish	Galvanized (default), unpainted unless to match an existing location

Light Standard Item Description	Typical Item Description (Alternative items are allowed)
Light Standard Foundation (per Section 1.1 & Appendix B)	<p>Below are typical foundations per streetlight installation, alternative foundations may be approved as listed in Appendix C or stamped by a professional engineer.</p> <p>Type I – Xcel owned: 4’ foundation w/ 2’ diameter, 12” bolt circle, 1 splice box</p> <p>Type II – Streetlight only: 4’ foundation w/ 2’ diameter (40-foot, or less, light standard), 12” bolt circle, 1 splice box</p> <p>Type III – Future small cell (default): 8.5-foot foundation w/ 3’ diameter, 24” bolt circle with 12” adaptor plate, 8 conduit stubs, 3 splice boxes</p> <p>Type IV – Small cell foundation: 8.5-foot foundation w/ 3’ diameter, 24” bolt circle, 8 conduit stubs, 3 splice boxes</p>
Splice boxes	<p>Xcel owned: Tier 8 (8,000 psi rated)</p> <p>CCD, District, Developer owned: Tier 22 (22,500 psi rated)</p>

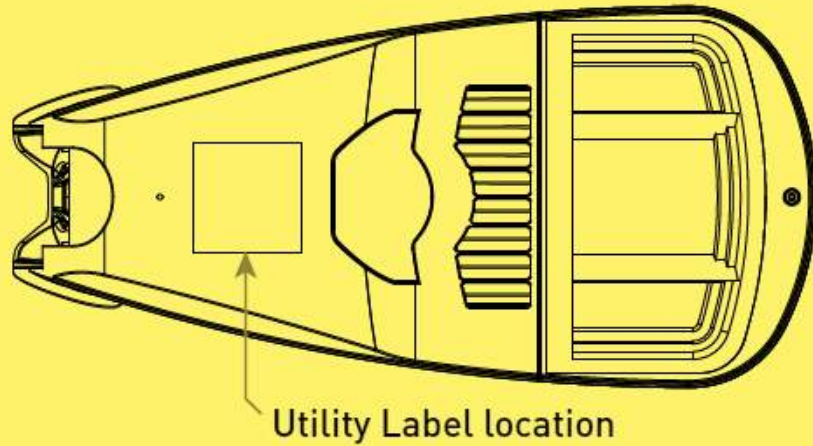
Table B.2-2: Typical Streetlight Plan Review Checklist

Plan Item Description	Typical Item Description
Light Standard Equipment is identified per the light standard checklist in Table B.2-1.	<ul style="list-style-type: none"> ■ Street Light Type I – City Owned Standard Street Light Only ■ Luminaire type, BUG rating, lumen output, wattage, CCT, finish ■ Light Standard height, type, finish ■ Mast Arm type and length ■ Foundation type ■ Splice box type ■ 7-pin receptacle, optional 4-pin receptacle ■ Photocell or control node
Legend	Provides symbol and description of lighting & electrical symbols shown on plans
Lighting Level Calculation	Table that lists the lighting criteria and calculated lighting level(s)
811 Call Before you Dig logo	Required
Plan North Arrow	Shown on plan sheets
Plan Scale	Plan scale clearly identified
ROW & Property Lines	ROW and property lines if known (when available from civil plans)
ROW Topography	Curb, shoulder, sidewalk, driveways, alleys, road striping if known (when available from civil plans)
Existing Streetlights	Symbol show existing streetlights within project limits that will remain in place

Plan Item Description	Typical Item Description
Reset Streetlights	Symbol showing streetlights to be reset, within project limits, clearly denoting where the streetlight will be moved from and the proposed reset location.
New Streetlight Location	Symbol of New streetlights shown on plans, symbol to match what is shown in the legend
Streetlight Clearances	<ul style="list-style-type: none"> ■ 25' from tree trunk (only applicable for streetlights) ■ Outside sight triangles (site triangles not shown on electrical plans) ■ Outside other utility conflicts (utility locations determined during SUE investigation)
Power Source Location	Xcel Energy owned power source (transformer or secondary service pedestal) shown with feeder to lighting equipment
Conduit Type	Schedule 80 PVC (min.) when located under roadway Schedule 40 PVC (min.) when located under sidewalk or softscape
Conduit Sizes	Each conduit size and type to be identified on plans
Wire Sizes	Each wire size, type, and grounding wire to be identified per circuit
Trenching / Bore Depth	Trenching depth identified (typically 24" to 36") Bore depth identified (typically 36" to 48") 48" maximum depth
Splice Boxes	Tier 22 rated with concrete collar (Xcel requires Tier 8 without concrete collar) Submersible insulated pedestal lug connectors
One-line Diagram	Not required when resetting light standards or connecting to an existing lighting control center or meter power pedestal <ul style="list-style-type: none"> ■ New/ existing transformer ■ Service later wire size and type and ground wire size ■ Service lateral conduit size and type ■ Short circuit ■ Maximum service lateral distance from transformer ■ Typical connected load
Lighting Control Center / Meter Power Pedestal (metered systems only)	<ul style="list-style-type: none"> ■ NEMA 3, 3R, or 4 rated enclosure ■ Cold sequence meter (disconnect ahead of meter) ■ Meter housing ■ Load center ■ Contactors ■ Ground rod (confirm 8'-0" in contact with earth) ■ 120V GFCI maintenance receptacle ■ Photocell (confirm no photocell is located on the streetlights if a photocell is located on the lighting control center)

Plan Item Description	Typical Item Description
Panel Schedule (metered systems only)	<ul style="list-style-type: none"> ■ Voltage and phase ■ Main breaker size ■ Enclosure NEMA rating ■ Minimum Amp Interrupting Current (A.I.C) ■ Breaker size and number of poles ■ Circuit number ■ Load description ■ Load per circuit ■ Load per phase ■ Total estimated load

C



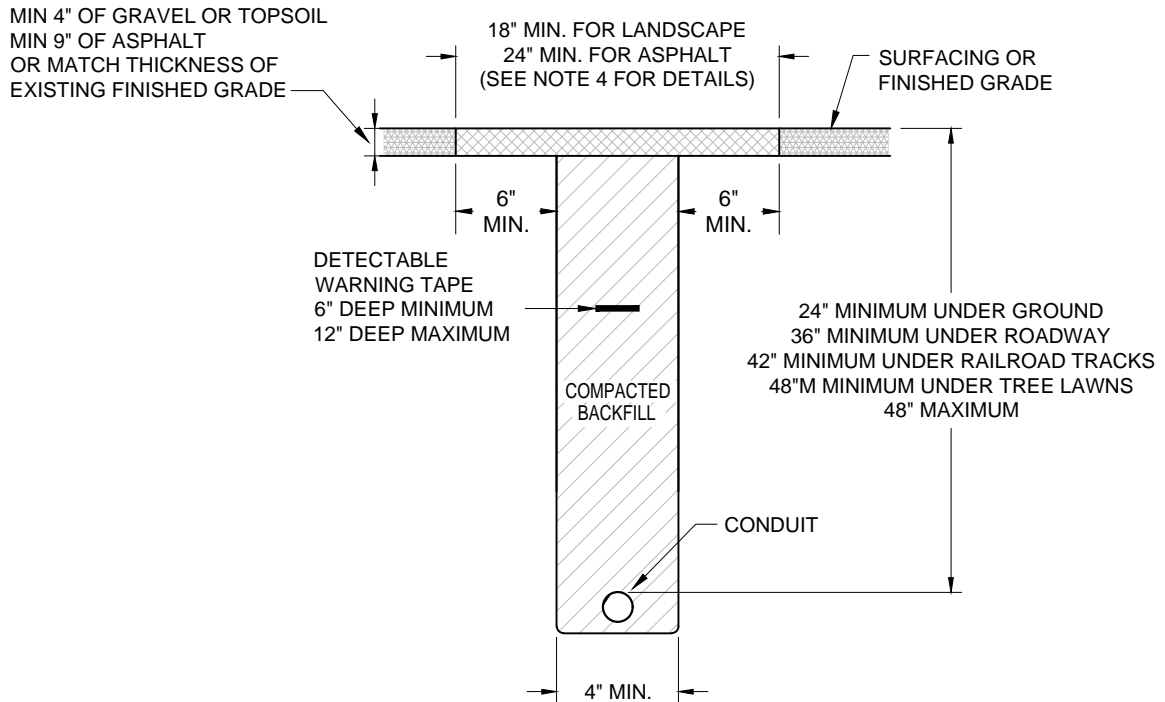
C DETAILS

The following pages provide details to be used in all CCD street and roadway projects. These pages detail conduit burial, pull box dimensions, light standard foundations, lighting control centers, light standards, and pole bases.

The details include Xcel Energy electrical requirements, shown in *red text*. The appropriate details, based on either the CCD specification or Xcel Energy specification, should be selected based on who will own and maintain the lighting system after installation. An explanation of the design process can be found in Appendix C.

List of Details

DS-01 Typical Conduit Burial Detail.....	C-2
DS-02 Pull Box/Splice Box Typical Dimensions	C-3
DS-03 Typical In-Grade Composite Pull Box/Splice Box Detail	C-4
DS-04 Typical Streetlight Standard Foundation Electrical Detail in Softscape.....	C-5
DS-05 Typical Streetlight Standard Foundation Electrical Detail in Hardscape.....	C-6
DS-06a Typical Lighting Control Center Cabinet Detail	C-7
DS-06b Typical Lighting Control Center Cabinet Components List	C-8
DS-07 Typical Lighting Control Center Cabinet Detail	C-9
DS-08 Typical Streetlight Standard Details	C-10
DS-09 Typical Non-Breakaway Pole Base Standard Detail.....	C-11
DS-10 Typical Light Standard Foundation Structural Detail.....	C-12
DS-11 Typical Small Cell Pier Foundation Detail.....	C-13
DS-12 Typical Small Cell Spread Footing Foundation Detail.....	C-14
DS-13 General Small Cell Foundation Structural Notes.....	C-15
DS-14 General Small Cell Foundation Structural Notes, Continued.....	C-16
DS-15 Typical Adaptor Plate Detail	C-17



DETAIL NOTES

1. CONTRACTOR SHALL COORDINATE BORING, DRIVING, OR TRENCHING WITH OTHER UNDERGROUND UTILITIES. CONTRACTOR SHALL USE COMMON TRENCHES AT ALL ROAD CROSSINGS WHEREVER POSSIBLE.
2. WHENEVER POSSIBLE, CONDUIT OR CABLE SHALL BE INSTALLED BY BORING, DRIVING, OR ANY OTHER ACCEPTABLE MEANS UNDER CONCRETE UNITS. OPEN CUTTING SHALL BE USED ONLY UNDER SPECIAL CIRCUMSTANCES AND ONLY WITH APPROVAL OF PUBLIC WORKS.
3. MINIMUM WIDTH AND TYPE OF RESTORATION TO BE DETERMINED BY PW INSPECTOR, BASED ON CONTRACTOR'S PRE-ACTIVITY PHOTOS, TO MATCH PRE-EXISTING CONDITIONS.
4. SOD REPLACEMENT SHALL BE A MINIMUM OF 18" IN WIDTH. ASPHALT REPLACEMENT SHALL BE A MINIMUM OF 24" IN WIDTH. CONCRETE REPLACEMENT SHALL BE PER THE DEPARTMENT OF PUBLIC WORKS TRANSPORTATION STANDARD DETAILS 12.3.
5. ANY HARDSCAPE (CONCRETE OR PAVERS) SHALL BE REPLACED IN FULL PANELS OR PAVERS OF THE SAME TYPE, COLOR, AND SIZE AS BEFORE.
6. 1-#12 AWG LOCATE WIRE AND A NYLON OR POLYESTER PULL TAPE WITH 1,250 LBS TEST STRENGTH AND FOOTAGE MARKINGS IN ALL EMPTY CONDUITS.
7. ALL CONDUIT, LANDSCAPE RESTORATION, ASPHALT RESTORATION, AND CONCRETE RESTORATION MUST BE INSTALLED IN ACCORDANCE WITH THE DEPARTMENT OF PUBLIC WORKS TRANSPORTATION STANDARD DETAILS.



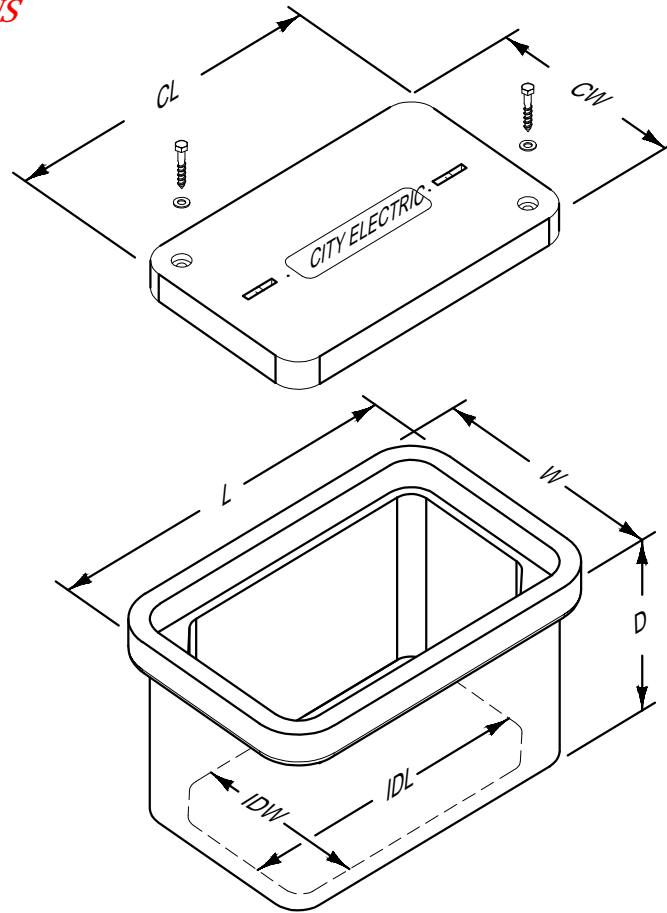
City and County of Denver
Department of Public Works

TYPICAL CONDUIT BURIAL DETAIL

Date:
SEPTEMBER 2019

Std. Dwg. No.
DS-01

XCEL ENERGY SPECIFICATIONS



PULL BOX / SPLICE BOX - COMPOSITE MINIMUM DIMENSIONS		
TYPE 1	TYPE 2	TYPE 3
L = 20"	L = 25"	L = 32"
W = 13"	W = 15"	W = 19"
D = 12"	D = 12"	D = 12"
IDL = 17"	IDL = 21"	IDL = 28"
IDW = 10"	IDW = 11"	IDW = 15"
CL = 18"	CL = 23"	CL = 30"
CW = 11"	CW = 13"	CW = 17"

XCEL PULL BOX / SPLICE BOX - COMPOSITE MINIMUM DIMENSIONS	
SMALL	LARGE
<i>CAT ID #: LID - 215570 BODY - 215571</i>	<i>CAT ID #: LID - 215567 BODY - 215569</i>
<i>L = 18"</i>	<i>L = 24"</i>
<i>W = 11"</i>	<i>W = 13"</i>
<i>D = 12"</i>	<i>D = 12"</i>

DETAIL NOTES

- BOX COVERS MUST BE POLYMER CONCRETE WITH FIBERGLASS REINFORCEMENT, INCIDENTAL TRAFFIC RATED TO TIER 22 AND BOLTED. *XCEL REQUIRES TIER 8 RATED.*
- BOX COVERS SHALL BE LABELED AS FOLLOWS:
 - "CITY ELECTRIC" ON ALL PULL BOXES CONTAINING CITY ELECTRICAL POWER.
 - "UTILITY ELECTRIC" ON ALL PULL BOXES CONTAINING UTILITY ELECTRICAL POWER.
 - "CITY LIGHTING" ON ALL PULL BOXES CONTAINING CITY OWNED STREET LIGHTING CONDUCTORS.
 - "UTILITY LIGHTING" ON ALL PULL BOXES CONTAINING UTILITY OWNED STREET LIGHTING CONDUCTORS.
 LABELING MUST BE CAST INTO THE COVER AND NOT A SEPARATE INDEPENDENT TAG.
- REFER TO N.E.C. ARTICLE 314 "PULL AND JUNCTION BOXES AND CONDUIT BODIES MINIMUM SIZE" FOR BOX SIZE REQUIREMENTS BASED ON CONDUIT AND WIRE SIZES



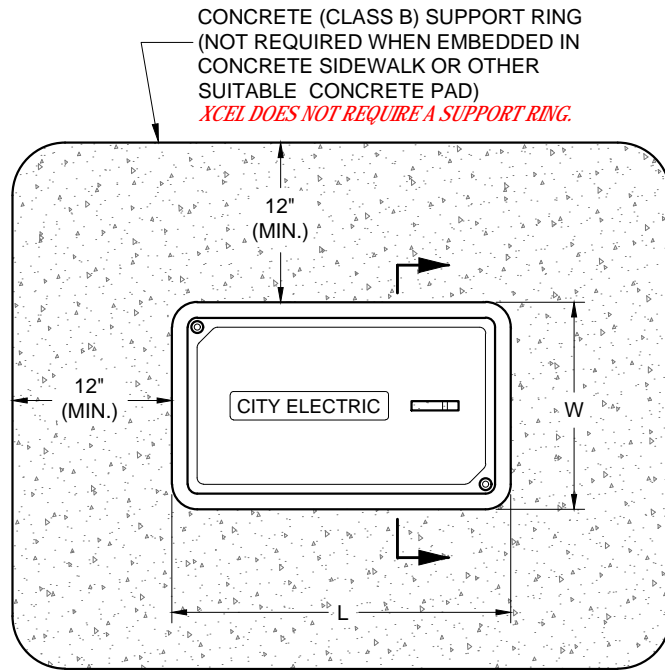
City and County of Denver
Department of Public Works

PULL BOX / SPLICE BOX TYPICAL DIMENSIONS

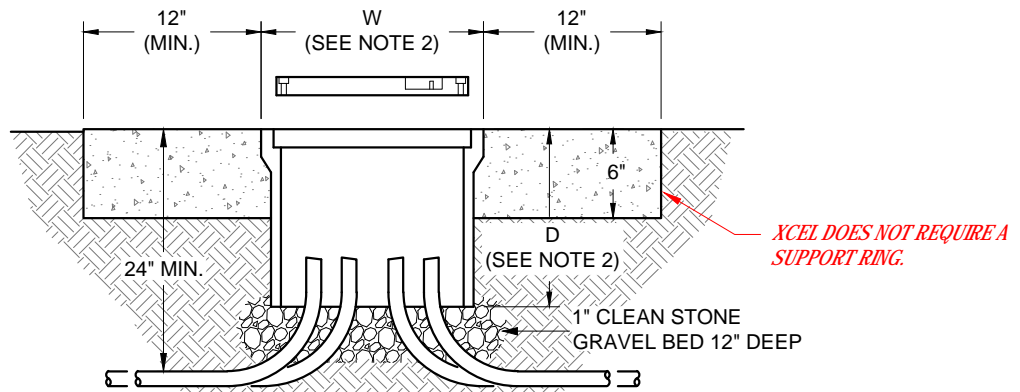
Date:
SEPTEMBER 2019

Std. Dwg. No.
DS-02

XCEL ENERGY SPECIFICATIONS



PLAN VIEW



SECTION A-A

TYPICAL PULL BOX / SPLICE BOX

DETAIL NOTES

1. ALL PULL OR SPLICE BOXES SHALL BE INCIDENTAL TRAFFIC RATED TO TIER 22 MINIMUM.
XCEL REQUIRES TIER 8 RATED PULL/SPLICE BOXES.
2. REFER TO DS-02 FOR PULL BOX SIZE REQUIREMENTS.



City and County of Denver
Department of Public Works

TYPICAL IN-GRADE COMPOSITE
PULL BOX / SPLICE BOX DETAIL

Date:
SEPTEMBER 2019

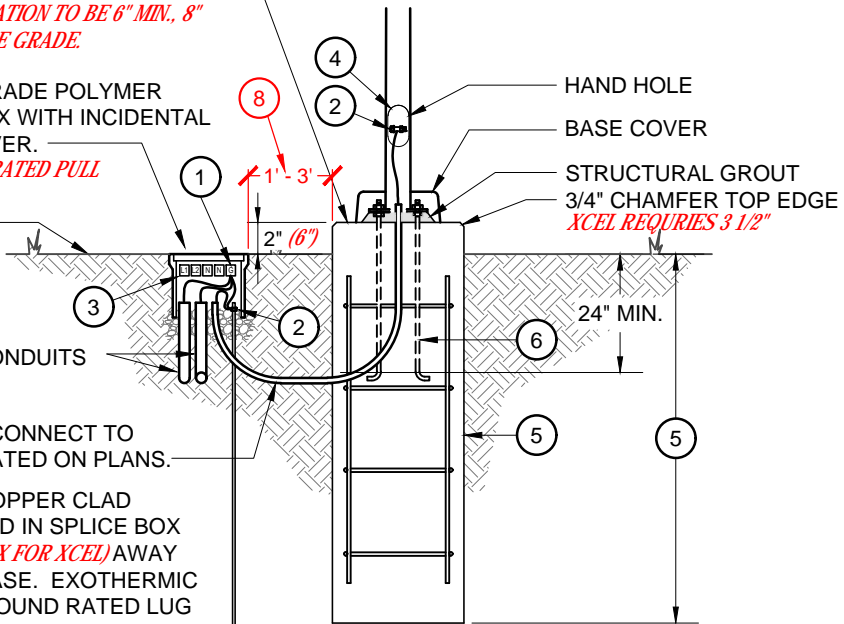
Std. Dwg. No.
DS-03

XCEL ENERGY SPECIFICATIONS

TOP OF FOUNDATION SHALL BE 2" ABOVE ADJACENT GRADE
XCEL REQUIRES FOUNDATION TO BE 6" MIN., 8" MAX. ABOVE SOFTSCAPE GRADE.

TIER 22 FLUSH-IN-GRADE POLYMER CONCRETE PULL BOX WITH INCIDENTAL TRAFFIC RATED COVER.
XCEL REQUIRES TIER 8 RATED PULL BOXES
 FINAL GRADE

2" PVC (MINIMUM) CONDUITS IN AND OUT.
 1" PVC (MINIMUM). CONNECT TO CIRCUIT AS DESIGNATED ON PLANS.
 5/8" DIA. X 8'-0" LG. COPPER CLAD DRIVEN GROUND ROD IN SPLICE BOX 6" (MIN.) *(1' MIN. - 3' MAX FOR XCEL)* AWAY FROM CONCRETE BASE. EXOTHERMIC WELD OR UNDERGROUND RATED LUG CONNECT CONDUCTOR TO GROUND ROD.




ELEVATION SECTION VIEW

FOUNDATION DETAIL NOTES

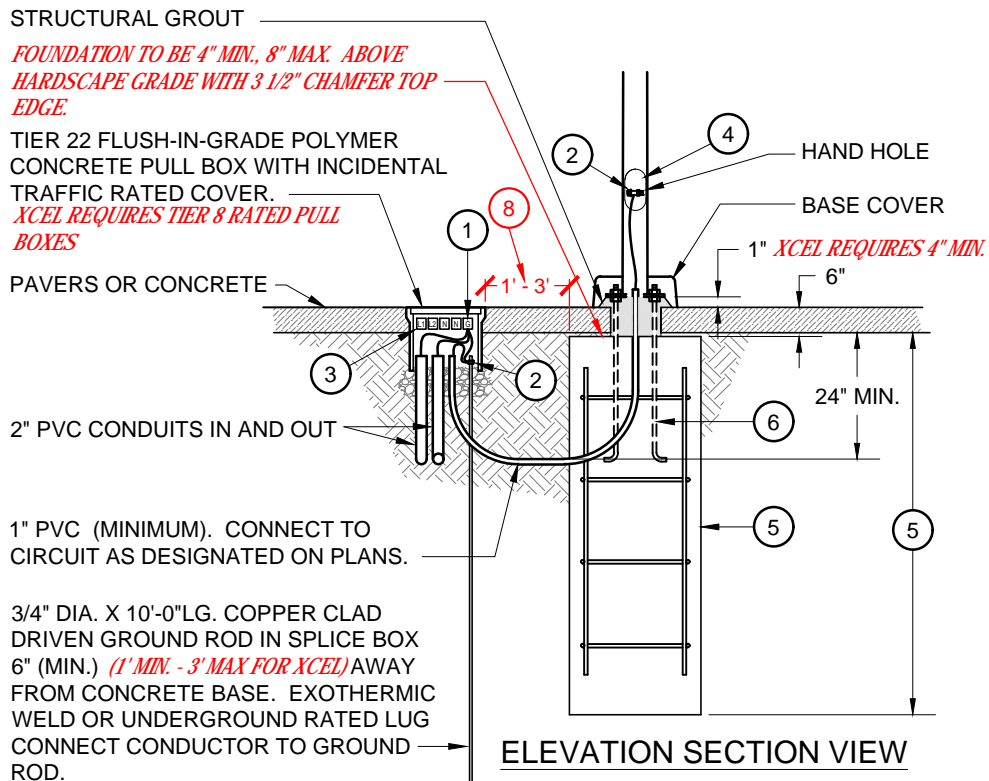
- ① BOND RACEWAY GROUND TO GROUND ROD IN PULL BOX / SPLICE BOX.
- ② BOND (1#6 SOFT DRAWN BARE CU) TO GROUND ROD IN PULL BOX / SPLICE BOX AND GROUNDING LUG IN POLE BASE HAND HOLE. *XCEL REQUIRES 1#4 CU.*
- ③ PROVIDE 3-TERMINAL UNDERGROUND RATED LUG CONNECTORS TO FIT #14AWG - #4AWG COPPER WIRE, BY BURNDY OR ILSCO NIMBUS OR APPROVED EQUAL. MAXIMUM OF (5) REQUIRED OR (1) FOR EACH CONDUCTOR IN HOME RUN.
XCEL REQUIRES 4-LUG TERMINAL FOR HOT CONDUCTORS AND 6-LUG TERMINAL FOR NEUTRAL /GROUND CONDUCTORS, 3-CONNECTIONS MAX. XCEL ALSO REQUIRES #12 AWG 350 KCMIL CU/AL.
- ④ AT EACH POLE BASE HAND HOLE, PROVIDE A BREAKAWAY, WATERPROOF, IN-LINE FUSE HOLDER BY EATON OR APPROVED EQUAL WITH FNQ-R 15A FUSE FOR EACH HOT AND A BREAKAWAY, WATERPROOF CONNECTOR ON NEUTRAL (IF REQUIRED).
- ⑤ LIGHT STANDARD FOUNDATION EMBEDMENT DEPTH, DIMENSIONS AND REINFORCEMENT SHALL BE PER DS-10 THROUGH DS-15 OR AS DESIGNED BY A STRUCTURAL ENGINEER LICENSED IN THE STATE OF COLORADO.
- ⑥ ANCHOR BOLT CIRCLE SHALL BE 12 INCH DIAMETER AND CENTERED ON FOUNDATION (OR PER SMALL CELL 24 INCH DIAMETER BOLT CIRCLE SPACING, FOR FUTURE SMALL CELL INSTALLATION).
- ⑧ *XCEL REQUIRES THE CLOSEST EDGE OF PULL BOX SHALL BE 1' TO 3' FROM FOUNDATION, EXCEPT WHEN FIELD CONDITIONS DICTATE OTHERWISE.*

GENERAL NOTE

FOUNDATION DETAILS ARE INCLUDED ONLY TO SHOW ELECTRICAL COMPONENTS. REFER TO DS-10 THROUGH DS-15 FOR STRUCTURAL REQUIREMENTS.

	City and County of Denver Department of Public Works	Date: SEPTEMBER 2019
	TYPICAL STREET LIGHT STANDARD FOUNDATION ELECTRICAL DETAIL IN SOFTSCAPE	Std. Dwg. No. DS-04

XCEL ENERGY SPECIFICATIONS



FOUNDATION DETAIL NOTES

- ① BOND RACEWAY GROUND TO GROUND ROD IN PULL BOX / SPLICE BOX.
- ② BOND (1#6 SOFT DRAWN BARE CU) TO GROUND ROD IN PULL BOX / SPLICE BOX AND GROUNDING LUG IN POLE BASE HAND HOLE. *XCEL REQUIRES 1#4 CU.*
- ③ PROVIDE 3-TERMINAL UNDERGROUND RATED LUG CONNECTORS TO FIT #14AWG - #4AWG COPPER WIRE, BY BURNDY OR ILSKO NIMBUS OR APPROVED EQUAL. MAXIMUM OF (5) REQUIRED OR (1) FOR EACH CONDUCTOR IN HOME RUN.
XCEL REQUIRES 4-LUG TERMINAL FOR HOT CONDUCTORS AND 6-LUG TERMINAL FOR NEUTRAL /GROUND CONDUCTORS, 3-CONNECTIONS MAX. XCEL ALSO REQUIRES #12 AWG 350 KCMIL CU/AL.
- ④ AT EACH POLE BASE HAND HOLE, PROVIDE A BREAKAWAY, WATERPROOF, IN-LINE FUSE HOLDER BY EATON OR APPROVED EQUAL WITH FNQ-R 15A FUSE FOR EACH HOT AND A BREAKAWAY, WATERPROOF CONNECTOR ON NEUTRAL (IF REQUIRED).
- ⑤ LIGHT STANDARD FOUNDATION EMBEDMENT DEPTH, DIMENSIONS AND REINFORCEMENT SHALL BE PER DS-10 THROUGH DS-15 OR AS DESIGNED BY A STRUCTURAL ENGINEER LICENSED IN THE STATE OF COLORADO.
- ⑥ ANCHOR BOLT CIRCLE SHALL BE 12 INCH DIAMETER AND CENTERED ON FOUNDATION (OR PER SMALL CELL 24 INCH DIAMETER BOLT CIRCLE SPACING, FOR FUTURE SMALL CELL INSTALLATION).
- ⑧ *XCEL REQUIRES THE CLOSEST EDGE OF PULL BOX SHALL BE 1' TO 3' FROM FOUNDATION, EXCEPT WHEN FIELD CONDITIONS DICTATE OTHERWISE.*

GENERAL NOTE

FOUNDATION DETAILS ARE INCLUDED ONLY TO SHOW ELECTRICAL COMPONENTS. REFER TO DS-10 THROUGH DS-15 FOR STRUCTURAL REQUIREMENTS.



City and County of Denver
 Department of Public Works

TYPICAL STREET LIGHT STANDARD
 FOUNDATION ELECTRICAL DETAIL IN HARDSCAPE

Date:
 SEPTEMBER 2019

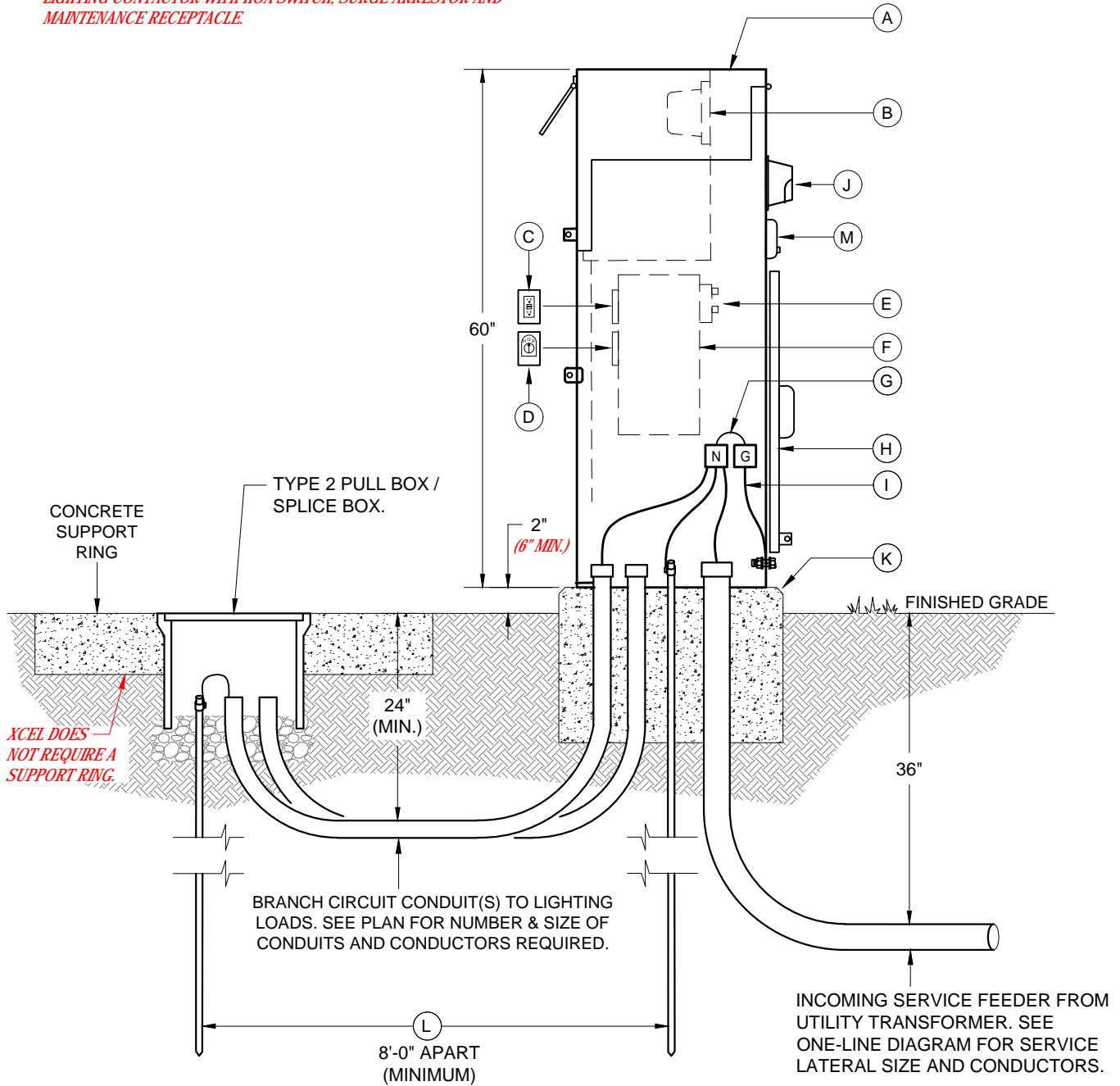
Std. Dwg. No.
 DS-05

XCEL ENERGY SPECIFICATIONS

NOTE:
REFER TO PLAN No. DS-07b FOR COMPONENT LIST.

XCEL NOTE:

1. XCEL ONLY REQUIRES CONTROL CABINETS FOR 70' AND GREATER LIGHT STANDARDS. TWO AMPERAGES AVAILABLE: 100AMP & 200AMP NON-METERED.
100AMP = CAT ID 54788
200AMP = CAT ID 212001
2. CABINET MOUNTED PHOTOCELL CONTROLS A 100A-2P OR 200A-2P LIGHTING CONTACTOR WITH HOA SWITCH, SURGE ARRESTOR AND MAINTENANCE RECEPTACLE.



City and County of Denver
Department of Public Works

TYPICAL LIGHTING CONTROL CENTER CABINET
DETAIL

Date:
SEPTEMBER 2019

Std. Dwg. No.
DS-06a

CABINET COMPONENT LIST

- (A) FULLY HINGED METER/TEST SECTION LOCKABLE COVER WITH HOLD OPEN ARM TO KEEP COVER FROM BLOWING SHUT PER XCEL ENERGY SPECIFICATION. COMBINATION ALL-IN-ONE COMMERCIAL METER POWER PEDESTAL IN A NEMA 3R STAINLESS STEEL ENCLOSURE.
- (B) UTILITY METER INSIDE NEMA 3R ENCLOSURE. METER SHALL HAVE LEVER BYPASS AND INTERNAL LOCKING TAB ON METER COVER.
- (C) GFCI MAINTENANCE RECEPTACLE FLUSH MOUNTED IN PANEL DEAD FRONT INSIDE OF THE NEMA 3R ENCLOSURE.
- (D) HAND-OFF-AUTO SWITCH - 15A-2P, HOA SWITCH WITH LEGEND, FLUSH MOUNTED IN PANEL DEAD FRONT INSIDE OF THE NEMA 3R ENCLOSURE.
- (E) UTILITY TERMINATION LANDING LUGS.
- (F) LOAD CENTERS WITH SERVICE MAIN AND BRANCH BREAKERS. ENGINEER SHALL PROVIDE PANEL SCHEDULE FOR BREAKERS REQUIRED.
- (G) PROVIDE NEUTRAL TO GROUND BONDING JUMPER.
- (H) LIFT OFF SERVICE COVER WITH PAD LOCK HASP.
- (I) CABINET GROUND BOND #6 BARE COPPER CONDUCTOR. *XCEL REQUIRES A #4 COPPER CONDUCTOR*
- (J) NEMA 3R 120V PHOTOELECTRIC CONTROL WITH 3-PRONG TWIST-LOCK RECEPTACLE BASE WIRED THROUGH THE H.O.A. SWITCH. THE PHOTOELECTRIC CONTROL SHALL BE MOUNTED ON THE NORTH SIDE ON ENCLOSURE TO MINIMIZE THE SUN'S INTERFERENCE.
- (K) REINFORCED CONCRETE (CLASS B) FOUNDATION PER STRUCTURAL ENGINEER LICENSED IN THE STATE OF COLORADO. MINIMUM 6" ABOVE GRADE, 3/4" CHAMFER ALL EXPOSED EDGES, 3" MINIMUM (6" MAXIMUM) OVERLAP ON ALL SIDES.
- (L) 3/4" X 10'-0" Lg. COPPER CLAD DRIVEN GROUND ROD. EXOTHERMIC WELD OR UNDERGROUND RATED LUG CONNECT CONDUCTOR TO GROUND ROD. (2) REQUIRED - 8'-0" APART (MIN.).
- (M) T-HANDLE, PULL-OUT FUSE HOLDER WITH FRN-R FUSES, METER DISCONNECT FOR METER PROTECTION (XCEL ENERGY SERVICE AREA), COLD SEQUENCE METER, WEATHERPROOF COVER WITH TAB LOCKABLE.

TYPICAL CABINET REQUIREMENTS:

200AMP MCB, 120/240V-1Ø-3W STAINLESS STEEL, NEMA 3R, METER/ POWER PEDESTAL WITH SEPARATE SEALABLE AND LOCKABLE CUSTOMER SECTION WITH:

1. LOAD CENTER (ENGINEER SHALL PROVIDE SCHEDULE FOR NUMBER OF CIRCUITS) FOR ALWAYS ON LOADS THAT INCLUDE:
(APPLIES TO STREET LIGHTS AND PEDESTRIAN LIGHTS)
 - SERVICE ENTRANCE M.C.B. - ENGINEER TO PROVIDE SIZE ON THE PANEL SCHEDULE.
 - CONTROL POWER CIRCUIT BREAKER - ENGINEER TO PROVIDE SIZE ON THE PANEL SCHEDULE.
 - SWITCHED LOAD CENTER MAIN BREAKER - ENGINEER TO PROVIDE ON THE PANEL SCHEDULE.
 - BRANCH BREAKERS AS SHOWN - ENGINEER TO PROVIDE SIZE AND QUANTITY ON THE PANEL SCHEDULE.
 - CIRCUIT DIRECTORY TO DOCUMENT CONFIGURATION IN POCKET ON HINGED DOOR.
 - MAINTENANCE RECEPTACLE FLUSH MOUNTED IN DEAD FRONT INSIDE ENCLOSURE.
2. CONTROL CIRCUIT INCLUDING:
(ONLY APPLIES TO PEDESTRIAN LIGHTS OR OTHER LIGHTS THAT DO NOT HAVE INDIVIDUAL ANSI 7-PIN RECEPTACLES.)
 - PHOTOCELL RECEPTACLE, MOUNTED EXTERNALLY ON NEMA-3R ENCLOSURE.
 - ONE HAND-OFF-AUTO (HOA) SWITCH FLUSH MOUNTED IN DEAD FRONT.
 - ONE LIGHTING CONTACTOR CONTROLLING ONE LOAD CENTER IN THIS SECTION.
 - ONE 12-CIRCUIT LOAD CENTER PHOTOCELL ON/OFF CONTROLLED.
 - A CIRCUIT DIRECTORY TO DOCUMENT CONFIGURATION IN POCKET ON HINGED DOOR.

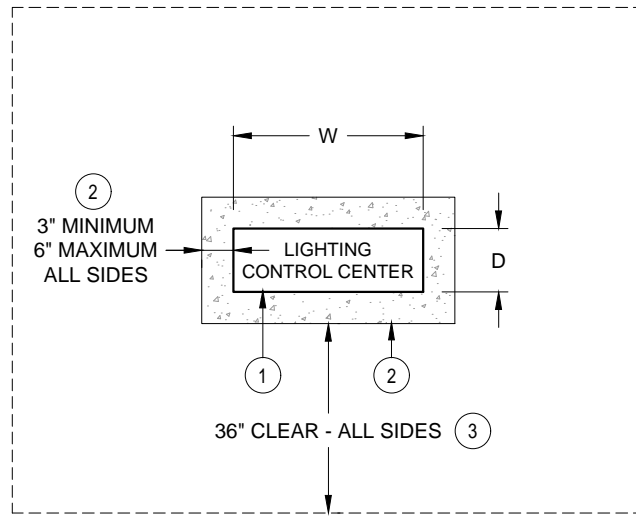


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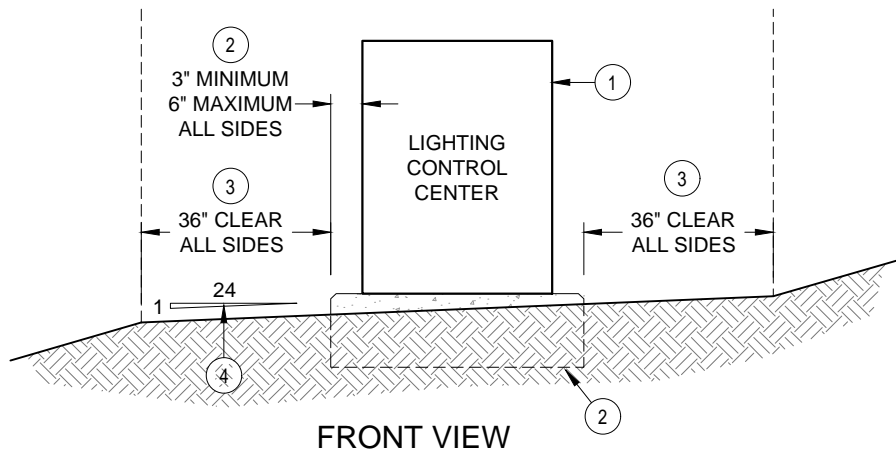
TYPICAL LIGHTING CONTROL CENTER CABINET
COMPONENTS LIST

Date:
SEPTEMBER 2019

Std. Dwg. No.
DS-06b



PLAN VIEW



FRONT VIEW

TYPICAL LIGHTING CONTROL CENTER DETAIL

DETAIL NOTES

- ① PREBUILT NEMA 3R LIGHTING CONTROL CENTER CABINET (LCC). REFER TO LIGHTING CONTROL CENTER DETAILS FOR MORE INFORMATION.
- ② REINFORCED CONCRETE (CLASS B) FOUNDATION PAD, PER STRUCTURAL ENGINEER LICENSED IN THE STATE OF COLORADO, WITH 1" CHAMFER ON ALL EXPOSED EDGES. EDGE OF CONCRETE TO EXTEND 3" (MINIMUM) OR 6" (MAXIMUM) BEYOND EDGE OF CABINET.
- ③ THE LCC SHALL NOT BE LOCATED IN ANY INTERSECTION SIGHT TRIANGLES. PLACEMENT SHALL CONFORM TO ALLOWABLE ENCROACHMENTS IN THE PUBLIC ROW.
- ④ MINIMUM OF 36" CLEAR ZONE ON ALL SIDES OF CONCRETE PAD.
- ⑤ MAXIMUM OF 1:24 SLOPE IN CLEAR ZONE AREA.



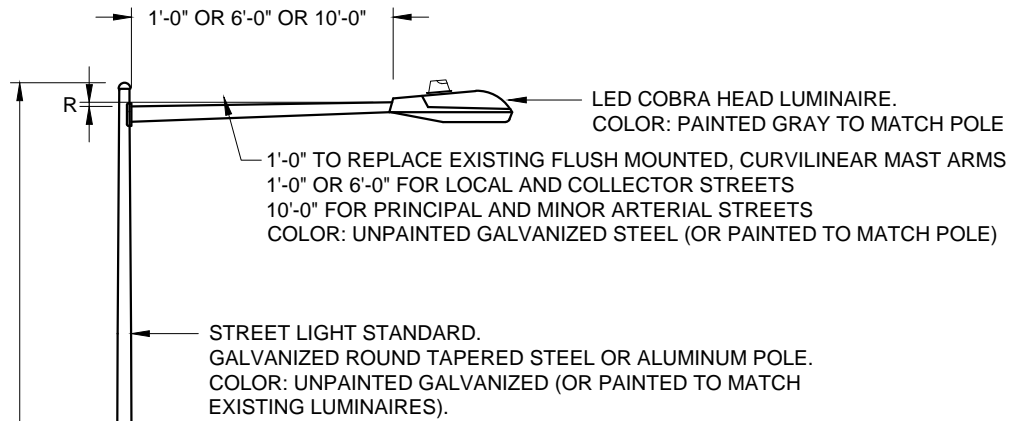
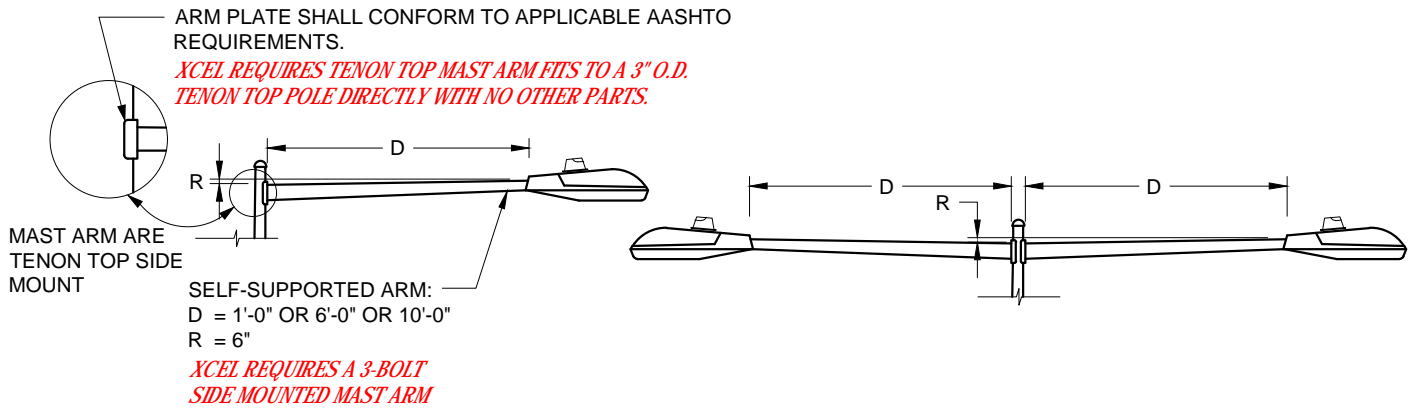
City and County of Denver
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TYPICAL LIGHTING CONTROL CENTER
CABINET DETAIL

Date:
SEPTEMBER 2019

Std. Dwg. No.
DS-07

XCEL ENERGY SPECIFICATIONS



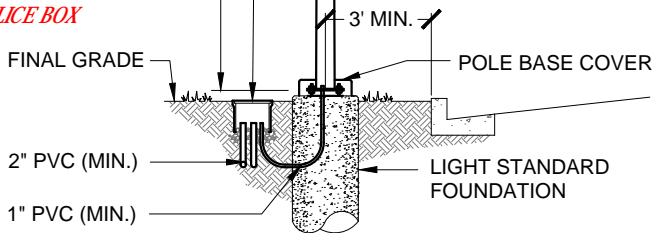
XCEL OFFERS 30'-0" TO 50'-0" POLE LENGTHS

NOTES

1. ALL LUMINAIRES SHALL BE LED.
2. COLOR TEMPERATURE 3000K, PER ANSI C78.377-2011 STANDARD.
3. ALL LUMINAIRES SHALL BE EQUIPPED WITH A SURGE SUPPRESSION DEVICE WITH A MINIMUM IMMUNITY LEVEL OF 10kV.
4. ALL LUMINAIRES SHALL BE EQUIPPED WITH A 0-10V DIMMING DRIVER.
5. ALL LUMINAIRES SHALL BE EQUIPPED WITH AN ANSI C136.41 7-PIN RECEPTACLE AND PHOTOCCELL OR CONTROL NODE.
6. ALL LUMINAIRES SHALL HAVE EITHER TYPE II OR TYPE III DISTRIBUTION.

PROVIDE A TYPE 1 OR TYPE 2 PULL / SPLICE BOX ADJACENT TO EACH POLE.

XCEL REQUIRES THE SMALL OR LARGE PULL/SPLICE BOX



30 FT. TO 50 FT. STANDARD

XCEL REQUIRES 30 FT. TO 40 FT. STANDARD

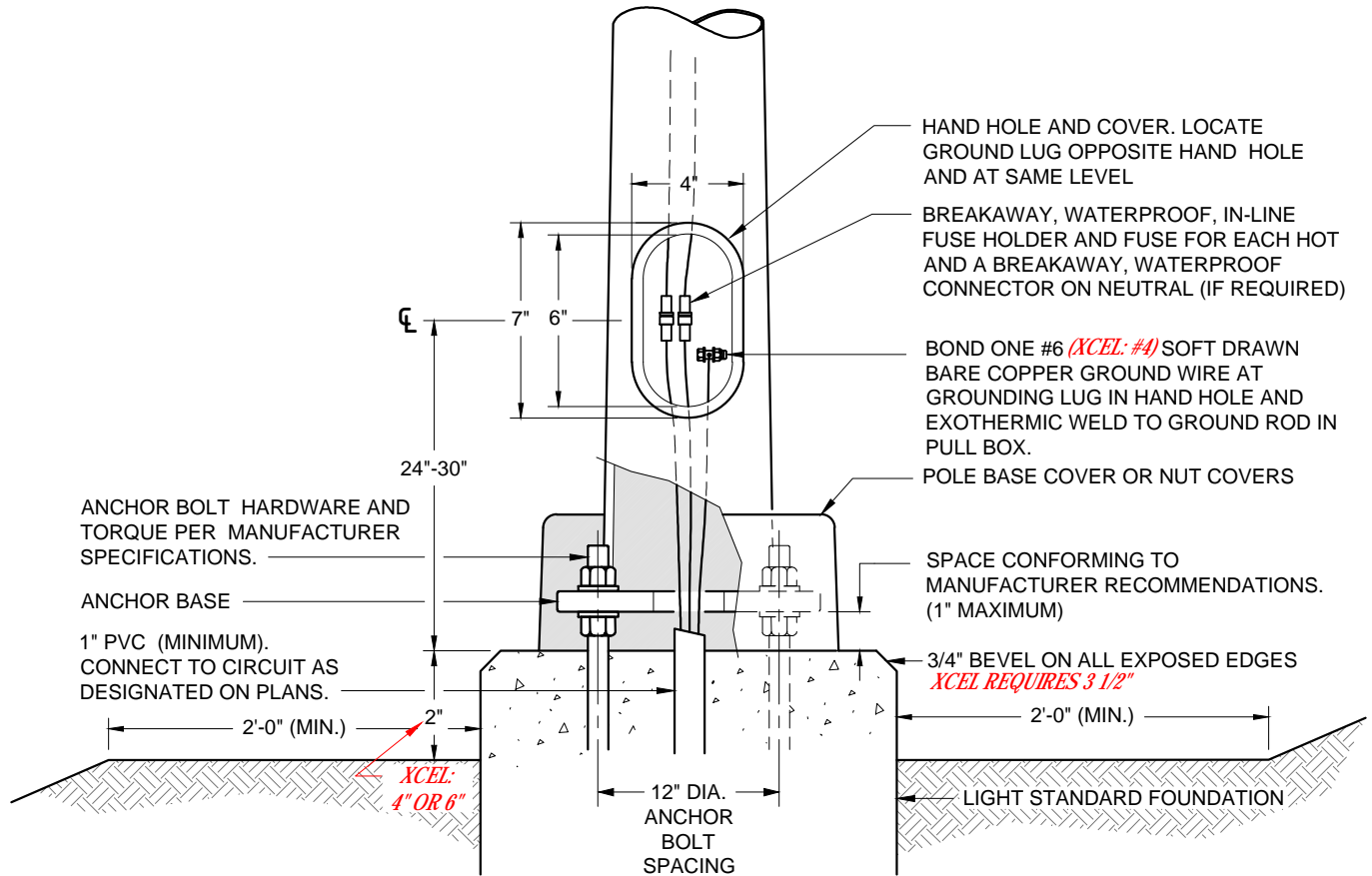


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TYPICAL STREET LIGHT STANDARD DETAILS

Date:
 SEPTEMBER 2019

Std. Dwg. No.
 DS-08



TYPICAL NON-BREAKAWAY BASE DETAIL

FOR USE ONLY OUTSIDE CLEAR ZONE OR IN PROTECTED INSTALLATIONS.

NOTES

1. LIGHT STANDARD FOUNDATIONS SHALL BE PRECAST CONCRETE.
2. ALL CONDUCTORS SHALL BE SIZED IN CONFORMANCE WITH N.E.C. REQUIREMENTS 3/C COPPER #12 AWG CABLE MINIMUM.
3. *XCEL REQUIRES SIZE BASED ON THE ODL MANUAL "MAXIMUM DISTANCE AND LUMNAIRES PER STREETLIGHT CONDUCTOR RUN-UG FED" USING ALUMINUM CONDUCTORS.*
4. *XCEL IS GOVERNED BY THE N.E.S.C. INSTEAD OF N.E.C.*



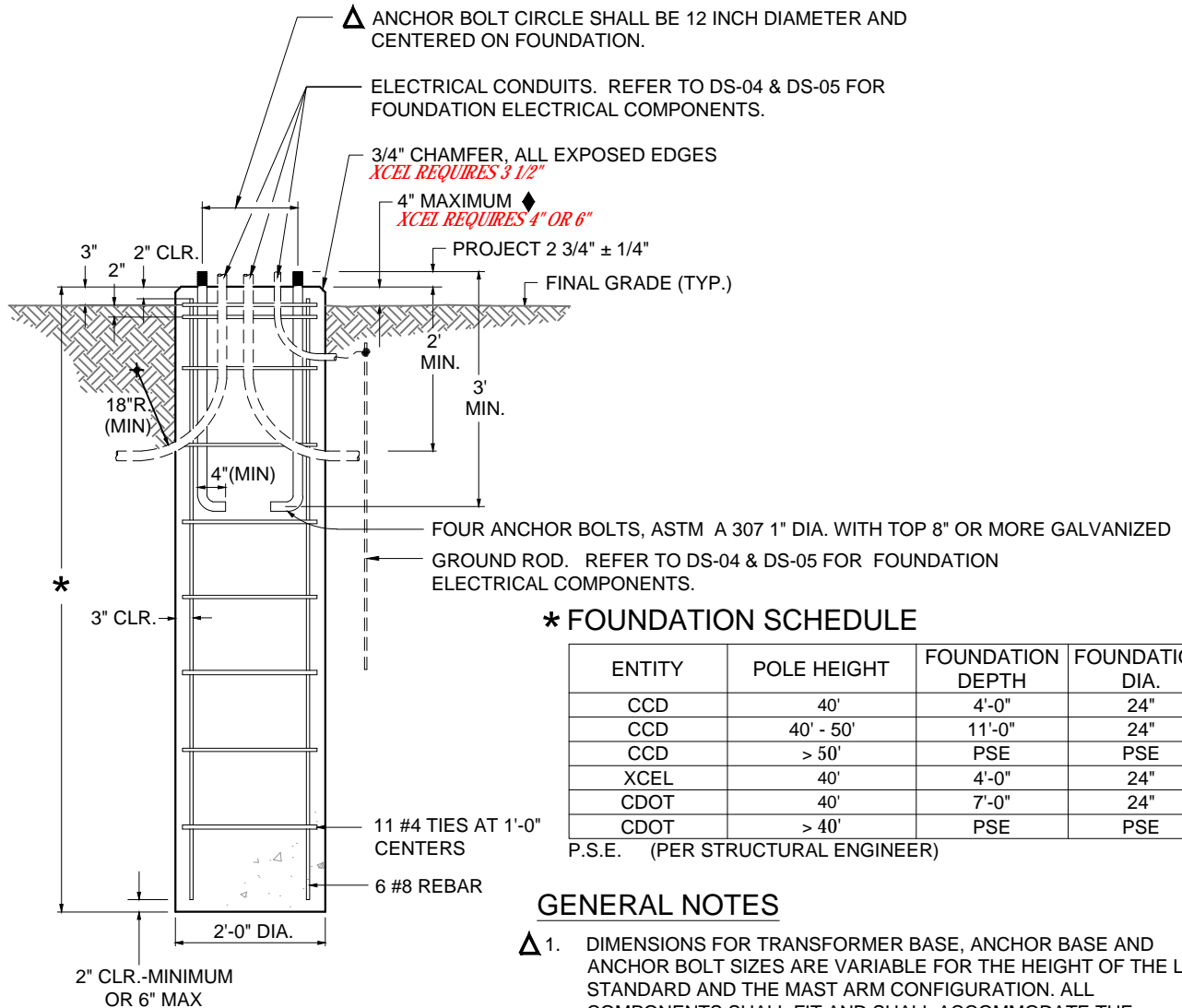
City and County of Denver
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Date:
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TYPICAL NON-BREAKAWAY POLE BASE
STANDARD DETAIL

Std. Dwg. No.
DS-09

XCEL ENERGY SPECIFICATIONS



*** FOUNDATION SCHEDULE**

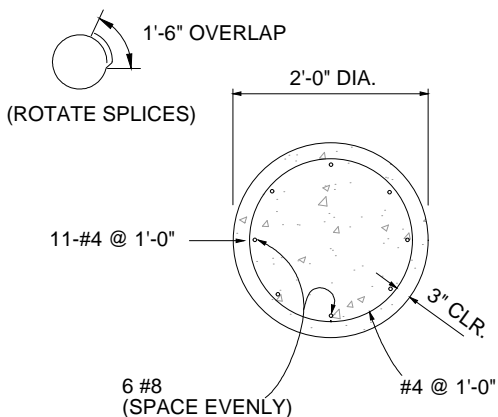
ENTITY	POLE HEIGHT	FOUNDATION DEPTH	FOUNDATION DIA.
CCD	40'	4'-0"	24"
CCD	40' - 50'	11'-0"	24"
CCD	> 50'	PSE	PSE
XCEL	40'	4'-0"	24"
CDOT	40'	7'-0"	24"
CDOT	> 40'	PSE	PSE

P.S.E. (PER STRUCTURAL ENGINEER)

GENERAL NOTES

1. DIMENSIONS FOR TRANSFORMER BASE, ANCHOR BASE AND ANCHOR BOLT SIZES ARE VARIABLE FOR THE HEIGHT OF THE LIGHT STANDARD AND THE MAST ARM CONFIGURATION. ALL COMPONENTS SHALL FIT AND SHALL ACCOMMODATE THE REQUIREMENTS OF THE LIGHT STANDARD SUPPLIED.
2. CAST-IN-PLACE FOUNDATIONS SHALL BE CONCRETE CDOT CLASS 'BZ'.
3. PRECAST CONCRETE FOUNDATIONS SHALL BE CDOT CLASS 'B'.
4. WHERE FOUNDATION IS LOCATED IN THE SIDEWALK, THE TOP OF THE FOUNDATION SHALL BE FLUSH WITH THE TOP OF THE SIDEWALK CONFORMING TO ADA REQUIREMENTS.
5. FOUNDATION DIMENSIONS PER FOUNDATION SCHEDULE BELOW. LIGHT STANDARDS HIGHER THAN 50'-0" OR WITH MULTIPLE LUMINAIRES OR BANNERS, OR VARYING SOIL OR WIND CONDITIONS, SHALL BE DESIGNED BY A STRUCTURAL ENGINEER LICENSED IN THE STATE OF COLORADO AND SHOWN ON THE PLANS.

XCEL REQUIRES CCD TO BE RESPONSIBLE FOR THE REMOVAL AND REPLACEMENT OF ANY FOUNDATIONS IF DAMAGED AND IF NOT SPECIFIED BY THE XCEL ENERGY OUTDOOR LIGHTING MANUAL GUIDE LINES. (48" Dp. x 24" Dia. PRECAST FOUNDATION. XCEL CAT ID# 54541)



TYPICAL FOUNDATION SECTION

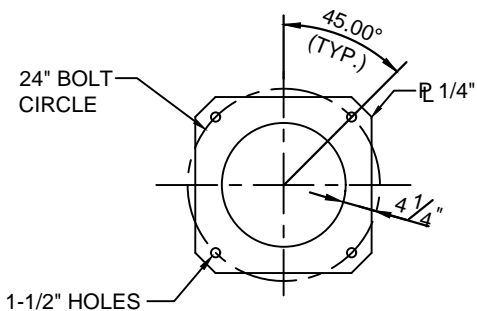


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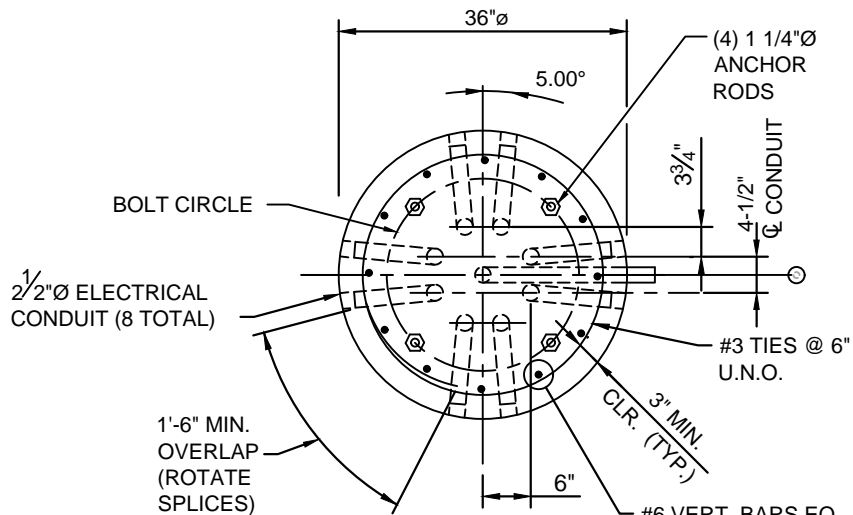
TYPICAL LIGHT STANDARD
FOUNDATION STRUCTURAL DETAIL

Date:
SEPTEMBER 2019

Std. Dwg. No.
DS-10

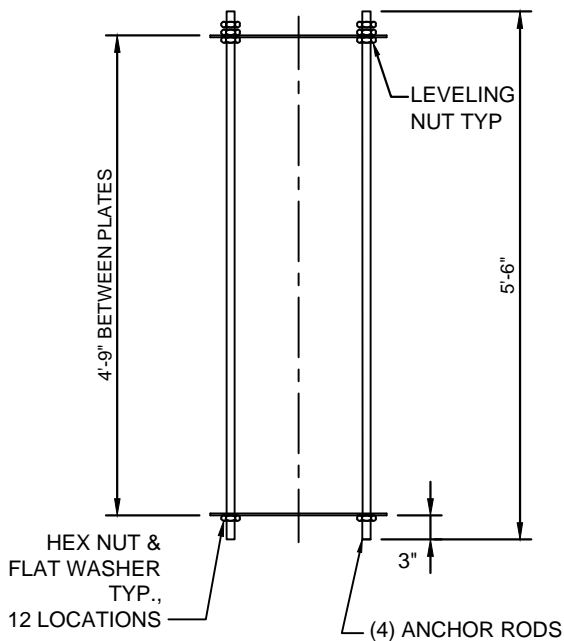


TEMPLATE/EMBEDMENT PLATE PLAN



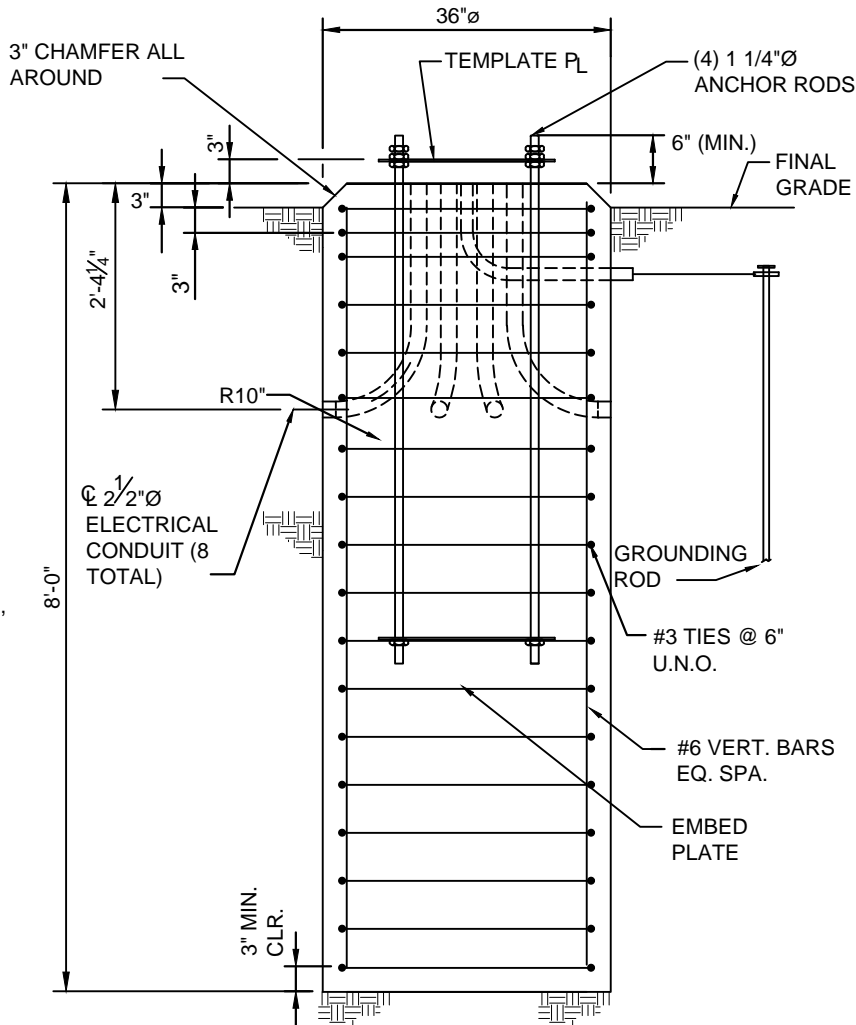
CAISSON SECTION

(TEMPLATE PL NOT SHOWN)



ANCHOR BOLT DETAIL

1 1/4"Ø ANCHOR BOLTS ASTM A193 GRADE B7 AND SHALL BE GALVANIZED w/HEAVY NUTS, LEVELING NUTS, AND ASTM F436 HARDENED STEEL WASHERS



CAISSON FOUNDATION DETAIL

NOTES:

- 1) REFER TO SS-13 FOR GENERAL STRUCTURAL NOTES.
- 2) REFER TO ELECTRICAL DETAILS FOR CONDUIT, ELECTRICAL, AND GROUNDING REQUIREMENTS.
- 3) POLE HEIGHTS GREATER THAN 40'-0" REQUIRE FOUNDATION DESIGN BY CONTRACTOR.

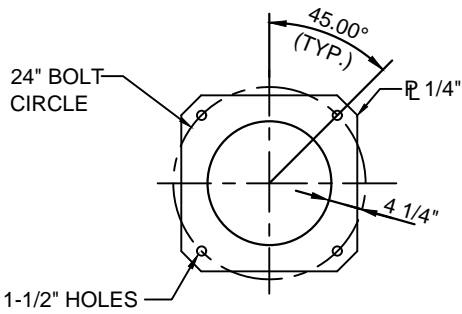


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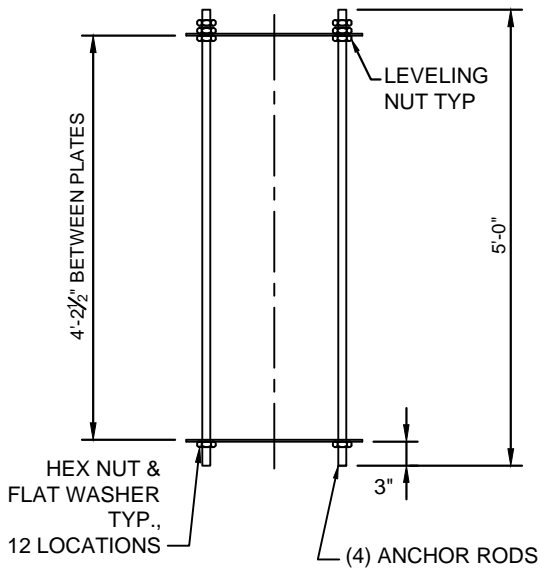
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TYPICAL SMALL CELL PIER FOUNDATION DETAIL

Std. Dwg. No.
DS-11

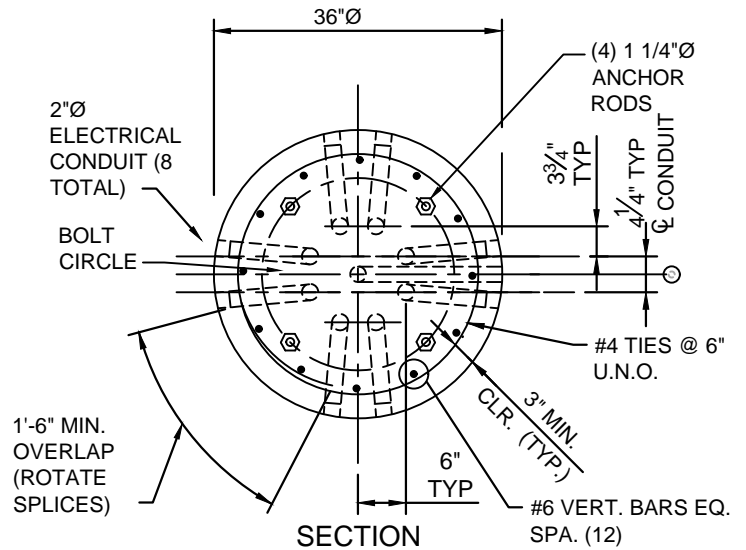


TEMPLATE/EMBEDMENT PLATE PLAN

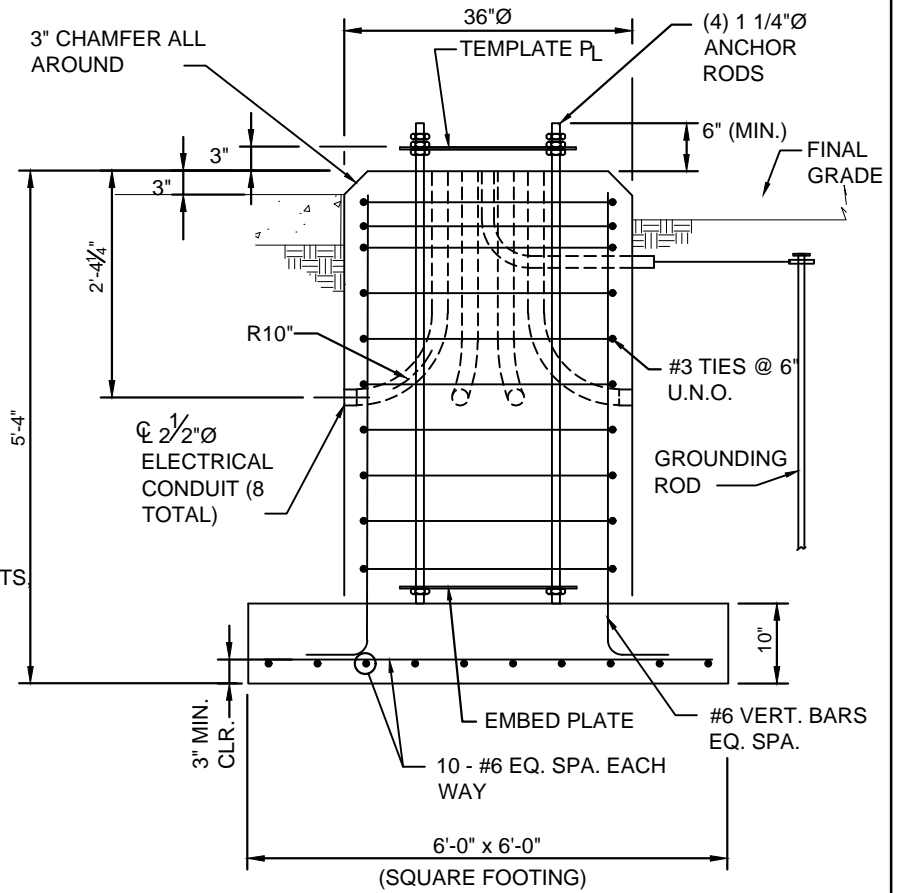


ANCHOR BOLT DETAIL

1 1/4"Ø ANCHOR BOLTS ASTM A193 GRADE B7 AND SHALL BE GALVANIZED w/HEAVY NUTS, LEVELING NUTS, AND ASTMF436 HARDENED STEEL WASHERS



SECTION



FOUNDATION DETAIL

NOTES:

- 1) REFER TO SS-13 FOR GENERAL STRUCTURAL NOTES.
- 2) REFER TO ELECTRICAL DETAILS FOR CONDUIT, ELECTRICAL, AND GROUNDING REQUIREMENTS.
- 3) POLE HEIGHTS GREATER THAN 40'-0" REQUIRE FOUNDATION DESIGN BY CONTRACTOR.



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TYPICAL SMALL CELL SPREAD FOOTING
FOUNDATION DETAIL

Date:
September 2019

Std. Dwg. No.
DS-12

GENERAL STRUCTURAL NOTES:

1. DESIGN INFORMATION AND GENERAL REQUIREMENTS

1.1. CODES AND DESIGN GUIDELINES

- A. 2015 INTERNATIONAL BUILDING CODE, WITH CITY & COUNTY OF DENVER (CCD) AMENDMENTS.
- B. TIA-222_G, STRUCTURAL STANDARD FOR ANTENNA SUPPORTING STRUCTURES AND ANTENNAS WITH EXCEPTION OF CCD REQUIREMENTS FOR FROST DEPTH.
- C. AASHTO LRFD SPECIFICATIONS FOR STRUCTURAL SUPPORTS FOR HIGHWAY SIGNS, LUMINAIRES, AND TRAFFIC SIGNALS, FIRST EDITION WITH LATEST INTERIMS.
- D. AMERICAN CONCRETE INSTITUTE (ACI) BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE 318-14.
- E. CITY & COUNTY OF DENVER STREET LIGHTING DESIGN GUIDELINES.

1.2. LOADS

- A. WIND LOAD SHALL BE 115 MPH ULTIMATE BASED ON ASCE 7-10 SPECIAL WIND REGION.
- B. MAXIMUM DEAD LOAD AT TOP OF FOUNDATION (INCLUDING POLE, POLE BASE, LUMINAIRES, CANTENNA AND EQUIPMENT) IS ASSUMED TO BE 2600 LBS.
- C. TYPICAL RISK CATEGORY WITH MEAN RECURRENCE INTERVAL = 700 YRS (AASHTO).
- D. STRUCTURE CLASS II (TIA)

1.1. GEOTECHNICAL

- A. THE FOLLOWING SOIL PARAMETERS WERE USED FOR STANDARD FOUNDATION DESIGN:
 - 1. LOOSE GRANULAR SOIL WITH A UNIT WEIGHT OF 110 PCF AND A 28 DEGREE ANGLE OF INTERNAL FRICTION (PHI ANGLE).
 - 2. SOFT COHESIVE SOIL WITH A UNIT WEIGHT OF 110 PCF AND A UNIT COHESION OF 500 PSF.
 - 3. PIER AND FOOTING FOUNDATION: COMPACTED FOUNDATION SOIL NET ALLOWABLE BEARING CAPACITY OF 500 PSF WAS USED FOR DESIGN.
- B. CONTACT THE CCD PROJECT REPRESENTATIVE IF ANY OF THE FOLLOWING SOIL CONDITIONS ARE ENCOUNTERED DURING DRILLING/EXCAVATION:
 - 1. THE SOIL HAS A HIGH ORGANIC CONTENT, VOIDS, DELETERIOUS SOILS OR CONSISTS OF SATURATED SOILS.
 - 2. THE SITE WON'T SUPPORT THE WEIGHT OF THE DRILLING RIG.
 - 3. THE FOUNDATION SOILS ARE NOT HOMOGENEOUS.
 - 4. FIRM BEDROCK IS ENCOUNTERED.

1.1. MISCELLANEOUS

- A. CONTRACTOR SHALL VERIFY ALL DIMENSIONS, ELEVATIONS, AND EXISTING CONDITIONS PRIOR TO PROCEEDING WITH THE WORK.

2. FOUNDATION NOTES

2.1. GENERAL

- A. HYBRID STANDARD FOUNDATIONS SHALL BE DRILLED CONCRETE CAISSON FOUNDATIONS. THE PIER AND FOOTING FOUNDATION DETAILS PRESENTED IN THESE GUIDELINES PRESENT AN ALTERNATIVE FOUNDATION TYPE THAT MAY BE PROPOSED BY THE CONTRACTOR WITH APPROVAL OF THE CITY & COUNTY OF DENVER.
- B. CAISSON OR PIER AND FOOTING FOUNDATION TYPES MAY BE PROVIDED AS CAST-IN-PLACE CONCRETE OR PRECAST CONCRETE CONSTRUCTION ELEMENTS AT THE OPTION OF THE CONTRACTOR.

2.2. EARTHWORK

- A. DESIGN, FURNISH, AND LEVEL ALL TEMPORARY SHEETING, SHORING, AND DRAINAGE TO MAINTAIN THE EXCAVATION AND PROTECT SURROUNDING STRUCTURES AND UTILITIES.
- B. CAISSON FOUNDATIONS:
 - 1. CAISSONS SHALL BE PLACED AGAINST UNDISTURBED EARTH WITH THE DRILLED HOLE MATCHING THE OUTER DIAMETER OF A CAST-IN-PLACE CAISSON.
 - 2. PRECAST CAISSON FOUNDATIONS SHALL BE DRILLED AT A DIAMETER NO LARGER THAN THE OUTER DIAMETER OF THE CAISSON PLUS 6 INCHES.
 - 3. OVER EXCAVATED AREAS OF THE PRECAST CAISSON SHALL BE BACKFILLED USING A LEAN CONCRETE SLURRY (FLOWABLE FILL) WITH A MINIMUM COMPRESSIVE STRENGTH OF 200 PSI.
- C. PIER AND FOOTING FOUNDATIONS:
 - 1. THOROUGHLY COMPACT BOTTOM OF FOOTINGS PRIOR TO PLACING ANY CONCRETE.
 - 2. BACKFILL SHALL BE COMPACTED TO 95% STANDARD PROCTOR.
 - 3. PRECAST PIER AND FOOTING FOUNDATIONS SHALL BE EXCAVATED SO THAT THE BOTTOM SURFACE IS LEVEL AND COMPACTED TO PROVIDE THE REQUIRED BEARING CAPACITY OF THE UNDISTURBED SOIL.



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GENERAL SMALL CELL FOUNDATION STRUCTURAL
NOTES

Date:
September 2019

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DS-13

GENERAL STRUCTURAL NOTES (CONTINUED):

2.3. CAST-IN-PLACE (CIP) OR PRECAST CONCRETE


- A. CONCRETE CONSTRUCTION SHALL BE IN ACCORDANCE WITH ACI 301 "SPECIFICATIONS FOR STRUCTURAL CONCRETE".
- B. CONCRETE MIX DESIGN TO BE IN ACCORDANCE WITH ACI 318, CHAPTER 26 AND THE SPECIFICATIONS INCLUDED IN THESE GUIDELINES.
- C. CAST-IN-PLACE CONCRETE SHALL BE CLASS BZ WITH A MINIMUM 28 DAY COMPRESSIVE STRENGTH OF 4500 PSI.
- D. PRECAST CONCRETE SHALL BE CLASS B WITH A MINIMUM 28 DAY COMPRESSIVE STRENGTH OF 4500 PSI.
- E. ALL CONCRETE SHALL MEET CDOT CLASS 2 SULFATE MITIGATION UNLESS A PARTICULAR SITE CAN BE TESTED FOR A LOWER OR MAY BE IDENTIFIED FOR HIGHER CLASS 3 SULFATE MITIGATION PER ACI 318.
- F. MAXIMUM SLUMP PRIOR TO THE ADDITION OF SUPER PLASTICIZER ADMIXTURES SHALL BE 3 INCHES.
- G. NO CALCIUM CHLORIDE ADMIXTURES OR OTHER AGGREGATES CONTAINING CHLORIDES SHALL BE USED IN ANY CONCRETE.
- H. COARSE AGGREGATE FOR NORMAL WEIGHT CONCRETE SHALL CONFORM TO ASTM C33 SIZE #57.
- I. COLD WEATHER PLACEMENT SHALL COMPLY WITH ACI 306.1.
- J. HOT WEATHER PLACEMENT SHALL COMPLY WITH ACI 305R.

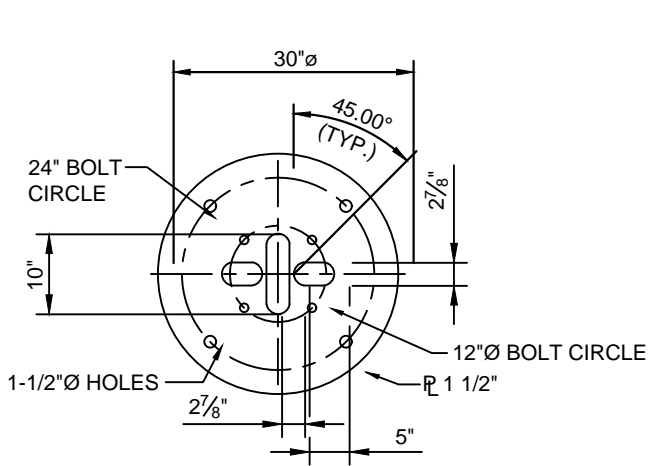
2.4. REINFORCEMENT

- A. REINFORCING STEEL SHALL CONFORM TO ASTM A615, GRADE 60.
- B. BARS SHALL BE SECURELY HELD IN ACCURATE POSITION BY SUITABLE ACCESSORIES, TIE BARS, SUPPORT CHAIRS, ETC.
- C. HOOK LENGTHS SHALL BE A MINIMUM 12 BAR DIAMETERS.
- D. CONCRETE COVER FOR REINFORCING SHALL BE AS FOLLOWS:
 - 1. CONCRETE CAST AGAINST EARTH: 3 INCHES.
 - 2. CONCRETE (CIP OR PRECAST) TO BE IN CONTACT WITH GROUND OR WEATHER: 2 INCHES.

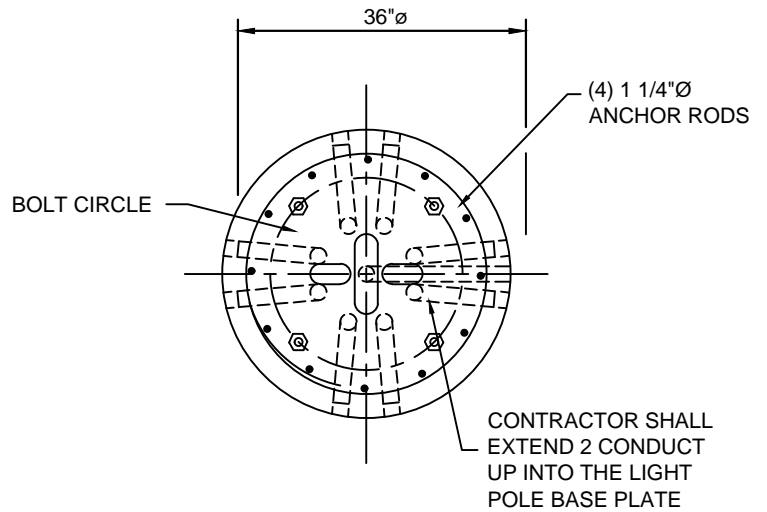
2.5. ANCHOR BOLTS, ANCHOR EMBED PLATE, NUTS AND WASHERS SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM A153.

2.6. ALL FOUNDATIONS SHALL HAVE GROUNDING IN CONFORMANCE WITH THE NEC.

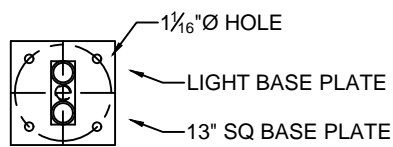
	City and County of Denver Department of Public Works	Date: September 2009
	GENERAL SMALL CELL FOUNDATION STRUCTURAL NOTES, CONTINUED	Std. Dwg. No. DS-14



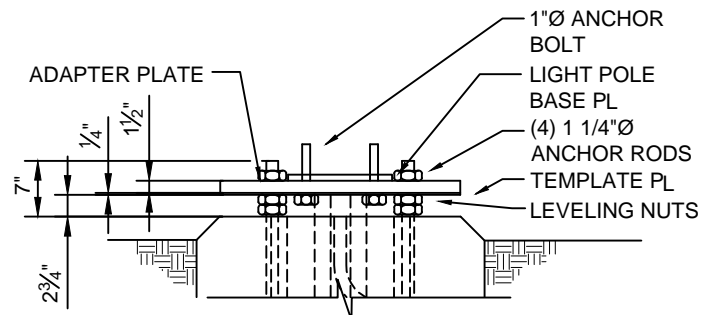
ADAPTER - PLATE PLAN



CAISSON PLAN



LIGHT POLE BASE PLATE DETAIL



CAISSON FOUNDATION DETAIL

1"Ø ANCHOR BOLTS ASTM A193 GRADE B7 AND SHALL BE GALVANIZED w/HEAVY NUTS, LEVELING NUTS, AND ASTM F436 HARDENED STEEL WASHERS

NOTES:

- 1) REFER TO DS-13 & 14 FOR GENERAL STRUCTURAL NOTES.
- 2) REFER TO ELECTRICAL DETAILS FOR CONDUIT, ELECTRICAL, AND GROUNDING REQUIREMENTS.
- 3) POLE HEIGHTS GREATER THAN 40'-0" REQUIRE FOUNDATION DESIGN BY CONTRACTOR.
- 4) APPROXIMATE WEIGHT OF LIGHT POLE 500 LBS
- 5) ADAPTER PLATE SHALL BE DESIGN BY OTHERS.



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September 2019

TYPICAL ADAPTOR PLATE DETAIL

Std. Dwg. No.
DS-15

D



Specifications

The following sections describe in detail luminaire, light standard, light standard foundation, and electrical specifications. All work completed in the ROW must be in accordance with the Denver Public Works Transportation Standards and Engineering Details.

D.1 Exterior Lighting

Description

This work consists of furnishing and installing foundations, light standards, luminaires, conduit, junction boxes, cable, wiring, junction boxes, and incidental materials for lighting in accordance with these specifications and in conformance with the details, lines, grades, and locations shown on the plans or established in the field.

Materials

Lighting materials shall conform to Section D.2 Lighting and Electrical Materials.

- a) *Foundations.* Concrete bases and equipment pads shall be pre-cast or cast-in-place concrete. A complete foundation includes the concrete, reinforcing steel, anchor bolts, leveling nuts, conduit stubs, ground rod and wire, excavation and backfill, restoration, accessories as required to provide a complete unit. Banner arm (if required) wind loading shall be incorporated into light standard structural design.
- b) *Lighting Standard.* A complete light standard includes the metal light pole, mounting bracket, mast arm or arms, base or transformer base, approved breakaway device (optional), grounding system, and all hardware. When a transformer base is not used, the pole shall have a handhole.

Pole and mast arm or arms shall be the type and size shown on the plans.
- c) *Conduit.* Conduit includes conduit, trenching, backfill, jacking, augering, fittings, drainage tees, sealing, restoration, and accessories as required to provide a complete installation.
- d) *Electrical Warning Tape.* Electrical warning tape shall consist of pre-manufactured non-adhesive polyethylene material that is unaffected by acids, alkalines, and other soil components. The color of the tape shall be red, and it shall be, at a minimum, 3.5 mils thick and 6 inches wide. Its tensile strength shall be 1,750 psi lengthwise.

The electrical tape shall include the following identification printed in black letters continuously along the length of the tap: "CAUTION BURIED ELECTRIC LINE BELOW".

The identification note and color of tape shall conform to the requirements of the "American Public Works Association (APWA) Uniform Color Codes (Red) – Electrical Power Lines, Cables, Conduit and Lighting Cables."

- e) *Luminaire*. A complete luminaire includes the housing, lens, Light Emitting Diode (LED) light source, luminaire housing, dimmable driver, mounting slip fitter or approved manufacturer mounting, all necessary internal wiring, and 7-pin dimming receptacle or control node.

Luminaires shall operate at either 120 VAC, 60 Hz or 240 VAC 60 Hz.

- f) Wireless Lighting Controls and Monitoring System (to be developed).
- g) *Lighting Control Center*. A complete lighting control center includes the load center, grounding system, contactors, meter base, meter, photoelectric control, lightning arrestor, control switch, wiring, NEMA 3R enclosure, service equipment and connections to the energy provider's secondary power supply, and accessories as required.
- h) *Conductors*. Conductor includes control wiring, luminaire wiring, main circuit wiring, ground wiring, service entrance wiring, pulling, splicing, connections, testing, and all other wiring necessary for a complete installation.
- i) *Pull boxes*. Pull box includes pull box, cover with bolts, excavation, gravel base, backfill, sealing, restoration, and accessories as required to provide a complete installation.
- j) *Materials List*. At the preconstruction conference the Contractor shall submit to the Engineer three copies of a list of all materials and equipment to be incorporated into the work. The Contractor shall include the following items on the list:
- a. Light standards
 - b. Luminaires
 - i. Luminaire manufacturer's product information including photometric data in Illuminating Engineering Society of North America (IESNA) format, IESNA photometric distribution type for vertical and lateral distribution (example: B2-U0-G1, Type III), and a photograph or line drawing
 - ii. Luminaire lumens
 - iii. LED dimming driver product information
 - iv. Twist lock 7-pin photoelectric receptacle or Itron SLV control node (or approved equal).
 - c. Lighting Control Center
 - d. Pull Box
 - e. Fuse holders
 - f. Conductors
 - g. Conduit
 - h. Wireless Lighting Control and Monitoring System
 - i. Light Pole Foundations
 - j. Equipment pads
 - k. All other items required for a complete installation

The Engineer will return lists that are incomplete or that include unacceptable materials to the Contractor for correction and re-submission.

The Contractor shall not order materials or equipment until the Engineer and the party or agency responsible for maintenance have reviewed and approved the materials and equipment list. The Engineer's approval of the list shall not relieve the Contractor responsibility for the proper functioning of the completed installation.

- k) *Luminaire Warranty.* The Contractor shall ensure that the LED Roadway Luminaire has a minimum warranty of 10 years for all parts, materials and shipping required to repair or replace the luminaire. The Contractor shall provide the manufacturer's warranty to the Engineer prior to installing the luminaire. The warranty shall cover all failures including:
- Failure in luminaire housing, wiring, connections, drivers and photoelectric control devices.
 - More than 10 percent decrease in lumen output
 - Significant change in color

The warranty shall begin upon the date on the Contractor receives the luminaire. The bill of lading shall be provided to the Engineer prior to final payment of the lighting.

- l) *Technical Support.* During the warranty period, technical support shall be available from the manufacturer via telephone within 24 hours of the time the call is made from the Contractor, and this support shall be made available from factory certified personnel or factory certified installers at no additional charge to the City and County of Denver.

General

All work shall conform to these specifications and the National Electrical Code (NEC).

The Contractor shall keep fully informed and comply with all Federal, State, and local laws, ordinances, and regulations, and all orders and decrees of bodies or tribunals having any jurisdiction or authority, which may affect those engaged or employed on the work, or affect the conduct of the work. The Contractor shall protect and indemnify the City and County of Denver and its representatives against any claim or liability arising from or based on the violation of any such law, ordinance, regulation, order or decree, whether by the Contractor, the subcontractors, suppliers of materials or services, or their employees.

Each system shall be installed as shown on the plans or as designated. The Contractor shall furnish and install all incidentals necessary to provide a complete working unit or system.

Concrete Foundation Pads and Light Standard Foundations.

Foundations shall be installed as shown on the plans, complete with grounding. The Contractor shall test and report soil conditions to the Engineer as necessary to ensure proper installation of foundations. Foundations shall be installed at the final grade as shown on the plans.

All anchor bolts shall be positioned by means of steel templates. The center of the template shall coincide with the center of the foundation. Anchor bolt size and 12" bolt circle shall accommodate pole manufacturer's requirements.

All light standard foundations shall be as detailed.

Conduits shall be properly positioned and anchored before the concrete is placed.

Coordinate the base setback and orientation with the Engineer and Landscape Architect.

All foundations shall have ground rods conforming to the NEC. All foundations on structures shall be grounded to the structural steel by a method that is in accordance with the NEC and which is approved by the Engineer.

Light Standards

Poles shall be set plumb on the light standard foundation using leveling nuts.

Defects and scratches on painted, powder-coated, or anodized poles shall be primed and painted with a color-matched paint.

Stainless steel mounting hardware shall be used to mount luminaires, arms, access doors, and other hardware to the poles. Apply an approved zinc-based anti-seize compound to all mounting hardware prior to assembly.

Banner arms (if required) shall be incorporated into light standard structural design.

Luminaires

Luminaires shall be mounted on the mast arm by a slip-fitter clamp or other approved device. Luminaires shall be mounted on the pole by tenon mount or other approved device. Luminaires shall be adjusted vertically and horizontally to provide the required orientation and maximum light distribution on the roadway and/or sidewalk and to meet Illuminating Engineering Society (IES) TM-15 uplight rating of U0. Backlight rating should minimize light trespass on adjacent property.

Each luminaire shall be controlled by either a photoelectric control device or by an I/P addressable control system per City and County of Denver's Specification.

After their installation and prior to their acceptance, refractors and lenses shall be cleaned to provide maximum lumen output.

Luminaires of the specified type and lumen output shall be installed as shown on the plans. The type and lumen output shall be marked on each luminaire or pole in accordance with American National Standards Institute (ANSI) specifications. ANSI approved tags shall be provided and installed by the Contractor.

Figure D-1 CCD Tag



Conduit

The electrical conduit system shall be installed in accordance the following:

In the conduit system, the locations of conduit, junction boxes, and expansion joints shown on the plans are approximate. Actual locations shall be established during construction. The conduit system shall be located to avoid interference with known present or known construction installations. All underground conduit runs and conduit risers on poles shall be installed as needed even though they may not be shown on the plans.

All conduit installed under the roadway shall be at least two inch inside diameter unless otherwise designated on the plans. The Contractor may use larger conduit than specified. If larger conduit is used, it shall be for the entire run from outlet to outlet. Reducer couplings shall not be used. Larger conduits shall be sized to accommodate the constraints established by the hole in the pole anchor base plate.

Conduit terminating in standards or pedestals shall extend approximately two inches vertically above the foundations and shall slope toward the junction box opening. Conduit entering pull boxes shall terminate two inches inside the box wall and two to five inches above the bottom, and shall slope toward the top of the box to facilitate pulling of conductors. Conduit entering through the bottom of a pull box shall be located near the end walls to leave the major portion of the box clear. At all outlets, conduits shall enter from the direction of the run.

The ends of all conduits, whether shop or field cut, shall be reamed to remove burrs and rough edges. Cuts shall be made square and true so that the ends will butt or come together for their full circumference.

Non-metallic conduit shall be cut with a hacksaw or other approved tool. Non-metallic conduit connections shall be the solvent-weld type.

Conduit connections at junction boxes shall be tightly secured and waterproofed. All conduit ends shall be sealed with duct seal after installation of wiring. The duct seal shall be rated for outdoor use.

When specified, conduit shall be installed under existing pavement by boring operations. Where plans show that existing pavement is to be removed, jacking the conduit is not required. Jacking or drilling pits

shall maintain a minimum of two feet clear of the edge of pavement. Water shall not be used as an aid in the jacking or drilling operations.

When trenching is specified to place conduit under existing pavement that is not to be removed, the trench width shall be six inches or less. Trenches shall be filled to two inches below the existing grade with structure backfill (flowfill), or another material if directed. The remaining two inches shall be filled to existing grade with hot mix asphalt within one calendar day after the roadway is trenched.

Trenching shall be backfilled and compacted as follows: Backfill shall be deposited in uniform layers. Each layer shall be six inches or less thick prior to compaction. The space under the conduit shall be completely filled. The remainder of the trench and excavation shall be backfilled to the finished grade. The backfill material shall be compacted to the density specified in section D.3. Each layer shall be mechanically compacted by tamping with power tools approved by the Engineer. Compaction methods or equipment that may damage the conduit shall not be used.

Red electrical warning tape shall be installed between six inches and 12 inches below finished grade for all underground conduit runs.

Underground conduit shall be buried a minimum of two feet below finished grade. There shall be no sag between boxes. Conduit under roadways shall be buried at least 36 inches below finished grade.

Junction Boxes shall be placed at conduit ends, at all conduit angle points, and at all other locations shown on the plans. The Contractor may install additional pull boxes to facilitate the work.

Excavate minimum 24 inches below base depth of each junction box and refill with pea rock to permit draining of water.

Placement and setback of the junction boxes shall be coordinated with the Engineer.

Unless otherwise shown on the plans or directed by the Engineer, junction boxes shall be installed so that the covers are level with the sidewalk grade. Covers shall be flush with the surrounding finished ground when no grade is established.

Where a conduit stub-out is called for on the plans, a sweeping elbow shall be installed in the direction indicated. All conduit stub outs shall be capped.

Wiring

All wiring shall be copper, 600 Volt rated, Type: Conform to the applicable UL and ICEA Standards for the use intended. Copper conductors with 600-volt insulation unless otherwise specified or noted on the drawings. Stranded conductors for No. 8 and larger, with the exception of the ground rod conductor shall be #6 AWG solid, bare, copper and where elsewhere specified or noted on the drawings.

Aluminum Conductors Prohibited: Aluminum conductors will not be permitted except as required by Xcel Energy.

Insulation: Type THWN/THHN insulation minimum unless otherwise specified or noted on the drawings.

Size: No. 12 minimum unless otherwise specified or noted on the drawings. Not less than NEC requirements for the system to be installed.

Color Coding: Phase, neutral and ground conductors color-coded in accordance with NEC. Connect all Conductors of the same color to the same phase conductor as follows:

208Y/120V-3PH-4W Color coding shall be:

- 1) Phase = Black
- 2) Phase = Red
- 3) Phase = Blue
- 4) Neutral = White
- 5) Ground = Green

120/240V-1PH-3W Color coding shall be:

- 1) Line 1 = Black
- 2) Line 2 = Red

- 3) Neutral = White
- 4) Ground = Green

Unless otherwise authorized, the multiple system of electrical distribution shall be used. Conductors of the size and material specified shall be installed for control wiring, luminaire wiring, main circuit wiring, ground wiring, service entrance wiring, and all other wiring necessary for a complete installation.

Conductors shall be sized to prevent a voltage drop of more than three percent per feeder run. All conductors shall be installed in conduit.

All power and lighting circuits shall include an insulated green grounding conductor.

A complete grounding system shall be installed for the entire lighting installation. Grounding shall consist of ground cables, conduits, grounding rods, wire or strap, and ground fittings, as required by the NEC.

Type THWN conductors shall be used for all underground conduit runs. Leave sufficient lengths of branch conductors to allow conductor splices to be extracted from pole base for maintenance. Type XHHW shall be used for the service entrance conductors.

Extend three conductor SOW cable feeder leads to the luminaires from the cables in the pole base.

Install in-the-line fuses on each feeder lead. Leave sufficient lengths of feeder conductors to allow fuses and conductors to be extracted from pole base for maintenance.

Provide a No. 6 AWG solid, bare, copper wire connection to ground rod with ample length to allow connection to light standard, and system ground conductor.

Attach grounding conductor to the energy suppliers neutral at the service point. Terminate grounding conductor with less than 25 ohms ground reference at the service point. If ground resistance is greater than 25 ohms, add additional ground rod(s) or other ground reference bond to bring the resistance to under 25 ohms resistance to earth. Provide ground rods elsewhere as shown on the drawings.

Butt splices within the bases are not acceptable.

At each pole, provisions shall be made for convenient sectionalizing of the circuits. This shall be done by providing ample length (18 to 24 inches) of branch conductor ends and performing splices using Burndy Uni-tap connectors or an approved equal. Wire nuts are not an acceptable method for splicing. Splicing shall only be performed within the pole bases and splice boxes where applicable.

Lighting Control Centers and Secondary Service Pedestals

Shall be all-in-one meter/power pedestals and non-metered power pedestals as follows:

Lighting Control Center (LCC) (typical) – 120/240V-1Ph-3W, provide all components in all-in-one commercial pedestal complete with meter T-handle pull-out fusible disconnect ahead of meter with tab lockable cover and meter housing with lever by-pass, tab lockable dead front, lever hold open for exterior meter cover to Xcel Energy's specifications. Provide panel with service entrance, main circuit breaker and branch breakers as indicated on the panel schedule in an all-in-one stainless steel NEMA 3R enclosure. Contractor shall coordinate with the City and County of Denver (CCD) for the address and apply for service on the Xcel Energy's builder's call line. These meters will be owned by CCD.

Each LCC shall include a circuit breaker load center, contactors, a meter base with lever bypass, a photoelectric control (if required), GFCI maintenance receptacle flush in dead front, a grounding rod system, test switch, lightning arrestor, a stainless steel NEMA 3R enclosure with all related components, and connections to the power supply.

Install on concrete foundations as per detail and locations indicated on plans.

One copy of the cabinet drawings, one-line diagram, a luminaire schedule, and a list of all system components and their manufacturers shall be placed in a heavy-duty plastic envelope with side opening that is attached to the inside cabinet door. Label to include "panel designation, voltage, amperage and fed from" information in a minimum of 1/8" high lettering.

"Arc-Flash Hazard Warning" labels shall be furnished and installed by the electrical contractor per the National Electric Code NEC 110.6 and the NFPA 70E, and all other labels required by NFPA 70 on all new panels.

Testing (City Owned and/or City Contract Only)

Prior to final acceptance, the Contractor shall demonstrate to the Engineer’s satisfaction that all electrical and lighting equipment installations are in proper working condition. Temporary power and all cable connections required for testing shall be provided by the Contractor.

The Contractor shall operate the lighting system from sunset to sunrise for ten consecutive days. Light sources, drivers, and photoelectric or I/P addressable control that fail shall be replaced immediately. However, replacement of these items will not require a restart of the test.

The Contractor shall perform grounding tests at lighting control center to show ground resistance of 25 ohms or less.

As-built Drawings and O&M Manual (City Owned and/or City Contract Only)

Contractor shall supply accurate as-built drawings of the project to CCD. Drawings shall indicate location and setback of conduit, lighting control center, and utility service point, and pole locations along the roadway measured from a reliable location.

The Contractor shall collect, gather and assemble into one book the installation details, instructions, schematics of actual equipment and operations directions supplied by the manufacturer with all equipment. Final acceptance of the work will be withheld until such data has been presented complete to CCD. The manual shall be available for instruction of operations and maintenance of the equipment and systems.

Method of Measurement (City Owned and/or City Contract Only)

Concrete bases and equipment pads will be measured by the actual number installed and accepted.

Light standards will be measured by the number of light standards installed. Measure each type separately as described in the Luminaire Schedule shown on the Plans.

Luminaires will be measured by the number of luminaires installed. Measure each type separately as described in the Luminaire Schedule shown on the Plans.

Lighting control centers will be measured by the number installed.

Conduit will be measured by the linear foot in place. Measure each type separately.

Wiring will be measured by the linear foot in place. Measure each type separately.

Basis of Payment (City Owned and/or City Contract Only)

The accepted quantities will be paid for at the contract unit price for each of the pay items listed on the plans and as they appear in the bid schedule. All associated work items will be considered incidental.

Table D-2: Pay Items and Units

Pay Item	Pay Unit
Light Standard Metal (___ foot)	Each
Luminaire (Type)(LED)(Lumens)	Each
___ Inch Electrical Conduit (Plastic)	Linear Feet
___ Inch Electrical Conduit (Bored)	Linear Feet
Wiring	Linear Feet
Lighting Control Center	Each
Secondary Service Pedestal	Each
Pull Box	Each
Light Standard Foundation	Each
Concrete Foundation Pad	Each

When the Contractor, at his option, installs larger conduit than specified, it will be paid for at the original contract price for the size specified.

The following items will not be measured and paid for separately, but shall be included in the work:

- 1) Soil testing for foundations
- 2) Pull wire, weatherheads, and adaptors and expansion joints for conduit
- 3) Additional pull boxes installed at the Contractor's option
- 4) Saw cutting; trenching; excavation; backfill; jacking; drilling pits; underground electrical warning tape; removal of pavement, sidewalks, gutters, and all other work necessary to complete conduit installation
- 5) Electrical conductor tagging
- 6) Testing of the lighting installation, including temporary power and all required cable connections

END OF SECTION

D.2 Lighting and Electrical Materials

General

Materials shall be of a standard line from a name brand manufacturer or as specified in this document. Electrical material shall be listed by the Underwriters' Laboratories, Inc. (UL), and shall conform to the National Electrical Code (NEC).

Material shall be the same as, or compatible with, that used and accepted by the agency responsible for maintenance.

The Engineer may inspect all lighting material and all electrical materials and accept or reject them at the project site. Samples may be taken or manufacturer's certifications may be accepted in lieu of samples.

Concrete Bases and Concrete Equipment Pads

Cast-in-place concrete shall be CDOT Class BZ, precast concrete shall be CDOT Class B.

Anchor bolts shall be designed by the Contractor's Engineer or as shown on the working drawings. The threaded ends of the anchor bolts, the nuts, and the washers shall be galvanized in accordance with ASTM A153.

Reinforcing steel shall conform to Section D.5.

Light Standards

- a) *General.* All structural components of light standards, bases, couplers, anchor bolts, luminaires, and other attachments to be used for lighting shall be designed for a minimum of 115 MPH wind velocity, in accordance with ASCE 7-10 special wind region.

All breakaway bases and couplers shall meet the breakaway requirements specified in AASHTO's *Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, Section 12. Conformance shall be verified by crash tests reviewed and accepted by FHWA. A certificate of compliance shall be provided.

- b) *Metal Light Standards.* Metal light standards shall be fabricated of either steel or aluminum, unless otherwise specified. Whenever Light Standard Metal is specified, the Contractor shall furnish galvanized steel. The Contractor may furnish aluminum light standards if the City Engineer gives approval. Material type and shape of light standards shall be the same throughout the project, unless otherwise shown in the Contract.

All standards shall have cable-entrance holes located in conformity with the type of arm mounting used. Metal surfaces shall be free of imperfections marring the appearance and of burrs or sharp edges that might damage the cable.

All metal poles shall be tapered and shall be supplied with pole caps.

Aluminum alloys shall have a minimum yield strength of 25,000 psi. Aluminum poles, arms, and fittings shall be made of aluminum alloy conforming to the following for the material form required:

Table D-3: ASTM Aluminum Alloy Numbers

ASTM Standard	Alloy number
B 209	6061-T6
B 211	6061-T6
B 221	6061-T6 6063-T6 6005-T5
B 241	6061-T6 6063-T6

Aluminum poles may also be made of aluminum alloy 5086-H34 conforming to ASTM B 313 (excluding pressure and burst tests).

Aluminum mast arms shall be tapered unless otherwise shown on the plans.

Steel mast arms shall be made of Schedule 40 standard steel pipe conforming to ASTM A 53.

All steel poles, mast arms and base flanges shall be hot-dip galvanized in accordance with ASTM A 123. Units on which the spelter coating has been damaged shall be repaired as provided in AASHTO M 36, or other approved method.

Base flanges for both aluminum and steel poles shall have continuous welds both inside and outside, unless otherwise permitted. Base flanges inserted into the pole and bonded shall meet the requirements for materials and strength stated herein.

Base flanges for aluminum poles and transformer bases shall be aluminum castings of alloy ANSI 356.0-T6 or UNS A03560 T6 conforming to ASTM B 26 or an acceptable equivalent.

Each metal light standard shall be wired with a breakaway fused connector of proper capacity rating. The fused connector shall be located in the transformer base. If the light standard has no transformer base, the fused connector shall be located in the pole at the hand hole.

All transformer bases shall have vandal resistant, removable access doors.

If required in areas where pedestrians are typically not present, the transformer base shall be a frangible breakaway type as shown on the plans and shall accommodate the anchorage and base flange of the light pole supplied. Each transformer base shall have a ½ inch bolt or lug fastened inside the base for grounding; the lug or bolt shall be visible from the door opening. The transformer base shall have a wire hole for outside grounding, if required.

Hardware used with steel standards shall be either cadmium plated steel, hot dip galvanized steel, or stainless steel. All hardware used with aluminum standards shall be anodized aluminum or stainless steel. Bolts to be inserted in aluminum threads shall be stainless steel.

Luminaires

Luminaires shall be UL or ETL Listed for use in wet locations with a minimum IP rating of IP65. Luminaires shall be adaptable to the type of power distribution system to be used.

- a) *General.* Luminaires shall conform to the following requirements:
 - a. *Optical Chamber.* The luminaire distribution shall be equal to or less than an Illuminating Engineering Society (IES) TM15-11 Backlight Uplight and Glare (BUG) ratings listed per Lighting Application, based on initial lumens or Light Loss Factor (LLF) = 1.0. Roadway luminaires with a U value greater than U0 shall not be accepted. The optical chamber shall be completely sealed from the housing, or the housing shall be completely sealed. A seamless one-piece memory-retentive gasket shall seal the optical chamber or housing against the luminaire lens door. All wires entering the optical chamber shall be gasketed at their point of entry. Socket mountings, rivets used in the construction or support of the reflector system, and all other penetrations into the optical chamber shall be completely sealed. The optical chamber shall be water tight when the luminaire door is closed.

- b. Electrical Components. All components shall be Underwriters Laboratory (UL) listed for wet locations or by an Occupational Safety & Health Administration Nationally Recognized Testing Laboratories (OSHA NRTL). Luminaires shall operate from 120 to 277 VAC as specified on the plans or adaptable to the type of power distribution system to be used. All internal wiring and quick disconnects shall be rated for at least 600 VAC and insulated for 150°C. The dimmable driver shall be easily removable from the luminaire housing without the use of tools. The following components shall be in accordance with corresponding sections of ANSI C136.37:
 - i. Wiring and grounding.
 - ii. Terminal blocks for incoming AC lines.
 - iii. pin photocontrol receptacle.
 - iv. Latching and hinging
- b) *Roadway Luminaires*. Roadway luminaires shall be LED type with integral dimmable driver, flat lens, aluminum housing, and be UL Listed for wet locations. All luminaires for the project shall be the same type and design unless the plans specify otherwise.
 - a. Housing. The luminaire enclosure shall be an injection-molded or die-cast opaque housing. The housing shall have a powder-coated, corrosion-resistant finish. The color shall be gray, unless otherwise specified on the Plans. The mounting shall be as shown on the Plans.

The housing shall have a door that provides access to all internal components. The door shall be equipped with a safety catch and a latch. The housing shall have an inner rolled flange to support the door frame. The door frame shall be an aluminum casting, hinged to the housing. The door frame shall be sealed to the housing with a molded silicone gasket and shall be secured with a minimum of four captive screws.

- b. Lens and Lens Door. The lens shall be thermal-resistant and impact-resistant. The lens shall be sealed to the door frame with continuous silicone gasketing. The door shall have an easy-access, quick-release safety latch. The door shall have aluminum or stainless steel quick-release hinge pins for tool-less or one-hand easy and secure opening. When the door is closed, the electrical component compartment and the optical chamber shall be completely sealed.
- c. The luminaire and all components shall be UL or Intertek Testing Services (ITL) listed for Wet Location and shall have minimum Ingress Protection Rating of IP65.
- d. Light source shall be comprised of LED modules connected to a non-integrated driver and ready for connection to a production line luminaire. Luminaires utilizing integrated driver LED light sources, screw-based or panel retrofit products shall not be accepted.
- e. Transmissive optical components shall be applied in accordance with LED manufacturer's Original Equipment Manufacturer (OEM) design guidelines to ensure suitability for the environment in which the luminaire is installed.
- f. Luminaires shall utilize an adjustable slipfitter-type mounting system for installation on 1.25-inch (1.66-inch o.d.) to 2-inch (2.375-inch o.d.) outside diameter pipe tenons. Slipfitter shall consist of a two-piece clamp and four 9/16-inch hex bolts. Slipfitter shall allow for a vertical tilt adjustment of ± 5 percent in order to mount luminaire plumb for a U0 rating. Luminaires shall be equipped with integrated leveling bubble.
- g. Access to all internal parts requiring replacement shall not require tools (i.e. "tool-less entry").
- h. The luminaire housing shall be constructed of aluminum alloy.
- i. Dimmable driver must be internal and thermally separated from LED compartment.
- j. Dimming 7 pin photocell receptacle shall conform to *Photocontrol Receptacle* requirements listed below.
- k. Luminaire finish shall be corrosion resistant Super triglycidyl isocyanurate (TGIC) polyester powdercoat. Color shall be gray or as indicated on the plans.
 - i. Powder coat: Super TGIC polyester powder coat 2.5 mil nominal thickness.
 - ii. Finish shall exceed a rating of 6 per ASTM D1654 after 1000hrs of testing per ASTM B117.
 - iii. The coating shall exhibit no greater than 30% reduction of gloss per ASTM D523, after 500 hours of QUV testing at ASTM G154 Cycle 6.

- l. Effective Projected Area (EPA) for wind-loading calculations shall be no greater than 1.2 square feet.
 - m. Luminaire weight shall not exceed 45 pounds.
 - n. Luminaire shall be tested in accordance with IES LM79 and TM21 certifying photometric performance and rated life, respectively. LM79 (performance) and TM21 (predicted life at 55°C) testing shall both be for the same luminaire's operating drive current as specified.
 - o. Luminaire shall have a maximum Backlight rating as shown in **Error! Reference source not found.**, an Uplight rating of U0, and a maximum Glare rating as shown in **Error! Reference source not found.**
 - p. Luminaire system efficacy shall be no less than 85 luminaire lumens per input watt.
 - q. Luminaire shall have an external label per ANSI C136.15 and internal label per ANSI C136.22.
 - r. Luminaires shall withstand low and high frequency vibration over the rated life of the luminaire, per ANSI C136.31.
 - s. Luminaires shall meet the performance requirements specified in ANSI C136.2 for dielectric withstand and Electrical Transient – Immunity Requirements, using the DC test level and configuration.
 - t. Luminaire shall have a minimum rated life of 100,000 hours per IES TM-21 at 25°C at the normal operating driver current for the specific luminaire. The lumen output shall be maintained at 70 percent of initial rated lumens (L70) or greater at the rated life of the luminaire.
- c) *Pedestrian Luminaires.* Pedestrian luminaires shall be LED type with integral dimmable driver, aluminum housing, and be UL Listed for wet locations. All luminaires for the project shall be the same type and design unless the plans specify otherwise.
- a. Housing. The housing shall have a powder-coated, corrosion-resistant finish. The color shall be gray, unless otherwise specified on the Plans. The mounting shall be as shown on the Plans.
 - b. Lens and Lens Door. The lens shall be thermal- resistant and impact-resistant. The lens shall be sealed to the door frame with continuous silicone gasketing. When the door is closed, the electrical component compartment and the optical chamber shall be completely sealed.
 - c. The luminaire and all components shall be UL or Intertek Testing Services (ITL) listed for Wet Location and shall have minimum Ingress Protection Rating of IP65.
 - d. Light source shall be comprised of LED modules connected to a non-integrated driver and ready for connection to a production line luminaire. Luminaires utilizing integrated driver LED light sources, screw-based or panel retrofit products shall not be accepted.
 - e. The luminaire shall have a Type II, III, IV or V distribution.
 - f. Transmissive optical components shall be applied in accordance with LED manufacturer's Original Equipment Manufacturer (OEM) design guidelines to ensure suitability for the environment in which the luminaire is installed.
 - g. Luminaires shall be mounted per Manufacturer's instructions. All luminaires shall be mounted plumb.
 - h. Dimmable driver must be internal and thermally separated from LED compartment.
 - i. Dimming 7 pin photocell receptacle shall conform to *Photocontrol Receptacle* requirements listed below.
 - j. Luminaire finish shall be corrosion resistant Super triglycidyl isocyanurate (TGIC) polyester powdercoat. Color shall be gray or as specified on the Plans.
 - i. Powder coat: Super TGIC polyester powder coat 2.5 mil nominal thickness.
 - ii. Finish shall exceed a rating of 6 per ASTM D1654 after 1000hrs of testing per ASTM B117.
 - iii. The coating shall exhibit no greater than 30% reduction of gloss per ASTM D523, after 500 hours of QUV testing at ASTM G154 Cycle 6.
 - k. Effective Projected Area (EPA) for wind-loading calculations shall be no greater than 1.2 square feet.
 - l. Luminaire weight shall not exceed 45 pounds.
 - m. Luminaire shall be tested in accordance with IES LM79 and TM21 certifying photometric performance and rated life, respectively. LM79 (performance) and TM21 (predicted life at 55°C) testing shall both be for the same luminaire's operating drive current as specified.

- n. Luminaire shall have a maximum Backlight rating as shown in **Error! Reference source not found.**, an Uplight rating of U0, and a maximum Glare rating as shown in **Error! Reference source not found.**
 - o. Luminaire shall have an internal label per ANSI C136.22.
 - p. Luminaires shall withstand low and high frequency vibration over the rated life of the luminaire, per ANSI C136.31.
 - q. Luminaires shall meet the performance requirements specified in ANSI C136.2 for dielectric withstand and Electrical Transient – Immunity Requirements, using the DC test level and configuration.
 - r. The luminaire shall have a minimum rated life of 50,000 hours per IES TM-21 at 25°C at the normal operating driver current for the specific luminaire. The lumen output shall be maintained at 70 percent of initial rated lumens (L70) or greater at the rated life of the luminaire.
- d) *Light Sources.* LED luminaires shall not be retrofit to existing luminaire housing; the Contractor shall replace housing along with the luminaire as a single unit. Light sources shall be compatible with dimmable drivers supplied with the luminaires in which they are to be installed. All light sources of a similar type shall be provided by the same manufacturer.

LED light sources shall meet or exceed the following requirements:

- a. CCT, CRI and Flux:
 - i. Correlated Color Temperature (CCT) – All LED light sources shall emit white light and have a CCT no greater than 3000K nominal in accordance with ANSI C78.277.
 - ii. Color Rendering Index (CRI) – All LED light sources shall have a minimum Color Rendering Index (CRI) of 70 per the LM79 test results.
 - iii. Luminous Flux – LED light sources shall not exceed the junction temperature recommended by the LED manufacturer. Luminous flux differences between LEDs shall not exceed 10 percent.
- b. LEDs shall have a minimum rated life of 70,000 hours per IES TM-21 at 55°C at the normal operating driver current for the specific luminaire. The lumen output shall be maintained at 70 percent of initial rated lumens (L70) or greater at the rated life of the luminaire.
- c. LED luminaires shall be temperature rated for operation and storage within the range of -40°C to +40°C, and shall withstand low and high frequency vibration (ANSI C136.31 Vibration Level 3G) over the rated life of the light source.
- d. Cooling System
 - i. Mechanical design of protruding external surfaces (e.g. heat sink fins) shall facilitate hose-down cleaning and discourage debris accumulation.
 - ii. The cooling system must be passive utilizing heat sinks, convection or conduction.
 - iii. Fans, diaphragms, pumps, or liquids shall not be acceptable.
- e) *Photocontrol Receptacle.* Each roadway luminaire shall be furnished with a multi-contact (7-pin) twist-lock outdoor lighting dimming receptacle per ANSI C136.41.

LED Drivers

LED drivers shall conform to the following:

- a) Dimming signal protocols are 0-10VDC or Digital Addressable Lighting Interface (DALI).
- b) Operating voltage shall be 120/277-volt at 50/60 Hz, and shall operate normally with input voltage fluctuations of ±10 percent, consistent with NEMA SSI-1-2010, Electronic Drivers for LED Devices, Arrays or Systems.
- c) Minimum Power Factor (PF) shall be no less than 0.90 at full input power and across specified voltage range.
- d) Maximum Total Harmonic Distortion (THD) shall be no greater than 20 percent at full input power and across specified voltage range.
- e) Factory-set drive current shall be 1050mA or less unless approved by Engineer. If higher drive currents are proposed, the submittal must be accompanied with IES LM79 and TM21 test results for higher operating drive current.

- f) Drivers shall be Restriction of Hazardous Substances (RoHS) compliant.
- g) Rated case temperature shall conform to the temperature requirements for roadway luminaires and pedestrian luminaires listed above.
- h) All electronics of the power supply and the LEDs shall be protected from all electrical surges with an elevated electrical immunity rating, including but not limited to lightning strikes and stray current in rebar and concrete. Surge protection shall be integral to the LED power supply.
- i) Luminaire, including driver, shall consume no more than 4 watts in the off-state power.
- j) Electrical immunity (including surge protection).
- k) Luminaire shall meet the "Elevated" (10kV/10kA) requirements per IEEE C62.41.2 -2002. Manufacturer shall indicate whether failure of the electrical immunity system can possibly result in disconnect of power to luminaire.
- l) Electromagnetic interference: Shall comply with Federal Communications Commission (FCC) 47 Code of Federal Regulations (CFR) part 15 non-consumer radio frequency interference (RFI) and/or electromagnetic interference (EMI) standards.

Conduit

Unless otherwise specified, conduit shall be rigid non-metallic electrical conduit currently recommended and approved by Underwriters' Laboratories, Inc. for the proposed use conforming to ASTM-F 441 schedule 40, (Schedule 80 where installed under roadways). Fittings shall be the type used outside the conduit and PVC cement welded. Fittings shall connect the conduit in a manner that makes the joints watertight.

All in-grade Pull Boxes shall be polymer concrete, bottomless and tier 22 rated bolted covers. 13 inches by 24 inches and 18 inches deep manufactured by Quazite; Cat. # PG1324BA18, unless otherwise noted on the plans. Covers shall be Cat. # PG1324HH00 with stainless steel bolts and the word "ELECTRIC" molded into the top.

Lighting Circuitry and Wiring

Lighting systems shall be photoelectric or I/P addressable controlled.

Photoelectric controls shall be the hermetically sealed, cadmium sulfide twist-lock type with high impact polypropylene cover with clear UV stabilized window. Photoelectric controls shall have a turn-on setting of 1.4 foot-candles plus or minus 0.2 foot-candles. The maximum ratio of the turn-off to turn-on setting shall be 3:1.

All electrical apparatus used in the lighting system shall be rated to adequately handle the necessary loads and shall conform to power source requirements.

Conductors shall be standard copper with 600-volt insulation, type THWN or XHHW for underground installation in conduit, and for aboveground installation within poles and service cabinets. The size and type shall be as shown on the plans.

Fuses

Each luminaire in the 120-volt system shall be fused with one 6-amp fuse. Fuse connectors shall be installed in the phase wires of their respective circuits at the pull box located adjacent to the light standards or in the pole base. The fuses shall be mounted in inline single-pole molded fuse connector/holders. The fuse holders shall be a DOT-PLUG (Catalog No. Duraline-16998), or approved equal. Fuses shall be of the breakaway type. The Contractor shall provide sufficient excess conductor length to allow withdrawal of the connected fuse holder. The grounding wires shall not be fused. Fuses and fuse holders shall be "UL" listed and shall be installed in such a manner that the fuse stays with the load side when holder is separated. In addition, the Contractor shall form loops in the leads on each side of the fuse holders and so position the fuse holders so that they may be easily removed or inserted through the opening at top of pull box.

Secondary Service Pedestals and Lighting Control Centers

The cabinets shall be constructed as shown in the plans and shall be stainless steel in color. Cabinets shall be NEMA 3R construction and shall be UL listed as "suitable for use as service equipment". Cabinets shall be vandal resistant dead-front enclosures. The wiring diagram for the service cabinet is show in detail in the Plans.

All external fasteners, hinges, rivets, screws, and bolts shall be stainless steel. Fasteners, except sealing screws, shall not be removable by external access.

External nameplates shall be permanently attached to the cabinet. A stainless steel handle shall be provided on the front exterior of each cabinet door or hood. Cabinet shall be equipped with a three-point catch and lock. These locks shall be furnished with two keys for each cabinet, and all locks shall be master keyed Type I police lock. When final acceptance of the project is made, the Engineer will distribute the keys to agencies responsible for maintenance of the system.

Distribution and control equipment shall be behind an internal dead-front door with a quarter-turn securing latch and be hinged to open more than 90 degrees. The dead-front door shall be hinged on the same side as the main door. A rubber gasket shall be placed between the cabinet and the equipment pad.

Equipment pad shall include concrete pad mounting base, anchor bolt kit, and hardware.

The service cabinet shall be grounded with grounding rods in conformance with the National Electric Code.

The internal wiring of cabinets shall be assembled by UL listed facility. Cabinets shall conform to one or more of the following standards where appropriate: UL 50, Cabinets and Boxes; UL 67, Panel Boards and UL 869A, Service Equipment.

Circuit breakers and equipment shall be labeled with an engraved permanent label on the dead-front panel to indicate the circuit controlled.

Contactors shall be "lighting" type, specifically rated for the type of lighting load specified. The contactors shall have a 600 Volt rating. Contactors shall open type with number of poles and rating shown or specified. Contactors shall be constructed for surface mounting on a false back or bracket within a weatherproof cabinet. The contactor coils shall operate on 120 volts. Contact material shall be designed for LED driver loads and require no maintenance such as filing, burnishing, or dressing at any time during the contactor service life.

A 300 VAC rated heavy duty test switch shall be installed in the control cabinets as shown.

The photoelectric control (if required) shall attach to a three pole locking receptacle by a twisting motion.

The photoelectric control shall have a built-in surge protective device for protection from induced high voltage and over currents. The photoelectric control shall meet or exceed the requirements of ANSI C136.10. The photoelectric control shall be factory set to turn on lights when ambient light falls to 1.4 foot-candle plus or minus 0.2 foot-candle when operated at 120 VAC. When operated at 250 VAC, turn on shall change more than plus or minus 0.3 foot-candles from the 120 VAC value. The maximum off to on ratio shall be 1.5:1.

The photoelectric control shall be a cadmium sulfide photoelectric control encapsulated for humidity protection, or a silicon junction type photo transistor. The photoelectric control shall be designed for normal operation at a dual voltage of 105 V and 285 V. Power consumption shall be less than 1 watt. At the designated voltage, the photoelectric control shall be capable of controlling a minimum load of 1000 watts.

Minimum operating temperature range shall be from -40°C to 65°C (-40°F to 150°F). A time delay control circuit shall prevent false turn offs by transient lighting conditions. The unit shall include a fail-safe circuit for the lighting load such that the lighting systems remain energized if any functional failure of the photoelectric control circuit occurs.

The service cabinet shall include all equipment necessary to connect to the energy provider's overhead secondary conductors or transformer. The meter socket shall include a lever bypass as specified by the energy provider.

All-In-One commercial meter/power pedestal and non-metered/power pedestals to meet or exceed City and County of Denver Standards.

"Arc-Flash Hazard Warning" labels shall be furnished and installed by the electrical contractor per the National Electric Code NEC 110.6 and the NFPA 70E, and all other labels required by NFPA 70 shall be installed on all new panels.

Wireless Lighting Controls (to be further developed)

The photoelectric control (provided on each street light luminaire) shall be type that is compatible to operate on City and County of Denver's wireless control system for on/off and dimming capabilities.

END OF SECTION

D.3 Moisture and Density Control

Construction of Moisture and Density Control Areas

Maximum dry density of all soil types encountered or used will be determined in accordance with AASHTO T 99, AASHTO T 180, or a modification thereof.

The amount of water to be used in compacting A-2-6, A-2-7, A-4, and A-6 through A-7 soils shall not deviate from optimum on the dry side by more than two percentage points as determined by AASHTO T 99, T 180, or a modification thereof, as designated in the Contract. A-4 soils which are unstable at the above moisture content shall be compacted at a lower moisture content to the specified density. The amount of water used in compacting all other soils shall be as required to obtain the percent relative compaction required.

Table D-4: Soil Compaction

Soil Classifications (AASHTO M 145)	AASHTO T 99 Minimum Relative Compaction (Percentage)	AASHTO T 180 Minimum Relative Compaction (Percentage)
A-1	100	95
A-3	100	95
A-2-4	100	95
A-2-5	100	95
All Others	95	90

The percent of relative compaction specified shall be equal to or greater than minimum values as shown in the following table for the various classes of soil and type of compaction.

END OF SECTION

D.4 Structural Concrete

Description

This work consists of furnishing and placing portland cement concrete in accordance with these specifications and in conformity with the lines, grades and dimensions as shown on the plans or established.

Classification

The classes of concrete shown in Table Error! No text of specified style in document.-1 shall be used when specified in the Contract.

Table Error! No text of specified style in document.-1: Concrete Table

Concrete Class	Required Compression Strength (psi)	Field	Cementitious Content: Minimum (lbs/yrds ³) or Range	Material Range	Air Content: % Range (Total)	Water/Cementitious Material Ratio: Maximum or Range
B	4500 at 28 Days		N/A		5 – 8	0.45
BZ	4000 at 28 days		610		N/A	0.45
D	4500 at 28 Days		615 to 660		5 – 8	0.45
H	4500 at 56 Days		580 to 640		5 – 8	0.38 to 0.42
P	4500 at 28 Days		660		4 – 8	0.44

Class B concrete is an air entrained concrete for general use. Class D, H or P concrete may be substituted for Class B concrete. Additional requirements are: The coarse aggregate shall have a nominal maximum size of 1½ inches or smaller.

Class BZ concrete is concrete for drilled caissons. Additional requirements are: Entrained air is not required unless specified in the Contract. When entrained air is specified in the Contract, the air content shall be 5 to 8 percent. High range water reducers may be added to obtain desired slump and retardation. Slump shall be a minimum of 5 inches and a maximum of 8 inches. The concrete mix shall be made with AASHTO M 43 size No. 67, No. 7 or No. 8 coarse aggregate.

Sulfate Resistance.

The Contractor shall provide protection against sulfate attack on concrete structures by providing concrete manufactured according to the requirements of Table D-. The sulfate exposure for all concrete shall be Class 2 unless otherwise specified on the plans. A higher level of requirements may be used for a lower level of exposure.

If the Contractor provides test reports that show another class of exposure exists at a structure location, then the Engineer may accept a concrete mix for that location that meets the corresponding sulfate protection requirements.

Table D-5: Concrete Sulfate Protection Requirements

Severity of Sulfate Exposure	Water-Soluble Sulfate (SO ₄) in Dry Soil, Percent	Sulfate (SO ₄) in Water, Ppm	Maximum Water to Cementitious Material Ratio	Cementitious Material Requirements
Class 0	0.00 to 0.10	0 to 150	0.45	Class 0
Class 1	0.11 to 0.20	151 to 1500	0.45	Class 1
Class 2	0.21 to 2.00	1501 to 10,000	0.45	Class 2
Class 3	2.01 or greater	10,001 or greater	0.40	Class 3

Cementitious material requirements are as follows:

- a) Class 0 requirements for sulfate resistance shall be one of the following:
 - a. ASTM C 150 Type I, II or V
 - b. ASTM C 595 Type IP, IP(MS) or IP(HS)
 - c. ASTM C 1157 Type GU, MS or HS

- d. ASTM C 150 Type III cement if it is allowed, as in Class E concrete
- b) Class 1 requirements for sulfate resistance shall be one of the following:
 - a. ASTM C 150 Type II or V; Class C fly ash shall not be substituted for cement
 - b. ASTM C 595 Type IP(MS) or IP(HS); Class C fly ash shall not be substituted for cement.
 - c. ASTM C 1157 Type MS or HS; Class C fly ash shall not be substituted for cement.
 - d. When ASTM C 150 Type III cement is allowed, as in Class E concrete, it shall have no more than 8 percent C3 A. Class C fly ash shall not be substituted for cement
- c) Class 2 requirements for sulfate resistance shall be one of the following:
 - a. ASTM C 150 Type V with a minimum of a 20 percent substitution of Class F fly ash by weight
 - b. ASTM C 150 Type II or III with a minimum of a 20 percent substitution of Class F fly ash by weight. The Type II or III cement shall have no more than 0.040 percent expansion at 14 days when tested according ASTM C 452
 - c. ASTM C 1157 Type HS; Class C fly ash shall not be substituted for cement.
 - d. ASTM C 1157 Type MS plus Class F fly ash where the blend has less than 0.05 percent expansion at 6 months or 0.10 percent expansion at 12 months when tested according to ASTM C 1012
 - e. A blend of portland cement meeting ASTM C 150 Type II or III with a minimum of 20 percent Class F fly ash by weight, where the blend has less than 0.05 percent expansion at 6 months or 0.10 percent expansion at 12 months when tested according to ASTM C 1012.
 - f. ASTM C 595 Type IP(HS); Class C fly ash shall not be substituted for cement.
- d) Class 3 requirements for sulfate resistance shall be one of the following:
 - a. A blend of portland cement meeting ASTM C 150 Type II, III, or V with a minimum of a 20 percent substitution of Class F fly ash by weight, where the blend has less than 0.10 percent expansion at 18 months when tested according to ASTM C 1012.
 - b. ASTM C 1157 Type HS having less than 0.10 percent expansion at 18 months when tested according to ASTM C 1012. Class C fly ash shall not be substituted for cement
 - c. ASTM C 1157 Type MS or HS plus Class F fly ash where the blend has less than 0.10 percent expansion at 18 months when tested according to ASTM C 1012.
 - d. ASTM C 595 Type IP(HS) having less than 0.10 percent expansion at 18 months when tested according to ASTM C 1012. Class C fly ash shall not be substituted for cement.
 - e. When fly ash is used to enhance sulfate resistance, it shall be used in a proportion greater than or equal to the proportion tested in accordance to ASTM C1012, shall be the same source and it shall have a calcium oxide content no more than 2.0 percent greater than the fly ash tested according to ASTM 1012.

Proportioning

The Contractor shall submit a Concrete Mix Design for each class of concrete being placed on the project. Concrete shall not be placed on the project before the Concrete Mix Design Report has been reviewed and approved by the Engineer. The Concrete Mix Design will be reviewed and approved following the procedures of CP 62. The Concrete Mix Design will not be approved when the laboratory trial mix data are the results from tests performed more than two years in the past or aggregate data are the results from tests performed more than two years in the past. The concrete mix design shall show the weights and sources of all ingredients including cement, pozzolan, aggregates, water, additives and the water to cementitious material ratio (w/cm). When determining the w/cm, the weight of cementitious material (cm) shall be the sum of the weights of the cement, fly ash and silica fume.

The laboratory trial mix data shall include results of the following:

- a) AASHTO T 119 (ASTM C 143) Slump of Hydraulic Cement Concrete.
- b) AASHTO T 121 (ASTM C 138) Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete.
- c) AASHTO T 152 (ASTM C 231) Air Content of Freshly Mixed Concrete by the Pressure Method
- d) ASTM C 39 Compressive Strength of Cylindrical Concrete Specimens shall be performed with at least two specimens at 7 days and three specimens at 28 days. Three additional specimens tested at 56 days shall be required for Class H concrete.
- e) Class H concrete shall include a measurement of permeability by ASTM C 1202 Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration.

- f) Class H concrete shall include a measurement of cracking by AASHTO T334 Standard Practice for Estimating the Cracking Tendency of Concrete. The sample shall be cured at a temperature of 65 to 75 °F and relative humidity not exceeding 40 percent.
- g) Class P concrete shall include AASHTO T 97 (ASTM C 78) Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) performed with at least two specimens at seven days and four specimens at 28 days. The Contractor shall provide maturity meters and all necessary wires and connectors.

The Contractor shall be responsible for the placement and maintenance of the maturity meters and wires. Placement shall be as directed by the Engineer.

The maximum slump of the delivered concrete shall be the slump of the approved concrete mix design plus 1½ inch. The laboratory trial mix must produce an average compressive strength at least 115 percent of the required field compressive strength specified in Table A-5.

The laboratory trial mix shall have a relative yield of 0.99 to 1.02. If the produced concrete does not have a relative yield of 0.99 to 1.02 for two consecutive yield determinations, concrete production shall cease and the Contractor shall present a plan to correct the relative yield to the Engineer.

Aggregate data shall include the results of the following:

- a) AASHTO T 11 (ASTM C 117) Materials Finer Than 75 um (No. 200) Sieve in Mineral Aggregates by Washing.
- b) AASHTO T 19 (ASTM C 29) Unit Weight and Voids in Aggregate.
- c) AASHTO T 21 (ASTM C 40) Organic Impurities in Fine Aggregate for Concrete.
- d) AASHTO T 27 (ASTM C 136) Sieve Analysis of Fine and Coarse Aggregates.
- e) AASHTO T 84 (ASTM C 128) Specific Gravity and Absorption of Fine Aggregate.
- f) AASHTO T 85 (ASTM C 127) Specific Gravity and Absorption of Coarse Aggregate.
- g) AASHTO T 96 (ASTM C 131) Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
- h) AASHTO T 104 (ASTM C 88) Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.
- i) CP 37 Plastic Fines in Graded Aggregates and Soils by use of the Sand Equivalent Test
- j) ASTM C 535 Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- k) ASTM C1260 Determining the Potential Alkali Reactivity of Aggregates (Accelerated Mortar-Bar Method). When an aggregate source is known to be reactive, ASTM C1567 results may be submitted in lieu of ASTM C1260 results.

Any aggregate tested by ASTM C1260 with an expansion of 0.10 percent or more, or that is known to be reactive, shall not be used unless mitigative measures are included in the mix design.

Test results from ASTM C1293 Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction may be substituted for ASTM C1260 test results. The ASTM C1293 test shall be run on an individual source of aggregate. The ASTM C1293 test shall not use fly ash or slag as part of the cementitious material content. Any aggregate source tested by ASTM C1293 with an expansion greater than or equal to 0.04 percent at one year shall not be used unless mitigative measures are included in the mix design.

Mitigative measures shall be tested using ASTM C1567 and exhibit an expansion less than 0.10 percent by one of the following methods:

- a) Combined Aggregates. The mix design sources of aggregates, cement and mitigative measures shall be tested. The proportions of aggregates, cement and mitigative measures shall be those used in the mix design.
- b) Individual Aggregates. Each source and size of individual aggregates shall be tested. The source of cement and mitigative measures shall be those used in the mix design. The highest level of mitigative measures for any individual aggregate shall be the minimum used in the mix design.

The Concrete Mix Design Report shall include Certified Test Reports showing that the cement, fly ash and silica fume meet the specification requirements and supporting this statement with actual test results. The certification for silica fume shall state the solids content if the silica fume admixture is furnished as slurry.

Approved fly ash may be substituted for ASTM C150 cement up to a maximum of 20 percent Class C or 30 percent Class F by weight of total cementitious material.

For all concrete mix designs with ASTM C595 or C1157 cements, the total pozzolan content shall not exceed 30 percent by weight of the cementitious material content.

When the Contractor's use of fly ash results in any delay, necessary changes in admixture quantities or source, or unsatisfactory work, the cost of such delays, changes, or corrective actions shall be borne by the Contractor.

The Contractor shall submit a new Concrete Mix Design Report meeting the above requirements when a change occurs in the source, type, or proportions of cement, fly ash, silica fume or aggregate. When a change occurs in the source of approved admixtures, the Contractor shall submit a letter stamped by the Concrete Mix Design Engineer approving the changes to the existing mix design. The change will be approved by the Engineer prior to use.

The use of approved accelerating, retarding or hydration stabilizing admixtures to existing mix designs will be permitted at the discretion of the Engineer when documentation includes the following:

- a) Manufacturer's recommended dosage of the admixture
- b) A letter stamped by the Concrete Mix Design Engineer approving the changes to the existing mix design.

Unless otherwise permitted by the Engineer, the product of only one type of hydraulic cement from one source of any one brand shall be used in a concrete mix design.

Review and approval of the Concrete Mix Design by the Engineer does not constitute acceptance of the concrete. Acceptance will be based solely on the test results of concrete placed on the project.

Batching

Measuring and batching of materials shall be done at a batching plant in accordance with AASHTO M 157.

The Contractor shall furnish a batch ticket (delivery ticket) with each load for all classes of concrete. Concrete delivered without a batch ticket containing complete information as specified shall be rejected. The Contractor shall collect and complete the batch ticket at the placement site and deliver all batch tickets to the Engineer on a daily basis. The Engineer shall have access to the batch tickets at any time during the placement. The following information shall be provided on each batch ticket:

- a) Supplier's name and date
- b) Truck number
- c) Project number and location
- d) Concrete class designation and item number
- e) Cubic yards batched
- f) Time batched
- g) Mix design number
- h) Type, brand, and amount of each admixture
- i) Type, brand, and amount of cement and fly ash
- j) Weights of fine and coarse aggregates
- k) Moisture of fine and coarse aggregate
- l) Gallons (Pounds) of batch water (including ice)
- m) Gallons of water added by truck operator plus quantity of concrete in the truck each time water is added
- n) Number of revolutions of drum at mixing speed (for truck mixed concrete)
- o) Discharge time
- p) Location of batch in placement
- q) Water to cementitious material ratio (required for deck concrete only)

The drum on each truck mixer shall be reversed prior to charging to eliminate any wash water remaining in the mixer.

- a) *Portland Cement and Fly Ash*. Either sacked or bulk cement may be used. No fraction of a sack of cement shall be used in a batch of concrete unless the cement is weighed.

All bulk cement shall be weighed on an approved weighing device. The bulk cement weighing hopper shall be sealed and vented to preclude dusting during operation. The discharge chute shall be so arranged that cement will not lodge in it or leak from it.

Separate storage and handling equipment shall be provided for the fly ash. The fly ash may be weighed in the cement hopper and discharged with the cement.

- b) *Water.* Unless water is to be weighed, the water-measuring equipment shall include an auxiliary tank from which the measuring tank shall be filled. The measuring tank shall be equipped with an outside tap and valve to provide for checking the calibration unless other means are provided for readily and accurately determining the amount of water in the tank. The volume of the auxiliary tank shall be at least equal to that of the measuring tank. In lieu of the volume method specified above, the Contractor will be permitted to use a water metering device that is accurate within the prescribed limits.
- c) *Aggregates.* Aggregates from different sources and of different gradings shall not be stockpiled together.

Aggregate shall be handled from stockpiles or other sources to the batching plant in such manner as to secure a uniform grading of the material. Aggregates that have become segregated, or mixed with earth or foreign material, shall not be used. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for draining at least 12 hours before being batched. Rail shipment requiring more than 12 hours will be accepted as adequate binning only if the car bodies permit free drainage. In case the aggregates contain high or non-uniform moisture content, storage or stockpile period in excess of 12 hours may be required.

- d) *Bins and Scales.* The batching plant may include bins, weighing hoppers, and scales for the fine aggregate and for each size of coarse aggregate. If cement is used in bulk, a bin, hopper, and scale for cement shall be included. A single weighing hopper with an accumulative scale will be permitted, provided a separate scale is used for weighing cement.

Mixing

Concrete may be mixed in stationary mixers, in a central-mix plant, in truck mixers, or in self-contained mobile mixers. Mixing time shall be measured from the time all materials, except water, are in the drum.

Silica fume, when specified, shall be added to the mix during initial batching.

- a) *Mixing General.* The concrete shall be deposited in place within 90 minutes after batching when concrete is delivered in truck mixers or agitating trucks, and within 60 minutes when delivered in non-agitating trucks.
 - a. The 90 minute time limit for mixer or agitating trucks may be extended to 120 minutes if:
 - i. No water is added after 90 minutes.
 - ii. The concrete temperature prior to placement is less than 90 °F
 - b. The 90 minute time limit for mixer or agitating trucks may be extended to 180 minutes if:
 - i. No water is added after 90 minutes.
 - ii. The concrete temperature prior to placement is less than 90 °F.
 - iii. The approved concrete mix contains a water reducing and retarding admixture which conforms to AASHTO M 194, Type D.
- b) *Stationary Mixing.* When mixed in a central mixing plant, the mixing time shall be between 50 and 90 seconds. Four seconds shall be added to the specified mixing time if timing starts the instant the skip reaches its maximum raised position. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The volume of concrete mixed per batch may exceed the mixer's nominal capacity, as shown on the manufacturer's standard rating plate on the mixer, up to 10 per cent provided concrete test

data for strength, segregation, and uniform consistency are satisfactory, and provided spillage of concrete does not occur.

The batch shall be so charged into the drum that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

The timing device on stationary mixers shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the Contractor will be permitted to operate while it is being repaired, provided the Contractor furnishes an approved timepiece equipped with minute and second hands. If the timing device is not placed in good working order within 24 hours, further use of the mixer will be prohibited until repairs are made.

- c) *Truck Mixing.* Truck mixed concrete shall conform with one of the following:
- a. Concrete mixed entirely in a truck mixer equipped with a mechanical counter shall be partially mixed at the plant or in transit for not less than 20 revolutions of the drum at mixing speed. The revolutions of the drum at charging speed shall not be counted as mixing revolutions. The concrete shall be mixed between 50 and 100 revolutions of the mixer drum at mixing speed at the delivery site before discharge of the concrete.
 - b. Concrete partially mixed in a stationary central mixing plant with mixing brought to completion in a truck mixer (known as shrink mixing) shall be mixed for a minimum of 30 seconds in the stationary mixer. Mixing shall be completed in the truck mixer for at least 20 but not more than 100 revolutions of the mixer drum at mixing speed at the delivery site before discharge of the concrete.
 - c. Concrete mixed entirely in a stationary mixer and delivered to the job in a truck mixer shall be remixed for a minimum of 20 revolutions of the mixing drum at mixing speed at the job site prior to discharge.

When water is added at the delivery site to control the consistency of the concrete, the concrete shall be mixed for at least 20 revolutions of the mixer drum at mixing speed for each addition of water before discharge. These revolutions are in addition to the minimum revolutions required for mixing at the delivery site. Water from all sources shall be documented by the ready mix producer on the delivery slip for each load of concrete.

The Contractor shall provide a Concrete Truck Mixer Certification. This certification shall show the various pick-up and throw-over configurations and wear marks so that the wear on the blades can be checked. Blades shall be replaced when any part or section is worn 1 inch or more below the original height of the manufacturer's design. A copy of the manufacturer's design, showing the dimensions and arrangement of blades, shall be available to the Engineer at all times.

The Contractor shall furnish a water-measuring device in good working condition, mounted on each transit mix truck, for measuring the water added to the mix after the truck has left the charging plant. Each measuring device shall be equipped with an easy-to-read gauge. Water shall be measured to the accuracy prescribed in AASHTO M 157.

- d) *Self Contained Mobile Mixer.* Proportioning and mixing equipment shall be of the self-contained, mobile, continuous mixing type subject to the following:
- a. The mixer shall be self-propelled and be capable of carrying sufficient unmixed dry, bulk cement, fine aggregate, coarse aggregate, admixtures and water to produce on the site not less than 6 cubic yards of concrete. The mixer shall have one bin for each size aggregate.
 - b. The mixer shall be capable of positive measurement of cement being introduced into the mix. A recording meter visible at all times and equipped with a ticket printout shall indicate the quantity of total concrete mix.

- c. The mixer shall provide positive control of the flow of water into the mixing chamber. Water flow shall be indicated by flow meter and be readily adjustable to provide for minor variations in the aggregate moisture.
- d. The mixer shall be capable of being calibrated to automatically proportion and blend all components of indicated composition on a continuous or intermittent basis as required by the finishing operation, and shall discharge mixed material through a conventional chute directly in front of the finishing machine.
- e. The Contractor shall perform calibration tests according to the equipment manufacturer's recommendations at the beginning of each project, and when there is a change in the mix design proportions or source of materials. The Engineer may require a calibration test or yield check whenever a change in the characteristics of the mixture is observed. The tolerances in proportioning the various ingredients shall be according to subsection 6.8 of AASHTO M 241.

Air Content Adjustment

When a batch of concrete delivered to the project does not conform to the minimum specified air content, an air entraining admixture conforming to AASHTO M 154 may be added. After the admixture is added, the concrete shall be re-mixed for a minimum of 20 revolutions of the mixer drum at mixing speed. The concrete shall then be re-tested by QC.

Acceptance and Pay Factors (City Owned and/or City Contract Only)

These provisions apply to all concrete. The Contractor shall sample concrete items in accordance with AASHTO T 23 Making and Curing Concrete Test Specimens in the Field. At CCD's discretion, CCD will witness the sampling and take possession of the samples at a mutually agreed upon location.

- a) *Air Content*. The first three batches at the beginning of production shall be tested by QC and QA for air content. When air content is below the specified limit, an air entraining admixture may be added. After the admixture is added, the concrete shall be re-mixed for a minimum of 20 revolutions of the mixer drum at mixing speed and then re-tested.
- b) *Slump*. Slump acceptance, but not rejection, may be visually determined by CCD. During the placement of the concrete, when a batch exceeds the maximum slump specified, the following procedure shall be used to analyze the acceptability of the concrete.
 - a. A batch that exceeds the maximum slump specified by more than 2 inch will be rejected. If the slump is greater than 2 inches lower than the approved concrete mix design, the load may be adjusted by adding a water reducer or by adding water and retested.
- c) *Strength (When Specified)*. The concrete will be considered acceptable when the running average of three consecutive strength tests is equal to or greater than the specified strength and no single test falls below the specified strength by more than 500 psi. A test is defined as the average strength of three test cylinders cast in plastic molds from a single sample of concrete and cured under standard laboratory conditions prior to testing. If the compressive strength of any one test cylinder differs from the average by more than 10 percent that compressive strength will be deleted and the average strength will be determined using the compressive strength of the remaining two test cylinders.

For concrete having specified strength of 4500 psi or greater, when the compressive strength test is below the specified strength by more than 500 psi but not more than 1000 psi, the concrete represented will be evaluated by CCD for removal, corrective action, or acceptance. When the compressive strength test is below the specified strength by more than 1000 psi, the concrete represented will be rejected. If the concrete in the structure is still found to be deficient, resulting time delays will be considered *non-excusable for this evaluation*.

Unless otherwise stated in the plans or specifications, tolerances for concrete construction and materials shall be in accordance with ACI 117.

END OF SECTION

D.5 Reinforcing Steel

Description

This work consists of furnishing and placing reinforcing steel in accordance with these specifications and in conformity with the plans.

Reinforcing Steel

Reinforcing steel shall conform to the requirements of the following specifications:

Deformed and Plain Billet-Steel Bars for Concrete Reinforcement	ASTM A 615
Axle-steel Deformed and Plain Bars for Concrete Reinforcement	ASTM A 996
Low-Alloy Steel Deformed Bars for Concrete Reinforcement [to be Welded]	ASTM A 706
Fabricated Deformed Steel Bar Mats for Concrete Reinforcement	ASTM A 184

Unless otherwise designated, bars conforming to ASTM A 615 & ASTM A 996 shall be furnished in Grade 60 for # 5 bars and larger and Grade 40 or 60 for bars smaller than # 5.

In ASTM A 184, bar material conforming to ASTM A 616 will not be permitted.

Bar List

Two copies of a list of all reinforcing steel and bending diagrams shall be furnished to the Engineer at the site of the work at least one week before the placing of reinforcing steel is begun. Such lists will not be reviewed for accuracy. The Contractor shall be responsible for the accuracy of the lists and for furnishing and placing all reinforcing steel in accordance with the details shown on the plans.

Bar lists and bending diagrams which are included on the plans, do not have to be furnished by the Contractor. When bar lists and bending diagrams are included on the plans, they are intended for estimating approximate quantities. The Contractor shall verify the quantity, size and shape of the bar reinforcement against those shown on the plans and make all necessary corrections before ordering.

Protection of Materials

Reinforcing steel shall be protected at all times from damage. When placed in the work, the reinforcing steel shall be free from dirt, loose mill scale, paint, oil, loose rust, or other foreign substance.

Bending

Unless otherwise permitted, all reinforcing bars shall be bent cold. Bars partially embedded in concrete shall not be field bent except as shown on plans or permitted. Bars shall not be bent or straightened in a manner that will injure the material. Should the Engineer approve the application of heat for field bending reinforcing bars, precautions shall be taken to assure that the physical properties of the steel will not be materially altered.

Placing and Fastening

The minimum spacing center to center of parallel bars shall be 2½ times the diameter of the bar. However, the clear distance between the bars shall not be less than 1½ times the maximum size of the coarse aggregate or 1½ inches, whichever is greater.

All reinforcement shall have a clear coverage of 2 inches, except as shown on the plans. Clear coverage shall be measured from the surface of the concrete to the outside of the reinforcement.

The placing, fastening, splicing and supporting of reinforcing steel reinforcement shall be in accordance with the plans and the latest edition of "CRSI Recommended Practice for Placing Reinforcing Bars." In case of discrepancy between the plans and the CRSI publication stated above, the plans shall govern.

END OF SECTION