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Standardization and Sustainability Initiative

Exterior Lighting for Navigation Locks and Dams

Sustainability and Standardization

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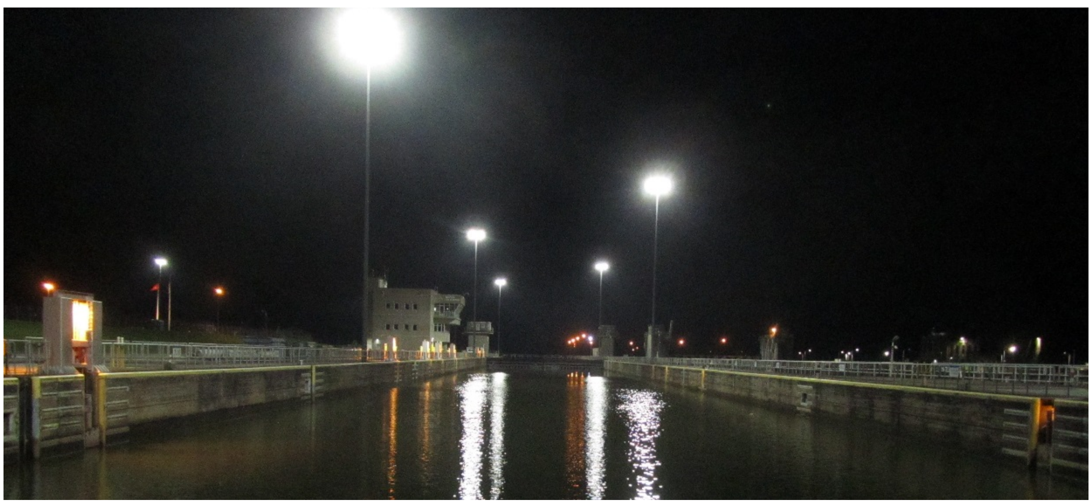
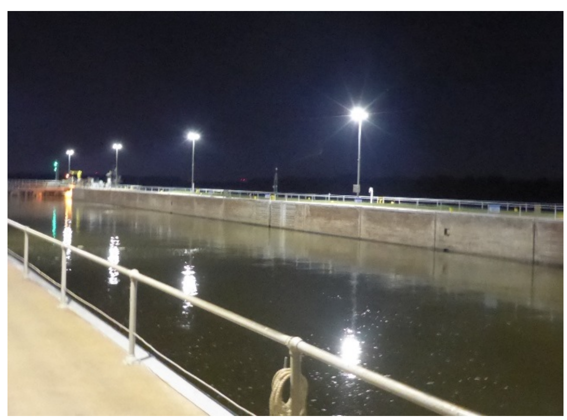


Winfield Lock, Kanawha River



Lock No. 18, Mississippi River

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Sustainability and Standardization

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Final Report

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Abstract

This report provides additional exterior lighting information in a format that will assist U.S. Army Corps of Engineers (USACE) operations managers, navigation lock and dam administrators, and design engineers to provide better, more economical light emitting diode (LED) lighting for navigation locks and dams. This report is also intended to be used by navigation lock and dam Lockmasters and Operations Project Managers (OPMS) as tools to create sustainability work packages that compete for project funding differently than Operation & Maintenance (O&M) project funding. It identifies LED light fixtures in use and reports lessons learned from existing LED light fixtures and LED lamps that have been installed at USACE navigation locks and dams. This report compares illumination values of LED light fixtures to high-pressure sodium (HPS) light fixtures installed at navigation locks using computer software models as well as field-measured illumination values. Finally, this report compares energy consumption and life-cycle cost estimates between LED and HPS light fixtures.

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Preface

The Inland Navigation Design Center Mandatory Center of Expertise was tasked by U.S. Army Corps of Engineers Headquarters to investigate opportunities across the enterprise for sustainability and standardization at navigation structures with emphasis given to mechanical and electrical components. This study and report was funded by Headquarters, U.S. Army Corps of Engineers (HQUSACE) and in part through the Corps' U.S. Army Engineer Research and Development Center (ERDC) Dredging Operations Technical Support (DOTS) program.

This study was conducted for U.S. Army Corps of Engineers Headquarters. The Inland Navigation Design Center Mandatory Center of Expertise (INDC-MCX) provides engineering, design, analysis and review services for studies, new locks & navigation dams, major rehabilitation of existing inland navigation locks and dams, and significant inland navigation lock and dam operations & maintenance (O&M) projects. The INDC strives to deliver quality products and services through design consistency, technical review, adherence to policy and regulation, standardization of design, risk analysis, collaboration with experts & stakeholders, and knowledge management of technical competency. The INDC develops solutions to complex engineering problems for the nation's inland waterways to serve the Army, the Department of Defense, Federal Agencies, and the Nation. To find out more about the Inland Navigation Design Center and this report please visit: https://apps.usace.army.mil/sites/TEN/IND/Pages/default.aspx

1 Exterior Lock & Dam Lighting

1.1 Introduction

The U.S. Army Corps of Engineers (USACE) is committed to ensuring that sustainability is not only a natural part of all our decision processes, but that it should also be part of our organizational culture. USACE defines sustainability as an umbrella concept that encompasses energy, climate change, and the environment to ensure that what we do today does not negatively impact tomorrow. Use of recent new technology light emitting diodes (LED), solid state light fixtures decrease navigation lock and dam light system energy consumption and decrease energy costs while either maintaining or improving the exterior illumination levels. The largest most common lighting system power loads are the lock chamber area light fixtures, the guide wall area light fixtures, and the guard wall (as applicable) area light fixtures. The focus of this report is to provide additional information for operations managers, navigation lock and dam administrators, and design engineers regarding solid state LED area light fixture technology and how it has been, and can be, applied to illuminate these specific navigation lock areas.

1.2 Sustainability

Compared to light fixtures currently in use, new LED lighting technology offers many tangible and intangible benefits, including energy savings from reduced lighting operating costs, better light color, reduced maintenance, improved lighting controls, and increased safety. Several navigation lock and dam facilities currently have LED light fixtures installed that will save energy and save operating costs while maintaining or improving the illumination levels to conduct safe lock and dam operations, as well as reduce lighting maintenance and lamp replacement costs.

The sustainability goal of this report includes providing some example comparisons between currently used high intensity discharge (HID) light fixtures and new LED light fixtures, and identify potential energy and cost savings.

LED light fixtures consume less energy and provide more illumination per watt when compared to HID or incandescent light fixtures currently in use.

Similarly, life-cycle lighting costs are comparatively less for LED light fixtures than for HID light fixtures. The color of LED light fixtures, measured in Degrees Kelvin, is more white, a better light color as compared to the yellow light color of high-pressure sodium (HPS). The whiter light color of LED tends to allow better vision for identification of surroundings and activities that may provide a safer working environment. Additionally, LED light fixtures have longer life cycle and therefore the lamp replacement need is reduced. This also affects maintenance safety and maintenance costs because the light fixtures do not have to be accessed by a hydraulic lift, a ladder, or other type of access devices as often, thereby avoiding and reducing the need for potentially dangerous maintenance activities.

1.3 Standardization

The following Internet websites provide USACE standard Computer-Aided Design (CAD) details and generalized characteristics for several types of exterior light fixtures and poles (including LED light fixtures):

1. Internet Reference: Exterior Light Fixture Standard Details Portable Document Format (PDF), http://www.wbdg.org/FFC/NAVGRAPH/exterior_lighting_english.pdf
2. Internet Reference: Standard Light Fixture CAD Details, http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-graphics-tables

These CAD details apply to many diverse applications. They are useful to identify specific LED light fixture characteristics, but they do not apply specifically to external lighting at navigation locks and dams. However, some of these details may be used as a basis for a design that may then be altered as needed to meet the needs of the navigation lock and dam light fixture application.

An inconsistency exists across USACE regarding light fixture selection for illumination of navigation locks and dams. No guidance exists that recommends standard types of LED light fixtures or how to choose an LED light fixture specifically applicable for outdoor fixtures at navigation locks and dams. No guidance or recommendations exist regarding retrofit of existing HID type light fixture to convert them to LED type light fixtures. Several navigation lock and dam facilities have performed independent market research investigations to find LED light fixtures suitable to their applications. Often times, lock facilities located within the same District use different types of light fixtures. The standardization goals of this report are to present lessons learned as reported from navigation locks and dam facilities that are using LED light fixtures and to also to provide lighting design criteria and LED light fixture information.

1.4 Units of measure

Units for luminous flux per square foot [foot-candles (fc)] and the Systeme Internationale (SI) units for luminous flux per square meter [Lux (lx)] are both used in this report. The unit conversion between fc and lx is:

1 foot-candle (fc) = 10.764 Lux (lx).

2 Lock Chamber Light Level Criteria

2.1 General

This chapter presents a review and comparison of engineering manuals, guidelines, and references used as criteria to determine a recommendation for navigation lock chamber light levels. For the purpose of this document, only light levels for the top of the lock wall and for the lowest elevation of tailwater were evaluated. The navigation lock light level criteria includes the following engineering manuals, guidelines, and references:

- USACE Engineer Manual (EM) 1110-2-2610. *Mechanical and Electrical Design for Lock and Dam Operating Equipment*. 30 June 2013.
- USACE EM 385-1-1. *Safety and Health Requirements*. 30 November 2014.
- Unified Facilities Criteria (UFC) 3-530-01. *Interior and Exterior Lighting Systems and Controls*. Change 3. 01 June 2016.
- Illuminating Engineering Society of North America (IESNA). *The Lighting Handbook*. 10^{th} ed. 2011.
- The St. Lawrence Seaway Management Corporation. *St. Lawrence Seaway Lighting Design Guide*. April 2010.

2.2 Summary of references

2.2.1 EM 1110-2-2610, *Mechanical and Electrical Design for Lock and Dam Operating Equipment*

EM 1110-2-2610 provides guidance for the electrical design of lock and dam operating equipment and controls systems for both new construction and the rehabilitation of existing projects. In Chapter 13, the manual states that all lighting intensity requirements can vary from district to district, but designers should attempt to provide uniformity between locks within a district. The manual says that there is no standard for lighting intensity levels at navigation locks, but there are suggested values. The manual suggests using 2.0 fc, average maintained, at the top wall of the lock chamber and 1.25 fc, average maintained, at the tailwater elevation with uniformity of 70 to 80%. Appendix A to EM 1110-2-2610 references a St. Lawrence Seaway Management Corp's *Lighting Design Guide* (Giday 2010) that prescribes light levels at navigation locks.

2.2.2 EM 385-1-1, *Safety and Health Requirements*

EM 385-1-1 is used to prescribe the safety and health requirements for all USACE activities and operations. Chapter 7 of this manual provides some general requirements for the proper illumination of a safe working environment at work spaces, project sites, roadways, and vessels. Table 1 lists the various facility areas along with their minimum light level requirement. None of the areas listed are specific to navigation locks, but the manual does list a minimum of 3 fc for General Outdoor Accessways, which could apply to the top of the lock wall.

2.2.3 UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls*

UFC 3-530-01, which is based on the requirements of The IESNA *Lighting Handbook*, is intended to address general lighting requirements for Department of Defense (DoD) facilities. The UFC provides minimal guidance for light level criteria at navigation locks. It also provides some guidance for general exterior lighting areas, which could indirectly be applied to navigation locks. Table 2 lists various exterior lighting zones, categorized by application. Lighting Zone 3 is most applicable to navigation locks as it lists Waterfront Facilities with Wharf and Pier Areas as needing moderately high ambient lighting. Appendix D to UFC 3-530-01 further defines the needs for Lighting Zone 3 as:

> Areas of human activity where the vision of human users is adapted to moderately high levels. Lighting may typically be used for safety, security and/or convenience and is often uniform and/or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

The UFC does not list specific light levels for Lighting Zone 3 or more specifically for Wharf and Pier Areas, but Chapter 5 of UFC 3-530-01 does include a section for Marinas. The performance requirement for Marinas is listed as 0.5 fc average.

Table 1. Minimum lighting requirements.

Facility or Function	Lux (lm/m^2)	fc (lm/ft^2)
Accessways		
- general indoor	55	5
- general outdoor	33	3
- exitways, walkways, ladders, stairs	110	10
Administrative areas (offices, drafting and meeting rooms, etc.)	540	50
Chemical laboratories	540	50
Construction areas	55	5
- general indoor	33	3
- general outdoor	55	5
- tunnels and general underground work areas (min 110 lux required at tunnel/shaft heading during drilling, mucking, and scaling)		
Conveyor routes	110	10
Dam Operating Areas (Interior)		
- tunnels and underground work areas	55	5
- control stations	150	15
Docks and loading platforms	33	3
Elevators, freight and passenger	50	5
Temporary Electrical Panels (Interior)	300	30
Temporary Electrical Panels (Exterior)	50	10
First-aid stations and infirmaries	300	30
Maintenance/operating areas/shops		
- vehicle maintenance shop	300	30
- carpentry shop	110	10
- refueling area, outdoors	55	5
- shops, fine – medium detail work	540-325	50-30
- welding shop	300	30
Mechanical/electrical equipment rooms	110	10
Outdoor parking areas	33	3
Toilets, wash, and dressing rooms	110	10
Visitor areas	215	20
Warehouse and storage rooms/areas		
- indoor rack storage	270	25
- outdoor storage	33	3
Work areas - general (not listed above)	325	30
Source: EM 385-1-1,Table 7-1		

Table 2. Lighting zones and DoD applications.

MLO Lighting Zones	Title	DoD Installation/Application	
LZ0	No Ambient Lighting	Training areas Night vision training areas, endangered waterfront areas and other areas where there is expected no nighttime activity.	Increasing Nighttime Activity
LZ1	Low Ambient Lighting	Personnel Support Districts Unaccompanied quarters, single and multi-family residential, campgrounds, administration, and other non-nighttime use areas, golf course, exercise fields and paths Airfield (Nearby facilities may be higher zone)	
LZ2	Moderate Ambient Lighting	Waterfront or Airfield Facilities Administrative areas, common areas, service areas, parking. Training Facilities Academic instruction, educational services, applied instruction, reserve training, operational simulators Administrative Facilities Offices, conference centers, command centers, parking Personnel Support Districts Officer clubs, lodge, food service, fire and security, ITT, medical and dental clinics, family services, schools, childcare facilities, youth programs, religious facilities, banks, exchange, commissary, libraries, morale, welfare and recreation, hobby shops, theaters, gyms indoor sport facilities, outdoor pools, sports (tennis, basketball) courts, baseball and football fields Industrial Facilities Shipyards, ordinance handling/storage, manufacturing facilities, maintenance shops, depots	
LZ3	Moderately High Ambient Lighting	Waterfront Facilities Wharf and pier areas Airfield Facilities Aircraft maintenance and hangars, air operations and headquarters, line shacks, terminal facilities, training areas, utility service areas	
LZ4	High Ambient Lighting	No areas qualify for this lighting zone.	
Source: UFC 3-530-01, Table 4-1			

2.2.4 Illuminating Engineering Society of North America, *The Lighting Handbook*

The Lighting Handbook is a guide that provides recommendations for lighting system designers to use as a source of information in the framework, design, and application of lighting. *The Lighting Handbook* does not have specific light level criteria for navigations locks, but there is a reference to shipyards. Chapter 30 is dedicated to lighting for manufacturing, and Table 30.2 lists industrial illuminance recommendations for various types of facilities, including shipyards. Table 3 lists some data taken from *The Lighting Handbook* Table 30.2. The “General” category of the ship yards section recommends a maintained illuminance target of 5 fc (50 lux) average. This value assumes that the visual age for at least half of the observers is between 25 and 65 years old. Older observers require higher light levels, and younger observers require lower light levels according to the reference. The Max:Min uniformity ratio coverage is recommended to be 5:1. The “General” category of ship yards is also considered to be Category K for the Recommended Illuminance Targets. Category K is described as an area where “Visual performance involves higher-level assessment of landscape, hardscape, architecture, and people and can be work related.”

Table 3. Industrial illuminance recommendations.

		Horizontal Targets (lux) Visual Age of Observers (years) where at least half are:				
Ship Yards	Category	<25	25-65	>65	Gauge	Max:Min
Fabrication area	P	150	300	600	Avg.	3:1
General	K	25	50	100	Avg.	5:1
Ways	M	50	100	200	Avg.	5:1
Source: Illuminating Engineering Society of North America (IES) Lighting Handbook 10th Edition: Table 30.2 (Partial)						

2.2.5 The St. Lawrence Seaway Management Corporation, St. Lawrence Seaway Lighting Design Guide

The St. Lawrence Seaway Lighting Design Guide (SLSLDG) is a guide intended to be used by lighting designers on lighting systems at St. Lawrence Seaway installations, including the navigation locks. Chapter 6 of the guide discusses specific lighting applications for tie-up walls and locks. The target illumination values for tie-up wall is 2.0 fc and for the operation areas of the locks is 2.5 fc. The values were established based on Canada’s Occupational Health and Safety Regulations. The uniformity ratio for Avg:Min is 3:1; the uniformity ratio for Max:Min is 6:1.

2.3 Reference summary and recommendations

When all of the different references are compared, there is inconsistency in terms of minimum light level and maximum to minimum (Max:Min) ratio recommendations. Because of the inconsistencies, lock and dam light levels still need to be evaluated and determined by design engineers on a case-by-case basis until a consensus can be reached among industry experts and users within USACE. The recommendations and revisions identified in this section will also be identified and coordinated with higher USACE authority to determine scheduling and funding.

As a preliminary recommendation, based on a comparison of the design references and manuals in this report, light levels should be in a range that is close to 5 fc average with a Max:Min of 5:1 at the top of the lock wall and 2 fc average with a Max:Min of 5:1 at the lowest tailwater level. The value for the top of the lock wall follows the most conservative reference recommendation from the Illuminating Engineering Society of North America (IES) handbook, while the lowest tailwater elevation recommendation accounts for the reduction in the amount of light available by using the same fixtures as the lock wall. These preliminary recommendations need further vetting, as a follow up to this report, by industry lighting experts and users with experience in lock and dam lighting.

Once minimum light levels and Max:Min ratios have been determined, USACE EM 1110-2-2610 and UFC 3-530-01 should be updated with matching recommendations specific to navigation lock and dams. Additionally, EM 1110-2-2610 should be revised to state that all USACE Districts should be consistent with each other, rather than allowing all USACE Districts and locks to have different lighting requirements. Chapter 5 of UFC 3-530-01 also needs to be updated to include the specific application of a Navigation Lock and Dam with the recommended foot-candle values, similar in format to the other exterior lighting application examples.

3 Lighting Technology

3.1 High intensity discharge (HID) background

For the past 100 years or so, HID lamps have been the leader in lighting technology. Due to their high level of brightness and low lumen per watt (LM/W) cost, these lights have been used in applications such as outdoor lighting, television, headlights, stadiums, high ceiling lighting, and many others. HID lamps produce light by creating an arc between two electrodes in a pressurized tube; these pressurized tubes are generally filled with gas and metal salts. The gas heating up acts as a catalyst for an initial "light-up" period, which allows for the metal salts to enter into a plasma state. It is this plasma state that gives off such a large amount of light. The types of salts and gasses within these lamps can be engineered to allow for different variations of light color and brightness, as well as to increase or decrease power draw.

The two specific types of HID lights typically found in outdoor lighting applications are the Metal-Halide (MH) and HPS lamps. MH lamps use vaporized mercury and a small discharge tube filled with metal halides to produce light from its own arc. This type of lamp typically produces an average of 65-115 LM/W, can last in excess of 20,000 hours, and has a color range of 3000-6,500 Kelvin (K). HPS lamps use vaporized sodium metal to produce light from its own arc. This type of lamp typically produces an average of 100-190 LM/W, can last approximately 18,000 hours, and has a color range of 1900-2800 K. The HPS lamp is currently the most efficient source of lighting within the HID family.

3.1.1 HID ballasts

Each HID lamp requires the use of a ballast for operation. Ballasts are used to regulate the varying amount of current flow required to maintain a specific voltage to the electrodes in order to produce the arc. Ballasts are typically known to last longer than the HID lamps, but not by much; the average ballast lifespan is approximately 20,000 hours, which is approximately 10-15% longer than the lamp being powered.

3.1.2 HID starting and re-strike times

When starting and stopping HID lamps, it is important to keep in mind that they require start-up and re-strike time delays. As the names imply, the startup time for HID lamps refers to the amount of time required to see full illuminance from the lamp while the re-strike time refers to the amount of time required to turn the lamp back on after a loss of power. According to the IES, MH lamps can take multiple minutes to warm up (depending on wattage of lamp) and can require 15 or more minutes of re-strike time. The IES also states that HPS lamps require approximately 10 minutes of warm up time, have a re-strike time of 1 minute, and a re-strike warm up time of 4-5 minutes.

3.1.3 HID lumen maintenance (life span)

Over the course of the HID lamps life, a certain level of depreciation happens to both lumen output and color range. The MH lamps are seen to have a shorter life span than all of the other HID lamp varieties due to the evaporative features found in the electrodes. MH lamps typically lose 13,000 lumens over the course of their 20,000 hour lifespan according to the IES. HPS lamps, however, have the highest amount of lumen maintenance found in the HID family. Instead of seeing a decline in the electrodes, HPS lamps typically lose life due to rising voltages caused by faulty or blackened arcs, which, in turn, vaporize the sodium within the lamp. HPS lamps typically see a gradual loss of lumens over the course of their, on average, 18,000-hour lifespan.

3.2 LED background and overview

Although HID lamps have been widely used for many years, new technology has led to the development of more efficient lighting sources. One such lighting source is that of the LED. An LED is a diode that emits light when a specific voltage is applied across it. Originally used for smaller applications, such as indication and display lighting, LEDs have made huge strides in industrial lighting applications in recent years. LEDs reduce energy costs, have longer life spans, and are available in smaller sizes that yield equivalent luminance in industrial applications. Unlike current lighting lamps, LEDs give off very small amounts of heat, which allows for a higher efficiency of power-to-light output. LEDs do not require any cool down or warm up period before operation; this is unlike HID lamps, which have required warm-up, cool-down, and re-strike times, before and after shutdowns.

LEDs can have variable color temperatures based on the materials used to make them; LEDs are capable of operating in infrared, ultraviolet, and visible color spectrums. LEDs typically produce an average of 55-140 LM/W, have average lifespans between 35,000-50,000 hours, and are capable of color ranges from 1,500 to 8,000 Kelvin (K).

3.2.1 Surface mounted technology (SMT)

New developments in surface-mounted technology have also given rise to greater affordability and applicability for industrial uses. Similar to computers, LEDs are now being mounted directly to printed circuit boards; this eases the automated manufacturing process, lowers prices, and allows a greater number of LEDs to be placed in close proximity. New LED fixtures can now be used in many different applications, which is extremely beneficial when new lighting fixtures must be fitted to specific site conditions.

3.2.2 Directional lighting

LEDs are known as "directional" lighting sources; this type of lighting is different from HID, incandescent, and other standard bulbs/lamps in that the LED will only emit light in the direction that the semi-conductor faces. This attribute has proven to be extremely beneficial in industrial applications because LEDs have the ability to illuminate specific areas with a larger amount of efficiency and brightness than can other types of lighting.

3.2.3 LED lumen maintenance (life span)

IES Technical Memorandum (TM)-21 *Projecting Long Term Lumen Maintenance of LED Light Sources* states that the lumen maintenance life of an LED is defined as the LED's elapsed operating time over which the light source's output has dropped by a given percentage. Typically, an LEDs lumen maintenance life is calculated based on a 30% drop from its initial light output. Therefore, even though an LED reaches "loss of life," it may still be capable of producing ~70% of its original light output.

3.3 LED advantages and disadvantages

As with all new technologies, the advantages and disadvantages LEDs should be considered before they are implemented on any project.

3.3.1 Disadvantages

Currently, the largest disadvantage of converting to LED technology is the initial start-up costs for upgrading to LED fixtures, even though the prices are falling as the technology improves. Converting to LEDs is not an easy or inexpensive decision to make when one considers the cost to purchase LED lamps and all of the necessary equipment, and the time required to install the fixtures. For example, LED fixtures, depending on the quality, can cost 2 to 4 times that of an HID bulb. In general, if moving to an LED lighting system, it is expected that a long return of investment (ROI) period will follow.

3.3.2 Advantages

LEDs have many advantages over HID or any other incandescent bulbs. The most notable advantages are: the LEDs' greater power efficiency, longer lifespan, easier level of control, and superior ability to select specific color temperatures.

Of all the LEDs' advantages, the most prominent is their power efficiency and, consequently, their cost savings. LEDs can produce, on average, approximately twice as many lumens per watt (LM/W), and can last 2 to 3 times longer than existing HID bulbs. On a similar note, LEDs also do not experience the "fading" effect towards the end of their life as do HID bulbs. With that in mind, LEDs are able to cut costs by eliminating high numbers of bulb replacements; they can lower the amount of labor time required for those multiple bulb replacements; and can also lower the projects energy cost because of their superior power efficiency.

Although cost is an important factor, better quality of light is also a feature that LEDs can provide to the workplace. As stated previously, LEDs are directional lights and can be focused on specific designated areas of illuminance. The ability to have more control of the illumination can lead to both a higher degree of light efficacy and fewer fixtures (lower cost); fewer fixtures also leads to less maintenance required by staff personnel and a smaller number of conductors required to power the lights.

LEDs can also improve safety in specific work areas by providing more light per square foot than that of their HID counterpart. Different areas of a project site require different illumination levels. Safety can be improved in certain areas by providing brighter lighting, for example, potential areas of hazard, pathways/walkways, and entrances and/or exits.

Because LEDs are solid state devices, new lighting control systems can incorporate LEDs more comprehensively. Typical lighting controls for LEDs include manual controls (on/off), occupancy sensors, scheduled on/off times, and dimming capabilities. The ability to implement such controls in conjunction with new LED lighting systems allows sites to add more versatility to programmed lighting control while cutting energy costs.

Lastly, LEDs offer a superior ability to choose the color temperature of their light output. This is extremely beneficial when working within light pollution restriction zones or around wildlife that may be affected by brighter color temperatures.

3.4 Industrial LED applications

In the past few years, LED manufacturers have vastly improved LED lighting for industrial applications. New LED fixtures are now being designed to withstand harsher outdoor environments, are typically brighter (which gives a higher level of safety to industrial workers), and have been shown to last through tougher handling conditions than can other bulbs. This newfound ability for LEDs to survive in harsh environments makes LED light fixtures ideal candidates for navigational lock lighting upgrades.

3.4.1 Industrial LED color temperature

When choosing an LED for an industrial setting, the first step is to choose the color temperature of the lights. Color temperature is measured in Kelvin (K) and is typically seen on a spectrum from around 2000 to 8000K. In industrial settings, daylight color typically ranges from 4,000-5000K, 5000K being the most prominent choice since it is closest to daylight, or brighter, conditions. Brighter color conditions typically offer a higher level of visibility and have also been known to raise alertness and attention levels of personnel in the area.

3.4.2 Industrial LED fixture types

LEDs come in a large assortment of fixture types and can be offered in almost every lighting capacity; flood, site, sport, wall pack, panel, and high bay lighting types are just a few of the various types of LED fixtures that can be found. For large lighting applications, HID lamps have begun to be phased out and replaced with high output LED high mast lights. These new LED fixtures are capable of having custom color temperatures, LED counts, illuminance outputs (dimming), and variable voltage inputs.

3.5 LED standards and certifications

In recent years, LED technology has grown so quickly that multiple new standards and certifications have been created to regulate the quality of these lights. The following sections discuss some primary standards and certifications for LED lighting that should be considered when purchasing new fixtures.

3.5.1 UL 8750, *Standard for Safety: Light Emitting Diode (LED) Equipment for Use in Lighting Products*

Underwriters Laboratories (UL) 8750 provides guidance standards for integral parts of LED luminaires as well as the LEDs components and parts. UL 8750 includes mechanical and electrical construction, performance testing, and markings.

3.5.2 NEMA SSL-1, *Electronic Drives for LED Devices, Arrays, or Systems*

National Electrical Manufacturers Association (NEMA) SSL-1 provides specifications and operating instructions for LED drivers (power supplies). This standard covers drivers for LED devices, arrays, or any other general lighting system. The drivers covered in this standard operate up to a maximum input voltage of 600 Volt AC (VAC) and at frequencies of either 50 or 60HZ.

3.5.3 National Electrical Manufacturers Association (NEMA) SSL-6

NEMA SSL-6 provides specifications and recommendations for dimming controls for LED lamps operating at 120VAC. This standard covers requirements to prevent damage to the dimming equipment and LED lamps, along with requirements for specific lighting performances within the dimming system.

3.5.4 IES LM-79, *Electrical and Photometric Measurements of Solid-State Lighting Products*

IES LM-79 covers the approved method and procedures to follow when creating reproducible measurements of total luminous flux, electrical power, luminous intensity, distribution, and chromaticity of solid state lighting (SSL) products. These measurements are meant for illumination and are assumed to be under standard lighting conditions. SSL devices within this standard are assumed to have Alternating Current (AC) voltage as main power and Direct Current (DC) voltage as power to operate the LED devices. IES LM-79, in short, maintains standardized and measurable values used in specification sheets for various LED lighting designs.

3.5.5 IES LM-80, *Measuring Luminous Flux and Color Maintenance of LED packages, Arrays, and Modules*

IES LM-80 provides the methods for the measurement of luminous flux and color maintenance of LED lamps; luminous, radiant, and photon flux; and LED color maintenance. IES LM-80 covers physical, environmental, and electrical conditions, along with photometric measurement and maintenance testing procedures.

4 Lock & Dam Facility Exterior Light Fixtures

4.1 General

This report focuses on exterior LED light sources (retrofit lamps, retrofit kits, and LED light fixtures) installed at navigation locks and dams. Many resources and guidance already exist for interior LED light fixtures, so they were not pursued in this report. Many navigation locks and dams have been changing their HID lights to LED lights with whatever resources they have available, including in-house labor or formal contracting methods. This chapter identifies a survey that was widely distributed by INDC to USACE navigation districts as part of this project to gather LED light fixture information from as many navigation facilities as possible. The results of the survey provide information regarding LED light fixtures and lamps (e.g., lock chamber light fixtures and guide wall light fixtures) installed at navigation locks. The survey also provides some information regarding LED light fixtures installed on navigation dams (e.g., service bridge path light fixtures). This Chapter includes both the survey and the resulting information.

4.2 Navigation LED lock light fixtures

It is recommended that a CAD drawing containing standard general details of acceptable and recommended LED light fixtures be developed for use at navigation locks and dams for use in exterior lighting projects. The drawings should contain details of the salient characteristics of each respective LED light fixture, similar in content to the light fixture details in existing in the USACE Standard CAD Details available for use for all USACE projects (see Section 1.3, p. 2). This proposed future development of CAD drawing standard general details, specifically for exterior light fixtures at navigation locks and dams, will be brought to the attention of the proper USACE authority, to seek direction and to determine scheduling and funding.

Some example generic salient characteristics of existing USACE Standard CAD Details for lock chamber area LED light fixtures would be:

- LED type fixture.

- Housing must be die-cast aluminum or die-cast and extruded Aluminum with integral self-cleaning heat sink fins, ribs, or equivalent passive cooling mechanism incorporated directly into housing to ensure maximum heat transfer and dissipation.
- Finish must be multi-stage pre-treatment finished with baked-on polyester powder coat. Finish must pass the 2500 hour salt spray test per American Society for Testing and Materials (ASTM) Standard B117. Provide finish color as silver, dark bronze, black, or other custom color if required.
- Provide LED arrays as required to provide the IES distribution Type IV. (Change the IES Type as required for each specific design.)
- Color Rendering Index (CRI) greater than or equal to 70 and correlated color temperature (CCT) of 5,000 Degrees K.
- UL listed for wet locations; 120 or 277 Volts LED Driver(s), 60 Hz. Provide surge protection that is compliant with American National Standards Institute (ANSI) C62.41.2.
- Options may include photocell, bird spikes, occupancy sensor, and 0-10Volt dimming driver.

Refer to TECHINFO, Unified Facilities Guide Specification (UFGS) Graphics, Exterior Lighting, Type XL-03, LED Area Luminaire, revision date March 2013. See following link: http://www.wbdg.org/FFC/NAVGRAPH/exterior_lighting_english.pdf

4.3 Lock lighting survey form

Figures 1 and 2 show the survey instructions and the survey distributed to USACE navigation locks and dams personnel to obtain information about the LED light fixtures in use and to share lessons learned from those installations. Figure 3 shows a typical completed survey response. Table 4 lists a complete tabulation of survey responses.

<u>USACE Navigation Lock & Dam OUTDOOR (only) LED Light Fixtures and LED Lamps</u>

<u>Documentation of Operations Division LED Experiences and Lessons Learned</u>

1. Introduction and Purpose: The use of outdoor LED light fixtures provides significant energy and cost savings for USACE. Many navigation lock and dam facilities have taken positive steps forward to research and install LED lighting technology. It is important for USACE to learn which LED light fixtures or LED lamps have been installed and what lessons can be learned from the locks and dams leading the way by installing and learning about outdoor LED light fixtures.
2. Please complete the requested information to enable sharing LED light fixture and LED lamp information with all USACE navigation locks and dams and email it to point of contact, INDC-MCX@usace.army.mil.
3. The following specific information is requested to the best of your knowledge and documentation for all of the LED light fixtures installed at your lock and dam facility. The following are some examples by name:
   Examples of navigation Lock and Dam Light Fixtures and Light Assemblies – For example, Identify L&D fixtures as …. Lock chamber light fixtures and poles, Guide wall lights and poles, Guard wall lights and poles, Wall lights, Dam path lights, floating mooring bit light fixtures, tow boat coupling light fixtures and poles, LED navigation lights, LED traffic lights, fisherman warning lights, dam service bridge LED path lights, dam entrance lights, dam storage yard lights, etc.
4. Table 1 only exists for general information to be completed once by each lock. Also, three (3) copies of Table 2.#. Table 2.1 is meant for one outdoor LED fixture you use, Table 2.2 is intended for a second type of outdoor LED fixture you use, and Table 2.3 for a third type you use

   <u>Please copy Table 2.3 and paste to make additional Table 2 survey forms for additional outdoor LED light fixtures that you can provide information about.</u>

Figure 1. INDC lock & dam outdoor LED light fixture survey instructions.

Navigation Lock & Dam Identification (Name):
River I.D. Location & MSC Division:
1. Identify LED Light (or LED lamp) Fixture Duty (a.k.a. purpose, e.g. lock chamber light fixture mounted on 30 ft. pole):
2. Identify if LED Light Fixture or LED Lamp: (CIRCLE APPLICABLE TYPE)
3. State how many LED Light Fixtures per Pole assembly when applicable)
4. State how many LED lamps per fixture when applicable:
5. Mounting: Wall Mounted (Mtg. Ht.) / 30 ft. Tall Pole / High Mast Light / or other (specify) – {Circle one and/or identify mounting height of fixture as well as any special mounting features if applicable}:
6. LED Fixture or Lamp Brand Name:
7. LED Fixture or Lamp Model Number:
8. LED Fixture or Lamp Wattage:
9. LED Fixture or Lamp Voltage:
10. LED Fixture or Lamp Color Temperature:
11. What is the IES distribution of this light fixture (i.e. Type II, Type III, Type IV, Type V, flood light or spot light):
12. If known, what original wattage and type of fixture was replaced by the identified LED Fixture?
13. What Lessons have you learned as a result of installing and using this new LED Fixture or LED Lamp?
14. Have you experienced any LED light fixture failures or LED driver failures? Please describe:
15. How is the light fixture controlled? (e.g. manual switch, timer, photocell, occupancy sensor…)
16. Email photos of any LED light fixtures as well as pole assemblies that you would like to share.

Figure 2. Outdoor (only) LED Light Fixture or LED Lamp Survey – Identification of LED Light Fixtures or LED Lamps installed at Navigation Locks & Dams

Table 2.1 Mississippi River Lock No. 19, District: CEMVR; Division: CEMVD
1. Identify LED Light (or LED lamp) Fixture Duty (a.k.a. purpose, e.g., lock chamber light fixture mounted on 30 ft. pole): ***LED Lock Chamber Light Fixture mounted on 30-ft tall light pole***
2. Identify if LED Light Fixture or LED Lamp: (CIRCLE APPLICABLE TYPE): ***LED Light Fixture***
3. State how many LED Light Fixtures per Pole assembly when applicable): ***Forty single fixture poles and three double fixture poles***
4. State how many LED lamps per fixture when applicable: ***LED Fixture is one assembly, counted as one LED lamp***
5. Mounting: Wall Mounted (Mtg. Ht.) / 30 ft. Tall Pole / High Mast Light / or other (specify) – {Circle one and/or identify mounting height of fixture as well as any special mounting features if applicable}: ***30 ft. tall light pole***
6. LED Fixture or Lamp Brand Name: ***RAB***
7. LED Fixture or Lamp Model Number: ***RAB ALED4T150***
8. LED Fixture or Lamp Wattage: ***150 Watts***
9. LED Fixture or Lamp Voltage: ***120-277 Volts***
10. LED Fixture or Lamp Color Temperature: ***5000 K***
11. What is the IES distribution of this light fixture (i.e., Type II, Type III, Type IV, Type V, flood light or spot light): ***IES Type IV***
12. If known, what original wattage and type of fixture was replaced by the identified LED Fixture? ***400 Watt High Pressure Sodium light fixtures. One for one replacement.***
13. What Lessons have you learned as a result of installing and using this new LED Fixture or LED Lamp? ***Better lighting for chamber.*** ***Light is more true color, not yellow.*** ***Instant on and no warm-up time is needed to start the fixtures.***
14. Have you experienced any LED light fixture failures or LED driver failures? Please describe: ***No failures so far***
15. How is the light fixture controlled? (e.g., manual switch, timer, photocell, occupancy sensor...) ***Manual Switch enabled by photocell***
16. Email photos of any LED light fixtures as well as pole assemblies that you would like to share. ***None.***

Figure 3. INDC Lock & Dam Outdoor LED Light Fixture Completed Survey

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Table 4. INDC Lock & Dam Outdoor LED Light Fixture Survey Responses.

	QUESTIONS																	
LOCATION	Lock & Dam Identification - River-Location - USACE District or Division	LED Fixture: Main Purpose	LED Lamp or LED Fixture	Number of Light Fixtures per Pole	Number of LED Lamps per Fixture	Mounting	Brand Name	Model Number	Fixture Wattage	Fixture Voltage	Fixture Color Temperature	Light Distribution Type	Type of Fixture Replaced by LED's	Wattage of Fixture Replaced by LED's	Number of Fixtures Replaced by LED's	Lesson's Learned	Number of Failures	Light Fixture Controll
	L&D 18 - Mississippi River Mile 410.5 - Gladstone, IL - USACE Rock Island District																	
	Fixture #1	Lock Chamber Wall, Guide Walls, and Guard Wall Light Fixtures	Fixture	1 Fixture per pole is typical except 2 fixtures per pole at 180 degrees on Intermediate Wall light poles		30 ft Pole Mounted (poles are tip-down type for maintenance)	RAB	ALED4T150	150	120V - 208V	5000K	IES Type IV	High Pressure Sodium	400W	23		0	Manual Switch
	L&D 19 - Mississippi River Mile 364.2 - Keokuk, IA - USACE Rock Island District																	
	Fixture #1	Lock Chamber Wall Light Fixtures	Fixture	1		30 ft Pole Mounted	RAB	ALED4T150	150	277V	5000K	IES Type IV	High Pressure Sodium	400W	23		0	Manual Switch
	L&D 24 - Mississippi River Mile 273 – Clarksville, MO - USACE St. Louis District																	
	Fixture #1	Upstream/Downstream Dam Lighting	Lamp	1 per Dam Gate 15 Upstream Dam Gates 15 Downstream Dam Gates	1	35 ft spacing mounted on Dam servce bridge upstream and downstream handrails	Keystone	KT-LED54HID-EX39-850-D	54W	120V - 277V	5000K	Flood Light	Metal Halide	250W	30 total 15 Upstream 15 Downstream	Clearer and Brighter light to read our gate settings on the dam	0	PLC
	Fixture #2	Dam Walkway Lighting	Lamp	6 per Gate	1	Bulb Mounted in Fixture	Westinghouse	35142	14W	120V - 277V	5000K	All Purpose	Left Blank	100W		Brighter and clearer walkway path, imporved safety	0	PLC
	L&D 25 - Mississippi River Mile 241 – Winfield, MO - USACE St. Louis District																	
	Fixture #1	Downstream Dam Lighting	Fixture	1 per Dam Pier *Currently 2 fixtures on trial basis*	1	20 ft Adjustbale Bracket to Dam Pier	Daylight	DL-S-100W	100W	120V - 277V	5000K	Flood Light	High Pressure Sodium	70W		Increased visibility with less current draw	0	PLC
	Fixture #2	Lock Chamber	Fixture	1	1	20 ft pole Adjustable Pole Mount Socket with Set Screws	Daylight	DL-S-100W-TD	100W	120V - 277V	5000K	Flood Light	High Pressure Sodium	70W		Improved visibility for lock operations. Need high light standards	0	PLC
	Melvin Price L&D - Mississippi River Mile 200.78 – Alton, IL - USACE St. Louis District																	
	Fixture #1	Lock Chamber High Mast	Fixture	4	3	80 ft High Mast	Global Tech LED	GTSOL5498	135W	480V	5000K		High Pressure Sodium	1000W	5	Brighter, lower energy cost, less maintenance	0	PLC
	Fixture #2	Dam Gate Lighting	Fixture	1	Left Blank	Yoke Mount Over Dam Gate	Westgate LED	LF3-100WW-TR	100W	120V	3000K	Flood Light	High Pressure Sodium	400W		Brighter, lower energy cost, less maintenance	0	Photocell
	Fixture #3	Miter Gate Recess	Fixture	1 per gate	1		Global Tech LED	GTRSOL-5498	125W	120V - 277V		Flood Light	High Pressure Sodium	150W		Brighter, lower energy cost, less maintenance	0	PLC
	L&D 27- Mississippi River Mile 185.5 – Granite City, IL - USACE St. Louis District																	
	Fixture #1	Lock Chmaber High Mast	Fixture	5	3	80 ft High Mast	Global Tech LED	GTSOL5498	135W	480V	5000K	Unknown	High Pressure Sodium	1000W	5	Much brighter, lower energy cost, less maintenance	0	PLC
	Fixture #2	Miter Gate Recess	Fixture	1 per gate	1	Mounted to Concrete	Lithonia Lighting	OFL3 LED YK	50W	120V	5000K	Flood Light	High Pressure Sodium	250W		Much brighter, lower energy cost, less maintenance	0	PLC
	Fixture #3	Building Wall Packs	Fixture	Varies per Building	Varies	Flush	Atlas	Classic HID Replacement	27W	120V	5000K		N/A	N/A	N/A	Bright	0	Photocell
	Old River Lock – Mississippi River/Atchafalaya – Vidalia, LA – USACE New Orleans District																	
	Fixture #1	Lock Chamber Light Fixtures	Lamp	1	1	Pole Mounted	ESL Vision	ESL-CL-120W-250M	120W	120V	5000K	Retrofit Lamp	Mercury Vapor	450W		Low Energy Cost and Longer Life	0	Manual Switch
	Fixture #2	Highway Bridge Locking Pins	Fixture	2		Pole Mounted	Atlas	PFMXW43LED	43W	120V - 277V	4500K	Flood Light (7Hx7W)				Low Energy Cost and Longer Life	0	Manual Switch
	Fixture #3	Miter Gate Spot Light	Fixture	1		Pole Mounted	Atlas	PFMXW43LED	43W	120V - 277V	4500K	Flood Light (7Hx7W)				Low Energy Cost and Longer Life	0	Manual Switch
	Fixture #4	River/Canal Ends Floating Guide Wall Light Fixtures	Lamp	1 (14 total)	1	Pole Mounted	SATCO	S9593	9.5W	120V	2700K	Retrofit Lamp	Incandescent Lamp	100W		Low Energy Cost and Longer Life	0	Manual Switch

QUESTIONS

Lock & Dam Identification - River-Location - USACE District or Division	LED Fixture: Main Purpose	LED Lamp or LED Fixture	Number of Light Fixtures per Pole	Number of LED Lamps per Fixture	Mounting	Brand Name	Model Number	Fixture Wattage	Fixture Voltage	Fixture Color Temperature	Light Distribution Type	Type of Fixture Replaced by LED's	Wattage of Fixture Replaced by LED's	Number of Fixtures Replaced by LED's	Lesson's Learned	Number of Failures	Light Fixture Controll
Old River Control Complex – Mississippi River/Atchafalaya – Vidalia, LA – USACE New Orleans District																	
Fixture #1	Crane Area	Fixture			Pole Mounted	Cooper	NFFLDA25S Night Falcon	85W	120V - 277V	4000K	Flood Light	High Pressure Sodium	250W		Easy installaltion. Better quality light. Less Maintenance.	0	Photocell
Fixture #2	Crane Area	Fixture			Wall Mounted	Morris	71421	30W	120V - 277V	5000K	Flood Light	Metal Halide	250W		Easy installaltion. Better quality light. Less Maintenance.	0	Manual Switch
Fixture #3	Grounds	Fixture			Wall & Pole Mounted	RAB	Yardblaster	26W	120V		Dust to Dawn	High Pressure Sodium & Metal Halide	250W		Easy installaltion. Better quality light. Less Maintenance.	0	Photocell
Fixture #4	Grounds	Fixture			Wall & Pole Mounted	Lithonia	1BH18LMVOLT	198W	120V	4000K	High Bay	High Pressure Sodium & Metal Halide	250W		Easy installaltion. Better quality light. Less Maintenance.	0	Photocell
Fixture #5	Grounds	Fixture			Wall & Pole Mounted	Lithonia	DSXF1LEDK	37W	120V		Flag Pole	High Pressure Sodium & Metal Halide	250W		Easy installaltion. Better quality light. Less Maintenance.	0	Photocell
Freshwater Bayou Lock – Kaplan, LA – USACE New Orleans District																	
Fixture #1	Lock Chamber Light Fixtures	Fixture	1		30 ft. Pole Mounted	Lithonia	Dsx1 led 60c 700 50k t2m mvolt ma ddbxd	131W	120V	5000K	Flood Light	Halophane High Pressure Sodium	250W			0	Manual Switch
Bayou Boeuf Lock – GIWW/Atchafalaya Basin – USACE New Orleans District																	
Fixture #1	Guide Wall, Chamber Wall, and Lock Wall	Fixture	1		12 ft. Pole Mounted	Westgate	LF3-80CW-TR	80W	120V	5000K	Flood Light	Metal Halide	250W			0	Photocell
Bayou Sorrel Lock – Atchafalaya Basin – USACE New Orleans District																	
Fixture #1	Lock Gate Bay Light Fixtures	Fixture	1		Pole Mounted	Atlas	PFL84LED	84W	120V	4100K	Flood Light	Mercury Vapor	200W		Better visibility	0	Manual Switch
Fixture #2	Guide Wall Light Fixtures	Lamp	1	1	Pole Mounted	EIKO	LED54WPT40KMOG-G5 Corn Lamp	54W	120V	4000K	Flood Light	Mercury Vapor	200W		Better visibility	0	Manual Switch
Fixture #3	Lock Gate Light Fixtures	Fixture	1		Mounted on Lock Gates	Atlas	PFL43LED	43W	120V	4100K	Flood Light	N/A	N/A		Better visibility	0	Manual Switch
Berwick Lock – GIWW/Atchafalaya Basin – USACE New Orleans District																	
Fixture #1	Lock Chamber Light Fixtures	Lamp	1	1	10 ft. Pole Mounted	Westgate	CL-36W Corn Lamp	36W	120V	5000K	Flood Light	High Pressure Sodium	400W		The entire fixture does not have to be replaced to obtain LED light	At least one Corn Lamp Base Failure	Photocell
Catfish Point Control Structure – Lock #22 Mermentau River Basin – Creole,LA – USACE New Orleans District																	
Fixture #1	Lock Chamber Light Fixtures	Fixture	1	6	14 ft. Pole Mounted	RAB	FXLED125SF	125W	120V	5000K	Flood Light (6H x 6V)	High Pressure Sodium	400W			0	Photocell
Lock #23 Calcasieu River Saltwater Barrier – Westlake, LA – USACE New Orleans District																	
Fixture #1	Lock Chamber Light Fixtures	Fixture	1	1	30 ft. Pole Mounted (can be lowered for fixture service)	Lithonia	TODLED2	36.9W	120V	5000K	Flood Light	Mercury Vapor	175W		Instant ON without warmup time.	0	Photocell or Manual Switch Bypass
Schooner Bayou Control Structure – Schooner Bayou, Mermentau River Basin – USACE New Orleans District																	
Fixture #1	Lock Chamber Light Fixtures	Fixture	1	1	20 ft. Pole Mounted	Westgate	LF3-220	220W	120V	5000K	Flood Light	Metal Halide Flood Light	500W		LED produce less heat, Brighter for less Watts, and Less Lamp Failures	0	Photocell

LOCATION	Lock & Dam Identification - River-Location - USACE District or Division	LED Fixture: Main Purpose	LED Lamp or LED Fixture	Number of Light Fixtures per Pole	Number of LED Lamps per Fixture	Mounting	Brand Name	Model Number	Fixture Wattage	Fixture Voltage	Fixture Color Temperature	Light Distribution Type	Type of Fixture Replaced by LED's	Wattage of Fixture Replaced by LED's	Number of Fixtures Replaced by LED's	Lesson's Learned	Number of Failures	Light Fixture Controll
	T.J. O'Brien L&D – Illinois Waterway Mile 326 – South Chicago, IL – USACE Rock Island District																	
	Fixture #1	Overhead Lock Lighting: Includes Lock Chamber, Guide Walls, & Parking Areas	Lamps	NA	1	30 ft. Pole Mounted	General Electric	ED37 / EX39 base	165W	240V	4000K		Metal Halide	400W	47	LED lamps came loose in fixture after a month. Had to retighten all lamps.	0	Photocell
	Fixture #2	Shop and Power House Wall Lights	Fixture	NA	1	8 - 12 ft Wall Mounted	Straits Lighting	SL923WPG2	50W	120V	5000K	Flood Light	Halogen Floods	300W	7	Less Maintence	0	Photocell
	Fixture #3	Navigation Lighting	Fixture	Two Poles - 1 Fixture Per One Pole - 3 Fixtures One Pole - Two Fixtures	1	30 ft Pole Mounted at approximately 25 ft	Dialight	RTO0G07004	9W	120V		Visual Signal Light	Incandescent	60W	7	Fixtures located near the op of light standards and are very dangerous to work on. Replacing the incandescent with LED's reduces risk of injusry as less maintenance or replacement is needed.	0	Photocell
	Fixture #4	Control House Lights	Fixture	NA		Wall Mounted	Straits Lighting	SL923FLF	100W	120V	5000K	Flood Light	Incandescent	250W			0	Manual Switch
	Motor Vessels – Illinois Waterway (ILWW) Peoria L&D and LaGrange L&D - USACE Rock Island District																	
	Fixture #1	Exterior Lights for Motor Vessel Beardstown and Maneuver Boat	Lamp	1	1	Wall Mounted on Vessel Bulkhead	Unknown	Unknown	9W	120V			Incandescent	60W		They outlast traditional rough service incandescent bulbs.	0	Manual Switch
	Fixture # 2	Traffic Light Lamps	Lamp	1	1	15ft Pole Mounted	Unknown	Unknown	9W	120V			Incandescent	60W		They outlast traditional rough service incandescent bulbs.	0	Flasher
	Lockport L&D – Illinois Waterway Mile 291 – Lockport, IL – USACE Rock Island District																	
	Fixture #1	Lock Chamber Wall	Lamp	Mostly 1 per pole Two Poles - 2 Per Pole	1	30 ft. Pole Mounted	LEDtronics	LEDRK03DL-480W-XCW-101WD	480W	100-277 VAC	5700K	Type C	High Pressure Sodium	1000W		Use safety strap/heavy duty cable tie with socket mount (on yoke). Make sure mount screws are tightened correctly (on yoke).	0	Photocell
	Fixture #2	Lock Chamber Wall	Lamp	Mostly 1 per pole Two Poles - 2 Per Pole	2	31 ft. Pole Mounted	LED Global Supply	GS-HB-KT-240-W	240W	100-277 VAC	5700K		High Pressure Sodium	1000W		This model is not suitable to replace 1000W HPS. Provides insuffcient light levels.	0	Photocell
	Fixture #3	Lower Guide Wall	Lamp	1	1	22 ft Pole Mounted	LED Global Supply	GS-CE40-100EF-CB	100W	100-277 VAC	5700K		High Pressure Sodium	250W		Overheating issues caused by small enclosed fixtures. This caused failures with 150W and 120W LED's. 100W have worked well.	2	Photocell
	Fixture #4	Traffic Light Lamps	Lamp	1	3		LEDtronics	TRF212-OER-120A (RED) TRF212-OPY-120A (Yellow) TRF212-OBG-120A (Green)	7.8-8.7W	120VAC				120-150W		Works great. Much brighter than old traffic signals.	0	PLC

	QUESTIONS																	
	Lock & Dam Identification - River-Location - USACE District or Division	LED Fixture: Main Purpose	LED Lamp or LED Fixture	Number of Light Fixtures per Pole	Number of LED Lamps per Fixture	Mounting	Brand Name	Model Number	Fixture Wattage	Fixture Voltage	Fixture Color Temperature	Light Distribution Type	Type of Fixture Replaced by LED's	Wattage of Fixture Replaced by LED's	Number of Fixtures Replaced by LED's	Lesson's Learned	Number of Failures	Light Fixture Controll
LOCATION	Lockport L&D – Illinois Waterway Mile 291 – Lockport, IL – USACE Rock Island District																	
	Fixture #5	Floater Lights & Flagpole lights	Fixture	1	1	Mounted on box cover above floater (with 1/2" Myers Hub). Flagpole lights mounted on single gang weather proof boxes.	LEDtronics	GDL002-200-TPW-001N	16W	100-240V/277V	4800-5200K	Spot Light	Quartz Halogen	300W		Use 1/2" Myers Hubs, instead of 1/2" locknuts. Myers hubs are stronger and weather tight. Don't mount lights on base of flagpole because someone can step on the lights and break them.	2 from a later batch. Repaired under warranty.	Photocell
	Fixture #6	Maintenance Building Lights	Lamp	1	4	Mounted on old light fixtures.	Lumegen T8 4' LED Tube	LEDTB4F1000037745	18W	100-277V	5000K		Fluorescent	32W		This direct wire model is best. It bypasses the old ballasts. The 2050 lumens work very well.	0	Switch/Occupancy Sensor
	Fixture #7	Pump house & Cable Building Exterior Wall Lights	Fixture		1	LED Wall Lights	LEDtronics	WWL20-24X2W-XPW-001W	56W	100-277V	5500K-6350K		Mercury Vapor	175W		This is a navigation friendly LED light.	0	Photocell
	Fixture #8	Pump House Exterior Wall Lights	Fixture		1	LED Wall Lights	Cooper Lighting (Crosstour)	XTOR5A	50W	120-277V	5000K		Mercury Vapor	175W	4	Easy to install.	0	Photocell
	Fixture #9	Upper Guide Wall Lights	Fixture	1	1	22 ft Pole Mounted	Holophane	LEDG084534KASGL3L3R	148W	120-277V	4000K		High Pressure Sodium	250W		Not sufficent lumen output for application. 9,156 lumens, need approximately 12,000 lumens.	0	Photocell
	Fixture #10	Lower Guide Wall & Upper Guide Wall	Fixture	1	1	23 ft Pole Mounted	LEDtronics	SLL002P-72X2W-XPW-104	130W	90-305 VAC	5000-5600K	Type C	High Pressure Sodium	250W	2	Not sufficent lumen output for application. 9,598 lumens, need approximately 12,000 lumens. Light dispersal is very poor.	1 - Repaired under warranty.	Photocell
	Fixture #11	Navigation Lighting	Fixture			Pole Mounted	Dialight	RTO-OrO7-001 (Red) RTO-OGO7-001 (Green)	8W	120-240 VAC				120-150W		Works great. Much brighter than old navigation lights.	0	Photocell

5 LED Retrofits vs. Replacements

5.1 Overview

The growth and expansion of new industrial LED technologies have opened up different and innovative ways to integrate new LED lighting into existing infrastructure, through full retrofits, or replacements.

5.1.1 LED retrofit

The term "retrofit" refers to removing the existing lamp and all of its components and replacing them with new LED lamps and drivers that are designed to fit into the existing fixture's housing. When installing new LED fixtures, there are two primary types of retrofits:

1. A full LED retrofit with a new driver, which is usually done using a "kit" that includes the LED lamp, the LED's driver, and general instructions on how to install the components into various lighting enclosures.
2. LED fixture installation or a ballast removal and wiring change. The installations use LED bulbs that have similar sockets to those of the HID bulb(s) being replaced, and that fit into the existing fixture. These LED bulbs typically have the driver built in, which requires less space and makes installation easier. With this type of retrofit, however, the ballast must be removed from the existing fixture and the socket must be re-wired to the voltage requirements of the light being installed (typically straight to line voltage).

Retrofits have several advantages compared to full replacements. Retrofit equipment is less expensive than that of full replacements. Retrofits also often do not require the replacement of conduit and cabling that often must be replaced during a replacement. Finally, retrofits reuse (i.e., reduce the waste of) existing equipment and can thereby help maintain a constant and similar lighting distribution around the site. Disadvantages of retrofits are that they can require a larger amount of labor time (and cost) for installation, and that they are more likely to not offer a standard amount of optical focus due to a lack of testing performed on specific retrofit fixtures.

5.1.2 LED replacement

The term “replacement” refers to the removal of the existing fixture, in its entirety, and replacing it with a new LED fixture. Many LED manufactures are designing their new LED fixtures to resemble, if not perfectly match, existing fixtures typically found in use today. These fixtures are usually sold as “as compared to” items and will normally have lists that outline the type of lighting source it is being compared to and the application for which it should be used. The process of full replacement usually has a higher upfront cost for the equipment but offers a higher cost savings due to the lower amount of labor required to install them when compared to a retrofit. LED replacements are usually done in outdoor installations due to the need to “buy new” to ensure watertight integrity and to prevent a general breakdown in the condition of older, existing fixtures.

5.2 Summary

When choosing between a retrofit and replacement for LED lighting upgrades, many different factors must be considered. Each upgrade choice has advantages and disadvantages.

An LED retrofit may help the site avoid costly infrastructure and installation costs. A retrofit may also result in higher degree of accuracy in lighting requirements, and a longer operable equipment lifespan. On the other hand, new retrofit equipment may also be more susceptible to weather conditions resulting from improper fittings. Newly installed replacement lights may not provide the same level of light due to optical changes. LED replacement projects may also incur a high upfront costs in both equipment and labor. In short, the choice between retrofit and replacement depends entirely on the individual project site’s current conditions and budget. The final decision for selecting the proper LED light upgrade must be based the following considerations:

- The amount of project funds available to address existing light fixtures
- The first cost for initial installation of the project
- The life-cycle cost estimate
- Proper illumination level for the lighting application
- Proper IES light distribution
- The need to maximize light fixture efficiency

- Proper LED lighting equipment integrity suitable for installation in the navigation lock and dam environment
- The need to minimize maintenance activity requirements
- The need to minimize maintenance activities thereby minimizing exposure to safety concerns.
- The need to maintain lock repairer/electrician's safety by minimizing maintenance requirements and maintenance activity safety requirements
- The need to maintain lock operator's safety by providing proper lighting.

6 Lighting Controls

6.1 General

Lighting controls are an important component in the navigation lock and dam lighting system. One of the advantages of using LED light fixtures, is the fixture's inherent flexibility to incorporate various control schemes. When lighting controls are properly applied with LEDs, power consumption can be reduced, which leads to lower energy costs. This chapter will present some of the common types of lighting controls and their recommended application to navigation lock and dam lighting. Note that this document is not meant to include all different types and combinations of lighting controls used in the industry.

6.2 Basic types of lighting controls

6.2.1 Photocell control

A photocell's operation is based on outdoor ambient light levels, which produce a current or voltage when exposed to light. Photocells can be integrally mounted on each individual light fixture, or a single head-end photocell can control a group of fixtures through a control relay. Photocell control is typically associated with dusk-to-dawn operation in which exterior light fixtures connected to a photocell turn on when the sun goes down and turn off when the sun comes up. Unless lighting control is done in combination with other control devices, photocell control is best suited for use on exterior, general area lighting where activity and illuminance is constantly needed throughout the night.

6.2.2 Timeclock control

Timeclocks provide control through a timed relay that can be set to turn a group of light fixtures on and off at specific times of the day. When the timeclock is "astronomical," it can be set for operation at dusk and/or dawn while automatically adjusting the operating time as days become shorter and longer. Basic timeclocks can be used similarly to photocells to turn lights off and on at sunrise and sunset, except that they also provide the option to set a specific time to turn the light fixtures on/off.

6.2.3 Occupancy (motion) control

Occupancy controls use a motion sensor to turn a single or group of light fixtures on or off based on object movement within a defined area near the sensor. Occupancy controls can be used with LEDs due to their instant on/off capability, unlike HID fixtures, which require several minutes for warm-up, cool-down, and restrike, therefore making occupancy control unpractical. LED light fixtures can be purchased with an integral occupancy sensor for independent occupancy control of that individual fixture. In applications where individual occupancy sensors in each fixture is not practical, then a single fixture or a group of fixtures can be connected to an external common occupancy sensor to control the fixture (or group of fixtures).

6.2.4 Occupancy (motion) control with dimming

LED light fixtures can be purchased with integral occupancy sensor that can be connected to an internal dimming driver. When no activity is detected for a certain period of time, the fixture will dim to 50% (or a different preset level). Once the occupancy sensor detects activity, the luminaire will return to full brightness. Occupancy with dimming control can be used with LEDs due to their dimming capability, unlike HID fixtures, which cannot be dimmed.

6.3 Lighting control recommendations

6.3.1 Navigation lock chamber and wall lighting controls

For the main navigation lock chamber and wall light fixture controls, a combination of photocells, timeclocks, and occupancy sensors with dimming should be used. At dusk, the light fixtures should turn on from a photocell or from a timeclock. Due to the irregularity of navigation lock traffic, it is recommended that occupancy sensors with dimming or shut-off capability be used. When a navigation lock sits idle at night, there is no need for full light output. Those light fixtures can be set to automatically dim to a lower output (or completely off) until motion from an oncoming barge returns the light fixtures to full brightness. The reduced output during idle times provides energy savings for the facility. At dawn, all of the light fixtures would turn off (regardless of motion) from the photocell or timeclock controls.

6.3.2 Navigation lock path lighting controls

Navigation lock path lighting should be controlled by a combination of photocells, timeclocks, and occupancy sensors and dimmers. Pathway lighting is intended to provide a safe means of travel for staff going to/from different locations at the navigation lock. At dusk, the pathway lighting should be turned on by a photocell or timeclock control. If there is no activity or staff using the pathways, the fixtures should be dimmed or turned off until motion detectors sense movement to turn the nearest pathway fixtures back on. By dimming or turning the light fixtures off when there is no staff movement, the facility saves on energy costs. At dawn, the photocell or timeclock would turn all of the pathway fixtures off regardless of motion detection.

6.3.3 Navigation dam wall lighting controls

Similar to the navigation lock chamber and wall, the navigation dam wall light fixtures should use a combination of photocells, timeclocks, and occupancy sensors with dimming capabilities.

6.3.4 Navigation dam path lighting controls

Controls for navigation dam path lighting should be similar to the navigation lock path light. Control the path lighting with a combination of photocells, timeclocks, and occupancy sensors.

6.3.5 Navigational aid lighting controls

Where light fixtures are used to provide navigational aid for boats and vessels approaching a lock and dam, a photocell or timeclock should be used for dusk to dawn operation. Fixtures may include fisherman's warning lights, dam warning lights, and navigation lights.

7 Illumination and Cost Example of 600-Foot Lock

7.1 Illumination study

The illumination study begins by defining the outdoor area and the level of detail of the activities that will be conducted in that area. The lighting designer must refer to the *IESNA Lighting Handbook* upon defining the area to be illuminated and select an illumination value. Market research may then be conducted to determine the light source and type of light fixture that best fits the application. Lighting design should include, but should not be limited to, determination if fixtures will be pole mounted or wall mounted and the mounting height of the fixture(s). The designer should use a commercially available lighting design software package to model the desired light fixture equipment to achieve a basis of design for the lighting. The lighting design software will base illumination in foot-candles or Lux for the lighting design.

Some factors that can affect the lighting design software accuracies are influences of obstructions, depreciation due to dirt, and fixture life. These characteristics should be modeled as accurately and as conservatively as possible for the environment in which the fixtures will operate. The lighting design software will allow the designer to virtually adjust the wattage and locations of the light fixtures to provide the best illumination for the area. In the examples of the Mississippi River Locks No. 14 and No. 18 that follow, the existing lock light poles were reused and modeled in their existing locations in the lighting design software model. An IES file (photometric test data file) to closely simulate the Lock No. 14 HID light fixtures was obtained from a light fixture manufacturer’s internet web page and used to model Lock No. 14. An IES file for the actual LED light fixtures installed at Lock No. 18 was used to model Lock No. 18.

7.2 Locks No. 14 and No. 18 computer software models

This section describes the output of commercially available lighting analysis software that modeled both Mississippi River Locks No. 14 and No. 18. The Lock No. 14 lighting system is in process of changing light fixtures and currently uses a combined mixture of HPS, MH, and LED light fixtures. The Lock No. 18 lighting system has been retrofitted from 400W HPS (IES

Type III distribution to 150W LED (IES Type IV distribution). Note that Figures 4 and 10 each show a lighting design software 3-D rendered model output of both Mississippi River Locks No. 14 and No. 18, respectively, which allows the user to see the effects of shadows. Figures 5 and 11 show the 2-D lighting analysis.

All lighting levels shown are measured in foot-candles, for the given area. Note that proper mounting height, arm length, and elevation levels were modeled. The dimensions of both main lock chambers is 600 x 110 ft. The light poles are 30-ft tall, square, hinged poles, and the fixtures are installed on a 10-in. arm. Two (2) fixtures are mounted per pole at Lock No. 18 on the intermediate wall only. The illumination (foot-candles) shown in the lock chamber between the top of the lock walls was calculated at 18 in. above the water level at lower pool elevation respective to each lock. The normal lift at Lock No. 14 is 11 ft and the normal lift at Lock No. 18 is 9.8 ft. The illumination (foot-candles) shown on the structure was calculated at the top of lock wall elevation specific to Locks No. 14 and No. 18, respectively. See the respective Figures 4 to 15 and Tables 5 to 8 for lighting level results.

7.3 Locks No. 14 and No. 18 measured data

Comparatively, Figures 6–9 and Figures 12–15 identify photometric data physically measured and recorded at both navigation locks, Locks No. 14 and No. 18. The illumination (foot-candles) shown in the lock chamber between the top of the lock walls was measured at approximately 18 in. above the water level at lower pool elevation respective to each lock. The illumination (foot-candles) shown on the structure were measured at the top of lock wall elevation specific to Locks No. 14 and No. 18, respectively.

The illumination results between the lighting design software illumination output and physically measured illumination data are not identical, but are reasonably comparable. The photometer used for the physically measured test was new at the time the measurements were taken, but the meter had not been calibrated. The photometer is now believed to have reported illumination foot-candle levels slightly lower than the actual, but reasonably close. The physically measured illumination data point locations were not necessarily measured at the same lighting design software illumination output point locations.

Some interpolation of illumination values is required to compare some software calculated points with some physically measured points. Also, the maximum and minimum illuminated locations physically measured may not be the actual maximum or actual minimum illuminated location for that lock area because the lighting design software may have calculated more data locations in slightly different locations resulting in a higher maximum or lower minimum compared to the lesser number of measured points taken. For example, the lighting design software may provide a maximum level that was not detected by the physically measured illumination value because the manual test did not measure the same data point location.

The lighting design software illumination data outputs for Locks No. 14 and No. 18 are not exactly the same, but the physically measured illumination data recorded for Locks No. 14 and No. 18 are close and comparable. Table 5 to 8 list the maximum and minimum illumination values manually read from both the lighting design software illumination output and from the physically measured recorded data for Locks No. 14 and No. 18, respectively.

Table 5. Mississippi River Lock No. 14 software model results summary.

Location	(fc)		Max/Min Ratio
	Minimum	Maximum	
Top of Working Lock Wall	0.8	6.0	4.8
Top of Upstream Guide Wall	0.72	5.8	8.1
Top of Downstream Guide Wall	0.51	5.2	10.2
Top of Lower Pool Elevation inside Lock Chamber	1.6	4.3	2.7
Top of Lower Pool Elevation at Downstream Gates	1.7	1.9	1.1

Table 6. Mississippi River Lock No. 14 photometer test measured results summary.

Location	(fc)		Max/Min Ratio
	Minimum	Maximum	
Top of Working Lock Wall	0.25	3.37	13.48
Top of Upstream Guide Wall	0.21	5.83	27.76
Top of Downstream Guide Wall	0.18	5.74	31.9
Top of Lower Pool Elevation inside Lock Chamber	0.34	4.81	1.8
Top of Lower Pool Elevation at Downstream Gates	0.6	0.7	1.1

Table 7. Mississippi River Lock No. 18 software model results summary.

Location	(fc)		Max/Min Ratio
	Minimum	Maximum	
Top of Working Lock Wall	0.06	2.8	47
Top of Upstream Guide Wall	0.12	2.8	23.3
Top of Downstream Guide Wall	0.27	4.5	10.2
Top of Lower Pool Elevation inside Lock Chamber	0.66	2.5	3.8
Top of Lower Pool Elevation at Downstream Gates	0.74	0.95	1.3

Table 8. Mississippi River Lock No. 18 photometric test measured results summary.

Location	(fc)		Max/Min Ratio
	Minimum	Maximum	
Top of Working Lock Wall	0.14	1.55	11.1
Top of Upstream Guide Wall	0.07	2.11	27.76
Top of Downstream Guide Wall	0.13	1.85	14.2
Top of Lower Pool Elevation inside Lock Chamber	0.42	2.27	5.4
Top of Lower Pool Elevation at Downstream Gates	0.31	0.84	2.7

Mississippi River Lock and Dam (L&D) No. 14
400W High Pressure Sodium, 400W Metal Halide, and 150W LED Types Light Fixtures Installed

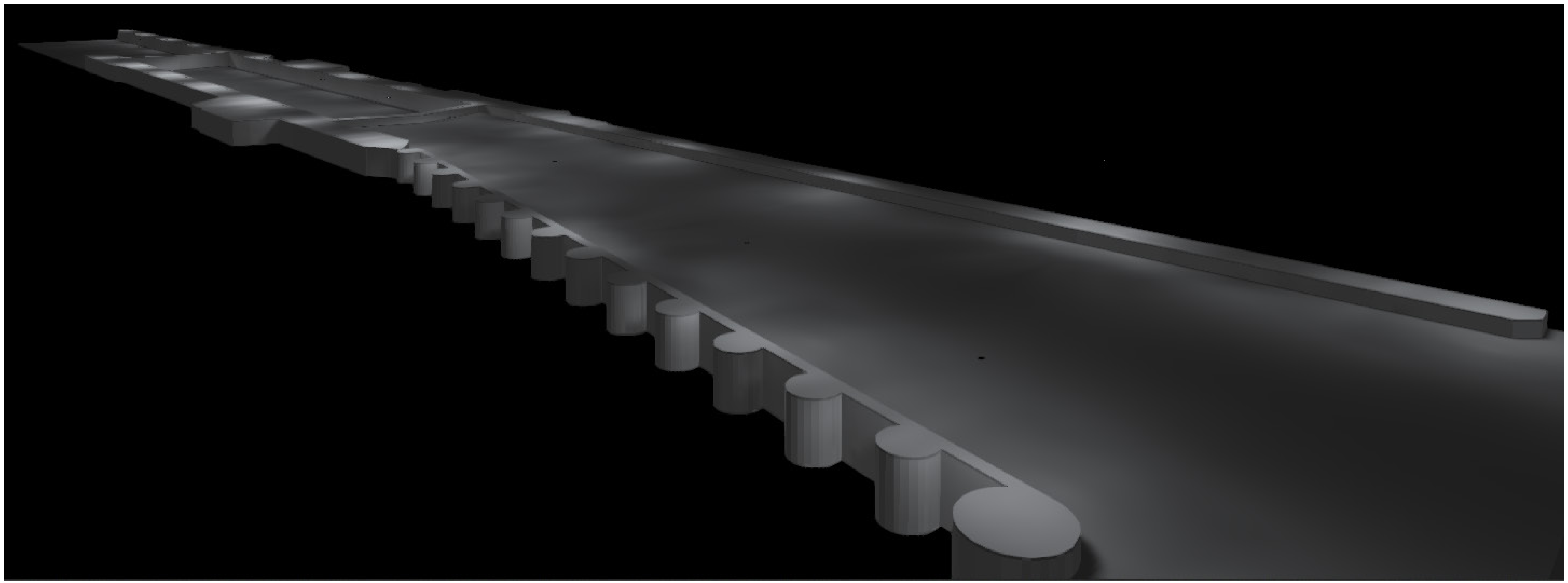

Figure 4. Mississippi River Lock No. 14 software model rendering with existing mix of 400W high pressure sodium, 400W metal and 150W LED light fixtures.

Mississippi River L&D No. 14

400W High Pressure Sodium, 400W Metal Halide, and 150W LED Types Light Fixtures Installed

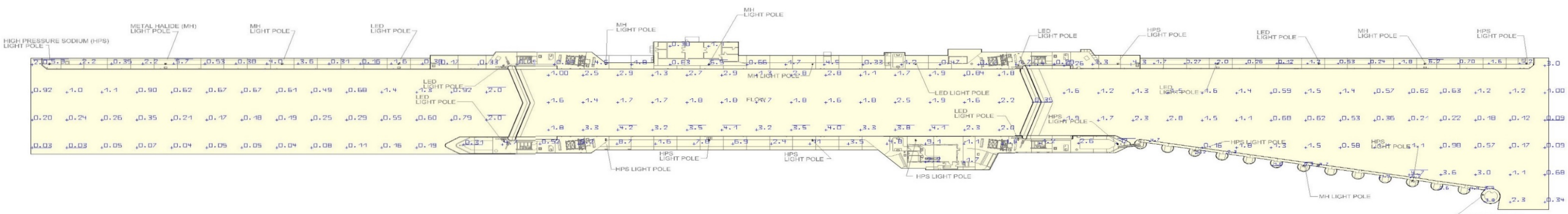

Figure 5. Mississippi River Lock No. 14 software modeled with existing mix of 400W high pressure sodium, 400W metal halide, and 150W LED light fixtures (units are in foot-candles).

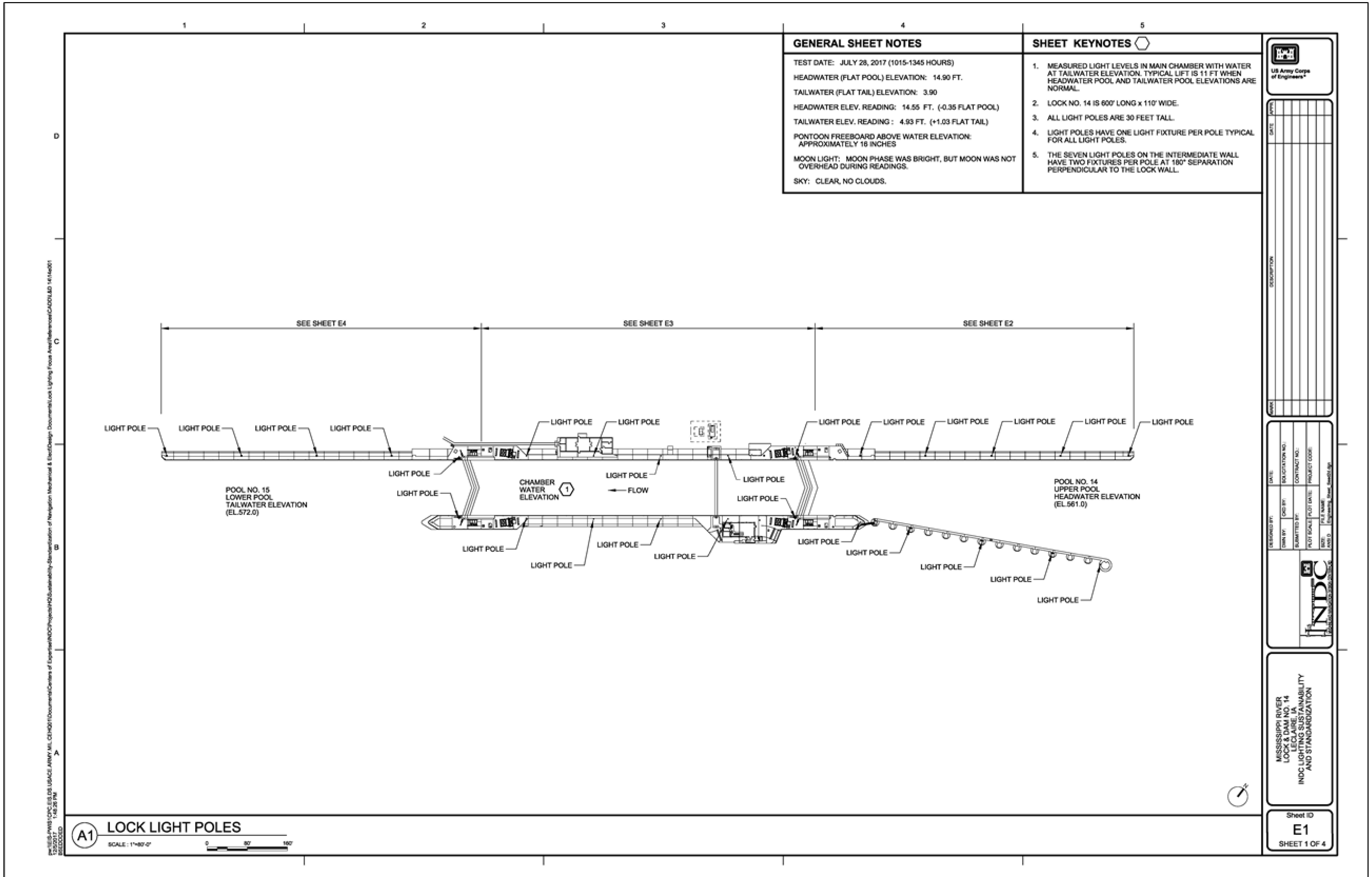

Figure 6. Mississippi River Lock No. 14 lock lighting plan.

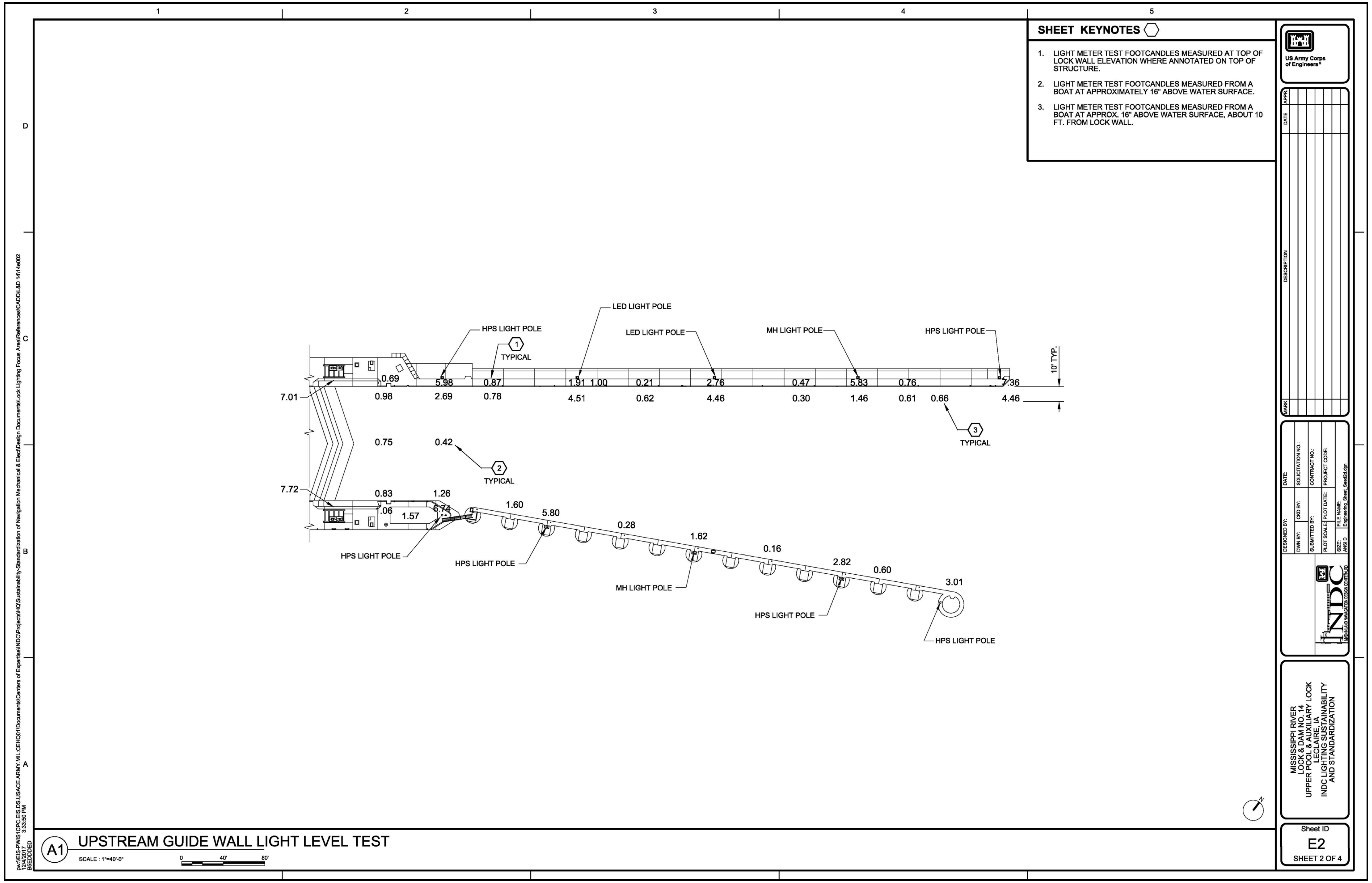

Figure 7. Mississippi River Lock No. 14 – upstream plan - measured photometric data for existing mix of 400W high pressure sodium, 400W metal halide, and 150W LED light fixtures (units are in foot-candles).

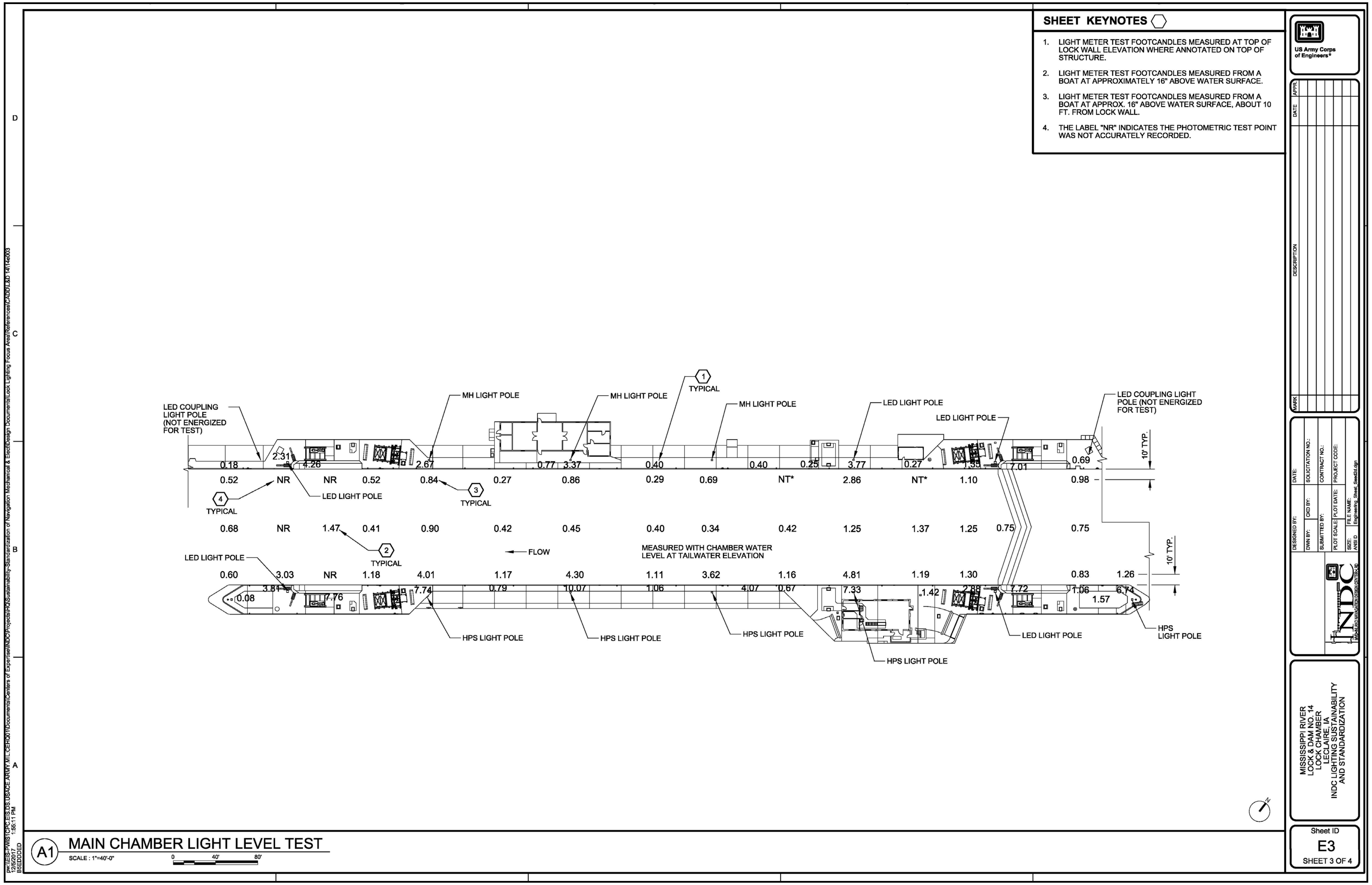

Figure 8. Mississippi River Lock No. 14 – lock chamber - measured photometric data for existing mix of 400W high pressure sodium, 400W metal halide, and 150W LED light fixtures (units are in foot-candles).

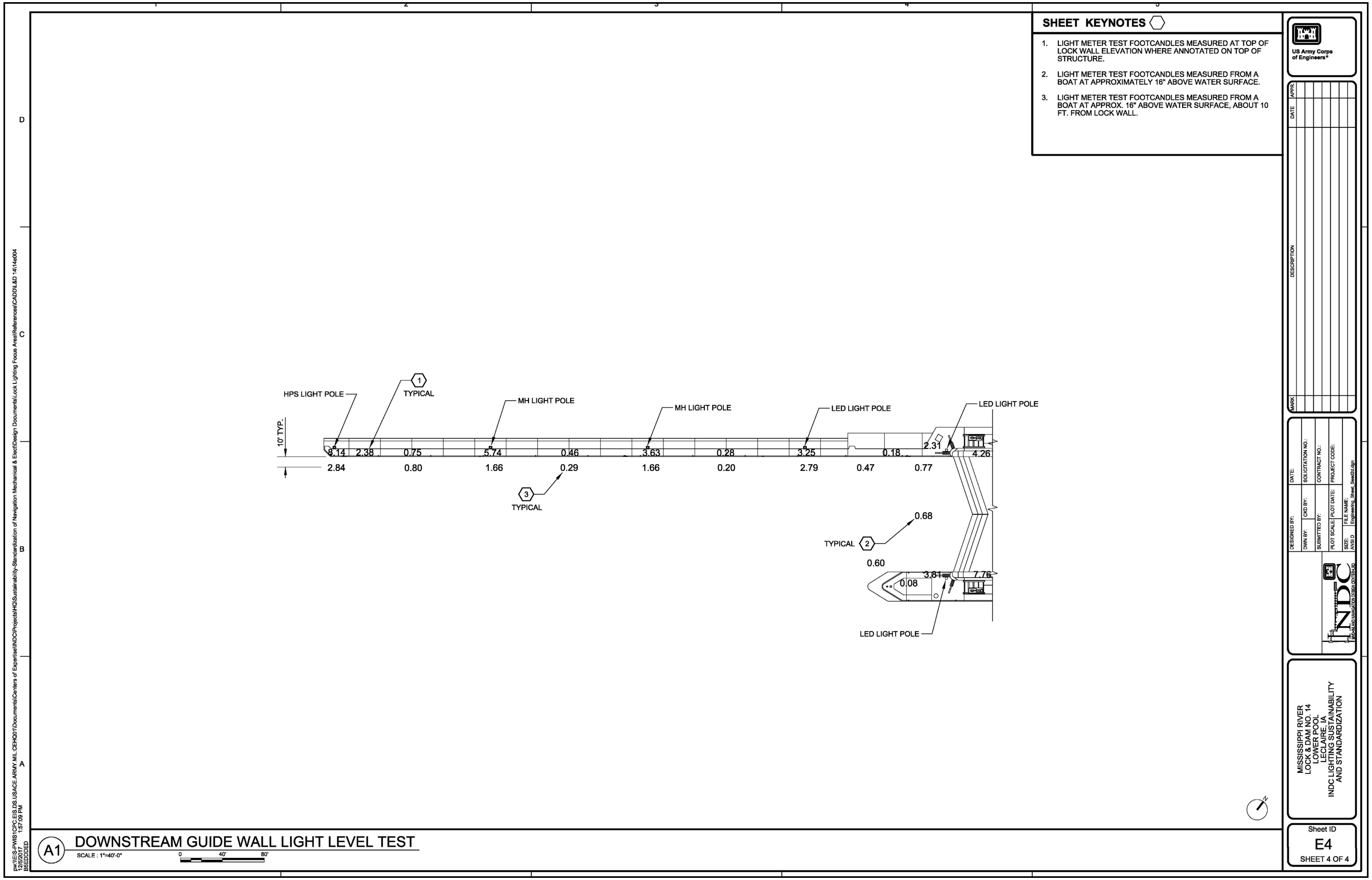

Figure 9. Mississippi River Lock No. 14 – downstream plan - measured photometric data for existing mix of 400W high pressure sodium, 400W metal halide, and 150W LED light fixtures (units are in foot-candles).

Mississippi River L&D No. 18
150W LED Light Fixtures Installed

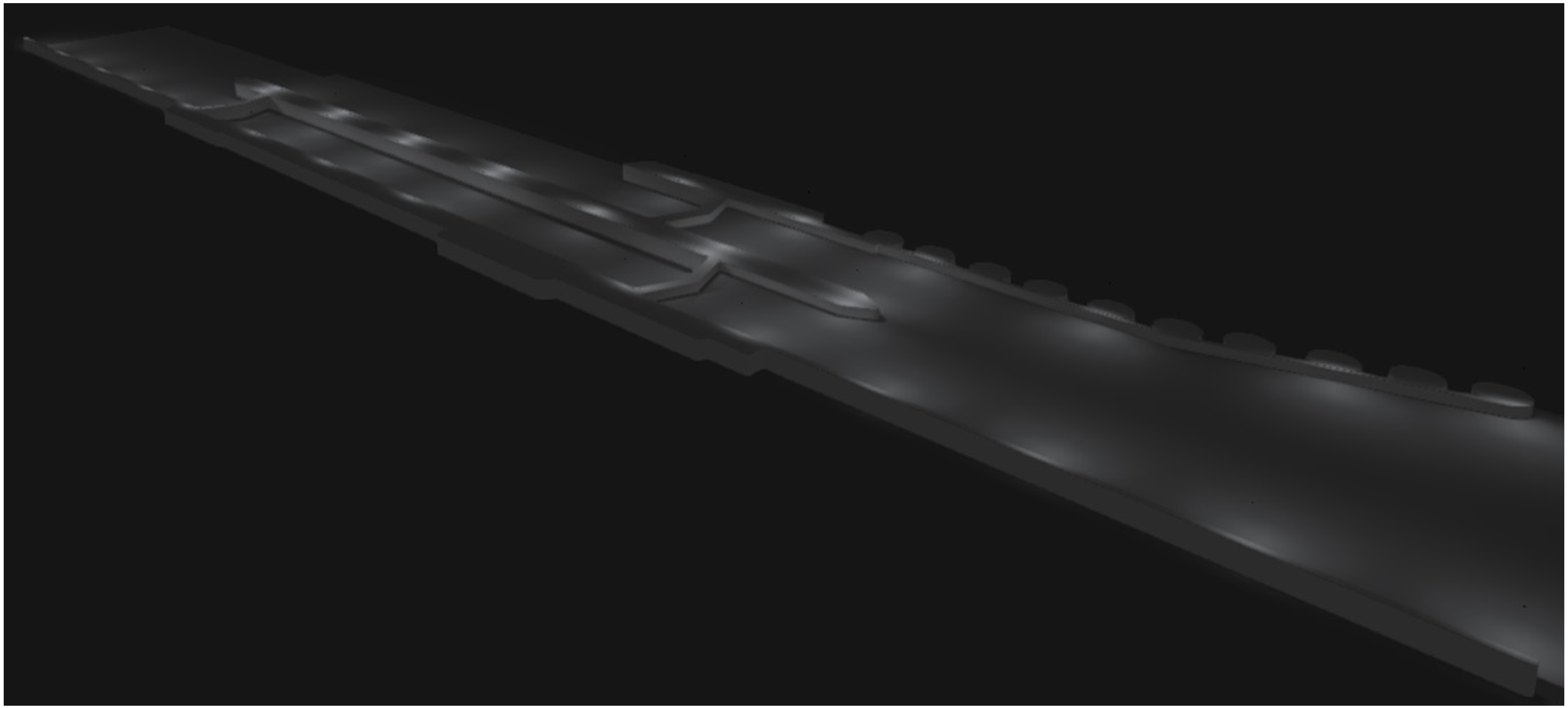

Figure 10. Mississippi River Lock No. 18 software model rendering with existing 150W LED light fixtures.

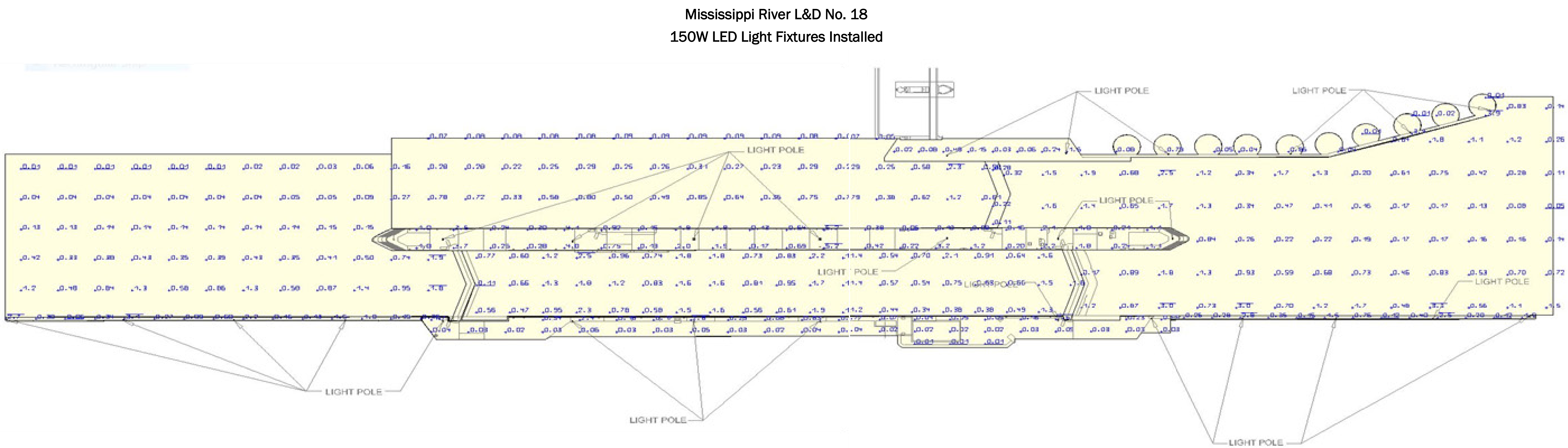

Figure 11. Mississippi River Lock No. 18 software modeled with existing 150W LED light fixtures (units are in foot-candles).

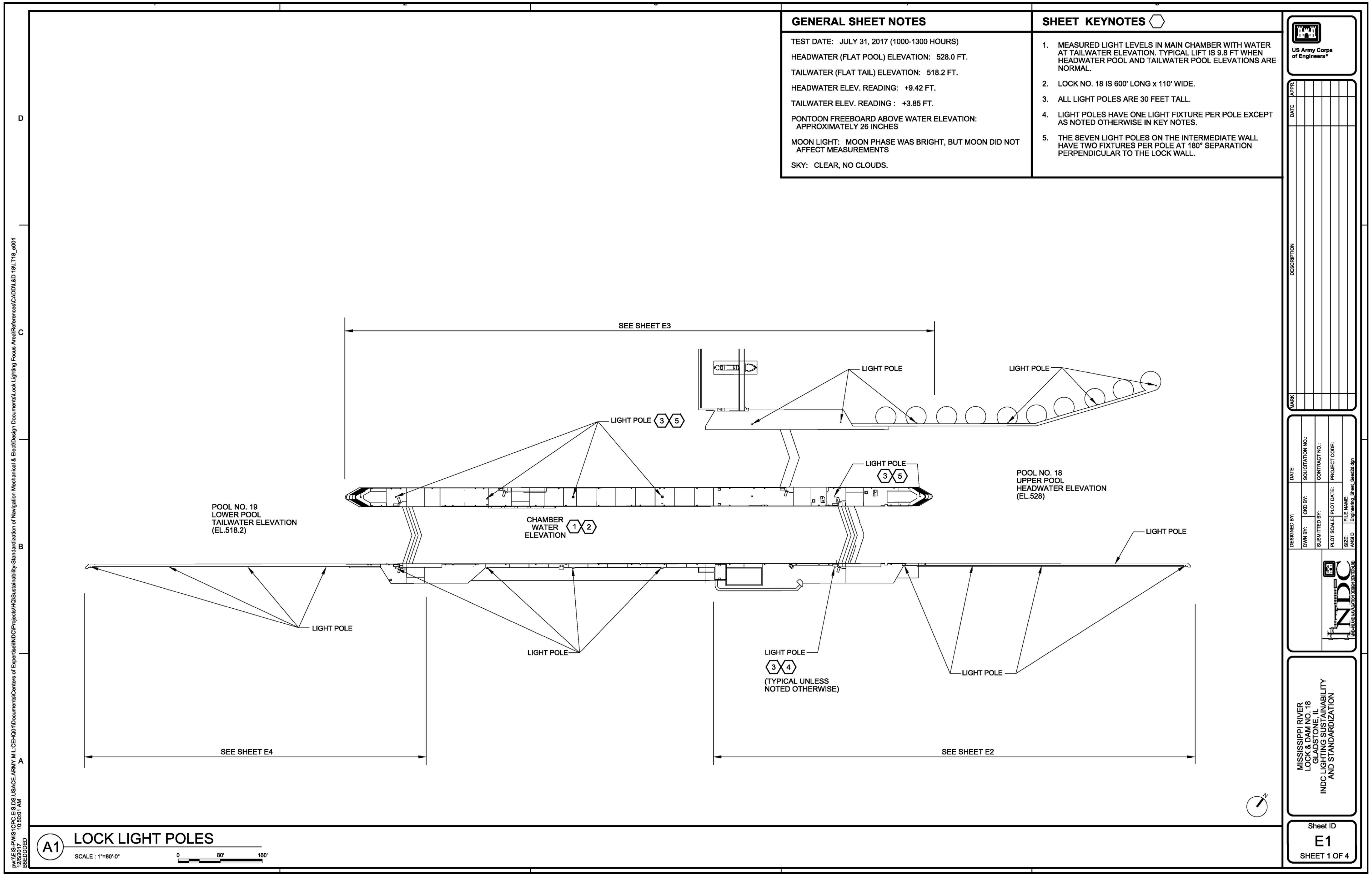

Figure 12. Mississippi River Lock No. 18 lock lighting plan.

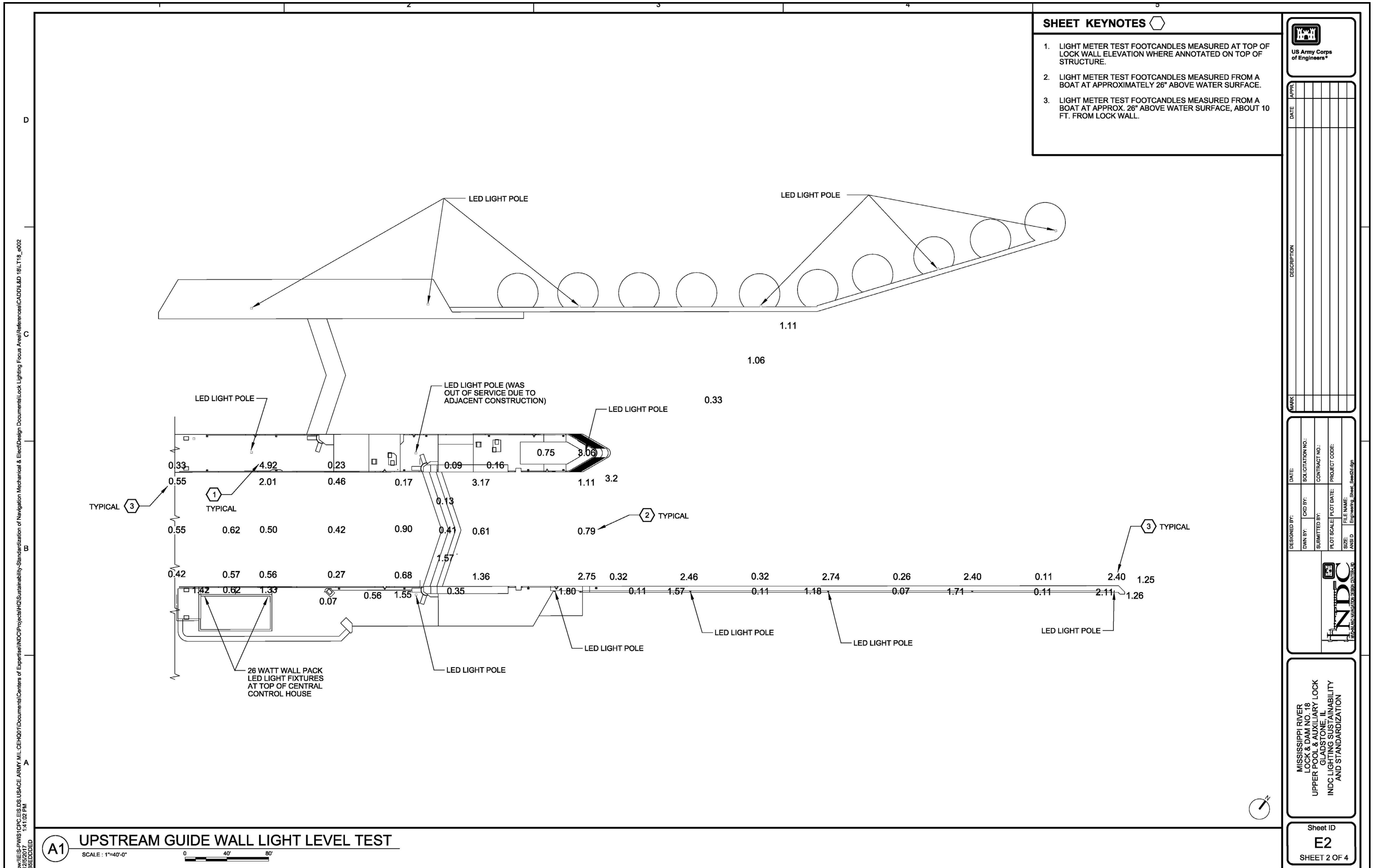

Figure 13. Mississippi River Lock No. 18 – upstream plan - measured photometric data for existing 150W LED light fixtures (units are in foot-candles).

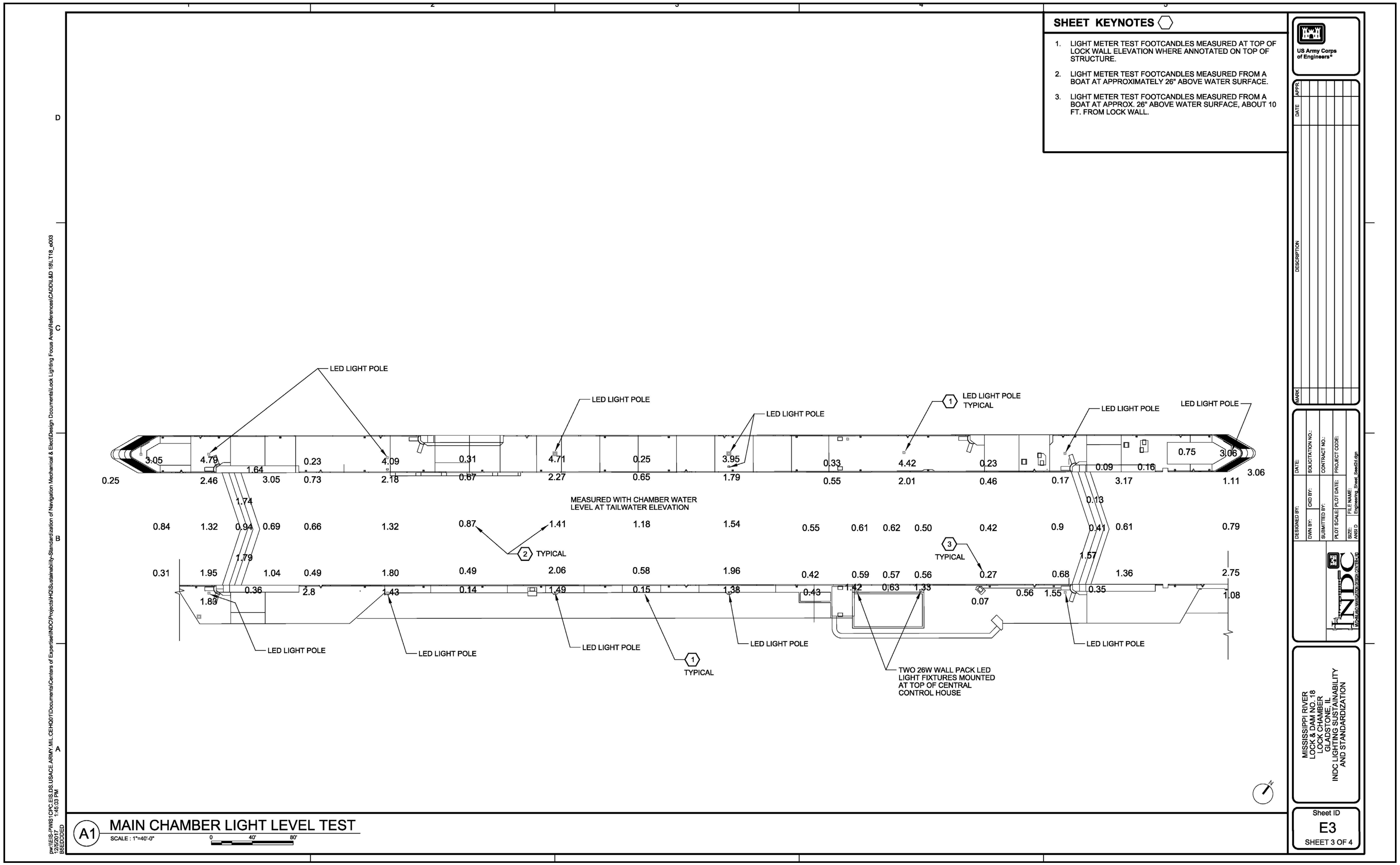

Figure 14. Mississippi River Lock No. 18 – lock chamber - measured photometric data for existing 150W LED light fixtures (units are in foot-candles).

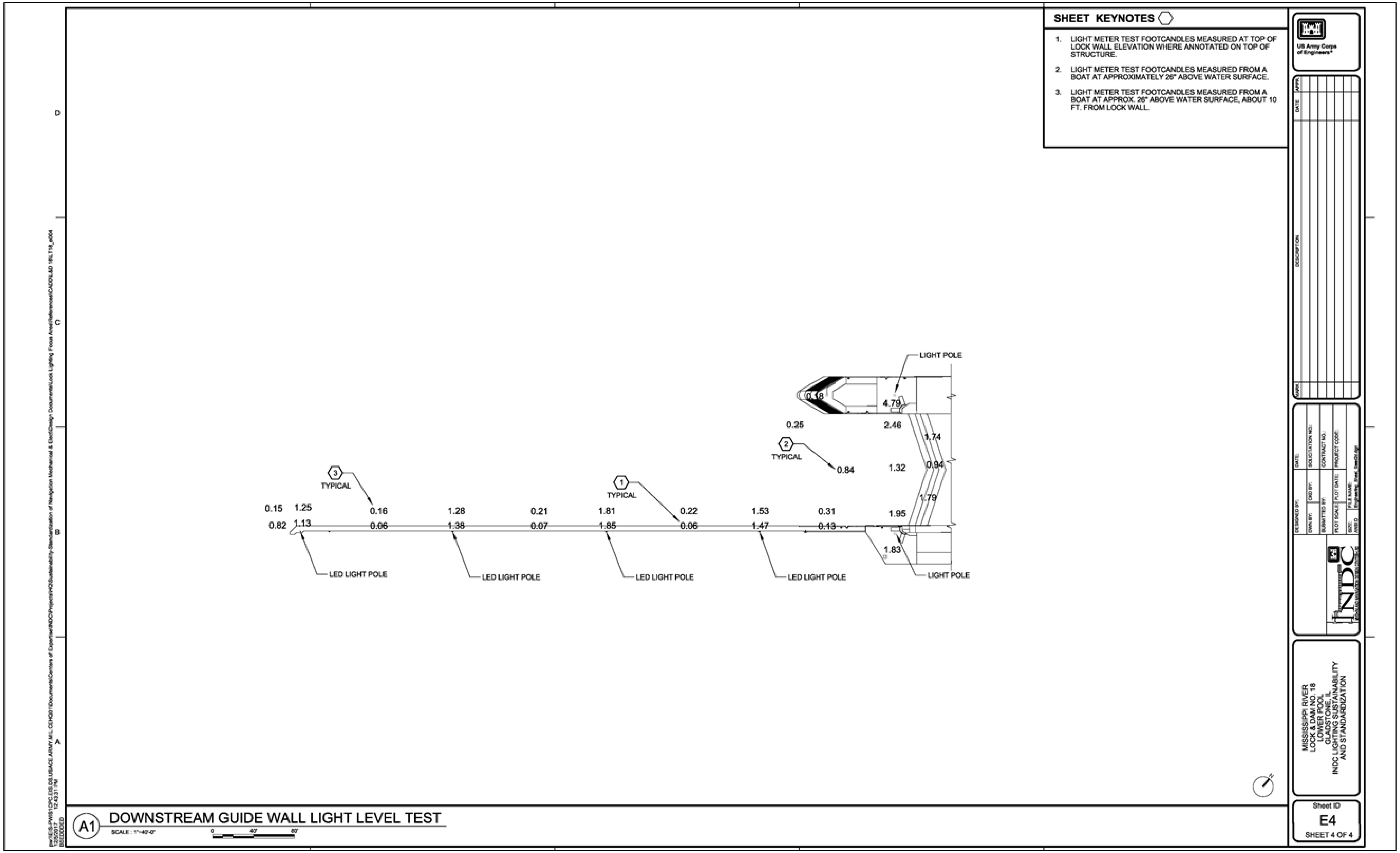

Figure 15. Mississippi River Lock No. 18, downstream plan - measured photometric data for existing 150W LED light fixtures (units are in foot-candles).

7.4 Cost and savings

The cost analysis that follows compares the costs of HPS and LED light fixtures installed on 30 ft tall poles, specifically analyzed for Mississippi River Lock No. 18. Table 9 lists the assumed parameters (assumptions) used for the analysis. Note that the first cost of the HPS fixtures is not used in calculations, but is provided for information only because this analysis assumes that the existing HPS fixtures are either being retrofit replaced with 150W LED light fixtures, or that the HPS lamps are being retrofitted (replaced) with LED corn type lamps.

Tables 9 and 10 list the assumptions and life-cycle cost estimate for Lock No. 18. This life-cycle cost estimate compares the costs of continued support for existing HPS (defined as the Baseline), against the costs of retrofit replacement with 150W LED light fixtures (defined as Scenario 1), and the costs of retrofit with HPS Lamp with LED Corn Lamp (defined as Scenario 2).

Operations managers, navigation lock and dam administrators, and design engineers should consider the life-cycle cost estimate for their specific systems to compare the costs between continued support for existing HID (defined as the Baseline), retrofit replacement with properly sized LED light fixtures (defined as Scenario 1), and retrofit of HID Lamp with compatible LED Corn Lamp (defined as Scenario 2). The least cost alternative may not be the best solution when other considerations such as proper illumination and maintenance safety are made part of the decision process. See Chapter 5 (p 27) for additional considerations for selecting LED lighting systems.

Table 9. Assumptions for Lock No. 18 life-cycle cost estimate.

	Cost or Quantity	Units	Notes
Product Cost to Change to 120W LED Corn Style Lamp:	$250.00	per Each	Note 1 (Typ.)
Product Cost to Change to 150W LED Fixed Light Fixture:	$642.86	per Each	
Keep 400 Watt high pressure sodium (HPS) light fixture:	$461.00	Each	See Note 2
120 Watt LED Corn Style **Replacement** Lamp Cost per each:	$250.00	Each	
150 Watt LED **Replacement** light fixture Cost per each:	$0.00	Each	See Note 3
400 Watt HPS **Replacement** Lamp Cost per each:	$10.00	Each	
120 Watt LED Corn Style Lamp L70 Expected Life in Hours:	35,000	Hours/Lamp	
150 Watt LED Light Fixture L70 Expected Life in Hours:	100,000	Hours/Fixture	
400 Watt HPS Lamp Expected Life in Hours:	24,000	Hours/Lamp	
Electric Utility Price/kWh:	$0.10	$/kWh	
Electrician Labor Rate/Hour including benefits:	$67.50	per Hour	
Estimated burn time per day for outdoors night lighting:	12	Hours/Day	
Life Cycle Period (in hours):	100,000.00	Hours	See Note 3
Life Cycle Period (in years):	22.83	Years	See Note 3
Lock Chamber (# of fixtures):	17	Fixtures	
Entire Lock (# of fixtures):	34	Fixtures	See Note 4

NOTES:

1. The new product costs shown in the Quantity column is in 2017 dollars. Also, the labor cost used is the 2017 Davis-Bacon Act current time wage rates for an electrician for the Illinois County in which L&D 18 exists.
2. The cost of new 400 Watt HPS light fixture is shown for information only. Note that the HPS "shoebox" style light fixture was difficult to locate on the internet. Commercial production of HID fixtures may be systemically reducing and essentially "phasing out" HID fixtures in preference of LED light fixtures.
3. The characteristic or estimated life of a LED Light Fixture is 100,000 Hours so this period of time was selected as the period of study for this life-cycle cost analysis. The LED light fixture is assumed to not require replacement during this life-cycle analysis period.
4. The number of fixtures for entire lock includes the lock chamber light fixtures plus the upstream guide wall, upstream guard wall, and the downstream guide wall light fixtures.

Table 10. Life-cycle cost estimate for Lock No. 18 lock light fixtures.

LIFE-CYCLE COST ANALYSIS SPREADSHEET				
	Baseline	Scenario 1	Scenario 2	See Note 1
Cost Item	400W HPS	150W LED	120W LED Corn Lamp	NOTES
Life-Cycle Fixture & Labor Cost				See Notes 2 & 4
Lock Chamber (11 Poles/17 Fixtures)	$0.00	$15,518.62	$6,545.00	
Entire Lock (27 Poles/34 Fixtures)	$0.00	$31,037.24	$13,090.00	See Note 3 (Typ)
Life-Cycle Energy Cost				
Lock Chamber (17 Lamps)	$68,000.00	$25,500.00	$20,400.00	
Entire Lock (34 Lamps)	$136,000.00	$51,000.00	$40,800.00	
Life-Cycle Lamp Replacement Cost				
Lock Chamber (17 Lamps)	$850.00	N/A	$12,750.00	
Entire Lock (34 Lamps)	$1,700.00	N/A	$25,500.00	
Life-Cycle Lamp Replacement LABOR Cost				
Lock Chamber (17 Lamps)	$22,950.00	$9,180.00	$13,770.00	
Entire Lock (34 Lamps)	$91,800.00	$73,440.00	$55,080.00	
Project Life				
Life Cycle Period (in hours)	100,000	100,000	100,000	Hours
Life Cycle Period (in years)	22.83	22.83	22.83	Years
Approximate Payback Period				
Lock Chamber (11 Poles/17 Fixtures)	NA	6.3 Years	2.63 Years	
Entire Lock (27 Poles/34 Fixtures)	NA	6.86 Years	2.27 Years	

NOTES:

1. Definitions of terminology:

a) Baseline: Continue using the existing HPS fixtures on 30 feet tall poles and maintain by replacing with HPS lamps when needed based on characteristic (expected) lamp life.

b) Scenario 1: Retrofit the existing HPS light fixtures on existing light poles with new 150W LED light fixtures and no replacements assumed during the time defined by this analysis.

c) Scenario 2: Retrofit the existing HPS light fixture LAMP with new 120W corn style LED lamps on existing light poles and maintain by replacing with new corn style LED lamps when needed based on characteristic (expected) lamp life.

2. Includes the original LED product cost and the labor cost to retrofit the existing HPS light fixtures to either LED light fixtures or to LED corn style lamps respectively.

3. The number of fixtures for entire lock includes the lock chamber light fixtures plus the upstream guide wall, upstream guard wall, and the downstream guide wall light fixtures.

4. The cost to install a corn lamp will typically be less expensive than replacing the existing light fixture with a new LED light fixture, however, the desired illumination characteristics and light levels may or may not be satisfactory for the application. Also the ventilation for proper heat dissipation required for the corn lamp must be considered to ensure it is compatible with the light fixture in which it will be retrofit.

8 Illumination Example of 110x1200-ft Lock

The illumination levels of a 1200 ft long x 110 ft wide navigation lock may be obtained by extrapolating the illumination data either calculated or measured in units of foot-candles, or in Lux, at the respective upstream or downstream miter gate area of a standard 600 ft long x 110 ft wide lock similar to Lock No. 18. If the navigation locks are the same width and the light fixtures/poles are the same height and spaced similarly, then the illumination for the area around a miter gate will be essentially the same for both a 600 ft long lock as will be for a 1200 ft long lock. A 1200 ft long lock will need an additional quantity of 30 ft tall light poles to properly illuminate along the length of the longer chamber. Alternatively, it may be more efficient to use a high mast light pole system instead of a 30 ft tall light pole system to illuminate a larger area with fewer number of light poles. Navigation lock chambers that are not 110 ft wide cannot be modeled by data extrapolation and must be independently modeled using commercial lighting software as exampled in this report.

9 600-Foot Lock, High Mast Lights Design Example

9.1 General

Figure 16. L&D No. 25, existing light fixtures.

As part of the American Recovery and Reinvestment Act (ARRA) of 2009, a high mast lighting (HML) design was developed for Lock and Dam (L&D) No. 25 in Winfield, MO. L&D No. 25 includes a 600-ft main lock chamber and the upstream gates of the auxiliary lock. While the design has been developed, the project has not been constructed. The existing lock lighting consists of 28, 20-ft high poles with a 400W HPS "shoebox" light fixture (Figure 16) operating at 120 VAC. The eight poles located on the intermediate wall support two fixtures per pole for a total of 36 fixtures. The poles are spaced approximately 110 ft apart and are shown in Figures 14 and 15 (pp. 57, 58). The lowest tailwater elevation at L&D No. 25 is 24 ft below the lock wall elevation. All lighting designs are calculated at this elevation. Note that energy savings calculations were performed using a rate of $0.0886/kWh at an annual usage of 4,380 hours per year.

9.2 High mast light design, HPS

The high mast lighting design shown in Figure 19 (p. 59) provides a total of 11, 80-ft high poles. The poles are spaced approximately 250-300 ft apart. Each pole includes four 1000W HPS fixtures. The system will operate at 480 VAC and include two lighting contactors to provide independent control of the land wall and both the intermediate wall and river wall. The A-

E's design shown in Figures 20-22 (pp. 61-63) provides an average illumination of 2.7 fc. The downside of this design is the minimum of 1.1 fc and the maximum of 9.0 fc providing a very high uniformity ratio. Holt Energy of St. Louis, MO calculated an energy increase of $12,286 annually (4300 hours per year) to power the 44, 1000W HML fixtures instead of the original 36, six 400W fixtures. The installation of the high mast light poles requires a significant amount of concrete work as suitable foundations must be constructed for each pole. While construction has yet to be completed at L&D No. 25, a similar system was installed at Locks No. 27 in Granite City, IL. The 1200-ft main and 600-ft auxiliary lock chamber required a total of 16 poles at a cost of $1.2M in 2010. The construction cost for L&D No. 25 is estimated at approximately $800k.

9.3 High mast light design, LED

Holt Energy updated the lighting design to use an LED fixture in lieu of the 1000W HPS. Four Global Tech LED GTL-AR-FL90 fixtures (Global Tech 2017, 2016) were used on each pole at an approximate cost of $1,350 each. The lighting design shown in Figure 23 (p. 65) provides an average illumination of 2.7 fc. The maximum of 7.1 fc and a minimum of 2.0 fc provides a better uniformity ratio of 3.6:1 when compared to the original HPS design. The use of LED in lieu of the 1000W HPS fixtures will provide an annual savings of $11,649 per year. Compared to the current 400W lock lighting system, the high mast system will cost an additional $638 per year to operate. While the HML system will slightly increase the operating cost of the lock, the use of LED fixtures and HML poles will provide better lighting and greater uniformity.

9.4 Retrofit of existing fixtures

Many projects will not be able to justify the expense of the high mast light poles and their foundation. Holt Energy considered an LED retrofit of the existing shoebox fixture mounted on the 20-ft pole. A Global Tech LED GTSOL5498-HO-GR-360S retrofit kit (Global Tech 2014a) was identified at a cost of approximately $300 each. The lighting design shown in Figure 24 (p. 66) indicates an average illumination of 0.6 fc. The maximum was only 1.6 fc and some areas were 0 fc. The lighting of the lock approach is awkward and much of the lighting is wasted on illuminating the top of lock wall as the retrofit cannot provide a Type IV distribution. The annual savings for using LED in lieu of the HPS is estimated at $4,610 per year.

9.5 Replacement of existing fixtures

The proposed retrofit of the existing light fixtures did not provide adequate coverage of the lock chamber. Holt Energy identified a Hubbell Outdoor ASL-24L-5K-210-4 fixture (Hubbell Lighting 2018, Hubbell Outdoor Lighting 2017) at an approximate cost of $390. The lighting design shown in Figure 25 (p. 67) provides an average illumination of 1.3 fc. The annual energy savings derived from using new LED fixtures instead of the 400W HPS is estimated at $4,009 per year.

9.6 Design example summary

This design example for L&D No. 25 started with high mast light poles with high pressure sodium fixtures. While the original high mast design will likely provide a better and more uniform lighting resulting in increased visibility and safety, the energy for the HPS fixtures will cost the project an additional $12k per year. The use of LED fixtures reduced the yearly energy costs to only an additional $600 per year. While LED fixture energy savings can pay back fixture upgrades, it cannot pay back the high cost of the HML poles and foundations. The HML system is an investment to provide better project lighting with fewer poles. The lowering system on the HML poles will reduce maintenance time by allowing multiple fixtures to be worked on simultaneously without the need for ladders or scissor lifts.

While projects can re-use existing light poles to reduce costs, the entire fixture should be replaced in lieu of retrofitting LEDs into an existing fixture. The new fixture can be selected to provide the distribution type needed for the lock and dam lighting application. While replacement fixtures on existing poles may not produce a lighting design to meet the recommended criteria, it certainly will be an upgrade over the existing fixtures.

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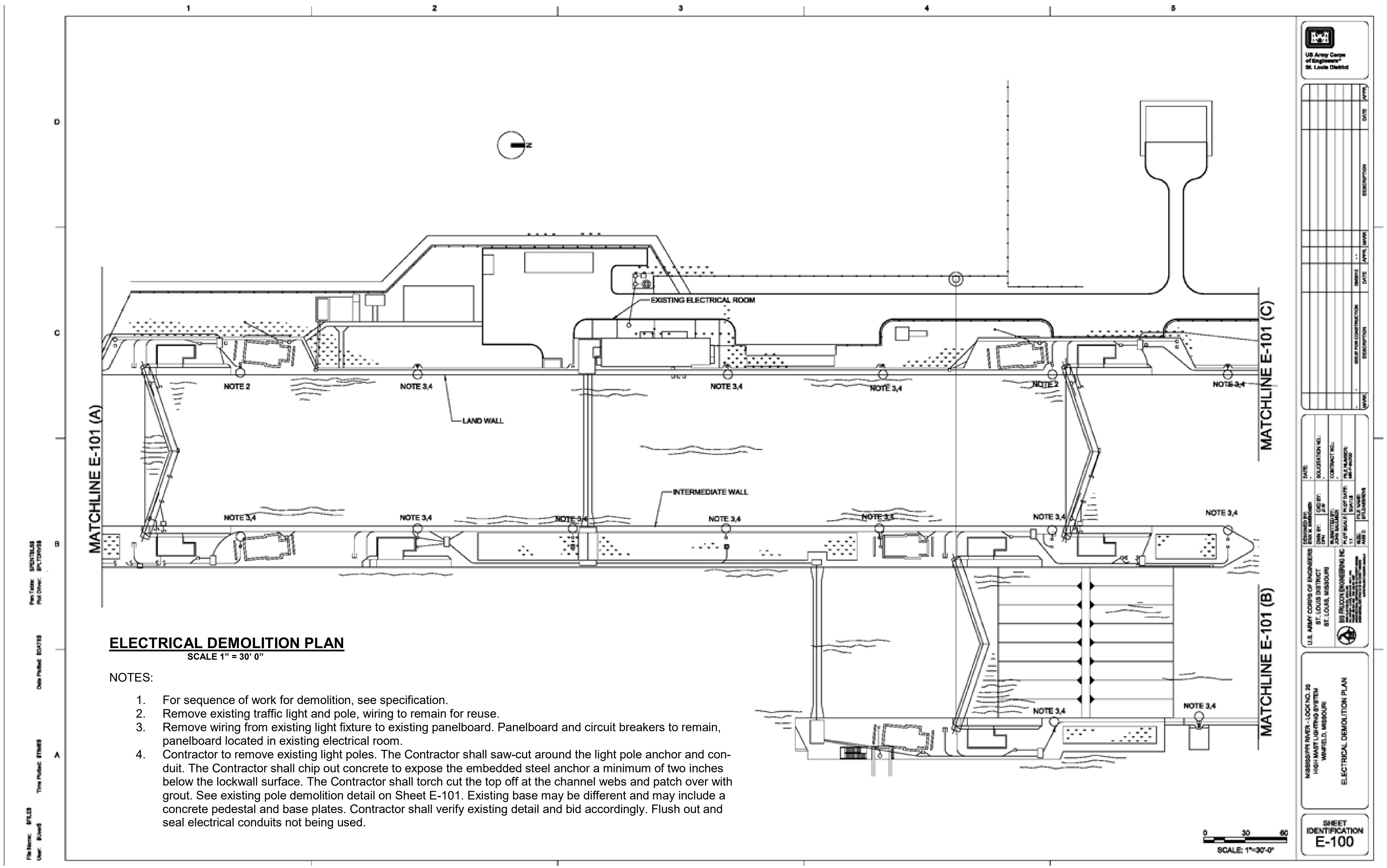

Figure 17. L&D No. 25, existing light pole layout, Sheet 1.

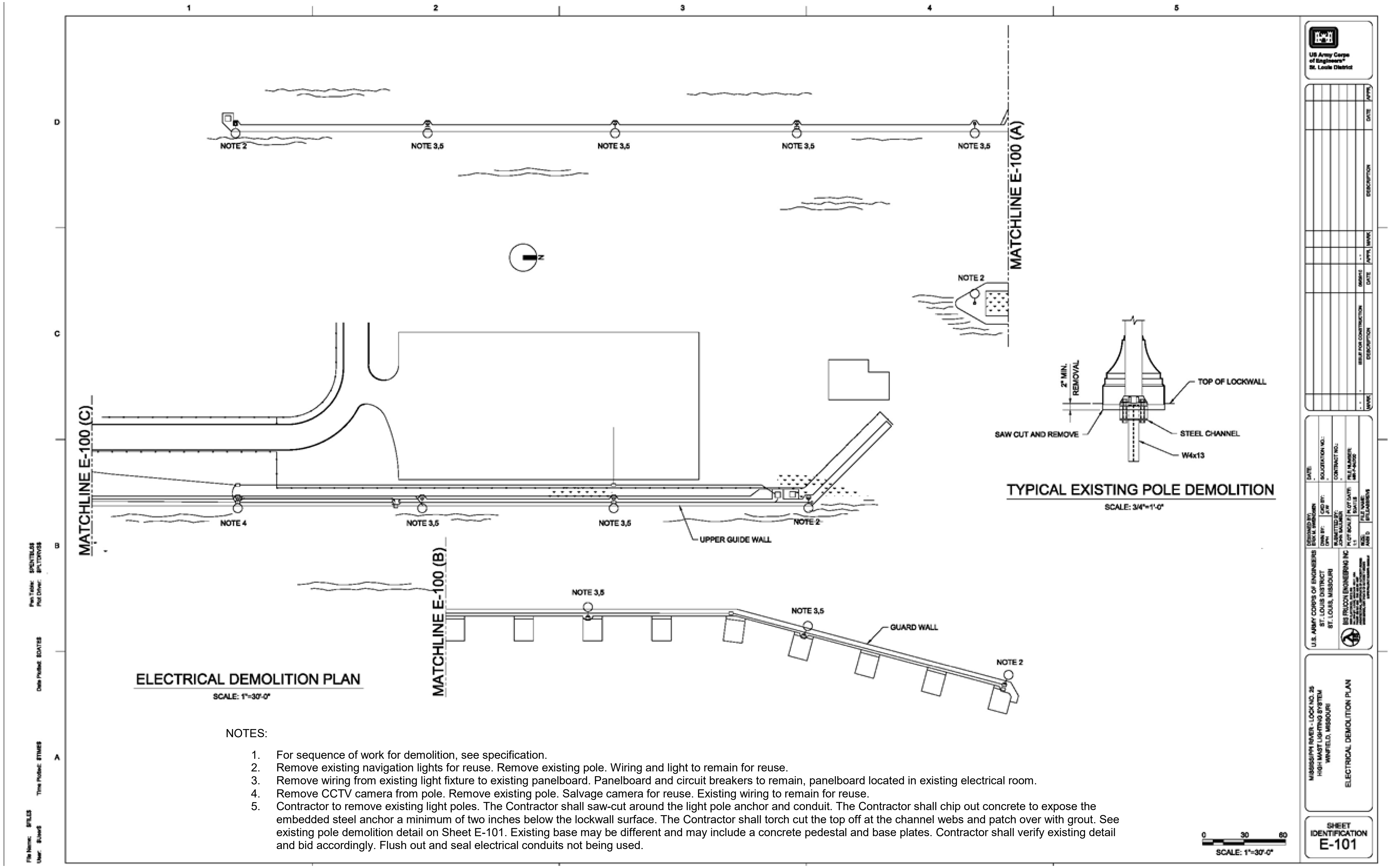

Figure 18. L&D No. 25, existing light pole layout, Sheet 2.

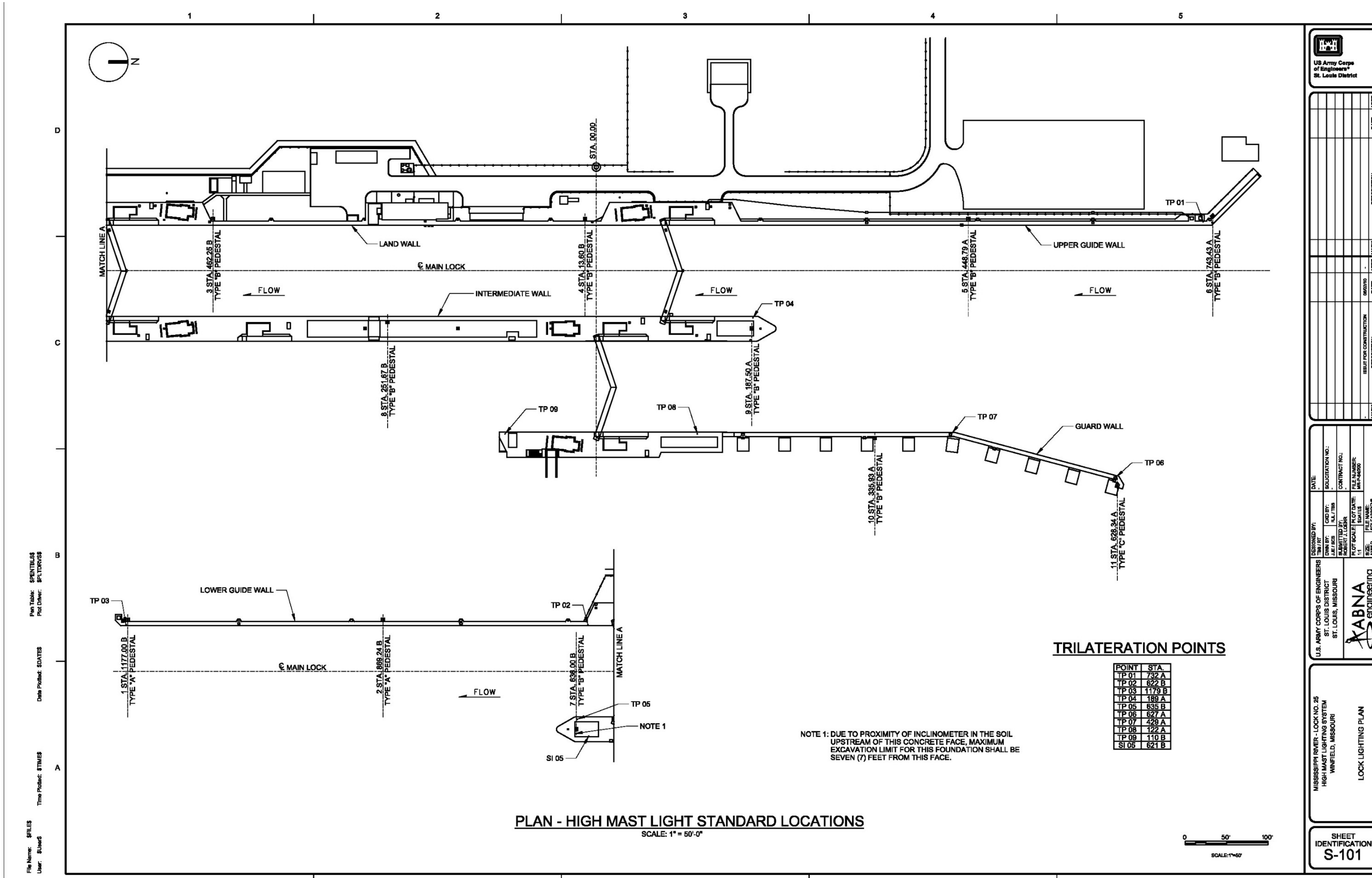

Figure 19. L&D No. 25, high mast light pole layout.

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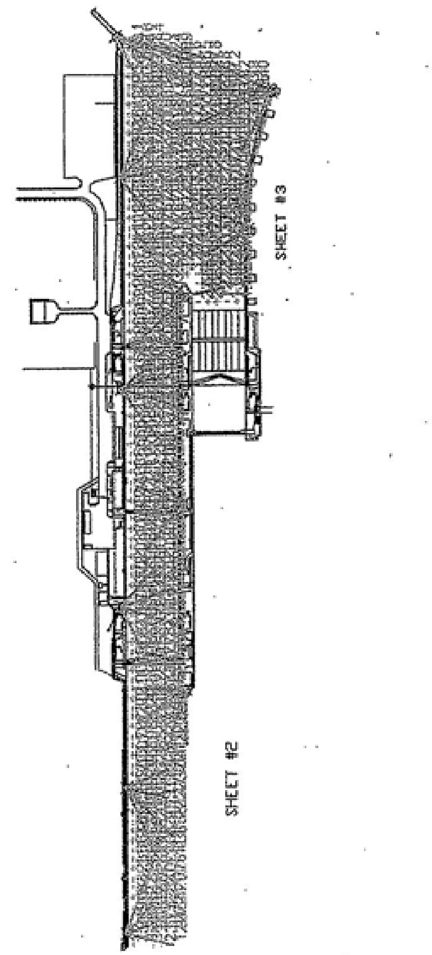
STATISTICS

Description	Symbol	Avg	Max	Min
Calculation Zone	+	2.7 fc	9.0 fc	1.1 fc

LUMINAIRE SCHEDULE

Symbol	Label	Qty	Description	Lamp	Lumens	LLF	Watts
●	A	44	1000W HPS TYPE III MCO HIGH MAST	1000W HPS CL E-25	140000	0.75	1000



SHEET 1 OF 3

Figure 20. L&D No. 25, 1000W HPS design, Sheet 1.

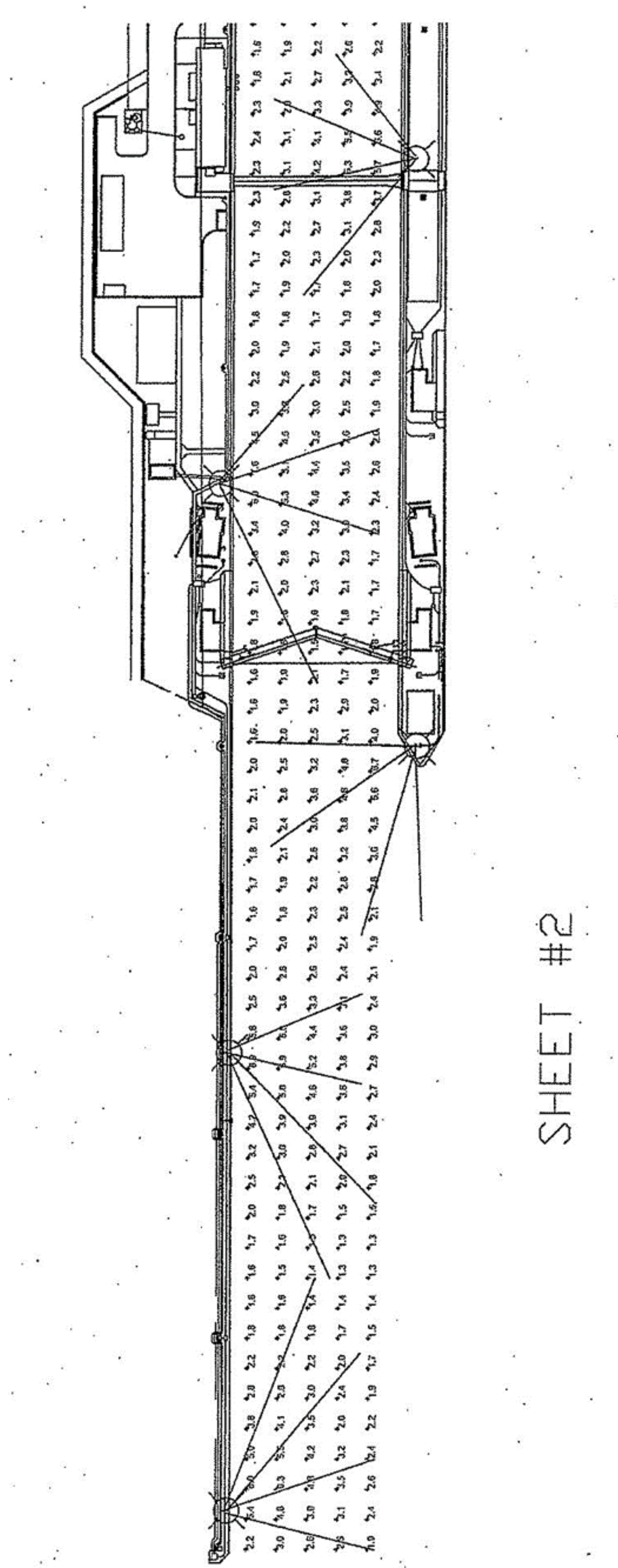


Figure 21. L&D No. 25, 1000W HPS design, Sheet 2.

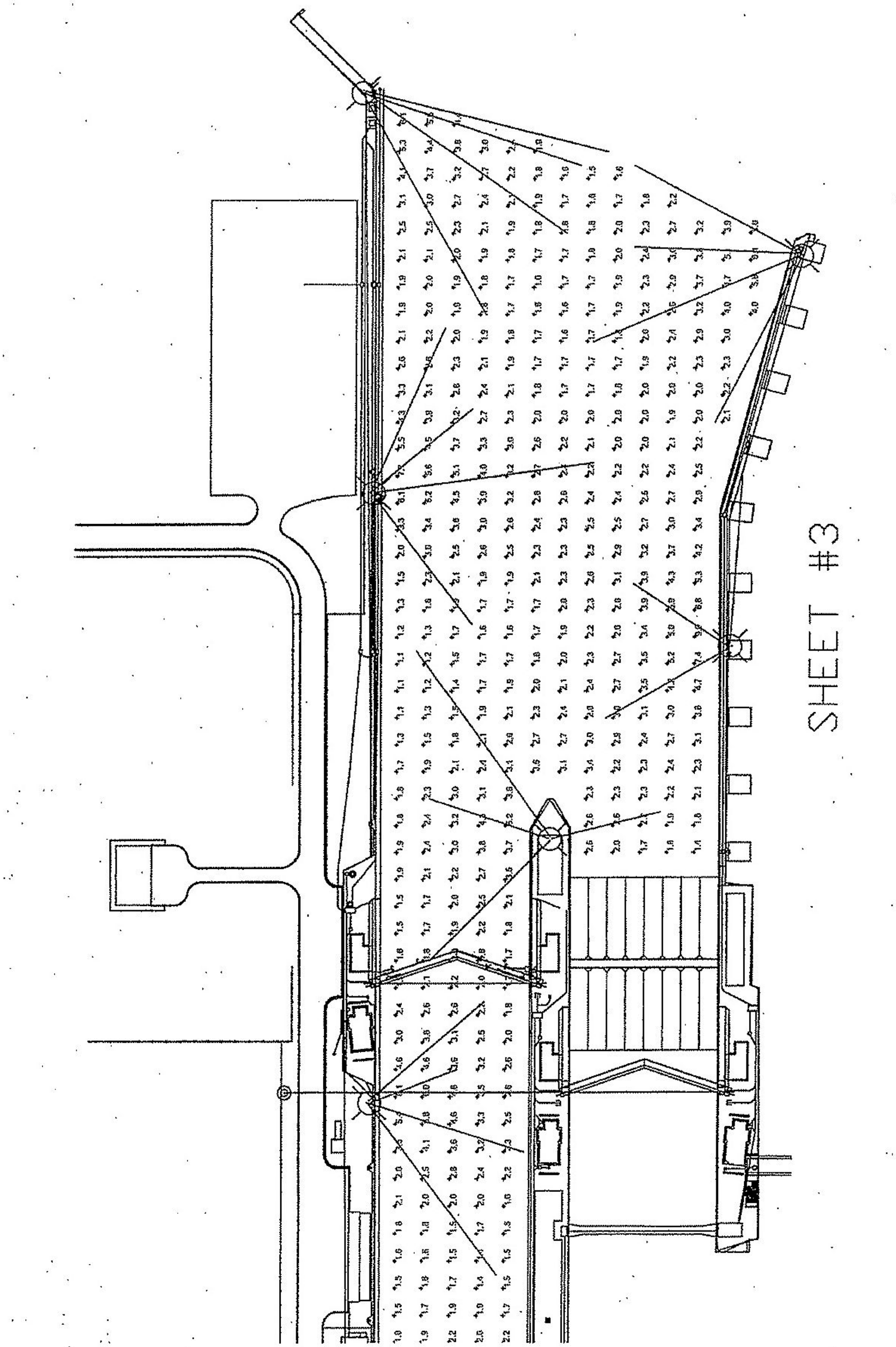


Figure 22. L&D No. 25, 1000W HPS design, Sheet 3.

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Schedule

Symbol	Label	Quantity	Manufacturer	Catalog Number	Description	Lamp	Number Lamps	Filename	Lumens Per Lamp	Light Loss Factor	Wattage
	A	11	GLOBAL TECH	GTSOL5498-HO-GR-50D	1923-7		3	GTSOL5498-HO-GR-50D(135W).IES	13219	0.95	1571.4

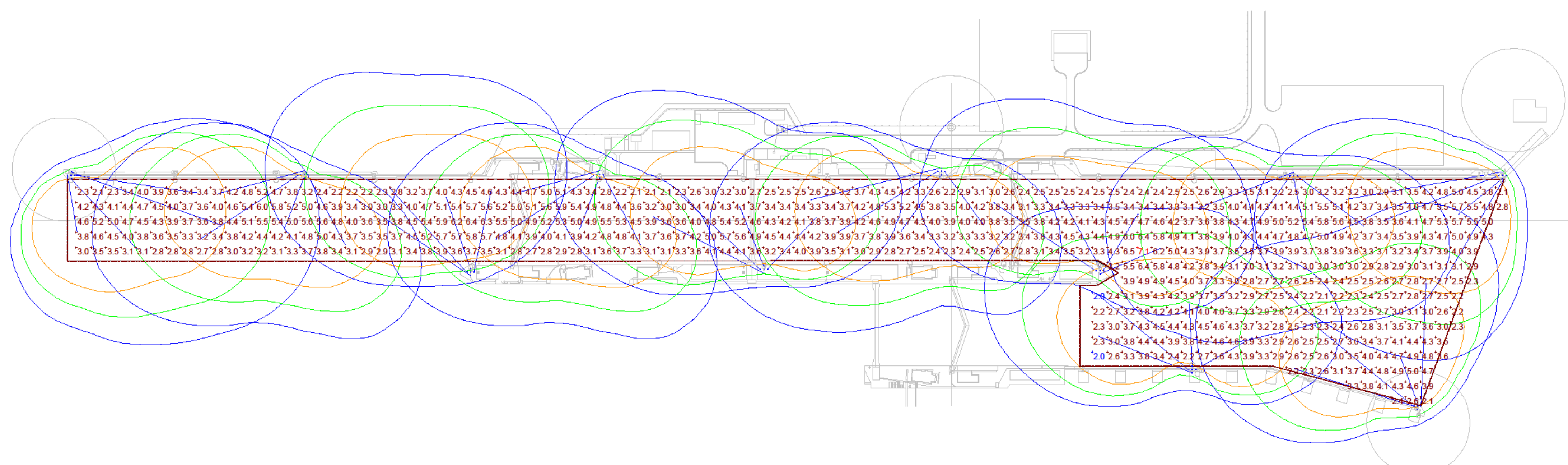
Statistics

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Calc Zone #1	+	3.7 fc	7.1 fc	2.0 fc	3.6:1	1.9:1

Note

1. FIXTURES MOUNTED AT 80' AFF
2. CALCS EVERY 20' TAKEN AT 24' BELOW THE LOCK WALL

These calculations are for estimation or informational purposes only. Actual light levels may vary due to reflectance, temperature, obstructions and other factors. HOLT ELECTRICAL SUPPLIES will not be held responsible for light levels that differ from what is shown on this or any layout provided. Consult with a professional engineer if a more detailed study is needed.



Plan View
Scale - 1" = 65ft

HOLT ELECTRICAL SUPPLIES

Winfield Lock Dam
Sandy Slough Road
Winfield, MO

Designer
BMW
Date
6/15/2017
Scale
Not to Scale
Drawing No.

Summary

1 of 1

Figure 23. L&D No. 25, HML pole layout, LED fixtures.

Schedule

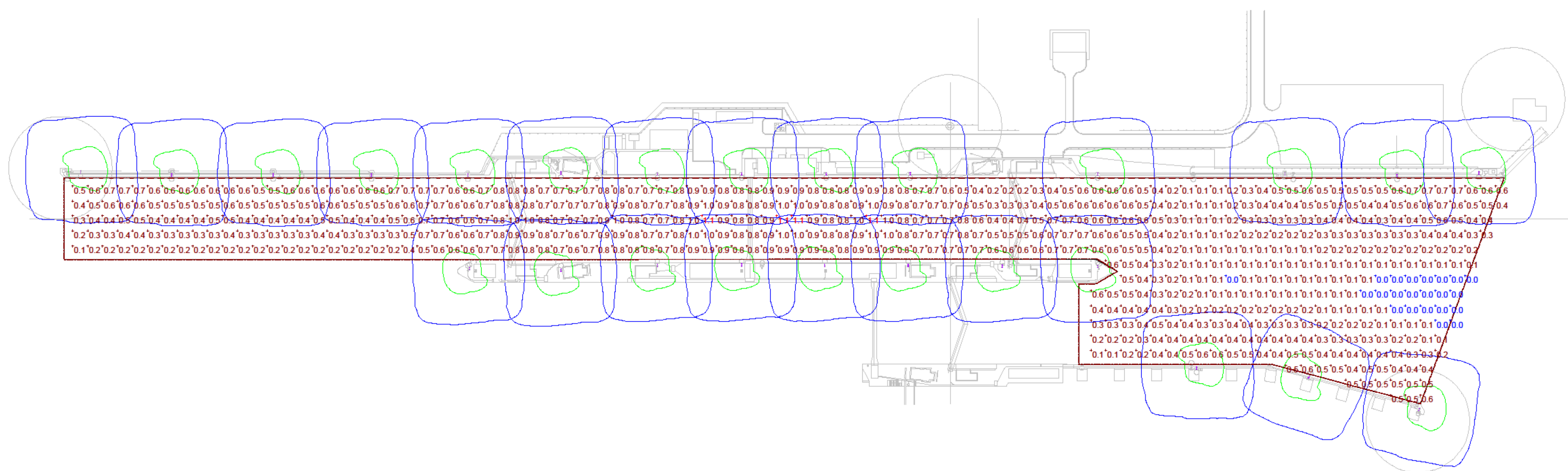
Symbol	Label	Quantity	Manufacturer	Catalog Number	Description	Lamp	Number Lamps	Filename	Lumens Per Lamp	Light Loss Factor	Wattage
	B	18	GLOBAL TECH	GTSOL5498-HO-GR-360S	1923-10 HO		1	GTSOL5495-HO-GR-360S(135W).IES	12894	0.95	132.21
	C	8	GLOBAL TECH	GTSOL5498-HO-GR-360S	1923-10 HO		1	GTSOL5495-HO-GR-360S(135W).IES	12894	0.95	264.42

Statistics

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Calc Zone #1	+	0.6 fc	1.6 fc	0.0 fc	N/A	N/A

Note
1. FIXTURES MOUNTED AT 20' AFF
2. CALCS EVERY 20' TAKEN AT 24' BELOW THE LOCK WALL

These calculations are for estimation or informational purposes only. Actual light levels may vary due to reflectance, temperature, obstructions and other factors. HOLT ELECTRICAL SUPPLIES will not be held responsible for light levels that differ from what is shown on this or any layout provided. Consult with a professional engineer if a more detailed study is needed.



Plan View
Scale - 1" = 65ft

HOLT ELECTRICAL SUPPLIES

Winfield Lock Dam
Sandy Slough Road
Winfield, MO

Designer
bmw
Date
6/22/2017
Scale
Not to Scale
Drawing No.
Summary
1 of 1

Figure 24. L&D No. 25, existing light poles, LED retrofit.

Schedule

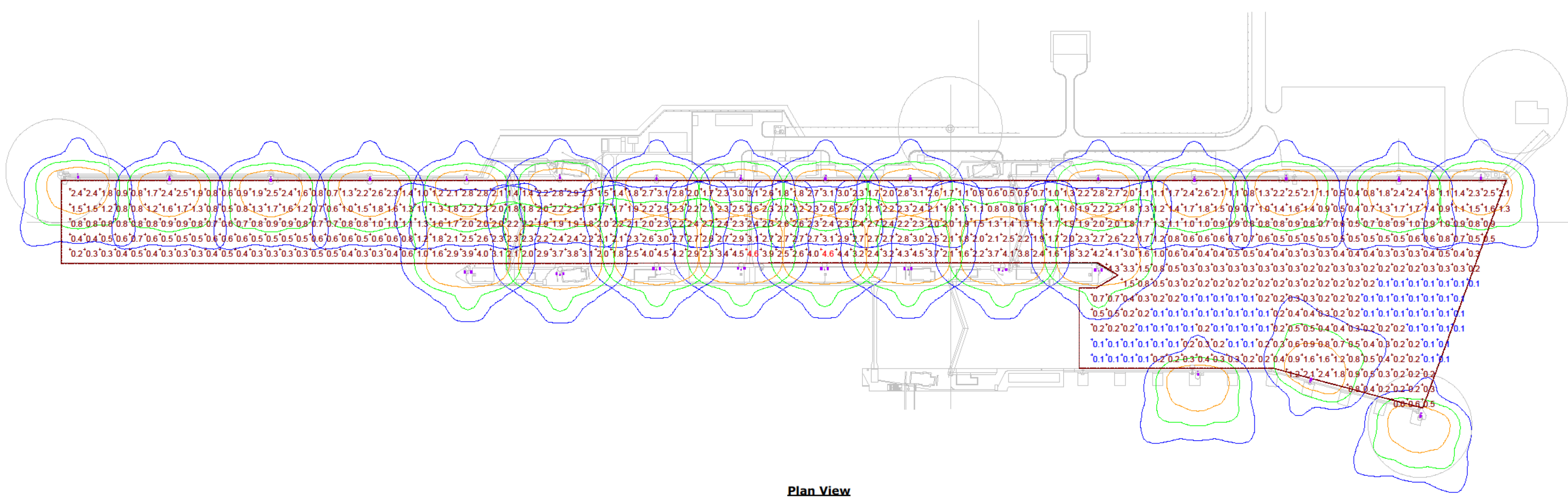
Symbol	Label	Quantity	Manufacturer	Catalog Number	Description	Lamp	Number Lamps	Filename	Lumens Per Lamp	Light Loss Factor	Wattage
	B	18	Hubbell Outdoor	ASL-24L-5K-210-4	ASL Area/Site Lighter	24 High Brightness LEDs - 5000K - 70 CRI	1	ASL-24L-5K-210-4.IES	18288	0.95	177.7
	C	8	Hubbell Outdoor	ASL-24L-5K-210-4	ASL Area/Site Lighter	24 High Brightness LEDs - 5000K - 70 CRI	1	ASL-24L-5K-210-4.IES	18288	0.95	355.4

Statistics

Description	Symbol	Avg	Max	Min	Max/Min	Avg/Min
Calc Zone #1	+	1.3 fc	4.6 fc	0.1 fc	46.0:1	13.0:1

Note
1. FIXTURES MOUNTED AT 20' AFF
2. CALCS EVERY 20' TAKEN AT 24' BELOW THE LOCK WALL

These calculations are for estimation or informational purposes only. Actual light levels may vary due to reflectance, temperature, obstructions and other factors. HOLT ELECTRICAL SUPPLIES will not be held responsible for light levels that differ from what is shown on this or any layout provided. Consult with a professional engineer if a more detailed study is needed.



Plan View
Scale - 1" = 65ft

HOLT ELECTRICAL SUPPLIES

Winfield Lock Dam
Sandy Slough Road
Winfield, MO

Designer: bmw
Date: 6/22/2017
Scale: Not to Scale
Drawing No.
Summary
1 of 1

Figure 25. L&D No. 25, existing light poles, LED replacement.

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10 Case Studies

10.1 Photometric measurements at CELRN Locks

The illuminance levels (units in Lux) at three different navigation locks located in the Corps of Engineers Nashville District (CELRN) were measured and recorded as follows. Each of the three locks have different types of light fixture sources, which are presented here for comparison purposes.

10.2 Observation during measurements at CELRN Locks

The CELRN electrical engineer that measured and recorded the illumination levels at these three CELRN navigation locks recommended a consideration that the extreme high-lift locks might be best served using HPS lights. It was reported that Wilson Lock (~93-ft lift) currently uses HPS, and that HPS light source seems to have more “driving” effect.

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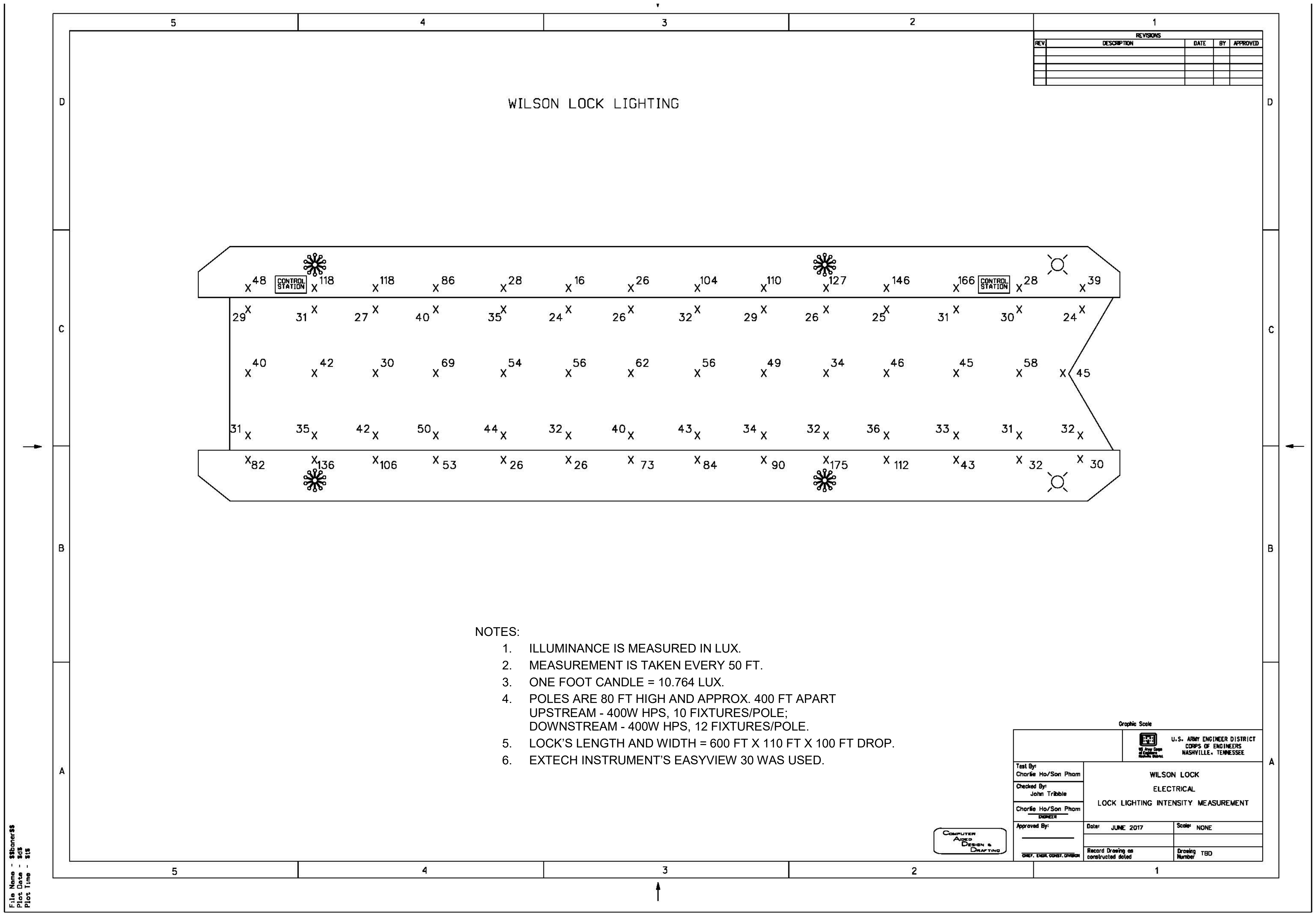

Figure 26. Wilson Lock, light levels, Sheet 1.

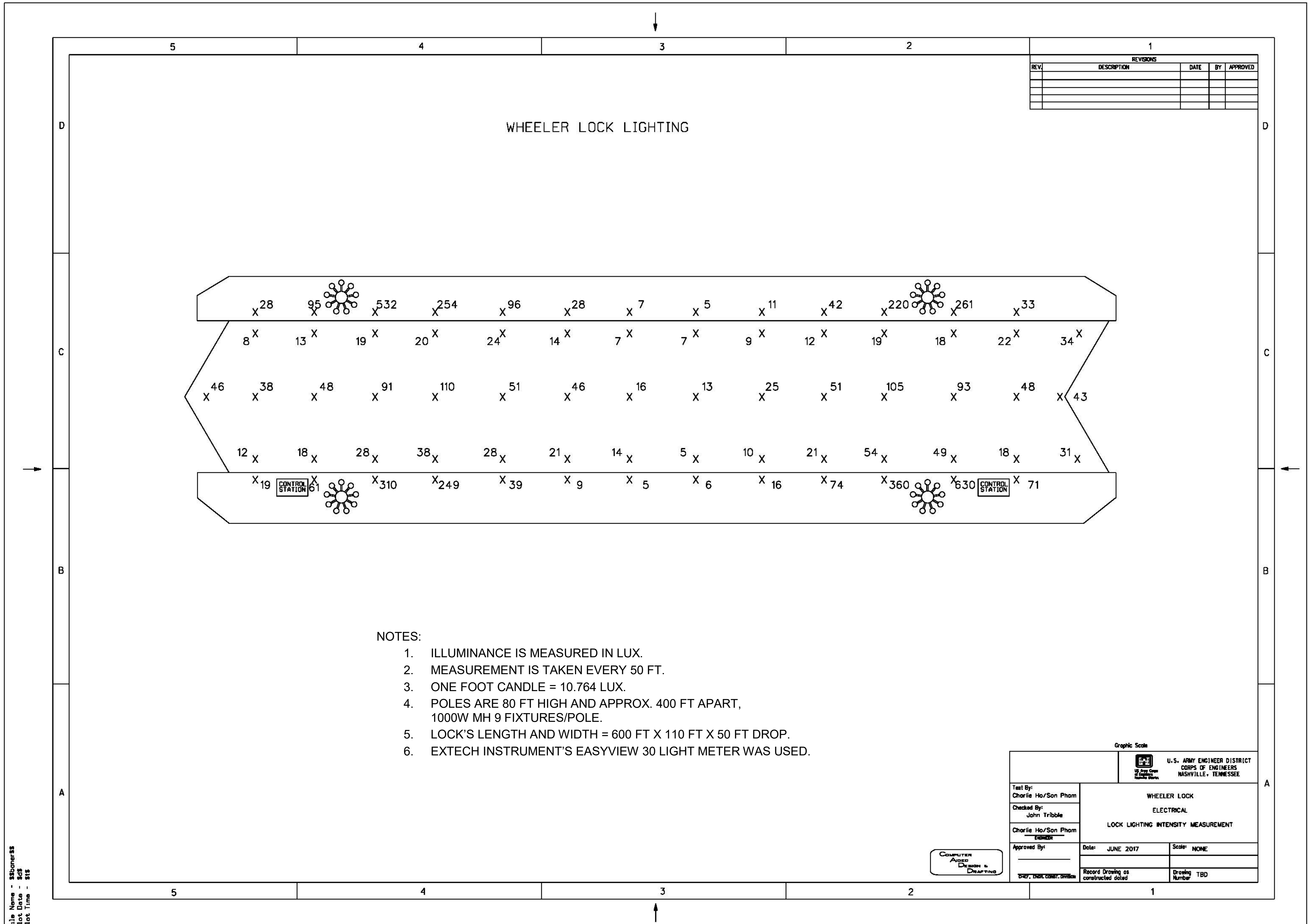

Figure 27. Wheeler Lock, light levels, Sheet 1.

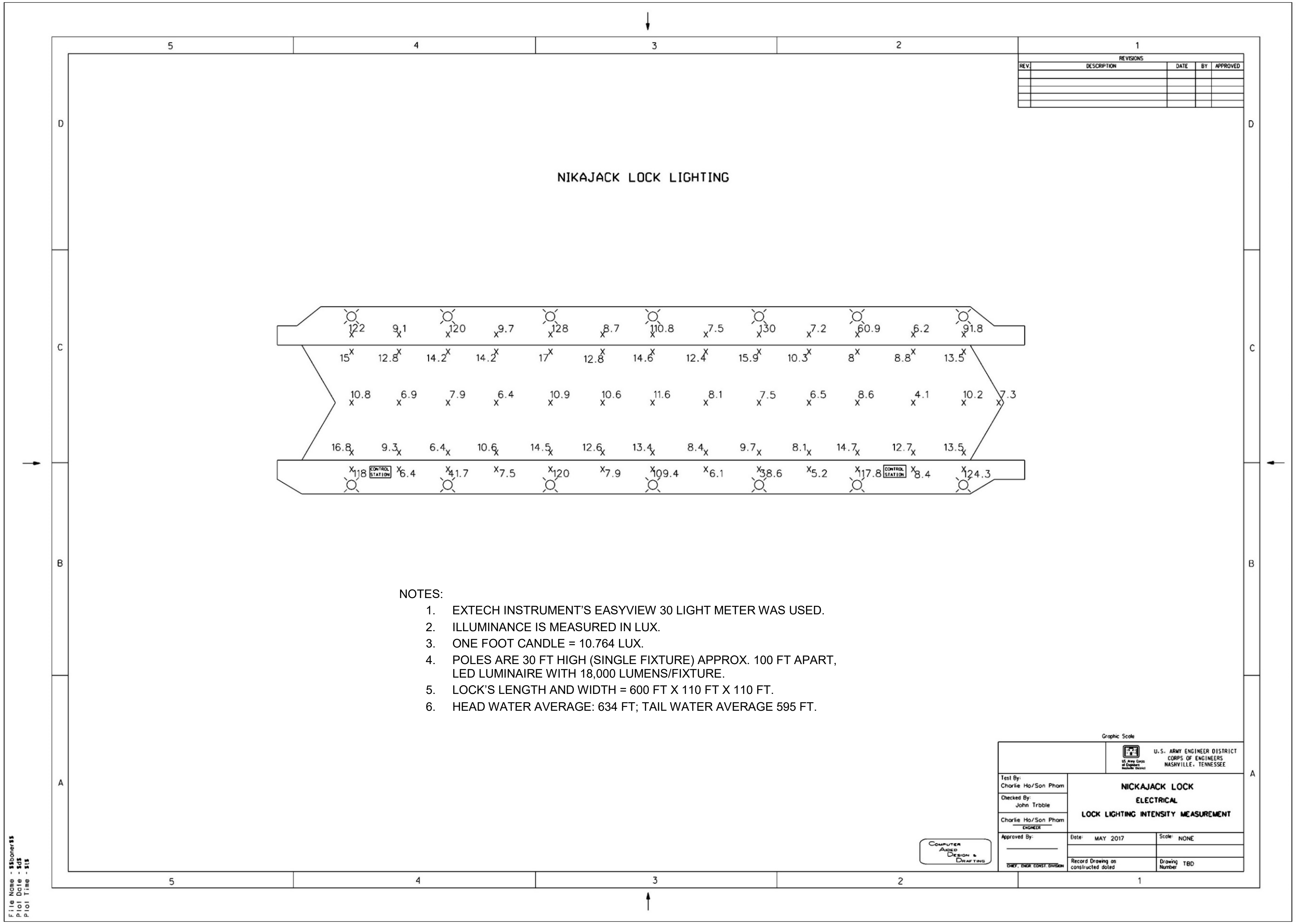

Figure 28. Nickajack Lock, light levels, Sheet 1.

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10.3 Photometric measurements at CEMVS locks and dams

The illuminance levels (units in foot-candles) at two different navigation locks and dams located in the Corps of Engineers St. Louis District (CEMVS) were measured and recorded as follows. Each lock has different types of light fixture sources, which are presented here for comparison purposes.

The design shown in Figures 29 through 32 (pp. 77-80) for the Mississippi River Melvin Price Locks and Dam uses 1000W High Pressure Sodium light fixtures, but the site has started the process of installing Global Tech GTSOL5498-HI-HV LED retrofit kits. Light source types are detailed in the attached figures, as are the HPS fixtures, which were out at the time of measurement. At the time of measurement the headwater elevation was 16.5 ft below the top of the wall. The chamber and tailwater elevations were 31.2 ft below the top of the wall. Overall light levels were very low with many dark spots, especially at the water level.

The design shown in Figures 33 through 36 (pp. 81-84) for the Mississippi River Locks No. 27 uses Global Tech GTSOL5498-HI-HV LED retrofit kits in the original HPS fixtures. At the time of measurement, the headwater elevation was 28.1 ft below the top of the wall. The chamber and tailwater elevations were 39.4 ft below the top of the wall.

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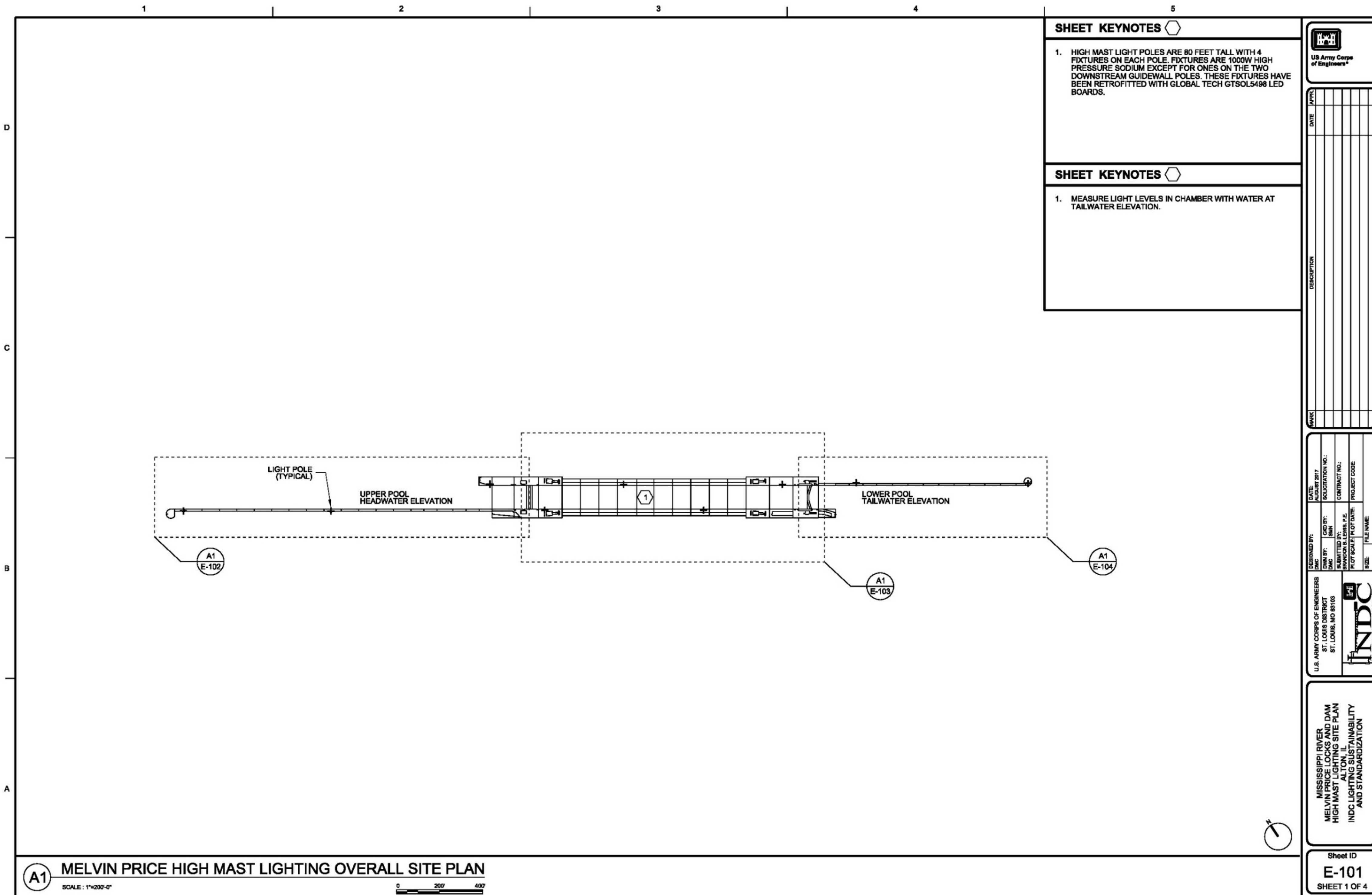


Figure 29. Melvin Price L&D, light levels, Sheet 1.

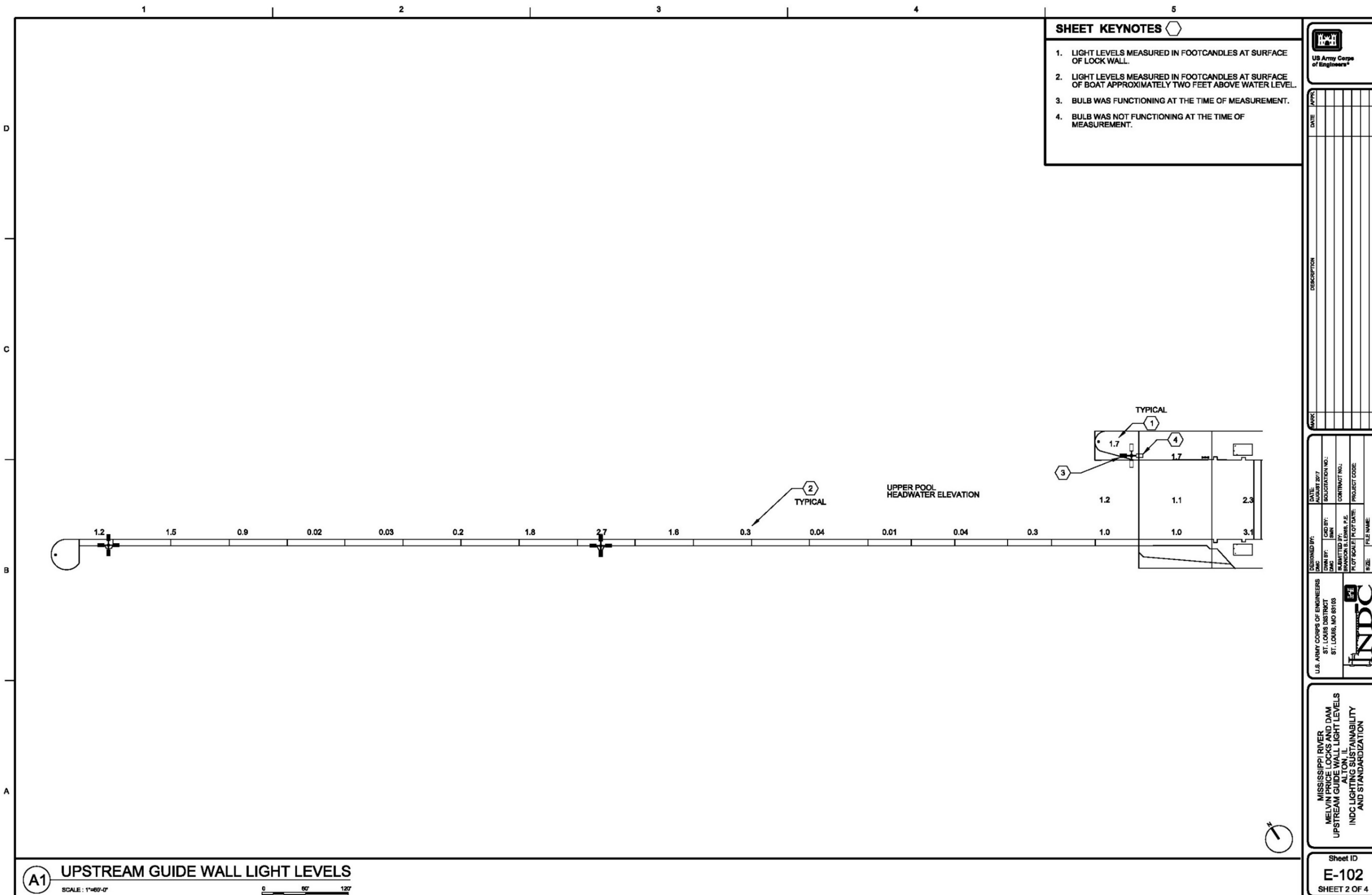


Figure 30. Melvin Price L&D, light levels, Sheet 2.

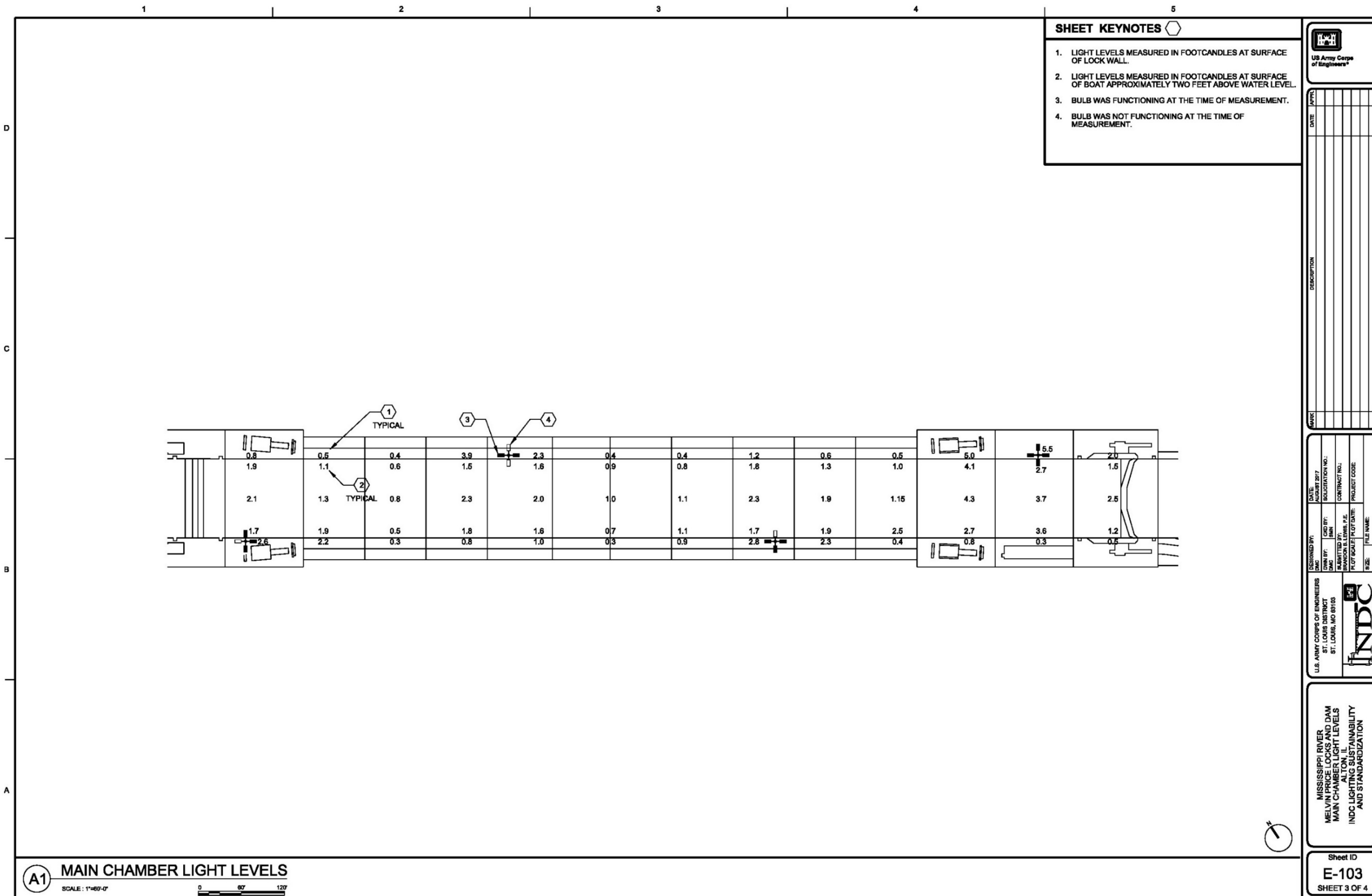


Figure 31. Melvin Price L&D, light levels, Sheet 3.

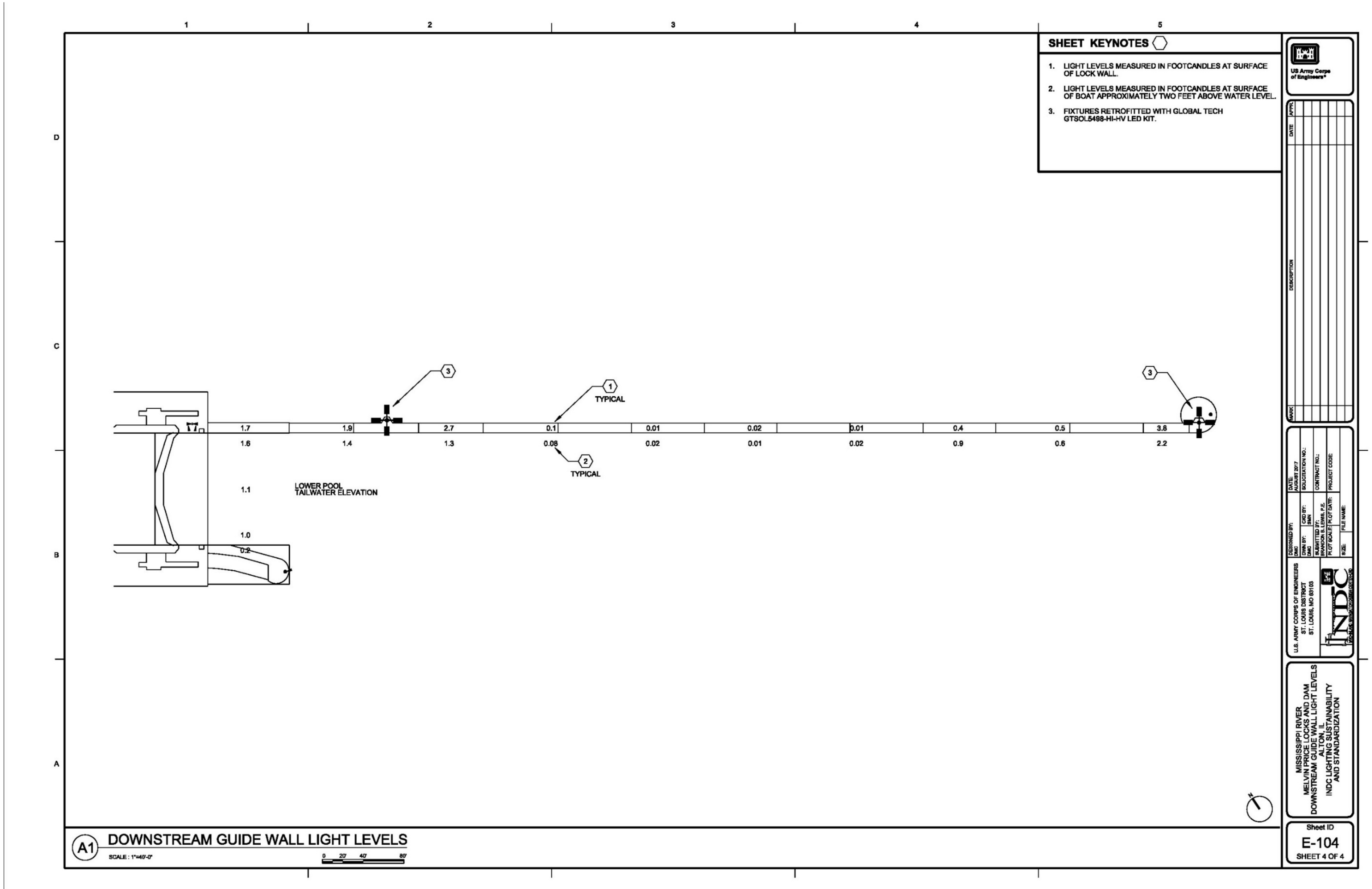


Figure 32. Melvin Price L&D, light levels, Sheet 4.

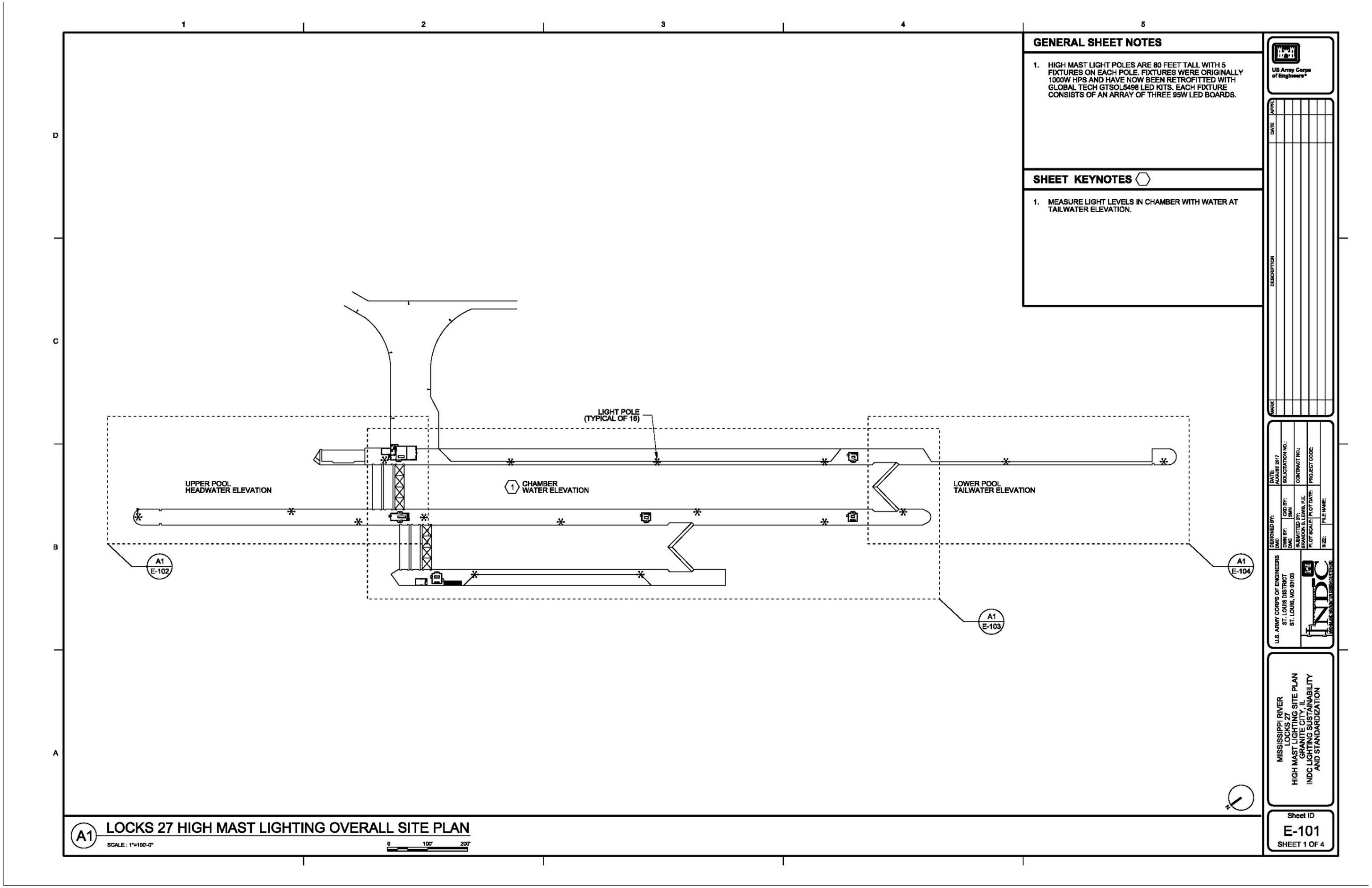


Figure 33. L27, light levels, Sheet 1.

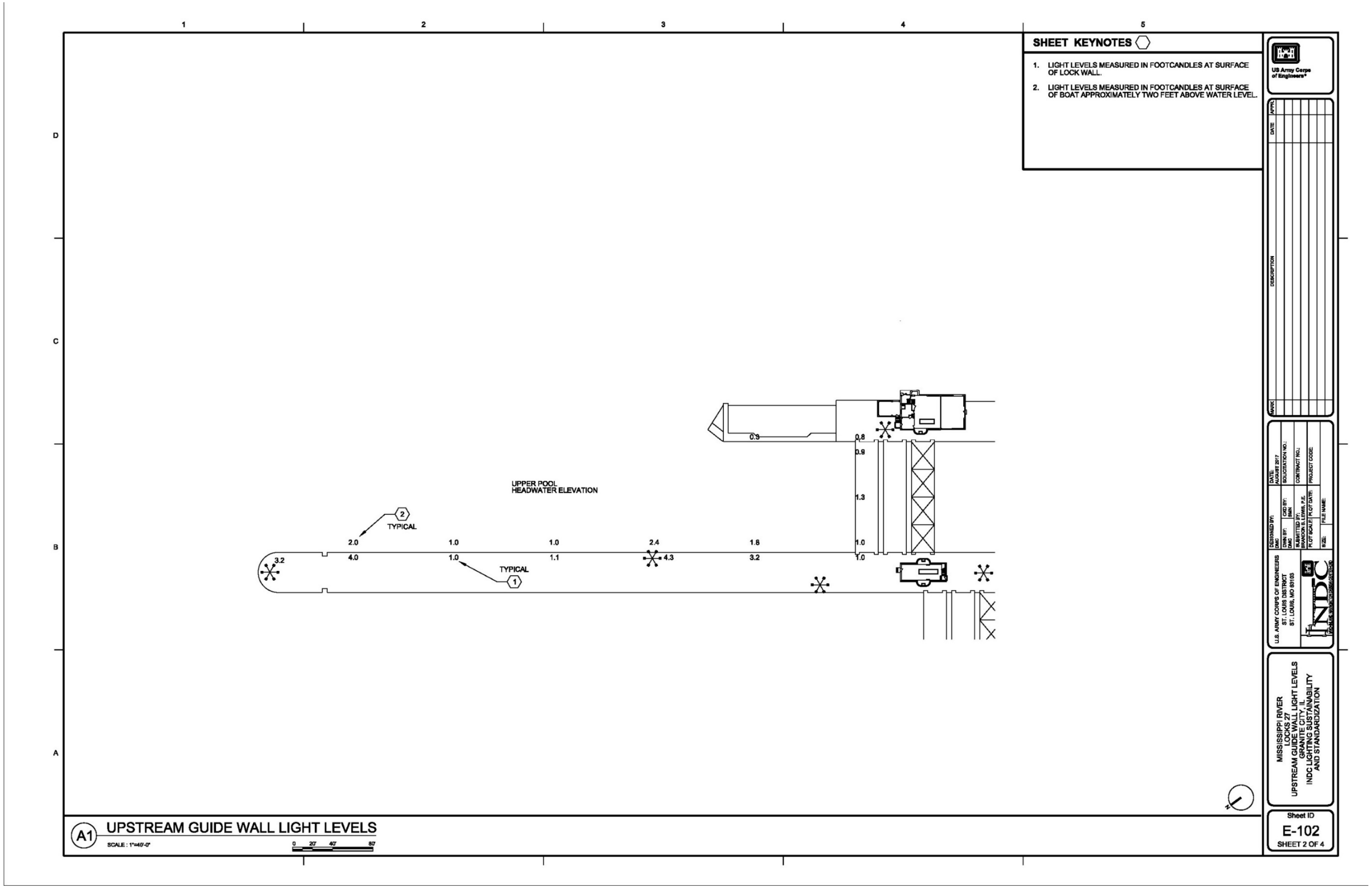


Figure 34. L27, light levels, Sheet 2.

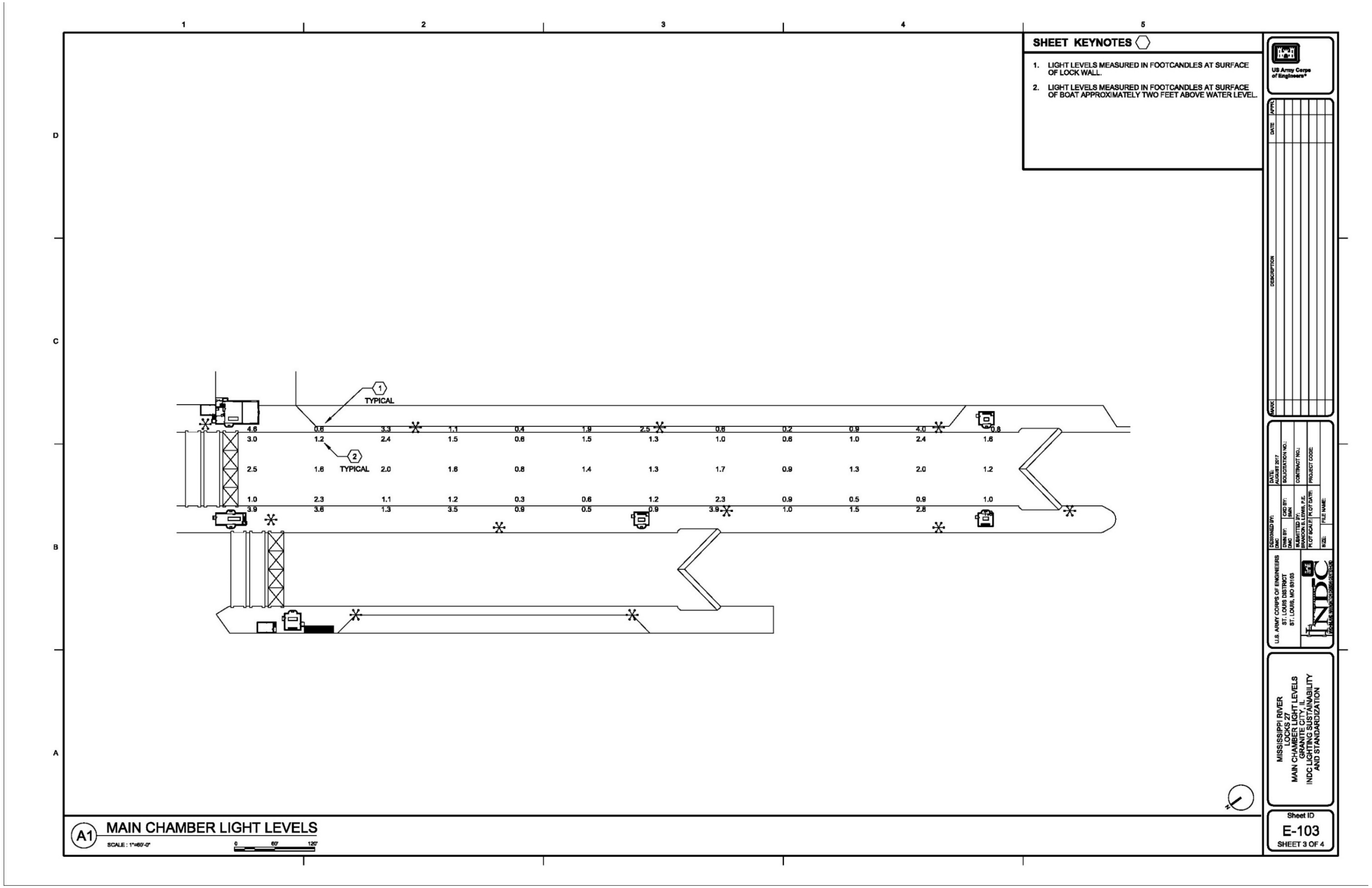


Figure 35. L27, light levels, Sheet 3.

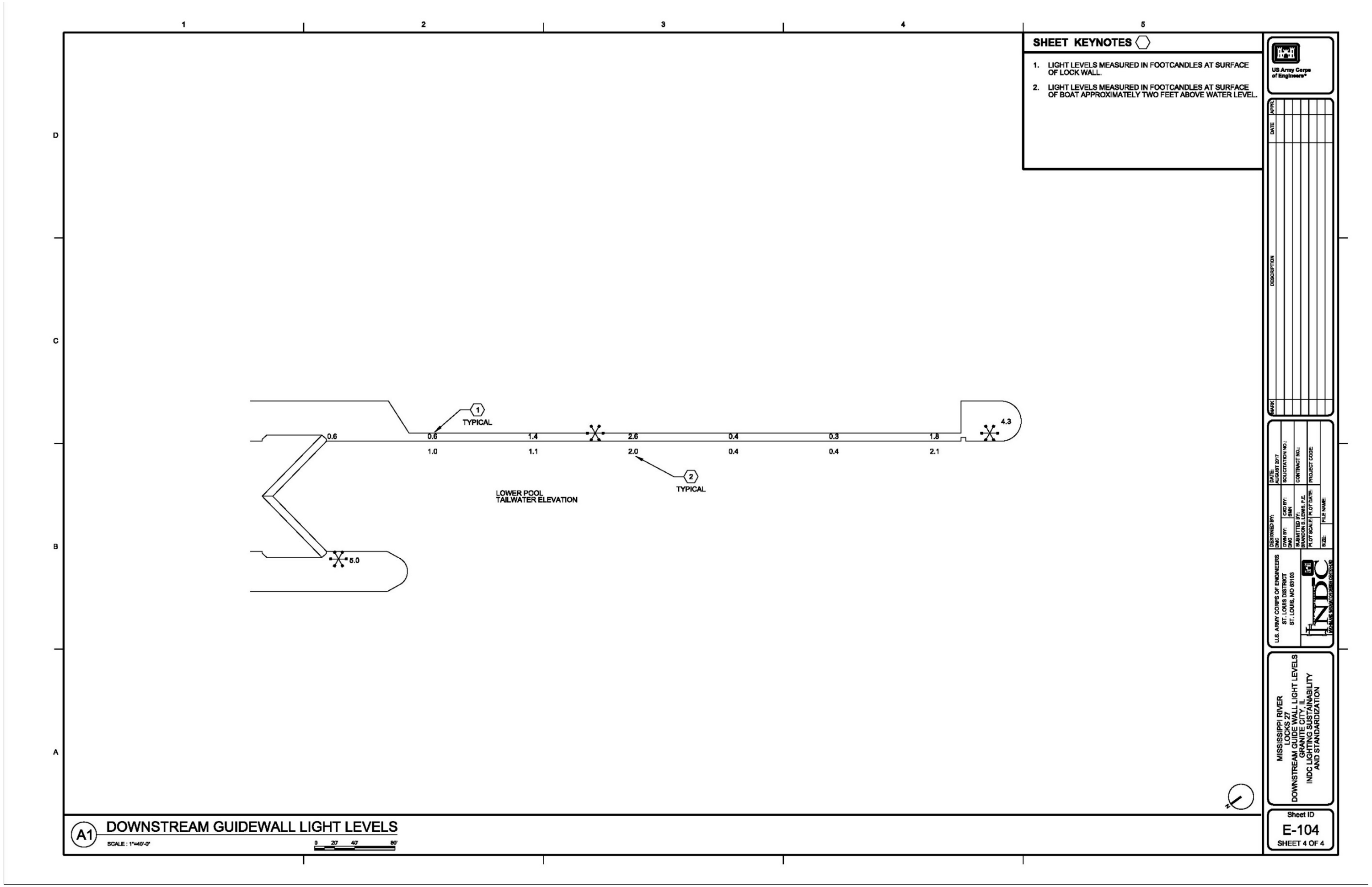


Figure 36. L27, light levels, Sheet 4.

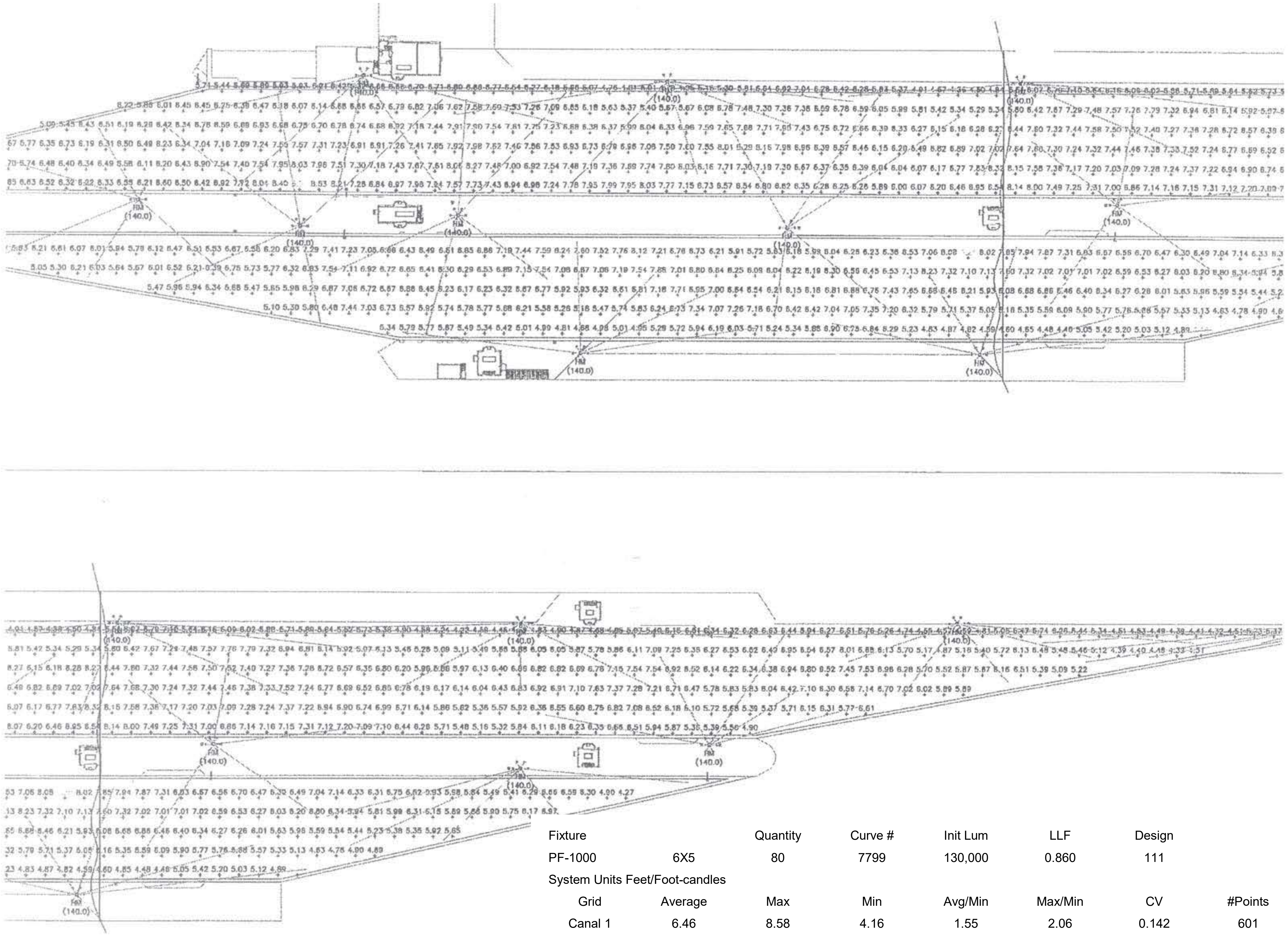
10.4 Mississippi River Locks No. 27, high mast lights, LED retrofit

The high mast lighting design shown in Figure 33 (p. 81) provides a total of 16, 80-ft high poles. The poles are spaced approximately 300-400 ft apart. The original HPS design shown in Figure 38 (p. 87) consisted of five 1000W fixtures for each pole. These fixtures have since been retrofitted with Global Tech GTSOL5498-GR-3XPLATE-340/480-HI-NL LED kits (Global Tech 2014b) for a total supply cost of $19,799. Each kit is comprised of three GTSOL5498 LED boards, which are 95W each for a total of 285W per fixture (compared to the 1000W HPS lamps). This results in an annual energy savings of $22,197 based on $0.0886/kWh at an annual usage of 4,380 hours per year. The LED boards or "pucks" are shown in Figure 37. Global Tech fabricates a custom mounting plate for an existing fixture.

Figure 37. Locks No. 27 fixture retrofit.

As can be seen from the above photographs, the existing fixtures installed at Locks No. 27 provide the ability to adjust or aim each fixture on the high mast light pole. This ability provides a much more even light distribution. The existing fixtures at Mississippi River Melvin Price Locks and Dam are traditional high-bay fixtures with large dome reflectors. Retrofitting these fixtures with LEDs places much of the light at the bottom of the pole. Replacing these fixtures with a yoke-mounted fixture could have provided an opportunity to more evenly distribute the light across the lock chamber.

The HPS lighting analysis included in Figure 38 shows an average of 6.46 fc with a maximum of 8.58 fc and minimum of 4.16 fc. Compared to the light levels measured in the field of the new LED retrofit system, the HPS numbers appear better. However, until the new LED system was installed boat crews would have difficulty seeing the feet signs while inside the chamber. Figures 39 through 42 (pp. 89-90) show the existing HPS fixtures and new LED lighting system. Compared with the HPS system at the Mississippi River Melvin Price Locks, the light level, uniformity, and color are all improved at Locks No. 27.



Fixture		Quantity	Curve #	Init Lum	LLF	Design	
PF-1000	6X5	80	7799	130,000	0.860	111	
System Units Feet/Foot-candles							
Grid	Average	Max	Min	Avg/Min	Max/Min	CV	#Points
Canal 1	6.46	8.58	4.16	1.55	2.06	0.142	601
Canal 2	6.25	8.25	4.16	1.50	1.98	0.128	316

Figure 38. L27, HPS lighting analysis.

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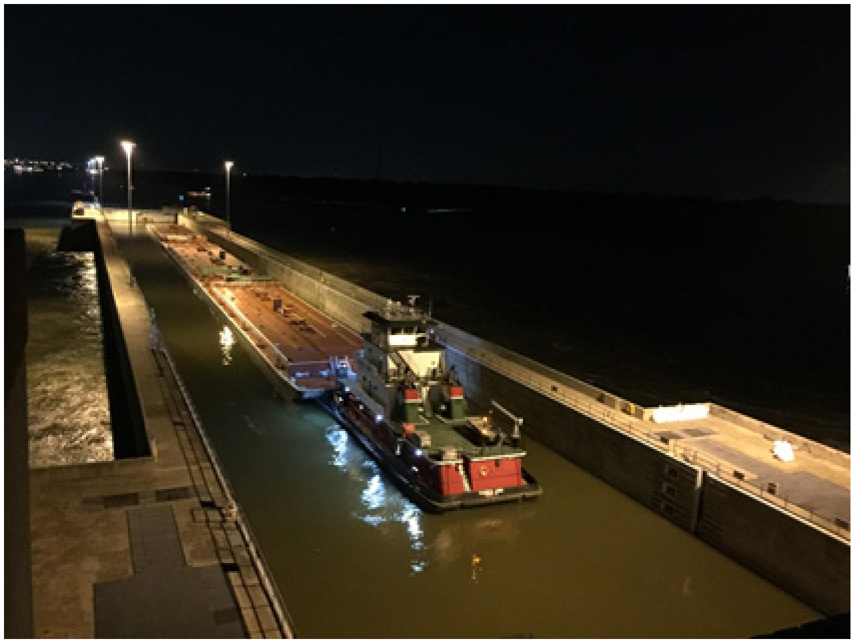

Figure 39. Mel Price, HPS lighting.

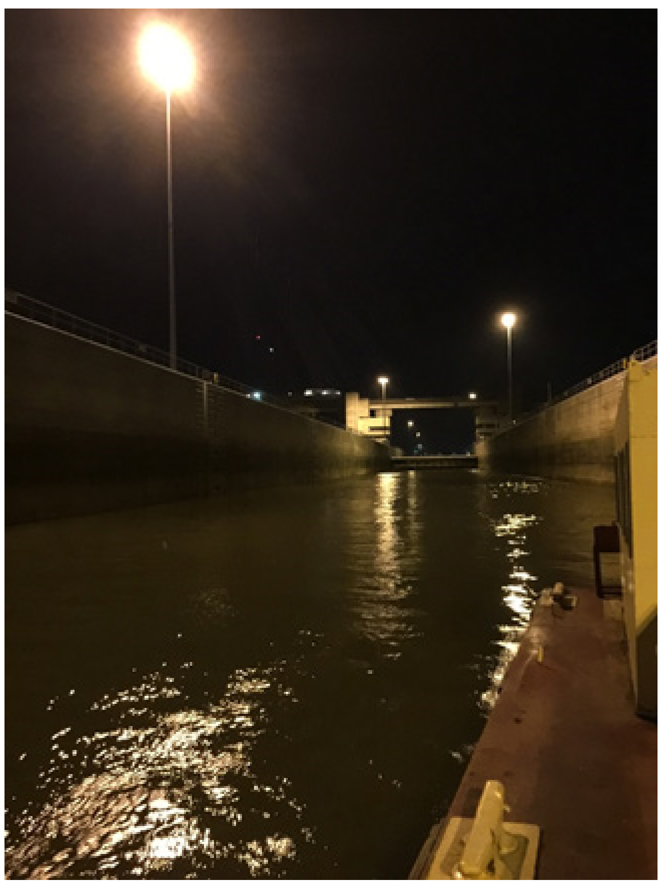

Figure 40. Mel Price, HPS lighting.

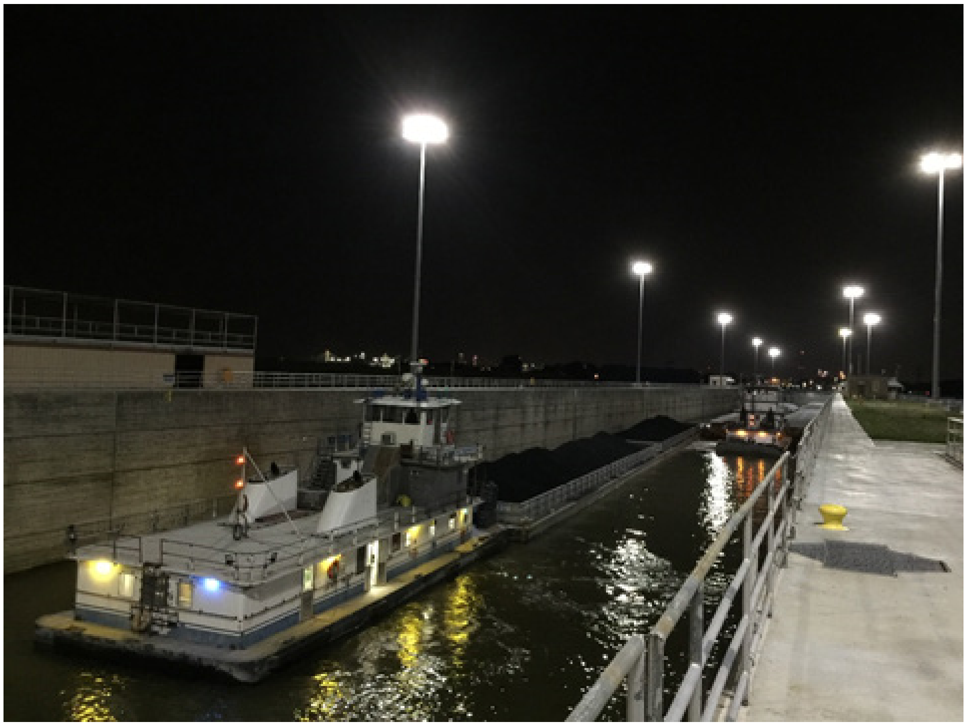

Figure 41. Locks No. 27, LED lighting.

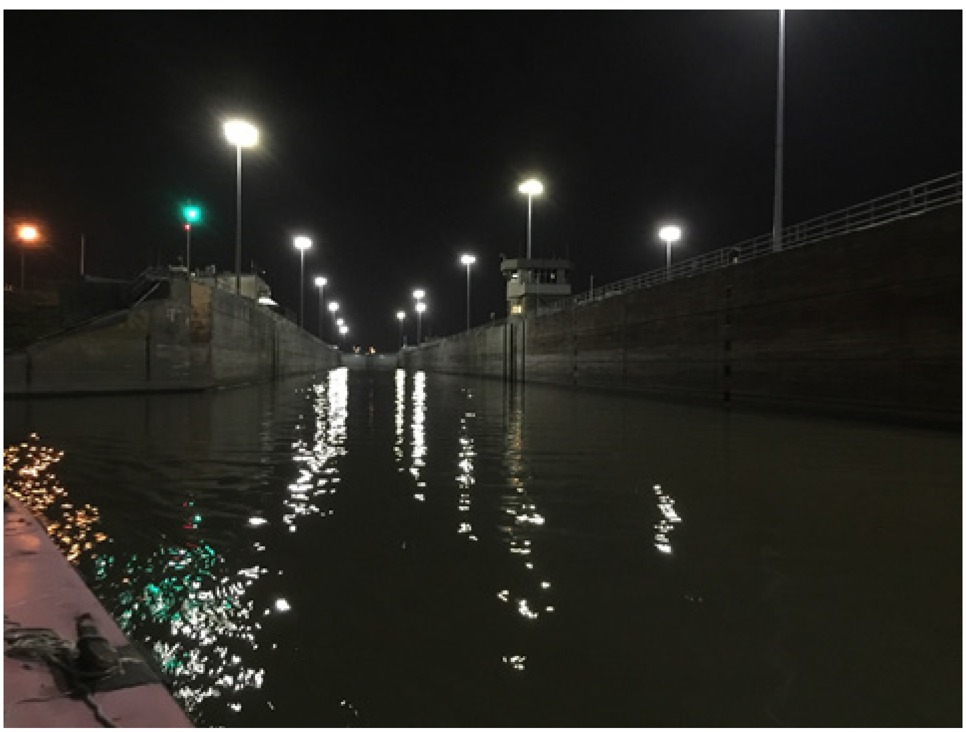

Figure 42. Locks No. 27, LED lighting.

11 Recommendations

11.1 General

The following recommendations will be brought to the attention of the proper USACE authority and direction will be sought to determine scheduling and funding for future development.

11.2 LED light fixtures for navigation locks and dams

It is recommended that LED light fixtures continue to be applied to new installations. Further, it is recommended that existing navigation lock and dam exterior HID light fixtures be retrofitted with the proper wattage and LED distribution pattern, LED light fixture replacement. LED light fixtures provide equal or better lighting with high energy savings and lower usage costs over the life of the fixtures. HID light fixtures are becoming more difficult to find in the marketplace and are being phased-out in lieu of solid state lighting alternatives, including LED light fixtures. It is recommended that USACE EM 1110-2-2610 be updated to include the use of solid state LED light fixtures specific to navigation lock and dams.

11.3 Computer software models

In all cases, whether new installation, retrofit, or replacement using new LED light fixtures, it is recommended that the respective District use an exterior lighting system modeling software program as a tool to identify the resultant point-by-point illumination, which determines the proper type of replacement LED light fixtures and ensures that the retrofits or replacement LED light fixtures provide adequate and expected illumination in locations on the top of the lock wall, along pathways, and in all working areas. Light modeling software may be provided by light fixture venders, or may be procured by the District.

11.4 Development of CAD details with integrated Unified Federal Guide Specifications (UFGS) style specifications for acceptable and recommended LED light fixtures for navigation locks and dams

It is recommended that CAD drawing details be developed for external light fixtures specific to navigation locks and dams. The CAD drawing details should contain standardized general details of acceptable, recommended LED light fixtures for exterior use at navigation locks and dams.

Brand names and model numbers should not be used. Details should be accompanied by the UFGS style, relevant characteristics of each respective LED light fixture. Such details should be similar to the light fixture details in USACE Standard CAD Detail Drawings available for use for all USACE projects (see Section 1.3, p 2).

11.5 Light levels

Navigation lock and dam light levels still need to be evaluated and determined by design engineers on a case-by-case basis until industry experts and users within USACE can reach a consensus. Based on a comparison of the design references and manuals in this report, light levels should be in a range that is close to 5 fc average with a Max:Min of 5:1 at the top of the lock wall and 2 fc average with a Max:Min of 5:1 at the lowest tailwater level. These values are preliminary recommendations that need further vetting, as a follow up to this report, by industry lighting experts and users with experience in lock and dam lighting.

11.6 Investigate St. Lawrence Seaway lighting policy

It is recommended that appropriate navigation lock and dam facility managers and/or lighting designers for the St. Lawrence Seaway navigation locks be contacted to determine their lighting policy. The St. Lawrence Seaway produced their lighting guide in the year 2010. They likely have historical experience and information regarding LED light fixtures from which USACE can learn.

11.7 Reference updates

Once minimum light levels and Max:Min ratios have been determined per the recommendation of Section 11.5, USACE EM 1110-2-2610 and UFC 3-530-01 should be updated to include those recommended light levels specific to navigation lock and dams. Additionally, EM 1110-2-2610 should be updated to state that all USACE navigation lock lighting requirements should be consistent with each other, rather than allowing USACE District navigation locks to have site-specific lighting requirements that depart from the standard. Chapter 5 of UFC 3-530-01 also needs to be updated to include the specific application of a Navigation lock and Dam with the recommended foot-candle values, similar in format to the other exterior lighting application examples shown in the reference.

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Acronyms and Abbreviations

Term	Definition
AC	Alternating Current
AFCESA	Air Force Civil Engineer Support Agency
ANSI	American National Standards Institute
ARRA	American Recovery and Reinvestment Act
ASTM	American Society for Testing and Materials
CAD	Computer-Aided Design
CCT	Correlated Color Temperature
CELRN	Corps of Engineers Nashville District
CEMVS	Corps of Engineers St. Louis District
CRI	Color Rendering Index
DC	Direct Current
DoD	U.S. Department of Defense
DOTS	USACE ERDC Dredging Operations Technical Support
EM	Engineer Manual
ERDC	U.S. Army Engineer Research and Development Center
HID	High Intensity Discharge
HML	High Mast Lighting
HPS	High-Pressure Sodium
HQUSACE	Headquarters, U.S. Army Corps of Engineers
IES	Illuminating Engineering Society of North America
IESNA	Illuminating Engineering Society of North America
INDC	Inland Navigation Design Center
INDC-MCX	Inland Navigation Design Center Mandatory Center of Expertise
ITT	Information, Tickets, and Tours Offices
L&D	Lock and Dam
LED	Light Emitting Diode
LM/W	Low Lumen per Watt
MH	Metal Halide
MLO	Model Lighting Ordinance
NEMA	National Electrical Manufacturers Association
O&M	Operations and Maintenance
OPM	Operations Project Manager
PDF	Portable Document Format
ROI	Return on Investment
SI	Systeme Internationale
SLSLDG	St. Lawrence Seaway Lighting Design Guide (SLSLDG)
SMT	Surface mounted technology
TM	Technical Memorandum

Term	Definition
TR	Technical Report
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriters Laboratories
USACE	U.S. Army Corps of Engineers
VAC	Volt AC