

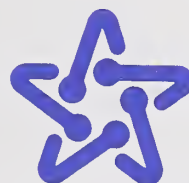
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# **TIVENESS OF HIGHWAY ARTERIAL LIGHTING**

## **Design Guide**

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**July 1977**

**Final Report**

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**Prepared for**

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| 16. Abstract<br>This research was undertaken to evaluate the cost-benefits of arterial lighting treatments in terms of traffic safety and energy use. As a result, a Design Guide has been developed to assist potential users in conducting cost-benefit analyses of lighting changes at specific locations. This Design Guide provides instructions for using a computer program to determine visibility on arterial streets and a method for conducting a cost-benefit analysis of new and upgraded lighting systems.<br><br>In addition to this Design Guide, a Final Report (FHWA-RD-77-37) has been prepared to summarize the results of this research. The results have shown that arterial streets with high population density, in CBD areas, with low visibility have higher accident potential than arterial streets with low population density, in other areas with high visibility. Regression equations have been developed which predict dry, nighttime accident potential based on population density, area type and visibility. In addition, the results have also shown that more cost beneficial lighting systems can be designed using HPS rather than Mercury luminaires. |                                                      |                                                                                                                                                                              |           |
| 17. Key Words<br>Lighting, Illumination, Luminance<br>Visibility, Photometrics, Traffic<br>Accidents, Economics, Cost/Benefits.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                      | 18. Distribution Statement<br>No restrictions. This document is<br>available to the public through the<br>National Technical Information Services,<br>Springfield, Va. 22161 |           |
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## PREFACE

The investigations described in this report were conducted by the Transportation Sciences Laboratory of the Franklin Institute Research Laboratories (FIRL) under Federal Highway Administration (FHWA) contract FH-11-8825. Mr. Michael S. Janoff was the Principal Investigator for FIRL, Messrs. Richard Schwab and Paul McMahon were the Program Managers for FHWA. Ms. Shelley Launey was Program Manager for FEA.

This report in two volumes describes all of the work accomplished during the research contract. The first volume includes the following:

- A literature review covering modern lighting methods, the energy use, costs and benefits of lighting and the relationships between lighting and visibility, traffic operations, safety and crime.
- The design of instrumentation to automatically record visibility data.
- The selection of test sites, field visibility measurements at these sites and determination of accident histories at these sites.
- The analysis of accident and visibility data to develop statistical relationships between visibility and accidents.
- The development of a computer program which can (1) predict visibility based on lighting and road geometry, pavement reflectance characteristics and luminaire distributions and (2) be employed as a user oriented package for designing new lighting systems or upgrading existing systems on arterial streets.
- The development of lighting system costs for modern designs.
- The development of an economic analysis methodology for selecting new or upgraded lighting systems on arterial streets.
- The development of an optimization process which considers costs, energy use, accident or visibility improvements and design limitations as constraints in the selection of new or upgraded lighting systems for arterial streets.



- The determination of the effect of reduced or more efficient use of electric power on visibility and accidents.

The present volume contains a Design Guide which provides the lighting or traffic engineer with a handbook for:

- (1) exercising the VI prediction computer program
- (2) use of the economic/optimization process to design new or upgrade existing arterial lighting systems in urban or suburban areas.

The authors wish to thank the Philadelphia, Chester and Cheltenham township police departments for their cooperation in conducting the experiments and in addition to the above, the Philadelphia Streets Department for helping us obtain all necessary accident data. We also wish to thank Dr. Alan Sockloff, Temple University for his help in performing all the facets of the statistical analyses.

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## 1. INTRODUCTION AND BACKGROUND

The overall objective of this research was to evaluate the cost effectiveness of several selected urban and suburban highway arterial lighting treatments. Benefits evaluated included those associated with traffic safety and traffic operations. Costs included monies associated with initial installation, conversion of luminaire types, energy usage and maintenance of various lighting treatments. Figure 1 presents an overview of the research program.

### 1.1 OBJECTIVES

The program was divided into several interrelated parts, and included the following tasks:

1. Reviewed, assimilated and critically evaluated the available literature on highway arterial lighting. These included: Roadway lighting methods and specifications; roadway lighting costs, the relationship between roadway lighting and traffic operations, crime and visibility, targets for visibility studies and photometric measurement parameters, and the energy used by roadway lighting systems.
2. Developed a computer program for predicting the level of visibility provided by fixed highway illumination systems.
3. Selected test sites at which visibility was measured. These sites included examples ranging from best to worst of various illumination levels, light sources, configurations, locations, traffic and pedestrian volumes and roadway configurations. Of primary importance was both an estimate of visibility level (based on lighting and roadway geometry) and night-time accident experiences. The sites selected had at least one years' accident data and included examples ranging from high to low population densities in 3 neighborhood types (Central Business District, Outlying Business District and Residential Fringe).
4. Designed apparatus and developed a methodology for field measurement of the visibility provided by highway arterial lighting systems. Including: illumination, luminance, static and dynamic visibility and their distributions.
5. Collected and analyzed the data to relate visibility variables to nighttime accident history variables.

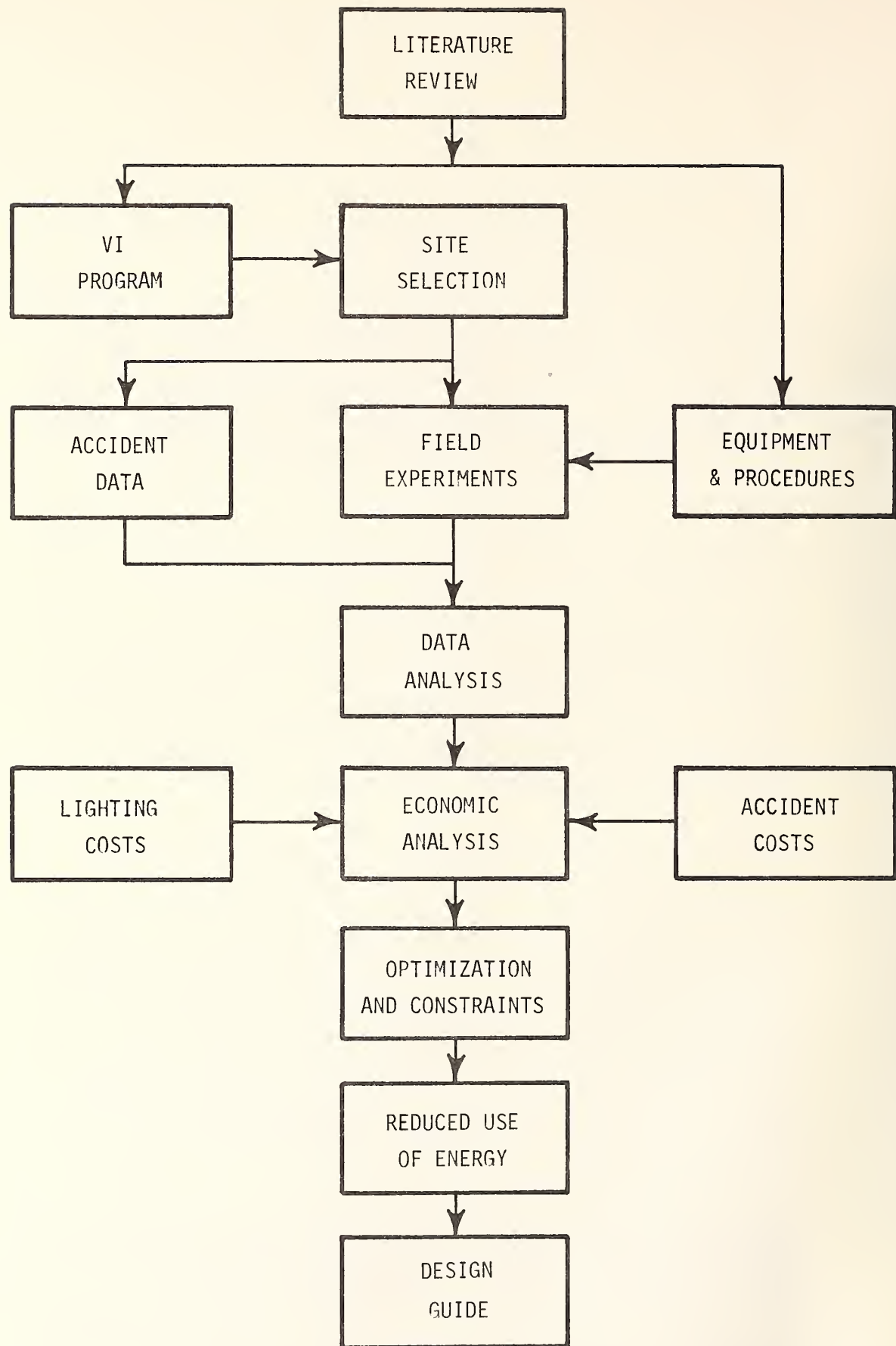


Figure 1. Overview of Research Program

6. Determined typical costs of modern arterial lighting systems - including capital, depreciation, installation, maintenance and operation (energy).
7. Developed a method of economic analysis for determining the effectiveness of arterial lighting systems based on the costs, projected accident reduction, benefit/cost ratios and other traffic flow or esthetic benefits.
8. Developed a method for determining economic/energy tradeoffs in upgrading existing systems to more effective ones - including upgrade costs, energy use (changes), benefit/cost ratios and visibility (changes).
9. Developed a method for determining optimum lighting system designs based on visibility, cost, lighting design and energy constraints.
10. Determined the impact on traffic safety of more efficient or reduced use of electricity for fixed illumination.
11. Developed a practical Design Guide which will assist traffic engineers and highway designers in designing new or upgrading existing lighting systems.

This volume contains the report on Task 11. The remainder of the tasks are covered in a separate Final Report (FHWA-RD-77-37).

## 1.2 BACKGROUND

Before reporting on the results of this program, it will be necessary to review two items which are fundamental to the understanding of the research. The first is the concept of visibility and the visibility metric derived by FIRL in past research (1), while the second is a computer program developed under this contract to predict visibility based on lighting design parameters, road geometry and pavement surface reflectance characteristics.

### 1.2.1 Visibility\*

Roadway lighting specifications are typically given as units of average flux with limits on uniformity or dispersion. Warrants are typically related to traffic, geometric and road-use conditions. The specification of lighting has undergone a long history of debate, especially as attempts are made to provide international standards. While there is much disagreement about the efficacy of certain of the warranting criteria, these criteria are generally recognized as being open for discussion and compromise. The fundamental source of disagreement is the

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\* See Reference (1) for more complete discussion of this topic.

question of flux units. Many groups responsible for setting such standards have expressed these requirements in terms of pavement luminance. Since the eye requires reflected light for the detection of objects in space, this approach is clearly related to the needs of drivers. While most scientific studies on the visual requirements of drivers have dealt in similar terms, luminance units present a complex dilemma. The basic problem is that pavement luminance is not yet easily predictable from knowledge of the distribution of flux output by the various luminaires. This is primarily due to the less-than-uniform diffusion of light reflected off paving surfaces.

The human visual-perception mechanism responds subtly to small differences in luminance intensity and exposure duration. It is fundamental that the limitations of this information-processing system must be considered in the context of the human operation under study. It is necessary, therefore, to address this problem in terms of driver information and visibility needs.

In order to determine motorists' visibility needs for the task of detecting an obstacle in the roadways, rigid control of the independent variable (visibility) is required. In addition, a precise method of measuring the responses of a large unbiased sample of motorists is essential.

FIRL developed and installed a variable intensity lighting system on an actual city street in South Philadelphia. The visibility was thus rigidly controllable over an extremely wide range(2).

Field experiments were designed and conducted at this location to determine the time-separation gap at which unalerted motorists responded evasively to a visual problem of known photometric characteristics. The basic hypothesis governing this research was that the time-separation gap characterizing the responses to low visibility targets should be highly constrained and thereby correspondingly shorter than the gap characterizing the responses to a target of higher visibility.

A method of monitoring the vehicle velocity and location was devised that permitted precise tracking of unsuspecting motorists' responses to the visual problem. The responses of over 1300 unalerted drivers under 23 conditions of task visibility were monitored and recorded electronically. The basic performance measure was target intercept time (termed Time-to-Target). This is the time-separation between vehicle and target at the point of an evasive maneuver. Figure 2 illustrates the relationship.



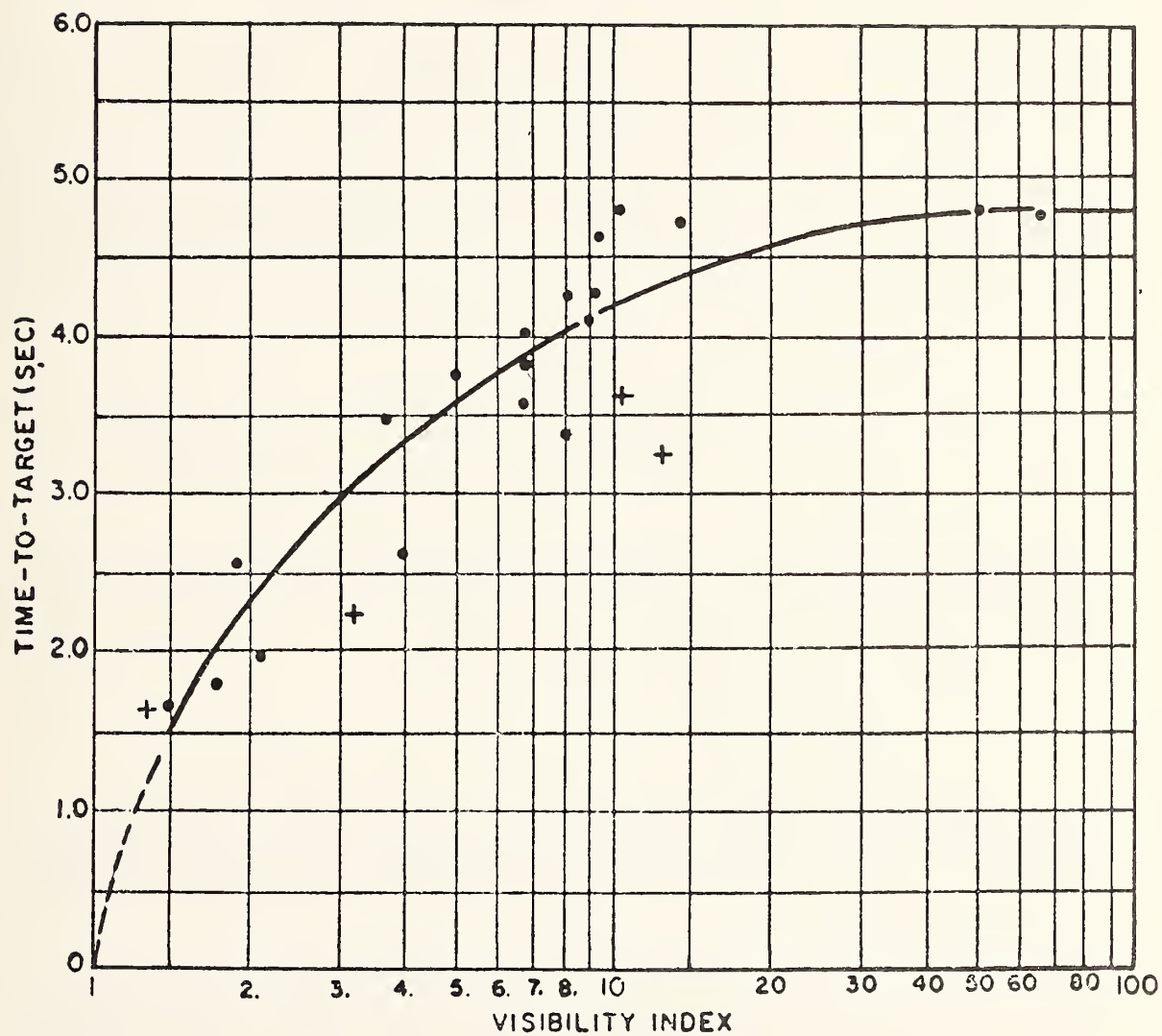


Figure 2. Regression Line for Mean Driver Responses (Raw Data) and Visibility Index



The Visibility Index used as a measure of task visibility is determined by the following expression:

$$VI = C(RCS_{Lb}) \times DGF$$

where  $C = \text{Physical contrast} = \frac{Lt - Lb}{Lb}$

$Lt = \text{Target Luminance}; Lb = \text{Background luminance}$

where  $C = \text{Physical contrast} = \frac{\Delta L}{Lb}$

$RCS_{Lb} = \text{Relative contrast sensitivity for drivers adapted to a luminance level equal to } Lb.$

$DGF = \text{Disability glare factor}$

$$= \frac{Lb}{Lb'} \times \frac{RCS_{Lb'}}{RCS_{Lb}}$$

where  $Lb' = \text{Background luminance (Lb) plus veiling luminance (Lv) divided by a correction for sphere base glare.}$

The major finding was that drivers' responses to a target, photometrically quantified by the metric described, were predicted with a high degree of accuracy.

## 1.2.2 Visibility Prediction Computer Program

### 1.2.2.1 Program Description

The computer program, known as "VI", was originally developed to assist in the evaluation of existing roadway lighting systems on straight roadway sections. The program has undergone several stages of refinement and presently is capable of both evaluation and design of roadway lighting systems.

The VI program calculates horizontal and vertical illumination, ( $E_h$  and  $E_v$ ) and the luminance of a target ( $L_t$ ) of user specified reflectance, at each point in a roadway grid defined between two adjacent luminaires and both curb lines. For each target point, a driver's position upstream and a background area downstream are defined. Background luminance ( $L_b$ ) of the roadway area which lies behind the target from a driver's line of sight, and veiling luminance ( $L_v$ ) produced by each luminaire downstream of the driver are computed for each grid point. The luminance contrast ( $C$ ), relative contrast sensitivity of the eye to background luminance ( $RCS_{Lb}$ ), relative contrast sensitivity to background plus veiling luminance ( $RCS_{Lb'}$ ) a disability glare factor ( $DGF$ ) and Visibility Index ( $VI$ ) are calculated for the simulated driver that is

associated with each grid point. The mean, standard deviation and 15th percentile values of the grid array of each of these parameters may also be calculated as an option.

Output may be in either U.S. customary or S.I. units, depending upon input units.

The program may be employed to evaluate existing roadway lighting designs using the conventional parameters of illumination and roadway luminance and more significantly, by using the visual performance measures of glare, contrast and Visibility Index. This is the most direct application of the program. The user must specify the directional candlepower distribution of the luminaire in question, the directional reflectance distribution of the pavement and roadway and lighting system dimensions and arrangement characteristics. The relationship of these data to program operations are shown as Inputs (1.) and (2.) in Figure 3. The user may select or suppress the printing of the arrays and/or statistical summaries of any of the calculation parameters by specifying certain output option codes, identified in Input (3.) in Figure 3.

The program may be used as a design tool as well. For any combination of a particular luminance, roadway surface and roadway geometry (width, curb height, crown slope, etc.), the user may indicate a range for variation of system configuration, overhang, spacing and mounting height in Input (3.). The design option program will then generate all system combinations within those ranges and identify each of the design configurations, and their associated photometric and performance measure arrays.

#### 1.2.2.2 Program Operation

The program operates as a series of loops following the input and storage of a luminaire candlepower distribution table and a roadway directional reflectance table. In the Analysis version, the outermost loop takes successive cases from Input (2.) and Input (3.) data. For each case, the program calculates and stores an array of location coordinates for each luminaire in the system. The next inner loop defines a roadway grid, and identifies a driver, target and background location for each grid point. The innermost loop examines each location, one at a time, and calculates and sums the contribution to  $E_h$ ,  $E_v$ ,  $L_t$ ,  $L_b$ ,  $L_b'$  and  $L_v$  from each luminaire in the system. When the innermost loop is exited,  $RCSL_b$ ,  $RCSL_b'$ ,  $DGF$ ,  $C$  and  $VI$  are calculated and stored for each grid point. When the middle loop is exited, all grid points have been considered and output may be printed. Then, a new case may be read in. The design program works the same way, except that new cases are generated internally as incremental steps of overhang, mounting height, and spacing, and variations in arrangement (single side, both sides-staggered both sides-opposite) and sidedness (near, far, both).

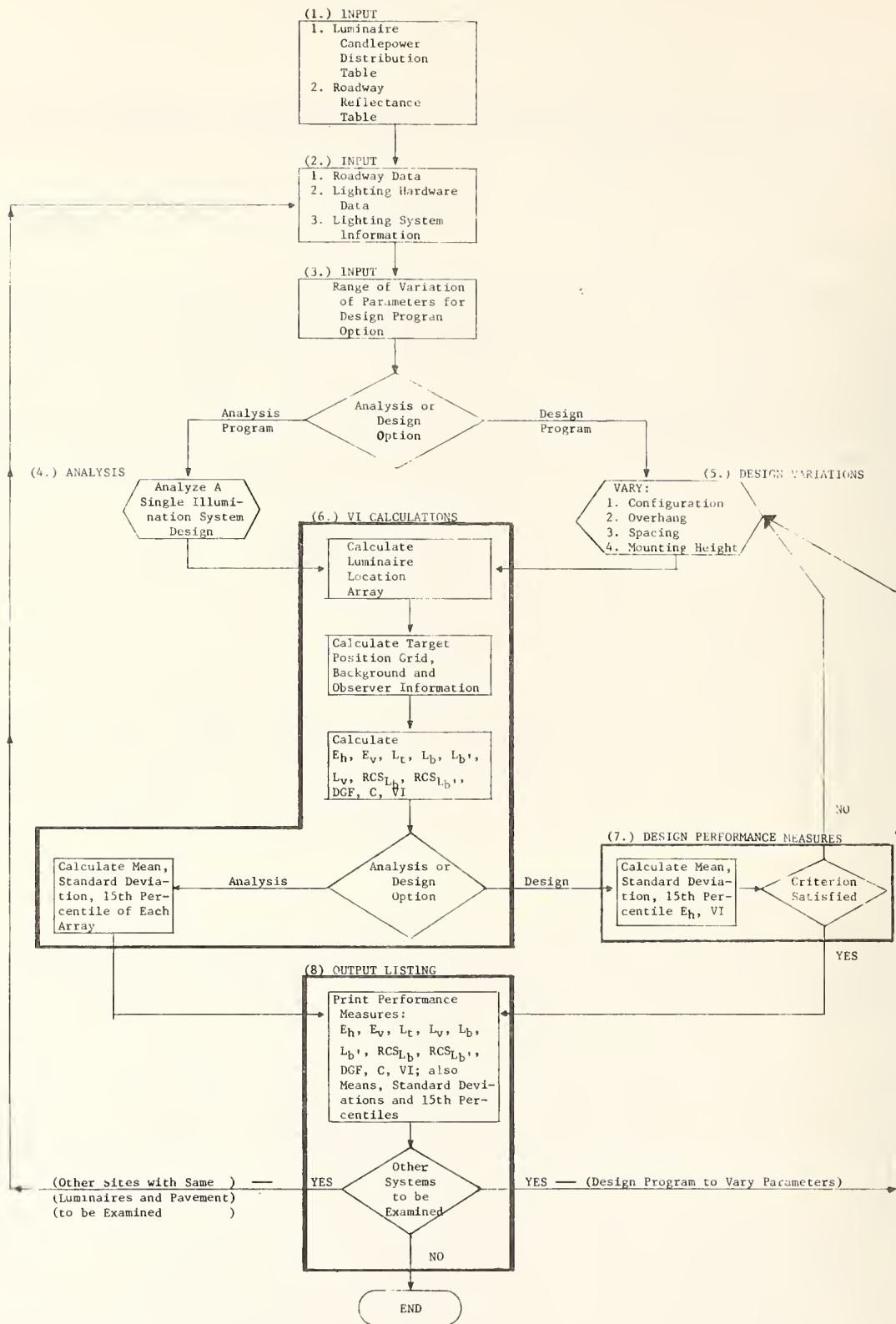


Figure 3. Block Diagram of VI Program

The program is organized as a main program, in which the photometric and performance parameters are calculated and five subroutines. The subroutines perform the functions of interpolation for candlepower and roadway reflectance, statistical calculations for mean, standard deviation and 15th percentile, output, and dump for in-depth analysis and debugging.

#### 1.2.2.3 Validation

The computer program was validated by comparison with field measurements taken on the 7th Street Lighting Test facility in Philadelphia(2). This facility is an isolated city block on which the input voltage, arrangement and sidedness of the lighted luminaires may be varied. Photometric measurements of Lt, Lb, Lv and Eh were conducted for three lighting configurations, using freshly cleaned Westinghouse OV 25 luminaires with clear mercury lamps. The configurations were:

1. 111 ft. (33.84m) spacing, both sides, opposite
2. 111 ft. (33.84m) spacing, single side, near
3. 222 ft. (67.68m) spacing, single side, near

A sample of the roadway surface was shipped to the Transport and Road Research Laboratory, Crowthorne, Berkshire, U.K., where the sample was goniometered and a table of directional reflectance factors were produced.

Comparison of computer predicted to measured parameters indicated acceptable levels of error, averaging 11% for Lt, 7% for Lb, and 12% for Lv.

The report on the research is organized into two main volumes: a final report (FHWA-RD-77-37) covering all research conducted and this volume, a Design Guide (FHWA-RD-77-38), which is provided as a self contained document, and which describes the use of the VI program and the methodology for selecting lighting on arterial streets.

This Design Guide has been developed for the engineer who is faced with the responsibility of designing new, or upgrading existing lighting systems on urban arterial streets. It provides a methodology for selecting cost-effective lighting designs and contains considerations of economic, energy, accident and design constraints that may limit the user's selection of optimal lighting designs.

This guide is structured into three distinct parts

1. Directions for use of the VI computer program.
2. Methodology for selecting lighting systems for new or unlit roadways.
3. Methodology for upgrading existing lighting systems.



## 2.0 DESCRIPTION OF VI PREDICTION PROGRAM

The computer program package which has been developed applies the concept of luminance to predict Visibility Index on arterial roadways as defined by Gallagher (1,2). In addition, the program calculates horizontal illumination (Eh), vertical illumination (Ev), target luminance (Lt), background luminance (Lb), relative contrast sensitivity (RCSLb and RCSLb'), veiling luminance (Lv), and disability glare factor (DGF). The program can print out the values of each of these parameters for each point on a user specified grid defined within one luminaire cycle. A summary for each parameter which includes mean, standard deviation, 15th percentile VI, and three measures of uniformity (max/min, max/avg, avg/min) is also printed for all grid points not located on either curb line or the centerline of two-way streets.\*

Two options are open to the user within the structure of the VI program.

- An 'analysis' package which provides the user with a method of judging the effectiveness of the existing lighting conditions of the arterial of interest. Under this option all existing lighting hardware and roadway conditions are specified by the user and are input into the program as a single case for each arterial under consideration. The user may direct that any or all of the eleven possible output parameters are printed, which provides the user with the data to evaluate the system under consideration.
- A 'design' package which provides the user with a technique for searching out the most cost effective new system, or evaluating various upgrading options. The user specifies an initial design case, and lets the program manipulate the variables to seek out improved alternatives. The user may specify any value for VII5 as the lower bound visibility condition. The computer program uses this criterion to report only new design alternatives which meet or exceed that pre-specified visibility level.

### 2.1 INPUT REQUIREMENTS

The user is required to provide three basic sets of input information. These include a set of data cards which specifies the candlepower distribution of the particular luminaire/lamp combination in question, a set of data cards which specifies the directional reflectance factors

\* A copy of the VI program is on file at FHWA and at FTRL. Copies may be obtained by writing Richard N. Schwab, Environmental Design and Control Division, Federal Highway Administration, HRS-42, Washington, D.C. 20590.

of the particular roadway surface, and finally a set of four cards which identify the specific physical details of each site which will be analyzed.

The first set of data cards, for the candlepower distribution, is derived from luminaire manufacturers' specifications or goniometric testing. The data contain a value of the luminaire's candlepower at each combination of 11 vertical angles from 0 degrees (nadir) to 90 degrees (horizontal), and 21 azimuth angles from 0° (perpendicular to curbline) to 180°. The vertical angles are 0, 5, 15, 25, 35, 45, 55, 65, 75, 85 and 90 degrees. The horizontal angles are 0, 5, 15, 25, 35, 45, 55, 65, 75, 85, 90, 95, 105, 115, 125, 135, 145, 155, 165, 175 and 180 degrees.\* Decks of this type of data currently exist for a number of lamp sources (175M, 400M, 150HPS, 400HPS). Data is available for many more.

The second set of data cards, for the directional pavement reflectance values, are derived from photometric measurements of the reflective characteristics of various pavement samples.+ In essence, this table provides the factor by which the horizontal illumination from each light source which contributes to the illumination at a point on the roadway must be multiplied to determine the luminance of that roadway point as seen by a driver. A directional reflectance factor is required for each intersection of 15 vertical angles (0, 10, 20, 35, 50, 60, 65, 70, 75, 80, 82, 84, 86, 88, 90 degrees) and 37 horizontal angles (0 to 180 degrees at 5 degree increments). Twelve sets of data cards, representing various types and conditions of pavement, are presently available.

The third input requirement is a set of four cards containing the following information:

| CARD 1. Fixed roadway information: | Field Length | Card Cols |
|------------------------------------|--------------|-----------|
| • Location of study site           | 10A5         | 1-50      |
| • Road width                       | F5.0         | 51-55     |
| • Lane width                       | F4.0         | 56-59     |
| • Observer to target distance      | F7.2         | 60-66     |
| • Crown slope                      | F6.4         | 67-72     |
| • Curb height                      | F4.2         | 73-76     |

\* Other increments could be incorporated into the program with a minimum of programming effort.

+ A complete description of the derivation and measurement procedure for directional reflectance factors may be found in Reference 3.



CARD 2. System hardware and configuration data

|                                                          |      |       |
|----------------------------------------------------------|------|-------|
| ● Mounting height                                        | F5.1 | 1-5   |
| ● Spacing                                                | F5.0 | 6-10  |
| ● Mast arm length                                        | F5.1 | 11-15 |
| ● Pole setback                                           | F5.1 | 16-20 |
| ● Luminaire type                                         | I5   | 21-25 |
| ● Sideness (near, far, both)                             | I2   | 26-47 |
| ● Arrangement(single side, both opposite both staggered) | I2   | 28-29 |
| ● Offset distance for staggered arrangement              | F6.1 | 30-35 |
| ● Target height                                          | F5.2 | 36-40 |
| ● Observer height                                        | F5.2 | 41-45 |
| ● Payment surface type                                   | I5   | 46-50 |
| ● Direction of traffic operation (one-way, two-way)      | I2   | 51-52 |

CARD 3. Variable calculation parameters

|                                                                                       | Field Length | Card Columns |
|---------------------------------------------------------------------------------------|--------------|--------------|
| ● Number of cycles to be considered                                                   | I5           | 1-5          |
| ● Number of upstream cycles                                                           | I5           | 6-10         |
| ● Number of downstream cycles                                                         | I5           | 11-15        |
| ● Number of reference luminare                                                        | I5           | 16-20        |
| ● Candlepower distribution correction factor(lamp life,dirt depreciation, maintenance | F6.2         | 21-26        |
| ● Directional reflectance correction factor(empirically determined)                   | F6.2         | 27.32        |
| ● Average target reflectance                                                          | F7.2         | 33-39        |
| ● 11 Selective printout codes                                                         | I-12         | 40-61        |
| ● Number of longitudinal roadway lines from curb to curb                              | I3           | 62-64        |
| ● Number of transverse roadway lines in the cycle                                     | I3           | 65-67        |

| CARD 4. Option 2, specified loop parameters and minimum VI <sub>15</sub> | FIELD LENGTH | CARD COLUMNS |
|--------------------------------------------------------------------------|--------------|--------------|
| ● Option code                                                            | I1           | 1            |
| ● Lower bound(loop index) on mounting height                             | I4           | 2-5          |
| ● Upper bound(loop index) on mounting height                             | I4           | 6-9          |
| ● Increment of mounting height                                           | I4           | 10-13        |
| ● Lower bound(loop index) on spacing                                     | I4           | 14-17        |
| ● Upper bound(loop index) on spacing                                     | I4           | 18-21        |
| ● Increment on spacing                                                   | I4           | 22-25        |
| ● Lower bound(loop index) on mast arm length                             | I4           | 26-29        |
| ● Upper bound(loop index) on mast arm length                             | I4           | 30-33        |
| ● Increment of mast arm length                                           | I4           | 34-37        |
| ● Minimum VI <sub>15</sub>                                               | F8.3         | 38-45        |
| ● 5 Selective configuration codes                                        | 5I3          | 46-60        |

## 2.2 INPUT DEFINITIONS

Card 1:

- Study site - any descriptive title may be specified for the particular site
- Road Width - in feet\*
- Lane Width - in feet
- Observer to target distance in feet. Standard 271.8 ft. (82.9m) is suggested based upon a driver whose eye level is 4.75 ft. (1.45m) above the roadway and whose line of sight is 1° below horizontal
- Crown slope - no units, ratio of the difference in elevation of the road surface at the curb and at the crown or center line, to the distance from curb to center line - may be estimated at 1/8 inch per foot (1cm per meter) = .0104

---

\* All units can be in U.S. Customary or SI, as long as the user is consistent.

- Curb height - in feet; may be estimated at 0.5 ft. (0.15m) for most urban streets

Card 2:

- Mounting height - distance from base of pole to luminaire height in feet
- Spacing - distance between two luminaires on the same side of the street, in feet
- Mast arm length - distance from center of pole to center of lamp in luminaire, in feet
- Pole Setback - distance from curb to center line of pole, in feet
- Luminaire type - a one digit code which identifies the luminaire type, code numbers defined by user
- Sidedness - the codes are defined at  
1 = far side, left hand side of roadway in relation to the direction of travel  
2 = near side, right hand side  
3 = both
- Arrangement - the codes are  
1 = single side  
2 - both opposite  
3 - both staggered
- Offset distance for staggered arrangement - longitudinal distance between a luminaire on one side of the roadway and the next luminaire on the opposite side of the roadway
- Target height - height, in feet, of center of target (0.25 ft. (0.08m) for spherical target for which VI is defined)
- Observer height - height, in feet, of observer (4.75 ft. (1.45m) is defined as driver eye height)
- Pavement surface type - a user specified code number identifying pavement type
- Direction of traffic - the codes are:  
1 = one way  
2 = two way

Card 3:

- Number of cycles to be considered - total number of luminaire cycles over which analysis is to be performed - 10 is usually sufficient for good accuracy. A luminaire cycle is defined as the smallest integral combination of luminaires (on one or both sides of a street) which establishes a repetitious pattern of luminaire placement. For example, in a street which has all luminaires on one side of the roadway, the total number of cycles is equal to the number of luminaires minus one ( $N-1$ ). From a point located at the same longitudinal location as one of the

luminaires, chosen for reference, there would be the same number of upstream and downstream cycles as upstream and downstream luminaires, respectively. On a street with luminaires located in a staggered arrangement on both sides of the street, a cycle is defined as the reoccurrence of a luminaire on the same side of the street as the reference luminaire from which cycles are counted.

- Number of upstream cycles - the number of cycles upstream from the luminaire which is chosen as the reference luminaire - three is usually sufficient. The upstream direction is always from the target to the observer, regardless of whether the street is one-way or two-way. On a two-way street, the upstream direction is defined opposite to the direction of travel of vehicles on the side of the street which is undergoing analysis.\*
- Number of downstream cycles - the number of cycles downstream from the reference luminaire. Seven is usually sufficient.
- Number of the reference luminaire - the sequence number assigned to the reference luminaire. Sequence is counted from upstream to downstream. This number is equal to the number of upstream cycles plus one.
- Candlepower distribution correction factor - a single number, less than one, which accounts for reduction in lumen output due to lamp life, dirt depreciation, maintenance, etc.
- Directional reflectance correction factor - a factor which is empirically determined - for FIRL sample pavement it may be set equal to 2.8. Must be determined for other surfaces.
- Average Target Reflectance - Value for standard target for research is 0.18.
- Selective printout codes - code 2 suppresses printout, code 1 commands printout of tables listing horizontal illumination, vertical illumination, target luminance, background luminance, veiling luminance,  $L_b$ , ( $L_b$  + background),  $RCSL_b'$  (Relative Contrast Sensitivity for  $L_b'$ ), luminance contrast, relative contrast sensitivity, disability glare factor, and visibility index, respectively.

---

\* A value of each of the output parameters cited in selective printout codes above, will be printed for each intersection of longitudinal and transverse roadway lines.



- Longitudinal Roadway Lines\* - imaginary lines which divide the roadway width into equal increments which are oriented parallel to the curb line. The number must be odd for two way streets; at least 3 for a one way street, and at least five for a two way street.
- Transverse Roadway Lines\* - imaginary lines which are oriented perpendicular to the curb line and divide the luminaire cycle length into equal increments.

Card 4:

- Option code - users choice, either  
1 = analysis  
2 = design
- Lower bound on mounting height - user specified minimum desired mounting height, in feet, for use in 'design' package
- Upper bound on mounting height - similarly specified maximum desired mounting height in feet
- Increment of mounting height - step size desired for iteration over minimum to maximum height, in feet
- Bounds and increments for spacing and mast length are defined the same as the mounting height
- Minimum VI15 - lower bound visibility condition in terms of VI15
- 5 Selective configuration codes - The 5 locations in the array represent the following configurations. Note, that near side is defined as the drivers right hand side, when facing the direction of the traffic flow.

#### Location

|   |                         |
|---|-------------------------|
| 1 | Single side far         |
| 2 | Single side near        |
| 3 | Dummy code (always = 0) |
| 4 | Both opposite           |
| 5 | Both staggered          |

## 2.3 CONSTRAINTS ON INPUT DATA

Certain constraints exist on the input data, some of which are applicable to both options and some to a single option only.

For both options the number of longitudinal roadway lines must be odd for a two-way street; odd or even for a one-way street. There must be five or more lines for a two way street and three or more for a one

\* A value of each of the output parameters cited in selective printout codes above, will be printed for each intersection of longitudinal and transverse roadway lines.



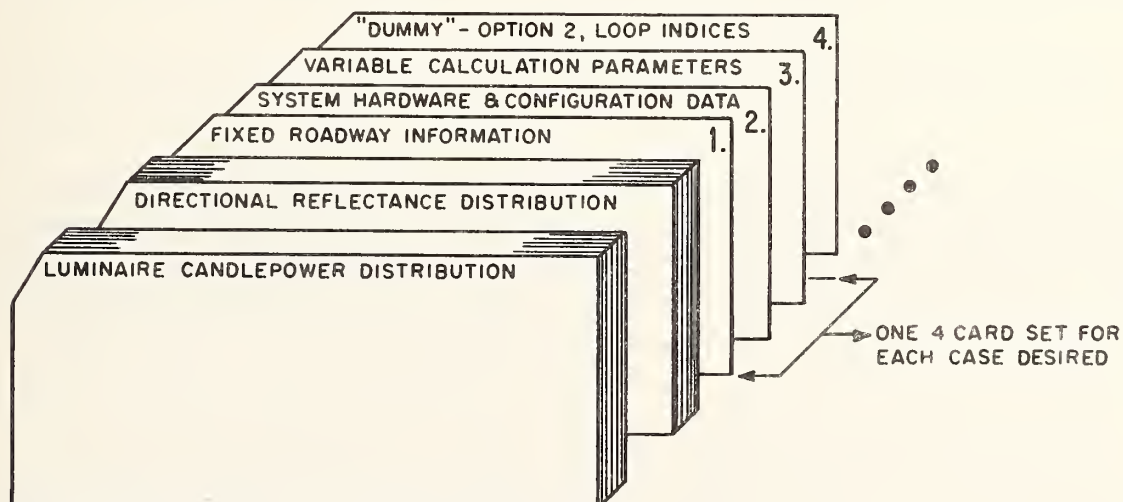
way street. All data must be entered on the data cards - blank spaces on some of the data fields will cause fatal errors. These errors may simply cause termination of a run, or they may cause an endless loop situation which would result in a very costly run.

For only the first option (analysis) the first three data cards (fixed roadway information, system hardware and configuration data, and variable calculation parameters) remain as described in the input definition section, but the fourth card with the user specified loop parameters becomes a 'dummy' card. Each data field, except the 5 selective codes, on this card must be filled in with a nominal value of *ONE*, and all others to *ZERO*.

For option two (design), modification of the system hardware and configuration data (card 2) is necessary. Since mounting height, spacing and overhang become loop parameters defined by card 4, in option two the values for these variables can be set to any number. A nominal value of *ONE* is recommended. Under option two, the configuration sidedness/arrangement) is also a loop variable. Initial values must be given to these two variables. The sidedness code must be set equal to *ONE*, and the arrangement code must be set equal to *ZERO*. *No other values are permitted.* The configuration of interest in the iterative process, can be executed by setting the appropriate location of the 5 selective codes to *ONE*. If that configuration is not desired set the location value to *ZERO*. In any event, location three must always be set to 0.

## 2.4 DATA DECK STRUCTURE

*Option 1: Analysis package*





The user has specified his data as follows. Card 1 begins with the intersection name in columns 1-50. The road width is given as 30 ft. (9.1m), with a lane width of 12 ft. (3.7m). Also given on card 1 are three more values. The first is the distance from the observer to the target, 271.82 ft. (82.8m), then the crown slope, 0.0104, and the curb height, 0.50 ft. (0.15m).

Card 2 lists the system hardware and configuration data. Taking the values left to right on the card, a mounting height of 35 ft. (10.7m), spacing, 200 ft. (61.0m), mast arm length, 7.0 ft. (2.1m) and setback of the pole from the curb of 2.0 ft. (0.6m), is specified.

The luminaire type is coded as a *ONE*, which in the example is a 400 watt Mercury lamp. The codes of *TWO* for sidedness and *ONE* for arrangement are equivalent to a near, single side, configuration. The offset is set to *ZERO* (as in this case), in all cases except a both sides staggered configuration, in which case the offset is one half the value of the spacing.

Next two heights are given. Target height is 0.25 ft. (0.08m) in this example, and observer height is 4.75 ft. (1.45m). Lastly on card 2 is the pavement type code (three in this example) and a directional code. The user has coded a one-way street.

Card 3, gives us the variable calculation parameters. Left to right again, it begins with the number of cycles in the system to be accounted for. Eleven, as is coded here, with two upstream and nine downstream (the next two values on card 3) has been tested and shown to include over 99% of the lighting contributions to the parameter values (e.g.,  $E_h$ ,  $VI$ , etc.). The reference luminaire is coded as number *THREE* which makes the location of the third luminaire the origin or point from which all distances are measured in the computer program.

Values for the candlepower and directional reflectance correction factor are given as 0.75 and 2.80 respectively. The next coded item is a value for average target reflectance, 0.18.

The next 11 values are output codes for the 11 parameters of interest. A code 2 is used for any parameter which printing is to be suppressed. In this example, only the eleventh parameter,  $VI$ , is of interest, and coded as a 1, to yield a printout.

The number of longitudinal and transverse line are given as 6 and 11 respectively. These numbers have been defined in an earlier section.

Card 4 in this analysis example is a 'dummy' card with option 1, specified in column 1, and nominal values of *ONE*, for all other variables, except the last four configuration codes, since none are used under option 1.



Table 1 is the resulting output after a successful run of the example case.

The output is divided into three major sections. First is a list of all input variables. Second is a matrix of parameter values for each longitudinal and transverse line intersection points. Finally the general statistical output for that parameter is printed.

Suppose now that the engineer is unsatisfied with a VII5 of 3.4781 and he wishes to upgrade his system by improving VII5. At this point the VI program allows the engineer to extrapolate new or upgraded lighting systems to compare a *change in system* to a *change in VII5*. This measure of improvement will help the engineer determine the best new or upgraded lighting system.

It is important to understand the flexibility of the VI program at this point. The engineer's original system could have been *no lighting* (VII5 = 1.00, or moonlight visibility conditions) and he may want to install a system to improve VII5 to some higher value. This *new* system he intends to install can be considered an *upgrade* also. New and upgraded systems are basically the same, although an engineer choosing a *new* system might have a great deal more leeway.

To return to the example, the engineer now makes the decision to investigate two basic upgrades. He also chooses 10.00 as the new criterion VI.\*

- (a) change the luminaire only and compare results with the criterion VI.
- (b) change some or all of the lighting system geometry variables and specify a new criterion VI to the desired level.

The first case (a), is easily taken care of by rerunning the same data set with a new luminaire candlepower distribution. Upgrade (b), requires an analysis of many cases, since several geometry variables may be involved. Here the engineer can use the 'design' version of the VI program

First he must choose his cases. Perhaps in his original case the poles were wooden and the option to raise or lower the mounting height by 10 ft. (3.0m) exists. He may also have the option of installing a new pole, between each pair to decrease the spacing to 50 ft. (15.2m), or to shut off every other luminaire and increase the spacing to 200 ft. (61.0m). Other options may also exist such as increasing the mast arm length to 13 ft. (4.0m), or changing the arrangement from single side near, to both opposite or both staggered. These cases are summarized in Table 2.

---

\* VI=10 corresponds to 85% performance as derived by Gallagher (1).

Table 1. Standard Tabular 'Analysis' Output

TEST EXAMPLE OF VI PROGRAM - ANALYSIS  
ROAD WIDTH = 30. LANE WIDTH = 12.  
OBSERVER-TARGET DISTANCE = 271.82  
CROWN SLOPE = .0104 CURB HEIGHT = .50  
MOUNTING HEIGHT = 55.0  
SPACING = 200.  
OVERHANG = 7.0  
SETRACK = 2.0  
LUMINAIRE TYPE = 1  
SIDEWALKS = 2 ARRANGEMENT = 1  
OFFSET = .0  
TARGET HEIGHT = .25  
OBSERVER HEIGHT = 4.75

11 CYCLES 2 UPSTREAM 9 DOWNSTREAM  
.75 = CANDLEPOWER CORR FACTOR  
2.80 = REFLECTANCE CORR FACTOR  
.1800 = TARGET REFLECTANCE  
1-WAY STREET  
NO. 3 - PAVEMENT TYPE

VISIBILITY INDEX--VI

| TRANS<br>LOCN | 20.0   | 40.0   | 60.0   | 80.0   | 100.0   | 120.0   | 140.0   | 160.0   | 180.0   | 200.0   |
|---------------|--------|--------|--------|--------|---------|---------|---------|---------|---------|---------|
| .0            | 3.6441 | .0824  | .0470  | 2.5415 | 4.1179  | 6.6109  | 8.2179  | 10.1525 | 12.605  | 15.6496 |
| 6.0           | 3.4781 | .7276  | 1.9852 | 4.0787 | 5.5275  | 7.3877  | 9.9024  | 11.5780 | 11.5153 | 3.4897  |
| 12.0          | 3.7890 | 1.7658 | 3.2397 | 4.0016 | 8.1365  | 9.5693  | 10.8773 | 12.6392 | 12.8852 | 3.8182  |
| 18.0          | 4.0100 | 1.9432 | 4.4313 | 7.3181 | 9.7602  | 11.8074 | 13.5418 | 14.2520 | 13.2644 | 4.0752  |
| 24.0          | 5.7804 | 2.8688 | 5.7572 | 8.2690 | 10.9908 | 13.0189 | 16.2797 | 13.9843 | 12.6553 | 3.8950  |
| 30.0          | .5924  | 4.9602 | 7.3766 | 9.1811 | 10.8967 | 12.6261 | 15.2457 | 11.7548 | 11.4346 | .5951   |

VI STATISTICS

MEAN = 8.1651  
STANDARD DEVIATION = 4.4594  
UNIFORMITY MAX/MIN = 22.3746  
UNIFORMITY MAX/AVG = 1.9938  
UNIFORMITY AVG/MIN = 11.2221  
15TH PERCENTILE = 3.4781



### Table 2. Optional Cases

|                                               | Low | High | Increment Size | No. of Cases     |
|-----------------------------------------------|-----|------|----------------|------------------|
| Mounting height:                              | 25' | 45'  | 5'             | 5                |
| Spacing:                                      | 50' | 200' | 50'            | 4                |
| Mast arm length:                              | 7'  | 13'  | 6'             | 2                |
| Configuration:<br>(Arrangement/<br>sidedness) | --  | --   | --             | <u>3*</u><br>120 |

$$1 \text{ ft.} = 0.3\text{m}$$

\* Single side near, both opposite, both staggered

Now that the engineer has set up his cases, the deck can be set up for his design runs. Here is how the deck will look.

|         |   |    |    |   |    |     |    |   |    |    |        |    |    |    |    |    |
|---------|---|----|----|---|----|-----|----|---|----|----|--------|----|----|----|----|----|
| CARD #4 | 2 | 25 | 45 | 5 | 50 | 200 | 50 | 7 | 13 | 6  | 10.000 | 1  | 0  | 0  | 1  | 1  |
| CARD #3 | 1 | 2  | 3  | 4 | 5  | 6   | 7  | 8 | 9  | 10 | 11     | 12 | 13 | 14 | 15 | 16 |
| CARD #2 | 1 | 2  | 3  | 4 | 5  | 6   | 7  | 8 | 9  | 10 | 11     | 12 | 13 | 14 | 15 | 16 |
| CARD #1 | 1 | 2  | 3  | 4 | 5  | 6   | 7  | 8 | 9  | 10 | 11     | 12 | 13 | 14 | 15 | 16 |

There are not many changes from the original case except that the type 4 card now becomes operational rather than a dummy card. As can be seen, the values of mounting height, spacing, and mast arm length on Card 2 have been set equal to *ONE* as required (columns 1-15), and the sidedness and arrangement (columns 26-29) have been set to their proper values *ONE* and *ZERO* respectively.

On the type 4 card, Option 2 is now specified. This allows us to loop over the values chosen. Also, the minimum VI15 is set at 10.00.

The user now implements his 'design' run. All 120 cases will be processed and compared against the minimum VII5 criteria, along with any other user specified criteria.

Using the 'design' version, output options are left open for the users needs. For example, the standard tabular printout (Table 1) may be executed for all cases or only those cases which satisfy the minimum VI15 criteria. A second choice might be to eliminate the standard tabular output and only include specific parameters. Table 3 displays an alternate type of output for one design case, in which the minimum VI15 = 10.00 criteria was satisfied. This specialized case only yields the geometry and parameters of interest.

Other criteria may also be specified. This other criteria may involve cost limitations. In the present example cost was not considered, only a certain level of VI15 improvement. The cost criteria might be evaluated after the results of the 'design' runs are known.

## 2.6 PROGRAM OPERATIONS

The program functions as a main program with an output subroutine and a statistical subroutine.

The logical program flow is as follows:

1. Definition of candlepower array, directional reflectance array, and basic system geometry and hardware information. Data is read in during this operation. An array of luminaire locations, in Cartesian coordinates, is then calculated.
2. Outer DO loops specifying option 2 indices which determine the number of cases to be run.
3. Middle DO loop specifying a target position and observer location coordinate set.
4. Inner DO loop calculating the contribution of each system luminaire toward roadway illumination, target luminance, background luminance, and veiling luminance. The interpolation of directional candlepower and directional reflectance is accomplished in this operation. DGF and RCS are also calculated.
5. Output and statistical routines produce matrix printouts of  $E_h$ ,  $E_v$ ,  $L_t$ ,  $L_b$ ,  $L_v$ ,  $L_b'$ ,  $RCS\ L_b'$ ,  $C$ ,  $RCS\ L_b$ ,  $DGF$  and  $VI$ , and summary statistics.

Table 3. Example of Specialized 'Design' Output

| LUMIN  | PAVEM | SIDE | ARRG   | OVER    | SPACE  | N.HT. | ROAD W | LANE W | NO. DIR | OFFSET |
|--------|-------|------|--------|---------|--------|-------|--------|--------|---------|--------|
| 1      | 3     | 3    | 2      | 7.0     | 100.0  | 45.0  | 30.0   | 12.0   | 1       | .00    |
| DOT    | CROWN | CURB | T. HT. | OB. HT. | TARREF | F1    | F2     |        |         |        |
| 271.82 | .01   | .50  | .25    | 4.75    | .18    | .75   | 2.80   |        |         |        |

# VI STATISTICS

MEAN = 16.7765  
 STANDARD DEVIATION = 1.5254  
 UNIFORMITY, MAX/MIN = 1.3415  
 UNIFORMITY, MAX/AVG = 1.1516  
 UNIFORMITY, AVG/MIN = 1.1649  
 15TH PERCENTILE = 15.0200

### 3.0 SELECTION OF LIGHTING SYSTEMS FOR NEW OR UNLIT ROADWAYS

This section, and the one that follows, present the methodology for selecting new lighting systems, or upgrading existing lighting systems on arterial streets. The process is illustrated in Figure 4 for both new (Steps 3-12) and upgraded (Steps 14-23) lighting systems.

#### 3.1 NECESSARY INPUT DATA

Before any of the subsequent methodology can be employed, the user must have certain basic inputs for each distinct roadway site describing the following environmental and geometric characteristics:

- Area Type (Central Business District or Other)
- Population Density
- Traffic Volume
- Road Width

Area type can easily be determined for a given roadway from the definition of Central Business District: "A concentration of stores, office buildings, environmental lighting, pedestrian and vehicular traffic as well as temporary on-street parking".

Population densities can be determined from census data found in most public libraries. Traffic volumes are normally available from municipal or state planning or engineering offices. Road widths are easily measured.

#### 3.2 INITIAL OPTIONS

In order to receive the most benefit from this guide, the user must first decide between two options

Option 1: If the user has data describing the candlepower distributions of the lamp/luminaire combinations he wishes to employ and has exact reflectance data for the road surfaces under consideration (both in a form suitable as input to the VI computer program described in Section 1 of this guide) then the analyses may be conducted using the VI computer program.

Option 2: If the user lacks the preceding data, or is satisfied with the range of variables presented in the FIRL data base, then he may conduct the analyses by referring to this data base, presented in Appendix A.

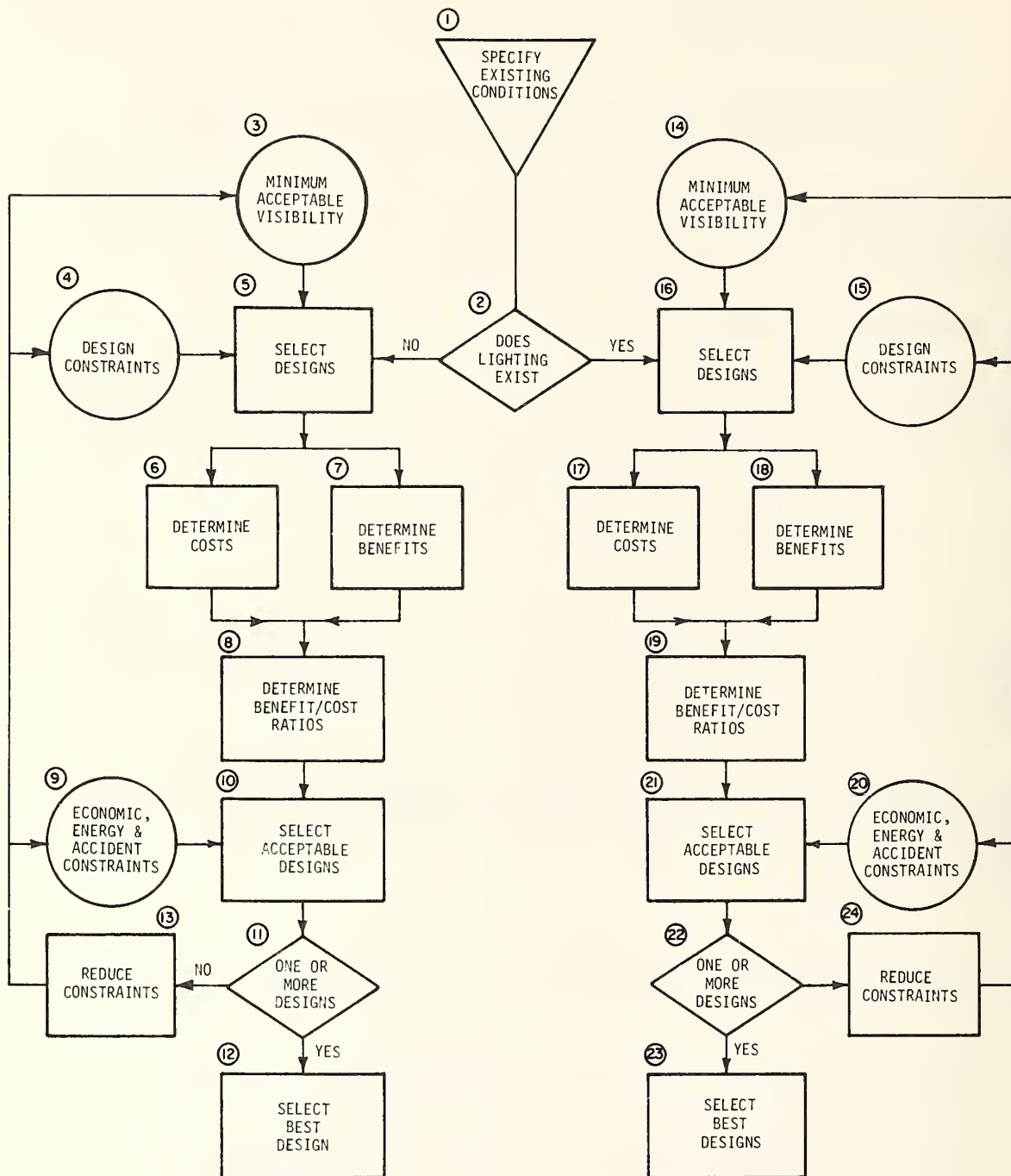


Figure 4.  
Block Diagram of Methodology for Selecting Lighting Designs



The FIRL data base defines the following roadway and lighting variables

#### Roadway Variables

Width: 30 ft. (9.1m); 60 ft. (18.3m)  
Directions: 1 (for 30 ft. (9.1m) road); 2 (for 60 ft. (18.3m) road)  
Surface Type: 1 (new asphalt)

#### Lighting Variables

Type/Size: Mercury 400 and 175\*  
HPS 400 and 150  
Arrangement: 1-sided; 2-sided opposite; 2-sided staggered  
Spacing: 50 ft.-250 ft. in 50 ft. increments (15.2m-76.2m)  
in 15.2m increments)  
Mounting Height: 20 ft.-45 ft. in 5 ft. increments (6.1m-13.7m)  
in 6.1m increments)  
Overhang: 5 ft. (1.5m) for 30 ft. (9.1m) road  
11 ft. (3.4m) for 60 ft. (18.3m) road

In addition, only traffic volumes from 5000VPD to 25,000VPD and population densities from 10,000 persons per square mile (3900 persons per square kilometer) to 60,000 persons per square mile (23,400 persons per square kilometer) are used in this data base.

### 3.3 DESCRIPTION OF THE PROCESS

The process can be broken down into an economic analysis which is based on the selection of lighting designs with the highest benefit-cost ratios, and an optimization analysis which considers constraints such as energy, accidents and economics. Figure 5 illustrates this for the part of the analysis covering new lighting designs.

#### 3.3.1 Specify Existing Conditions (Step 1)+

In this step the user merely records the existing geometric and environmental conditions on the following checklist, Figure 6.

#### \* Distributions

400M: Medium - Semi Cutoff - Type IV  
175M: Medium - Semi Cutoff - Type II  
400HPS: Medium - Non Cutoff - Type IV  
150HPS: Medium - Non Cutoff - Type III

+ All steps refer to the Block Diagram in Figure 5, that is an enlarged version of the left half of Figure 4 dealing with first time installations.

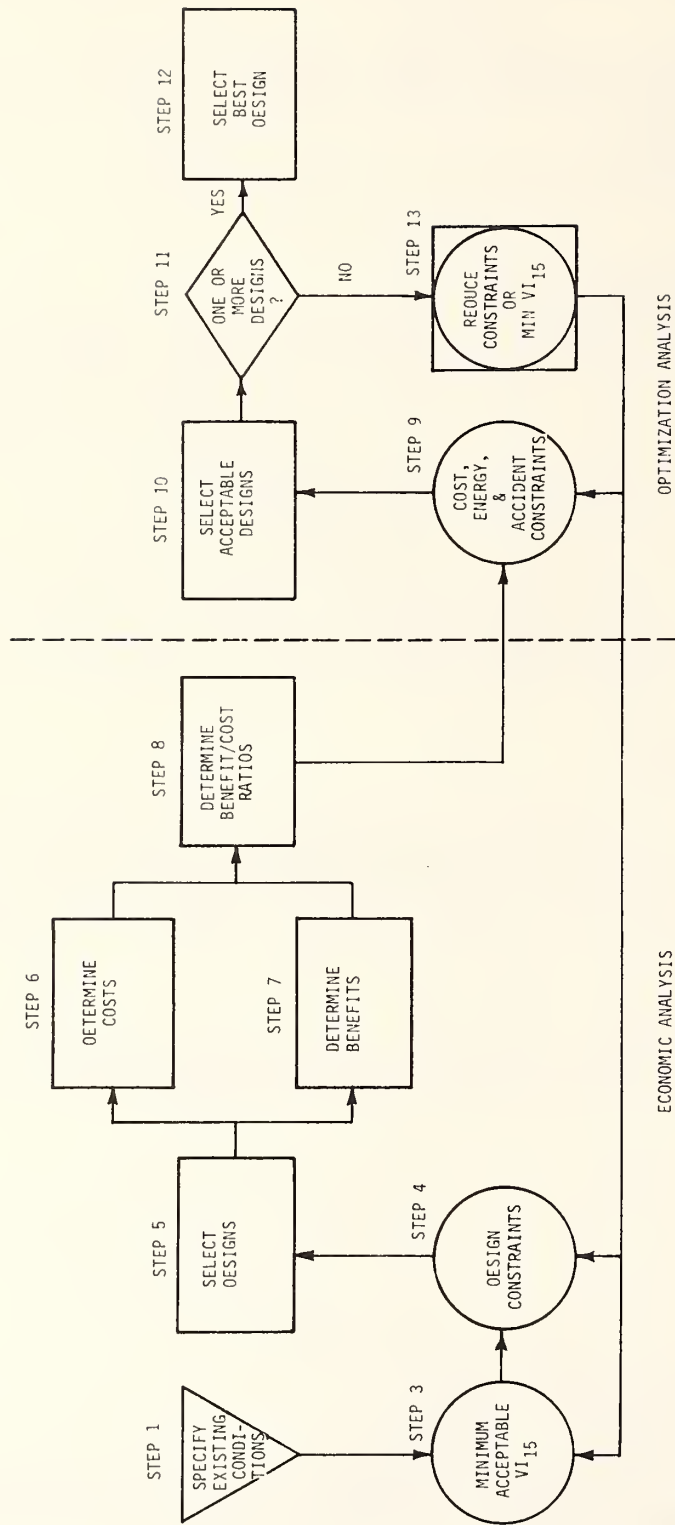


Figure 5. Methodology for New Systems

|                                  |       |
|----------------------------------|-------|
| Area Type                        | _____ |
| Population Density               | _____ |
| Traffic Volume                   | _____ |
| Road Width                       | _____ |
| Surface Type (Reflectance Table) |       |

Figure 6. Site Checklist

### 3.3.2 Determine Minimum Acceptable Visibility Level (Step 3)\*

The specification of a minimum acceptable visibility level is entirely up to the descretion of the user. It has been documented in the Final Report of this research that increasing the visibility on arterial streets reduces the potential for nighttime accidents.+ In addition, past research has shown that by increasing the visibility, an improvement (asymptotic near VI=15) in driver performance results (1). The prospective user may determine his minimum acceptable visibility based on either of the Final Report or Reference #1.

The selection of a minimum acceptable visibility level (VI15) at this step in the analysis is optional, and only acts to limit the number of possible system designs to those with VI15 equal to or greater than the minimum acceptable VI15. This step may be summarized into two options:

- (1) Option A - Ignore the selection of a minimum acceptable VI15 and consider all lighting system designs as possibilities.
- (2) Option B - Select a minimum acceptable VI15 and consider only those lighting system designs that provide VI15 equal to or greater than the selected VI15.

### 3.3.3 Determine Design Constraints (Step 4)

Based on the geometric and environmental conditions specified in Section 3.3.1, the user may wish to stress a particular design for his lighting system. The design constraints of a lighting system may include:

- Light Source Type, Size and Distribution
- Arrangement
- Spacing

\* Step 2, which was omitted, only determines if lighting presently exists on the site under study.

+ Final Report, FHWA-RD-77-37

- Mounting Height
- Overhang

The purpose of this step is to permit the user to specify his own design criteria to delineate only those systems that conform to those criteria. For example, design criteria may be specified in the following manner.

1. The system options must employ HPS light sources, or,
2. The lighting configuration must be staggered and the pole spacings must be no less than 100 ft. (30.5m) apart.

The design constraints outlined above are not essential to the final selection of system designs but are mentioned only to allow the user to formulate possible lighting systems based on his own preferred components.

This step therefore requires that the user specify whether or not a design constraint exists.

- No: Proceed to 3.3.4 and select lighting system designs based on minimum acceptable VII5 (if any)  
or  
Yes: Specify the constraints and proceed to 3.3.4 selecting only those systems that satisfy the design constraints and minimum acceptable VII5 (if any)

### 3.3.4 Select Possible Lighting System Designs (Step 5)

The selection of possible lighting system designs is performed in one of two ways:

1. If the user is employing the VI computer program he follows the instructions presented in Section 2 of this guide. The computer output, illustrated in Tables 1 and 3 of Section 2 would then be transferred to the form (Work Sheet number 1) provided in Table 26 of Appendix B of this guide,\* or
2. If the user is employing the FIRL data base, he reviews the entries in Table 21 of Appendix A to select those systems meeting his design and minimum visibility constraints. He then enters the systems he has selected on worksheet 1 illustrated in Table 26 of Appendix B.

---

\* A complete set of worksheets is presented in Appendix B for the user employing the VI program. When completed, they will form a user generated data base for new systems.

In either of the above cases, the result is a list of possible lighting system designs which includes the complete characteristics (e.g., road geometry and lighting parameters), the visibility (VI15) provided by such a system, and a user assigned case number. An illustration is presented in Table 4.

### 3.3.5 Determine Lighting System Costs (Step 6)

Three methods for computing costs are provided in this section.

1. User provided cost data
2. FIRL provided cost data (components only)
3. FIRL Data Base

#### 3.3.5.1 User Provided Data

In the first method, the user must provide either the total annual costs per mile for every possible lighting design, or compute this figure from component costs he provides. The method is as follows.

1. Determine Number of Poles per mile (NPM)

Using the equation:

$$\begin{aligned} \text{NPM} &= \frac{5280}{\text{Spacing}} && \text{for 1-sided configurations} \\ &= \frac{5280}{\text{Spacing}} \times 2 && \text{for 2-sided configurations} \end{aligned}$$

2. Calculate Pole costs.

Multiply number of poles per mile times the cost per pole to obtain the total initial cost (P) then use the simple interest equation:

$$\text{Annual Cost} = P \frac{(1+ni)}{n} \quad \text{where}$$

n = number of years over which pole is amortized  
(user specified)

i = interest rate (user specified)

to determine the annual costs per mile. This cost should include the labor and transportation costs to install the pole.

3. Calculate luminaire costs.

This calculation is done in the same way as in number 2 above (pole costs) but with a possibly different n and with individual luminaire costs.



Table 4. VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 10.7             | 30                  | 400M               | STG                | 200              | 45                          | 5                      | 30/400M/STG/200/45/5/- | 100         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
| 13.5             | 30                  | 400H               | SS                 | 150              | 45                          | 5                      | 30/400H/SS/150/45/5/-  | 160         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
| 10.7             | 30                  | 150H               | SS                 | 100              | 30                          | 5                      | 30/150H/SS/100/30/5/-  | 258         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
| 11.0             | 30                  | 150H               | SS                 | 100              | 35                          | 5                      | 30/150H/SS/100/35/5/-  | 259         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
| 11.9             | 30                  | 150H               | STG                | 200              | 30                          | 5                      | 30/150H/STG/200/30/5/- | 308         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |

#### 4. Calculate Wiring Costs

The initial costs are computed as cost per linear foot (installed) x number of linear feet (5280 if 1-sided; 10,560 if 2-sided). Amortized costs are computed as in number 2 and 3 above.

#### 5. Calculate Annual Maintenance Costs

These must be user provided. They should be computed per mile of roadway.

#### 6. Calculate Annual Energy Costs per mile

This can be user provided or may be calculated using the equation:

Total Energy cost per mile = Total number of poles per mile x number of burn hours per year x number of kilowatt hours per lamp x cost per kilowatt hour.

#### 7. Calculate total costs per mile per year: sum of 2, 3, 4, 5 and 6 above and enter all appropriate figures in worksheet #2 (Table 27) of Appendix B.

### 3.3.5.2 FIRL Provided Data (Components only)

In this case, the user wishes to employ our component costs, but not total costs. This may result from a different spacing, different interest rates etc. than used in the FIRL data base. The method is the same as in Section 3.3.5.1 above, except that the component costs may be read directly from Tables 5 through 9 and then amortized following the simple interest equation presented in Section 3.3.5.1 above. Total annual costs would be computed as before and entered on worksheet number 2 (Table 27 in Appendix B).

### 3.3.5.3 FIRL Data Base

If the lighting and road parameters provided in the FIRL data base presented in Appendix A, Table 21 meet with the users specifications, then total system costs can be obtained directly from Table 22 of Appendix A. The following procedure is suggested:

1. Take the system code and case number for each selected design in Table 21 of Appendix A and locate the system in Table 22.
2. For each selected design, enter the pertinent cost data on worksheet #2 (Table 27) in Appendix B.

Table 5. Luminaire Costs\*

| Type                 | Average Costs (\$)<br>Per Luminaire (Installed) |
|----------------------|-------------------------------------------------|
| Mercury              | \$126                                           |
| High Pressure Sodium | \$188                                           |

\*Including luminaire lamp and wiring to top connector  
(labor and material)

Table 6. Pole Costs

| Type                 | Height <sup>(1)</sup> | Average Cost (\$)<br>Per Pole (Installed) |
|----------------------|-----------------------|-------------------------------------------|
| Wood <sup>(2)</sup>  | Low                   | 339                                       |
|                      | Medium                | 443                                       |
|                      | High                  | 598                                       |
| Metal <sup>(3)</sup> | Low                   | 467                                       |
|                      | Medium                | 692                                       |
|                      | High                  | 906                                       |

- (1) Low: less than 25 ft. (7.6m); Medium: 25 ft. (7.6m) to 35 ft. (10.7m); High: over 35 ft. (10.7m)  
 (2) Including bracket arm  
 (3) Including Transformer base

Table 7. Maintenance Costs

| Lamp Type | Average Costs Per Luminaire<br>(Annual) (\$) |
|-----------|----------------------------------------------|
| Mercury   | 7.02                                         |
| HPS       | 23.79                                        |

Table 8. Wiring Costs

| Type                          | Average Cost per foot<br>(Installed) (\$) |
|-------------------------------|-------------------------------------------|
| Aerial                        | 0.99                                      |
| Underground (direct)          | 1.99                                      |
| Underground (rigid conduit)   | 13.83                                     |
| Underground (plastic conduit) | 13.19                                     |

Table 9. Energy Costs

| Item   | Average Cost per Kwh (\$) |
|--------|---------------------------|
| Energy | 0.0248                    |
| Other* | 0.0620                    |
| Total  | 0.0868                    |

\* Including cost per watt demand or capacity charges, facility charges etc. See Section 6 of the Final Report for a complete description of these costs.

An example of the data is provided in Table 10. This data base covers a range of geometry values (spacing and mounting height) but is restricted to four luminaire, each with one photometric distribution. Also, only one pavement surface is included as a variable (new asphalt) of the type found on our test street in Philadelphia (3).

### 3.3.6 Determine Benefits (Step 7)

The benefits of lighting systems were developed from the regression equation\*

$$\begin{aligned} \text{Accident Rate per 10,000 vehicle miles} &= 3.61 + \\ &7.85 (\text{CBD vs Other}) + 0.000164(\text{Population Density}) \\ &- 0.532 (\text{VI15}) \end{aligned}$$

where CBD vs Other is either 1 or 0 and population density is in persons per square mile.

Average accident costs were developed by the National Highway Traffic Safety Administration. This cost data provided an average cost per accident of \$2,130 and included both direct and indirect costs. This average cost has developed from the average cost per fatality, per injury and per property damage accident, weighted by frequency of each.\*

To determine the benefits of a lighting system, the following data (from Figure 6) is necessary.

Area Type (CBD or Other)  
Population Density (Persons per square mile)  
Traffic Volume (VPD)

as well as the VI15 provided by each lighting design (either generated by the user with the VI computer program, or read from Table 21 in Appendix A of the FIRL data base).

If the user desires to employ accident costs other than those presented above, he completes the worksheet #3 (Table 28 of Appendix B) using his own accident cost data and the regression equation above as follows:

1. Compute accident rate for the no-lighting condition (VI15=1) using the regression equation.
2. Compute accident rate for each lighting design using the appropriate VI15 for each design.

---

\* Discussed fully in Section 5 of the Final Report



Table 10. Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr) | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|---------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                           | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400M/STG/200/45/5/M | 100      | 10.7             | 852                       | 64038            | 6927                 | 8062                 | 398                            | 15387                     |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
| 30/400H/SS/150/45/5/M  | 160      | 13.5             | 573                       | 45003            | 4872                 | 5374                 | 899                            | 11145                     |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
| 30/150H/SS/100/30/5/M  | 258      | 10.7             | 319                       | 52294            | 5642                 | 2854                 | 1274                           | 9769                      |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
| 30/150H/SS/100/35/5/M  | 259      | 11.0             | 319                       | 52294            | 5642                 | 2854                 | 1274                           | 9769                      |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
| 30/150H/STG/200/30/5/M | 308      | 11.9             | 319                       | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
|                        |          |                  |                           |                  |                      |                      |                                |                           |
|                        |          |                  |                           |                  |                      |                      |                                |                           |

3. Compute accident reduction (The difference between #1 and #2 above divided by #1)
4. Compute benefits (#3 times the average cost per accident).

If the FIRL data base is employed the user may refer directly to Table 11 for the benefits. For traffic volumes other than 10,000 VPD or high values of VI15 (greater than 15) a series of multipliers is provided at the bottom of Table 11. When using this table, values of VI15 should be rounded to the nearest whole number. To compute accident reduction (to be used subsequently) the user can employ the procedure described above (Steps 1-3) or employ the equation

$$\text{Accident Reduction} = \frac{\text{Benefits (at new VI15)} - \text{Benefits (at VI15=1)}}{\text{Benefits (at VI15=1)}}$$

### 3.3.7 Determine Benefit-Cost Ratios (Step 8)

Benefit-cost ratio is defined as the total annual benefits computed in Section 3.3.6 divided by the total annual costs computed in Section 3.3.5. For the user generating his own data, worksheet #4 (Table 29 of Appendix B) is then completed by recording the appropriate data from worksheets #2 and 3. When using the FIRL data base, Table 23 of Appendix A can be used. An example is presented in Table 12.

## 3.4 OPTIMIZATION ANALYSIS

The objective of this part of the methodology is to develop a procedure for selecting optimum lighting designs based on possible economic, energy and accident constraints.

### 3.4.1 Specify the Constraints (Step 9)

The user must specify the data in Worksheet #5 (Table 30 of Appendix B). Each entry comes from a preceding worksheet and the data is all combined here so that the user may compare alternatives based on his own applicable constraints. The data includes:

1. Lighting System Codes (From Worksheet 1)
2. Visibility (From Worksheet 1)
3. Energy Use (From Worksheet 2)
4. Lighting Costs (From Worksheet 2)
5. Site Characteristics (From Checklist - Figure 6)
6. Accident Reduction (Described in Section 3.3.6)
7. Accident Benefits (From Worksheet 3)
8. Benefit-Cost ratios (From Worksheet 4)

Table 11. Benefits of New Systems

| AREA TYPE                   | C B D  |        |        |        |        |        |  | OTHER  |        |        |        |        |        |  |
|-----------------------------|--------|--------|--------|--------|--------|--------|--|--------|--------|--------|--------|--------|--------|--|
| VI <sub>15</sub><br>Density | 10,000 | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 |  | 10,000 | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 |  |
| 1                           | 0      | 0      | 0      | 0      | 0      | 0      |  | 0      | 0      | 0      | 0      | 0      | 0      |  |
| 2                           | 1129   | 1129   | 1129   | 1129   | 1129   | 1129   |  | 1129   | 1129   | 1129   | 1129   | 1129   | 1129   |  |
| 3                           | 2280   | 2280   | 2280   | 2280   | 2280   | 2280   |  | 2280   | 2280   | 2280   | 2280   | 2280   | 2280   |  |
| 4                           | 3409   | 3409   | 3409   | 3409   | 3409   | 3409   |  | 3409   | 3409   | 3409   | 3409   | 3409   | 3409   |  |
| 5                           | 4538   | 4538   | 4538   | 4538   | 4538   | 4538   |  | 4538   | 4538   | 4538   | 4538   | 4538   | 4538   |  |
| 6                           | 5667   | 5667   | 5667   | 5667   | 5667   | 5667   |  | 5667   | 5667   | 5667   | 5667   | 5667   | 5667   |  |
| 7                           | 6796   | 6796   | 6796   | 6796   | 6796   | 6796   |  | 6796   | 6796   | 6796   | 6796   | 6796   | 6796   |  |
| 8                           | 7947   | 7947   | 7947   | 7947   | 7947   | 7947   |  | 7947   | 7947   | 7947   | 7947   | 7947   | 7947   |  |
| 9                           | 9076   | 9076   | 9076   | 9076   | 9076   | 9076   |  | 9076   | 9076   | 9076   | 9076   | 9076   | 9076   |  |
| 10                          | 10205  | 10205  | 10205  | 10205  | 10205  | 10205  |  | 10054  | 10205  | 10205  | 10205  | 10205  | 10205  |  |
| 11                          | 11337  | 11337  | 11337  | 11337  | 11337  | 11337  |  | 10054  | 11337  | 11337  | 11337  | 11337  | 11337  |  |
| 12                          | 12471  | 12471  | 12471  | 12471  | 12471  | 12471  |  | 10054  | 12471  | 12471  | 12471  | 12471  | 12471  |  |
| 13                          | 13604  | 13604  | 13604  | 13604  | 13604  | 13604  |  | 10054  | 13549  | 13604  | 13604  | 13604  | 13604  |  |
| 14                          | 14738  | 14738  | 14738  | 14738  | 14738  | 14738  |  | 10054  | 13549  | 14738  | 14738  | 14738  | 14738  |  |
| 15                          | 15870  | 15870  | 15870  | 15870  | 15870  | 15870  |  | 10054  | 13549  | 15870  | 15870  | 15870  | 15870  |  |

\* = Density in people  
per square mile

APPLY FACTOR FOR VOLUME CHANGE

|       |        |        |        |        |
|-------|--------|--------|--------|--------|
| 5,000 | 10,000 | 15,000 | 20,000 | 25,000 |
| 0.5   | 1.0    | 1.5    | 2.0    | 2.5    |

$$\text{BENEFITS(B) for } VI_{15} > 15 = B(VI_{15}=15)(1-0.002 \times \Delta VI_{15})$$

Table 12. Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400M/STG/200/45/5/M | 100      | 10.7             | 15387            |             | 30000                  | 20000        | 22674               | 1.47               |
|                        |          |                  |                  |             |                        |              |                     |                    |
| 30/400H/SS/150/45/5/M  | 160      | 13.5             | 11145            |             | 30000                  | 20000        | 29476               | 2.64               |
|                        |          |                  |                  |             |                        |              |                     |                    |
| 30/150H/SS/100/30/5/M  | 258      | 10.7             | 9767             |             | 30000                  | 20000        | 22674               | 2.32               |
|                        |          |                  |                  |             |                        |              |                     |                    |
| 30/150H/SS/100/35/5/M  | 259      | 11.0             | 9767             |             | 30000                  | 20000        | 22674               | 2.32               |
|                        |          |                  |                  |             |                        |              |                     |                    |
| 30/150H/STG/200/30/5/M | 308      | 11.9             | 10344            |             | 30000                  | 20000        | 24942               | 2.41               |
|                        |          |                  |                  |             |                        |              |                     |                    |
|                        |          |                  |                  |             |                        |              |                     |                    |
|                        |          |                  |                  |             |                        |              |                     |                    |
|                        |          |                  |                  |             |                        |              |                     |                    |
|                        |          |                  |                  |             |                        |              |                     |                    |



The derivation of each of these data has been discussed previously. Accident reduction (#6) is the only constraint whose derivation is based on area type, hence will be different for CBD and "Other" types of sites. A rough approximation of accident reduction in "Other" area types can be obtained from the accident reduction in CBD areas by multiplying the latter value by 2 (if all other environmental, geometric and lighting variables are the same). For a more exact determination, the factors illustrated in Table 13 may be employed.

At this point the user must specify his own constraints. They may take the form of budgetary limitations, maximum energy use, minimum visibility (or accident reduction) or some combination. However, all of the constraints are interactive in that an adjustment or specification of one constraint will affect the other constraints and ultimately limit the number of alternative system designs.

Table 13. Correction Factor Used to Calculate Accident Reduction for "Other" Area Types from Accident Reduction at CBD Sites

| Population Density* (Persons per square mile) |        |        |        |        |        |        |
|-----------------------------------------------|--------|--------|--------|--------|--------|--------|
| VI15                                          | 10,000 | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 |
| 1-9                                           | 2.66   | 2.23   | 1.98   | 1.81   | 1.70   | 1.61   |
| 10                                            | 2.62   | 2.23   | 1.98   | 1.81   | 1.70   | 1.61   |
| 11                                            | 2.36   | 2.23   | 1.98   | 1.81   | 1.70   | 1.61   |
| 12                                            | 2.15   | 2.27   | 1.98   | 1.81   | 1.70   | 1.61   |
| 13                                            | 1.97   | 2.22   | 1.98   | 1.81   | 1.70   | 1.61   |
| 14                                            | 1.82   | 2.05   | 1.98   | 1.81   | 1.70   | 1.61   |
| 15                                            | 1.69   | 1.91   | 1.98   | 1.81   | 1.70   | 1.61   |

#### 3.4.2 Select Acceptable Designs (Steps 10 and 11)

The completed Worksheet #5 (Table 30 of Appendix B) will present a profile of the system characteristics with respect to all possible constraints. The user can review the completed table to identify each design which meets his constraints and then, if such designs exist, proceed to select the one with the most attractive cost-benefit ratio. If no options exist, then the user must reduce his constraints.

Table 14 presents an example of the results that would be obtained at this step.





### 3.4.3 Select Best Design (Step 12)

This step is the culmination of the optimization process if one or more system designs were isolated through the economic and optimization analysis. The best option can be defined as one with highest benefit-cost ratio which meets the design, economic, energy and accident constraints of the user.

### 3.4.4 Reduce Constraints (Step 13)

As discussed throughout this procedure, the benefit-cost ratio and the various constraints are the foundation for selecting an optimum lighting system. When constraints are set too high the result will be a paucity of acceptable options meeting those constraints. If this is the case, then it is necessary to reevaluate by reducing the constraint or perhaps selecting other luminaires. This requires repeating Steps 3, 4 or 9 and selecting another set of acceptable designs.

The options presented to the user at this step include the following:

1. Reduce minimum acceptable VI15 (Step 13)
2. Reduce design constraints (Step 4)
3. Reduce economic, energy or accident constraints (Step 9)

The process then begins again at the steps indicated above.

## 3.5 SAMPLE PROBLEMS

For the following sample problems, all data was drawn from the FIRL data base presented in Appendix A. If the prospective user employs the VI program or provides his own lighting cost or benefit data he would generate his own data base by completing the Worksheets in Appendix B.

### Example 1

#### Existing Conditions

Area Type: CBD  
Population Density: 30,000 persons per square mile (11,700  
persons per square kilometer)  
Traffic Volume: 20,000 VPD  
Road Width: 30 ft. (9.1m)  
Surface Type: New Asphalt

Minimum Acceptable VI15: 10\*

Design Constraint:

- Case 1. Use only HPS - Metal Pole
- Case 2. Use only Mercury - Metal Pole

Solutions

Case 1. HPS

|                  |                 |               |                          |
|------------------|-----------------|---------------|--------------------------|
| Luminaire:       | 400 HPS         | VI15: 13.5    |                          |
| Arrangement:     | Single Sided    | Annual Costs: | \$11,145 <sup>5</sup>    |
| Spacing:         | 150 ft. (45.7m) | Energy Use:   | .573x10 <sup>5</sup> Kwh |
| Mounting Height: | 45 ft. (13.7m)  | B/C Ratio     | 2.64                     |
| Overhang:        | 5 ft. (1.5m)    | Case #:       | 160                      |

Case 2. Mercury

|                  |                 |               |                           |
|------------------|-----------------|---------------|---------------------------|
| Luminaire:       | 400 M           | VI15: 13.5    | 10.7                      |
| Arrangement:     | Staggered       | Annual Costs: | \$15,387 <sup>5</sup>     |
| Spacing:         | 200 ft. (61.0m) | Energy Use:   | 0.852x10 <sup>5</sup> Kwh |
| Mounting Height: | 45 ft. (13.7m)  | B/C Ratio:    | 1.47                      |
| Overhang:        | 5 ft. (1.5m)    | Case #:       | 100                       |

These solutions were obtained by searching Table 24 of Appendix A for those systems with the highest Benefit/cost ratio meeting all of the constraints and input conditions.

Example 2

Area Type, Population Density, Traffic Volume, Road Width and Surface Type the same as Example 1.

|                          |                                                    |
|--------------------------|----------------------------------------------------|
| Minimum Acceptable VI15: | 10                                                 |
| Design Constraint:       | Use HPS                                            |
| Economic Constraint:     | Total Annual Cost less than \$10,000               |
| Energy Constraint:       | Total Energy Use less than 0.5x10 <sup>5</sup> Kwh |

An optimum design will be derived for each constraint separately, and then in combination. For the design constraint in conjunction with the minimum acceptable VI15 the optimum was presented in example 1.

\* About 85% of maximum performance is derived from a VI = 10. See Reference 1 for additional information

### Case 1 - Economic Constraint

For the economic constraint, the same solution will not suffice since it has total annual cost of \$11,145 per mile.

Case #258 and #259 both have VI 15 greater than 10 with annual costs less than 10,000 and both have B/C = 2.32 therefore both would suffice as solutions.

|                  |                                   |                    |                         |
|------------------|-----------------------------------|--------------------|-------------------------|
| Luminaire:       | 150HPS                            | VI15:              | 10.7 and 11.0           |
| Arrangement:     | Single Sided                      | Annual Cost:       | \$9759                  |
| Spacing:         | 100 ft.(30.5m)                    | Annual Energy Use: | $0.319 \times 10^5$ Kwh |
| Mounting Height: | 30 ft. (9.1m)<br>or 35 ft.(10.7m) | B/C ratio:         | 2.32                    |
| Overhang:        | 5 ft. (1.5m)                      | Case #:            | 258/259                 |

### Case 2 - Energy Constraint

For the energy constraint (again in conjunction with the minimum acceptable VI15), Case #308 is the optimum.

|                  |                 |                    |                         |
|------------------|-----------------|--------------------|-------------------------|
| Luminaire:       | 150HPS          | VI15:              | 11.9                    |
| Arrangement:     | Staggered       | Annual Cost:       | \$10,344                |
| Spacing:         | 200 ft. (61.0m) | Annual Energy Use: | $0.139 \times 10^5$ Kwh |
| Mounting Height: | 30 ft. (9.1m)   | B/C ratio:         | 2.41                    |
| Overhang:        | 5 ft. (1.5m)    | Case #:            | 308                     |

In comparing the last two examples it should be noted that for the energy constraint, the optimum was selected based on maximizing the B/C ratio with annual energy less than  $0.5 \times 10^5$  Kwh/mile. For the economic constraint, the optimum was selected with maximum B/C ratio with annual costs less than \$10,000 per mile. Note that neither would suffice as optimum for the other.

### Case 3 - Combined Constraints

The optimum for this case is the same as in the example above with an economic constraint (Case 1).

The solutions for each of the preceding three cases was obtained by reviewing Table 24 of Appendix A for the system with highest B/C ratio meeting individual (or combined) constraints.

#### Example 3

##### Existing Conditions

|                     |                                                                         |
|---------------------|-------------------------------------------------------------------------|
| Area Type:          | CBD                                                                     |
| Population Density: | 30,000 persons per square mile<br>(11,700 persons per square kilometer) |

|                          |                                                               |
|--------------------------|---------------------------------------------------------------|
| Traffic Volume:          | 20,000 VPD                                                    |
| Road Width:              | 60 ft. (18.3m)                                                |
| Surface Type:            | New Asphalt                                                   |
| Minimum Acceptable VI15: | None                                                          |
| Design Constraint:       | None                                                          |
| Economic Constraint:     | Total Annual Costs less than \$10,000                         |
| Energy Constraint:       | Total Annual Energy Use less than<br>0.75x10 <sup>5</sup> Kwh |

#### Optimum Solutions

##### No Constraints

|                  |                                   |                    |                              |
|------------------|-----------------------------------|--------------------|------------------------------|
| Luminaire:       | 400HPS                            | VI15:              | 12.5/12.7                    |
| Arrangement:     | Staggered                         | Annual Cost:       | \$16,719                     |
| Spacing:         | 200 ft. (61.0m)                   | Annual Energy Use: | 0.852x10 <sup>5</sup><br>Kwh |
| Mounting Height: | 40 ft. (12.2m)/<br>45 ft. (13.7m) | B/C ratio:         | 1.63                         |
| Overhang:        | 1 ft. (3.4m)                      | Case #:            | 139/140                      |

##### Economic Constraint

|                  |                 |                    |                              |
|------------------|-----------------|--------------------|------------------------------|
| Luminaire:       | 150HPS          | VI15:              | 6.8                          |
| Arrangement:     | Staggered       | Annual Cost:       | \$9949                       |
| Spacing:         | 250 ft. (76.2m) | Annual Energy Use: | 0.258x10 <sup>5</sup><br>Kwh |
| Mounting Height: | 40 ft. (12.2m)  | B/C ratio:         | 1.37                         |
| Overhang:        | 11 ft. (3.4m)   | Case #:            | 250                          |

##### Energy Constraint

|                  |                 |                    |                              |
|------------------|-----------------|--------------------|------------------------------|
| Luminaire:       | 150HPS          | VI15:              | 13.8                         |
| Arrangement:     | Staggered       | Annual Cost:       | \$19,540                     |
| Spacing:         | 100 ft. (30.5m) | Annual Energy Use: | 0.639x10 <sup>5</sup><br>Kwh |
| Mounting Height: | 35 ft. (10.7m)  | B/C ratio:         | 1.51                         |
| Overhang:        | 11 ft. (3.4m)   | Case #:            | 234                          |

##### Combined Constraint

(Same as economic constraint)



## 4. UPGRADING OF EXISTING LIGHTING SYSTEMS

This section describes the methodology for upgrading existing lighting systems on arterial streets. Many of the steps and calculations described in this section and illustrated in Figure 4, Steps 14 through 23, are similar or the same as the ones described in Section 3 and illustrated in Figure 4, Steps 3 through 12. They will normally not be repeated here.

### 4.1 NECESSARY INPUT DATA

Before the methodology can be employed, the user must have certain basic input data describing the roadway geometry, existing lighting and environmental characteristics.

These include

1. Area Type
2. Population Density
3. Traffic Volume
4. Road Width
5. Description of Existing Lighting

Luminaire size, type and distribution  
Mounting Height  
Spacing  
Arrangement  
Overhang

The first four items were described in Section 3.1. The description of the lighting system should be available from the municipal or state lighting department\* or the local power company. It can be measured on-site (except for luminaire characteristics).

### 4.2 INITIAL OPTIONS

There are two options available, as described in Section 3.2

1. User provides candlepower distributions and road reflectance data, and generates his own data base using the VI program described in Section 2.
2. FIRL data base employed.

These options were described in Section 3.2

\* Sometimes called the Engineering Department, Public Works Department, Streets Department etc.

### 4.3 DESCRIPTION OF THE PROCESS

The process can be broken down into an economic analysis which is based on the selection of upgraded lighting systems with the highest benefit-cost ratios and an optimization analysis which considers constraints such as economics, energy and accidents.

The process is illustrated in Figure 7 for upgraded systems.

#### 4.3.1 Specify Existing Conditions (Step 1)\*

In this step the user records the existing geometric, environmental and lighting conditions on the following checklist, Figure 8.

All of the input data in this checklist, except VII5, is provided by the user. The specification of the VII5 provided by the existing lighting systems at each site is accomplished in one of two ways.

1. Use the roadway and lighting characteristics as input to the VI computer program and calculate VII5 for each site under analysis.
2. Refer to the FIRL data base in Table 21 of Appendix A and after locating the correct combination of arrangement/spacing/mounting height/overhang/luminaire type and size/road width, record the related visibility (VII5) as well as the existing geometric and lighting characteristics on Worksheet #6 (Table 31 in Appendix C).

#### 4.3.2 Determine Minimum Acceptable Visibility Level (Step 14)

This was fully discussed in Section 3.3.2 and will not be repeated here other than to reiterate that this step is optional and only acts to limit the number of possible upgrades to those with VII5 equal to or greater than the minimum acceptable VII5.

#### 4.3.3 Determine Design Constraints (Step 15)

Based on existing geometric, environmental and lighting conditions at each site, the user may wish to stress a particular design or preserve certain features of the existing lighting system. These constraints may include retaining (or changing) some of the existing lighting conditions based on component availability, costs, maintenance practices or energy availability. The effect is to limit the number of possible upgrades to those that meet the users own preferred criteria or specifications.

---

\* All steps refer to the Block Diagram, Figure 7.

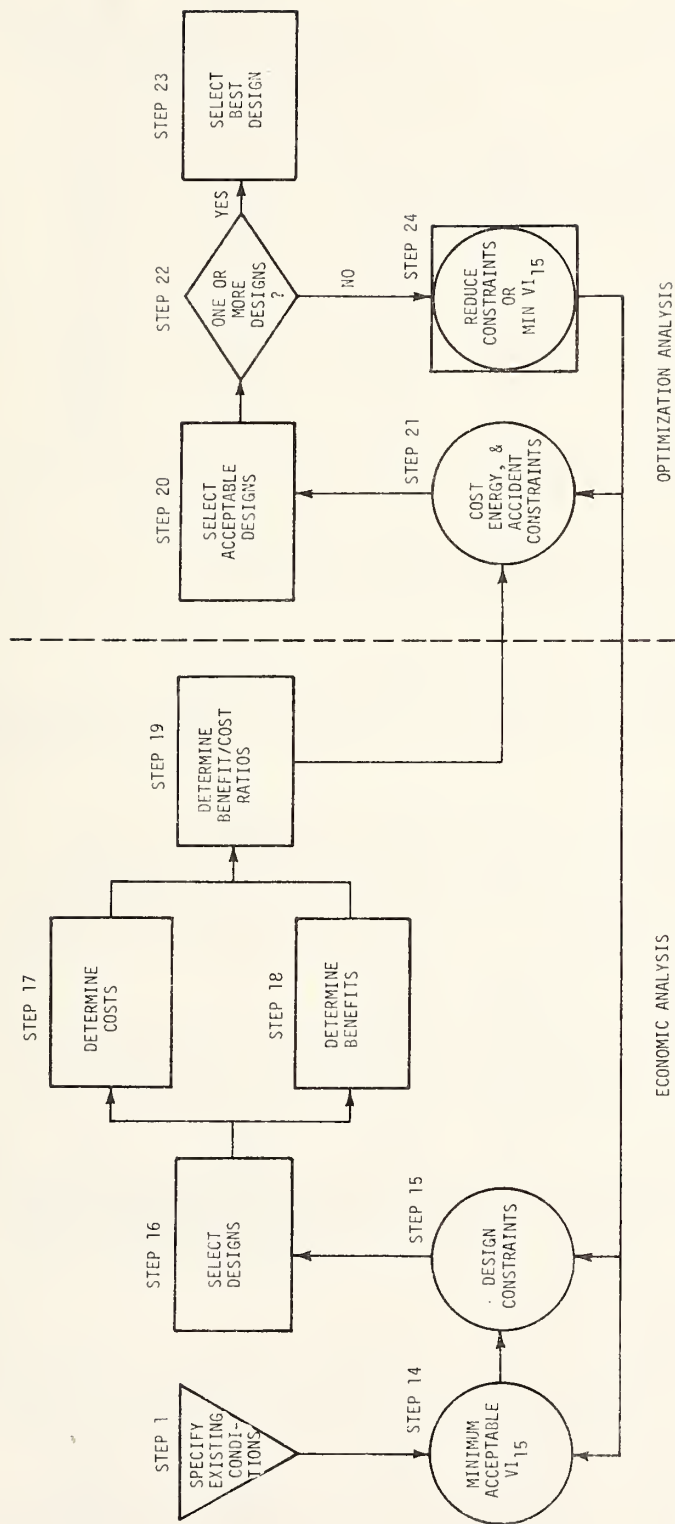


Figure 7. Methodology for Upgraded Systems

|                                  |       |
|----------------------------------|-------|
| Area Type                        | _____ |
| Population Density               | _____ |
| Traffic Volume                   | _____ |
| Road Width                       | _____ |
| Surface Type (Reflectance Table) | _____ |
| Luminaire Size/Type/Distribution | _____ |
| Arrangement                      | _____ |
| Spacing                          | _____ |
| Mounting Height                  | _____ |
| Overhang                         | _____ |
| Visibility (VI15)                | _____ |

Figure 8. Site Characteristic Checklist  
for Upgraded Systems

#### 4.3.4 Select Possible Lighting System Upgrades (Step 16)

The selection of possible upgrades for each site under consideration can be accomplished in one of two ways.

1. For the user employing the VI computer program, the methods of Section 2 are used to generate possible lighting upgrades based on his own design constraints and minimum acceptable visibility. The computer output, illustrated in Tables 1 and 3 of Section 2 is then transferred to Worksheet #6 (Table 31 of Appendix C)\* or
2. For the user employing the FIRL data base, he reviews the entries in Table 21 of Appendix A to select those systems meeting his design and minimum visibility constraints.

In either of the above cases, the result is a list of possible upgrades, with complete system descriptions, visibility (VI15) and a user assigned case number. An illustration is provided in Table 15.

#### 4.3.5 Determine Upgrade Costs (Step 17)

Three methods for computing costs are provided for the prospective user.

\* A complete set of Worksheets is provided in Appendix C for upgraded systems.

Table 15 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 4.6170           | 60                  | 400M               | STG                | 200              | 30                          | 11                     | 60/400M/STG/200/30/11/- | 32          |
| 8.2351           | 60                  | 400H               | STG                | 200              | 30                          | 11                     | 60/400H/STG/200/30/11/- | 137         |
| 6.2879           | 60                  | 150H               | STG                | 200              | 30                          | 11                     | 60/150H/STG/200/30/11/- | 243         |
| 9.3536           | 60                  | 400M               | OPP                | 100              | 30                          | 11                     | 60/400M/OPP/100/30/11/- | 2           |
| 17.7087          | 60                  | 400H               | OPP                | 100              | 30                          | 11                     | 60/400H/OPP/100/30/11/- | 107         |
| 13.2493          | 60                  | 150H               | OPP                | 100              | 30                          | 11                     | 60/150H/OPP/100/30/11/- | 213         |
|                  |                     |                    |                    |                  |                             |                        |                         |             |
|                  |                     |                    |                    |                  |                             |                        |                         |             |
|                  |                     |                    |                    |                  |                             |                        |                         |             |



#### 4.3.5.1 User Provided Data

In this first method the user must provide either the total annual increased costs per mile for each possible upgrade or at a minimum, the individual component costs, from which total increased annual costs may be computed. If individual component costs are used the steps to be followed include:

1. Determine number of new poles
2. Determine initial cost for new pole
3. Determine cost for new luminaires
4. Determine additional wiring costs
5. Determine increased maintenance costs
6. Determine increased energy/power costs
7. Calculate increased total costs per mile  
(sum of 2, 4, 5 and 6 above)

All costs include labor and material for an installed item. The calculations are basically the same as those described in Section 3.3.5.1 except that

1. Only those items being changed (upgraded) are considered in the cost calculations (e.g., new luminaires or additional poles).
2. Only changes in maintenance costs or changes in energy costs are included (may be positive signifying an increase; or negative signifying a decrease).
3. Either the existing lighting system is completely paid off, in which case the costs to upgrade are the total costs, or the existing system is still being paid for and the upgrade costs are in addition to the existing costs.

#### 4.3.5.2 FIRL Provided Data (Component only)

In this case, the user will employ our component costs, presented in Tables 5 through 9 in Section 3. The method and restrictions are the same as described in Section 4.3.5.1 above, except that FIRL component costs are used.

#### 4.3.5.3 FIRL Data Base

If the lighting, road geometry and environmental conditions covered in the FIRL data base in Appendix A meet with the user specifications, then total system costs can be computed from the individual "cost per mile" figures of Table 25 in Appendix A. The method employs Worksheet #7 (Table 32 of Appendix C) and proceeds as follows:

1. Record existing system code
2. Record upgrade code
3. Record VII5 of existing system
4. Record VII5 of upgraded system

These four items are all available in Table 21 of Appendix A in the FIRL data base. The following items would be recorded from the data in Table 25 of Appendix A.

5. Energy use of existing system
6. Energy use of upgraded system
7. Initial costs of individual items in each upgraded system (e.g., luminaires, poles, wiring)
8. Annual costs of individual items, maintenance and energy
9. Total Annual Costs of each upgraded system (total of items in #8 above).

An example of this upgrade cost data is illustrated in Table 16.

#### 4.3.6 Determine Benefits (Step 18)

The calculations are almost the same as those presented in Section 3.3.6 except two calculations must be made, instead of one.

1. Benefits of existing system (Bo)
2. Benefits of Upgraded system (B1)

The actual benefits B, derived from an upgrade is determined from the equation:

$$B = B1 - Bo$$

which is positive for upgradings with higher VII5 and negative for upgradings with lower VII5.

The assumptions concerning accident rates, accident costs etc. were described in Section 3.3.6. Table 11 from that section provides the basic benefit for the user employing the FIRL data base as well as the regression equation relating accident rate to visibility which is employed if the user desires to employ his own accident cost data. In this latter case, the user will generate his own table equivalent to Table 11 by completing Worksheet #8 (Table 33 in Appendix C).

#### 4.3.7 Determine Benefit-Cost Ratios (Step 19)

As in Section 3.3.7, Benefit-cost ratio for each upgrade is computed by dividing the total annual benefits computed in Section 4.3.6 by the total annual costs computed in Section 4.3.7. Worksheet #9 (Table 34 of Appendix C) is then completed by recording the appropriate

Table 16 Costs of Upgraded Systems

[illegible]

data in Worksheets #7 and #8. An example is presented in Table 17.

#### 4.4 OPTIMIZATION ANALYSIS

The methodology is exactly the same as that presented in Section 3.4 except that the user must complete Worksheet #10 (Table 35 of Appendix C) by combining the entries from the previous four worksheets in Appendix C. Table 18 presents an example of the results obtained after completing Worksheet #10. Steps 20 through 24 of Figure 4 are identical to Steps 9 through 13 described in Sections 3.4.1 through 3.4.4 and will not be repeated. The sample problems that follow will provide examples of the methodology.

#### 4.5 SAMPLE PROBLEMS

For the following sample problems, all data was drawn from the FIRL data base in Appendix A. If the prospective user employs the VI program or provides his own lighting cost or benefit data he would generate his own data base by completing the worksheets in Appendix C.

##### Example 1

##### Existing Conditions

|                     |                                                                      |
|---------------------|----------------------------------------------------------------------|
| Area Type:          | CBD                                                                  |
| Population Density: | 30,000 persons per square mile (11,700 persons per square kilometer) |
| Traffic Volume:     | 20,000 VPD                                                           |
| Road Width:         | 60 ft. (18.3m)                                                       |
| Surface Type:       | New asphalt                                                          |
| Luminaire:          | 400M                                                                 |
| Arrangement:        | Staggered                                                            |
| Spacing:            | 200 ft. (61.0m)                                                      |
| Mounting Height:    | 30 ft. (9.1m)                                                        |
| Pole Type:          | Metal                                                                |
| Overhang:           | 11 ft. (3.5m)                                                        |
| Visibility (VI15):  | 4.6                                                                  |

##### Possible Upgradings

1. 400M —→ 400HPS
2. 400M —→ 150HPS
3. 200 ft. (61.0m) —→ 100 ft. (30.5m) spacing
4. Combination of 1 and 3
5. Combination of 2 and 3

Table 18 illustrates the data described above. The optimum upgrade would be that design with highest benefit-cost ratio. It is Case 243 for this example.









## Example 2

Existing Conditions: Same as example 1.

Possible Upgradings: Same as example 1.

### Constraints:

Design: None  
Visibility: Minimum acceptable VI15 = 10  
Accident: 25% reduction  
Economic: Total increased costs less than \$2,000.  
Energy: Total energy use less than  $0.5 \times 10^5$  kwh

An optimum design will be derived for each constraint separately, then in combination.

### Combination

#### 1. Visibility

The optimum design is Case 213 with a VI15 =13.2. Case 107 has a higher VI15 (17.7) but the Benefit-cost ratio is less than 1. Similarly, Case 243 has a higher Benefit-cost ratio, but its VI15 is less than 10.

#### 2. Accident

Case 213 is optimum with a 31% accident reduction and Benefit-cost ratio = 1.13.

#### 3. Economic

Case 243 is optimum with an increased cost of \$1172 and a Benefit-cost ratio = 1.65. Case 137 is only slightly less good with a Benefit-cost ratio = 1.61.

#### 4. Energy

Case 243 is the only solution, with annual energy use =  $0.319 \times 10^5$  kwh and Benefit-cost ratio =1.65.

#### 5. Combined

There is no solution for all four constraints taken simultaneously. Case 213 will satisfy constraints 1 and 2 while Case 243 will satisfy constraints 3 and 4. No case will satisfy three constraints.

## Example 3

### Existing Conditions

Area Type

Other

|                     |                                                                      |
|---------------------|----------------------------------------------------------------------|
| Population Density: | 30,000 persons per square mile (11,700 persons per square kilometer) |
| Traffic Volume:     | 20,000 VPD                                                           |
| Road Width:         | 30 ft. (9.1m)                                                        |
| Surface Type:       | New asphalt                                                          |
| Luminaire:          | 175M                                                                 |
| Arrangement:        | Single Sided                                                         |
| Spacing:            | 200 ft. (61.0m)                                                      |
| Mounting Height:    | 25 ft. (7.6m)                                                        |
| Pole Type:          | Wood                                                                 |
| Overhang:           | 5 ft. (1.5m)                                                         |
| Visibility (VI15):  | 1.3                                                                  |

#### Possible Upgradings

1. 175M ———→ 150HPS
2. 200 ft. (61.0m) ———→ 100 ft. (30.5m) spacing
3. Combination of 1 and 2
4. 25 ft. (7.6m) ———→ 30 ft. (9.1m) mounting height
5. Combination of 1 and 4

Table 19 illustrates the data described above.

The optimum upgrade would be that design with highest Benefit-cost ratio. It is Case 373 for this example.

Example 4 - Same Existing Conditions as Example 3.

#### Constraints:

|             |                                                  |
|-------------|--------------------------------------------------|
| Design:     | Use HPS                                          |
| Visibility: | None                                             |
| Accident:   | 25% reduction                                    |
| Economic:   | Total increased costs less than \$2000           |
| Energy:     | Total energy use less than $0.3 \times 10^5$ kwh |

An optimum design will be derived for each constraint separately, then in combination.

- |                |          |
|----------------|----------|
| 1. Design:     | Case 268 |
| 2. Visibility: | -----    |
| 3. Accident:   | Case 268 |
| 4. Economic:   | Case 268 |
| 5. Energy:     | Case 268 |
| 6. Combined:   | Case 268 |

## 4.6 EFFECT OF MORE EFFICIENT OR REDUCED USE OF ENERGY ON TRAFFIC SAFETY

As a result of recent energy shortages and energy conservation programs, many communities are seeking ways to reduce their energy

Table 19 Summary of Upgraded Systems

[illegible]

consumption. One obvious method is by using more efficient sources of illumination for roadway lighting. Others may include reducing the number or size of roadway luminaires or even the entire rebuilding of lighting systems with more efficient combinations of spacings, heights, arrangements and types of luminaires. However, before such changes are made, those responsible for system modifications should know the impact of the proposed lighting changes on visibility and traffic safety.

This section will describe how the methodology of Sections 3.4 and 4.4 (Optimization) can be applied to select lighting system upgrades with reduced or more efficient energy use and then to determine the effect of this reduction in energy use on traffic safety. The only upgraded systems that will be considered at each site will be those whose energy use is less than the existing lighting system.

#### 4.6.1 Methodology

The methodology is built around the users' completion of Worksheet #11 (Table 36 in Appendix C). The data required for this worksheet includes

1. Existing System Code
2. Reduced Energy Options
3. Case Numbers
4. Energy Use of Options
5. Energy Changes (absolute)
6. Energy Changes (%)
8. VI15 of Options
8. VI15 Changes (%)
9. Area Type
10. Density
11. Volume
12. Accident Rates
13. Changes in Accident Rates

Of the 13 items above, each reduced energy option may be user developed (e.g., using the VI program) or selected from the FIRL data base in Appendix A. In either case most of the methodology is the same as described previously. Items 1, 2, 3, 4, 7, 9, 10 and 11 were all derived from Worksheet #9. The remaining items are calculated as follows:

Energy change (#5) = Energy use of existing system - energy use of option

Energy change (#6) =  $\frac{\#5}{\text{Energy use of existing system}}$

VI15 change (#8) =  $\frac{\text{VI15 (Existing)} - \text{VI15 (Option)}}{\text{VI15 (Existing)}}$



Change in accident rate (#3) =

$$\frac{\text{Accident rate of existing system} - \text{Accident rate of option}}{\text{Accident rate of existing system}}$$

Table 20 illustrates the results which would be obtained after completing the above items.

#### 4.6.2 Sample Problems

Example 1 - Find the most energy efficient lighting option for a system consisting of:

|                    |   |                                |
|--------------------|---|--------------------------------|
| Area Type          | = | CBD                            |
| Population Density | = | 30,000 persons per square mile |
| Traffic Value      | = | 20,000 VPD                     |
| Road Width         | = | 60 ft.                         |
| Arrangement        | = | Opposite                       |
| Spacing            | = | 100 ft.                        |
| Mounting Height    | = | 30 ft.                         |
| Luminaire          | = | 400M                           |

Options that will be considered include:

1. 400 —→ 150HPS
2. 100 ft. (30.5m) —→ 200 ft. (61.0m) Spacing
3. 400M —→ 400HPS plus #2
4. 400M —→ 150HPS plus #2

Table 20 provides all the relevant data required for analysis of this sample problem. The most energy efficient upgrade is Case #223 which provides an 81% reduction in energy use (saving  $1.385 \times 10^5$  kwh/mile). The effect of this change is to increase accident rate by 23%.

Example 2 - For the same system as in Case 1, find the most energy efficient upgrade that will not increase accident rate.

Case 213 provides a 63% reduction in energy use ( $1.065 \times 10^5$  kwh/mile) with an 18% decrease in accident rate.

Example 3 - Find the most energy efficient lighting option for a system consisting of:

|                    |   |                                |
|--------------------|---|--------------------------------|
| Area Type          | = | CBD                            |
| Population Density | = | 30,000 persons per square mile |
| Traffic Volume     | = | 20,000 VPD                     |
| Road Width         | = | 30 ft.                         |
| Arrangement        | = | Staggered                      |
| Spacing            | = | 100 ft.                        |

Table 20 Reduced Energy Options

| EXISTING SYSTEM CODE    | REDUCED ENERGY OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | ENERGY USE<br>(Kwh/mi/yr)<br>(x10 <sup>2</sup> ) | ENERGY<br>CHANGE<br>(Kwh/mi/yr) | ENERGY<br>CHANGE<br>(%) | V115    |               | AREA<br>TYPE | DENSITY<br>(People/<br>Sq. Mi.) | VOLUME<br>(ADT) | ACCIDENTS              |               |
|-------------------------|-----------------------------------------|-------------|--------------------------------------------------|---------------------------------|-------------------------|---------|---------------|--------------|---------------------------------|-----------------|------------------------|---------------|
|                         |                                         |             |                                                  |                                 |                         | UPGRADE | CHANGE<br>(%) |              |                                 |                 | NEW RATE<br>(ac/mi/yr) | CHANGE<br>(%) |
| 30/400M/STG/100/30/5/M  | 30/400M/STG/100/30/5/M                  | 87          | 1704                                             | 0                               | 0                       | 16.3    | 0             | CBD          | 30000                           | 20000           | 8.38                   | 0             |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 30/150H/STG/100/30/5/M                  | 298         | 639                                              | -1065                           | -63                     | 16.4    | 1             | CBD          | 30000                           | 20000           | 8.38                   | 0             |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 30/400M/SS/100/30/5/M                   | 47          | 852                                              | - 852                           | -50                     | 7.4     | -55           | CBD          | 30000                           | 20000           | 12.66                  | 51            |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 30/400H/SS/100/30/5/M                   | 152         | 852                                              | - 852                           | -50                     | 15.0    | - 8           | CBD          | 30000                           | 20000           | 8.4                    | 0             |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 30/150H/SS/100/30/5/M                   | 258         | 319                                              | -1385                           | -81                     | 10.7    | -34           | CBD          | 30000                           | 20000           | 10.53                  | 26            |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
| 60/400M/OPP/100/30/11/M | 60/400M/OPP/100/30/11/M                 | 2           | 1704                                             | 0                               | 0                       | 9.4     | 0             | CBD          | 30000                           | 20000           | 11.59                  | 0             |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 60/150H/OPP/100/30/11/M                 | 213         | 639                                              | -1056                           | -63                     | 13.2    | 40            | CBD          | 30000                           | 20000           | 9.46                   | -18           |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 60/400M/OPP/200/30/11/M                 | 12          | 852                                              | - 852                           | -50                     | 2.0     | -79           | CBD          | 30000                           | 20000           | 15.32                  | 32            |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 60/400H/OPP/200/30/11/M                 | 117         | 852                                              | - 852                           | -50                     | 3.0     | -68           | CBD          | 30000                           | 20000           | 14.78                  | 28            |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         | 60/150H/OPP/200/30/11/M                 | 223         | 319                                              | -1385                           | -81                     | 4.2     | -55           | CBD          | 30000                           | 20000           | 14.25                  | 23            |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |
|                         |                                         |             |                                                  |                                 |                         |         |               |              |                                 |                 |                        |               |

Mounting Height        = 30 ft.  
Luminaire               = 400M

Options that will be considered include:

1. 400M ———> 150HPS
2. Staggered ———> 1-sided
3. 400M ———> 400HPS plus #2
4. 400M ———> 150HPS plus #2

Table 20 provides all the relevant data for this analysis. The most energy efficient lighting system is Case 258 which provides an 81% reduction in energy use (a saving of  $1.385 \times 10^5$  kwh/mile) with an increase in accident rate of 26%.

Example 4 - For the same condition as in Example 3, find a reduced energy option which does not increase accident rate. Case 298 provides a 65% reduction in energy use ( $1.865 \times 10^5$  kwh/mile) with no increase in accident rate.

#### REFERENCES

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3. King, L.E., "Measurement of Directional Reflectance of Pavement Surfaces and Development of Computer Techniques for Calculating Luminance", IERl-87, Final Report, Illumination Engineering Research Institute, July 1973 (unpublished draft).

## APPENDIX A

### FIRL Data Base

This appendix contains the data base generated by the VI computer program of Section 2, the regression equation of Section 3, NHTSA average accident costs and the input conditions described in Section 3 of this report. In addition, the last table provides average "per mile" costs for the components of lighting systems based on data obtained and analyzed by FIRL. The use of this data base is described in Sections 3 and 4 of this guide.



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| .8810            | 60                  | 400M               | OPP                | 250              | 25                          | 11                     | 60/400M/OPP/250/25/11/- | 16          |
| 1.5449           | 60                  | 400M               | OPP                | 200              | 25                          | 11                     | 60/400M/OPP/200/25/11/- | 11          |
| 1.6674           | 60                  | 400M               | OPP                | 250              | 35                          | 11                     | 60/400M/OPP/250/35/11/- | 18          |
| 2.0309           | 60                  | 400M               | OPP                | 200              | 30                          | 11                     | 60/400M/OPP/200/30/11/- | 12          |
| 2.1465           | 60                  | 400M               | OPP                | 250              | 30                          | 11                     | 60/400M/OPP/250/30/11/- | 17          |
| 2.5871           | 60                  | 400M               | STG                | 250              | 25                          | 11                     | 60/400M/STG/250/25/11/- | 36          |
| 2.5957           | 60                  | 400M               | OPP                | 150              | 25                          | 11                     | 60/400M/OPP/150/25/11/- | 6           |
| 2.6439           | 60                  | 400M               | OPP                | 250              | 40                          | 11                     | 60/400M/OPP/250/40/11/- | 19          |
| 3.1498           | 60                  | 400M               | STG                | 250              | 30                          | 11                     | 60/400M/STG/250/30/11/- | 37          |
| 3.2670           | 60                  | 400M               | OPP                | 200              | 35                          | 11                     | 60/400M/OPP/200/35/11/- | 13          |
| 3.4387           | 60                  | 400M               | OPP                | 250              | 45                          | 11                     | 60/400M/OPP/250/45/11/- | 20          |
| 3.7183           | 60                  | 400M               | STG                | 200              | 25                          | 11                     | 60/400M/STG/200/25/11/- | 31          |
| 4.3430           | 60                  | 400M               | STG                | 250              | 35                          | 11                     | 60/400M/STG/250/35/11/- | 38          |
| 4.4109           | 60                  | 400M               | OPP                | 200              | 40                          | 11                     | 60/400M/OPP/200/40/11/- | 14          |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 4.6170           | 60                  | 400M               | STG                | 200              | 30                          | 11                     | 60/400M/STG/200/30/11/- | 32          |
| 5.1213           | 60                  | 400M               | STG                | 250              | 40                          | 11                     | 60/400M/STG/250/40/11/- | 39          |
| 5.2472           | 60                  | 400M               | OPP                | 150              | 30                          | 11                     | 60/400M/OPP/150/30/11/- | 7           |
| 5.2887           | 60                  | 400M               | OPP                | 200              | 45                          | 11                     | 60/400M/OPP/200/45/11/- | 15          |
| 5.5039           | 60                  | 400M               | STG                | 150              | 25                          | 11                     | 60/400M/STG/150/25/11/- | 26          |
| 5.8409           | 60                  | 400M               | STG                | 250              | 45                          | 11                     | 60/400M/STG/250/45/11/- | 40          |
| 6.0017           | 60                  | 400M               | STG                | 200              | 35                          | 11                     | 60/400M/STG/200/35/11/- | 33          |
| 6.9845           | 60                  | 400M               | STG                | 200              | 40                          | 11                     | 60/400M/STG/200/40/11/- | 34          |
| 7.1639           | 60                  | 400M               | OPP                | 150              | 35                          | 11                     | 60/400M/OPP/150/35/11/- | 8           |
| 7.2646           | 60                  | 400M               | STG                | 150              | 30                          | 11                     | 60/400M/STG/150/30/11/- | 27          |
| 7.6937           | 60                  | 400M               | OPP                | 100              | 25                          | 11                     | 60/400M/OPP/100/25/11/- | 1           |
| 7.7776           | 60                  | 400M               | STG                | 200              | 45                          | 11                     | 60/400M/STG/200/45/11/- | 35          |
| 7.9566           | 60                  | 400M               | OPP                | 150              | 40                          | 11                     | 60/400M/OPP/150/40/11/- | 9           |
| 8.3169           | 60                  | 400M               | OPP                | 150              | 45                          | 11                     | 60/400M/OPP/150/45/11/- | 10          |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 8.9928           | 60                  | 400M               | STG                | 150              | 35                          | 11                     | 60/400M/STG/150/35/11/- | 28          |
| 9.3536           | 60                  | 400M               | OPP                | 100              | 30                          | 11                     | 60/400M/OPP/100/30/11/- | 2           |
| 9.9268           | 60                  | 400M               | STG                | 150              | 40                          | 11                     | 60/400M/STG/150/40/11/- | 29          |
| 10.5406          | 60                  | 400M               | STG                | 100              | 25                          | 11                     | 60/400M/STG/100/25/11/- | 21          |
| 10.6611          | 60                  | 400M               | STG                | 150              | 45                          | 11                     | 60/400M/STG/150/45/11/- | 30          |
| 10.9258          | 60                  | 400M               | OPP                | 100              | 35                          | 11                     | 60/400M/OPP/100/35/11/- | 3           |
| 11.8463          | 60                  | 400M               | OPP                | 100              | 40                          | 11                     | 60/400M/OPP/100/40/11/- | 4           |
| 12.4308          | 60                  | 400M               | STG                | 100              | 30                          | 11                     | 60/400M/STG/100/30/11/- | 22          |
| 12.6741          | 60                  | 400M               | OPP                | 100              | 45                          | 11                     | 60/400M/OPP/100/45/11/- | 5           |
| 13.3502          | 60                  | 400M               | STG                | 100              | 35                          | 11                     | 60/400M/STG/100/35/11/- | 23          |
| 13.7586          | 60                  | 400M               | STG                | 100              | 40                          | 11                     | 60/400M/STG/100/40/11/- | 24          |
| 13.8469          | 60                  | 400M               | STG                | 100              | 45                          | 11                     | 60/400M/STG/100/45/11/- | 25          |
|                  |                     |                    |                    |                  |                             |                        |                         |             |
|                  |                     |                    |                    |                  |                             |                        |                         |             |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| .8994            | 30                  | 400M               | SS                 | 250              | 25                          | 5                      | 30/400M/SS/250/25/5/-  | 61          |
| 1.1146           | 30                  | 400M               | OPP                | 250              | 25                          | 5                      | 30/400M/OPP/250/25/5/- | 81          |
| 1.1876           | 30                  | 400M               | SS                 | 250              | 30                          | 5                      | 30/400M/SS/250/30/5/-  | 62          |
| 1.2269           | 30                  | 400M               | SS                 | 200              | 25                          | 5                      | 30/400M/SS/200/25/5/-  | 56          |
| 1.5359           | 30                  | 400M               | SS                 | 250              | 35                          | 5                      | 30/400M/SS/250/35/5/-  | 63          |
| 1.6293           | 30                  | 400M               | OPP                | 200              | 25                          | 5                      | 30/400M/OPP/200/25/5/- | 76          |
| 1.6937           | 30                  | 400M               | OPP                | 250              | 30                          | 5                      | 30/400M/OPP/250/30/5/- | 82          |
| 2.0427           | 30                  | 400M               | SS                 | 200              | 30                          | 5                      | 30/400M/SS/200/30/5/-  | 57          |
| 2.6482           | 30                  | 400M               | OPP                | 250              | 35                          | 5                      | 30/400M/OPP/250/35/5/- | 83          |
| 2.9871           | 30                  | 400M               | SS                 | 150              | 25                          | 5                      | 30/400M/SS/150/25/5/-  | 51          |
| 3.0416           | 30                  | 400M               | SS                 | 250              | 40                          | 5                      | 30/400M/SS/250/40/5/-  | 64          |
| 3.0849           | 30                  | 400M               | STG                | 250              | 25                          | 5                      | 30/400M/STG/250/25/5/- | 101.        |
| 3.1334           | 30                  | 400M               | OPP                | 200              | 30                          | 5                      | 30/400M/OPP/200/30/5/- | 77          |
| 3.4781           | 30                  | 400M               | SS                 | 200              | 35                          | 5                      | 30/400M/SS/200/35/5/-  | 58.         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 3.8717           | 30                  | 400M               | SS                 | 250              | 45                          | 5                      | 30/400M/SS/250/45/5/-  | 65          |
| 4.0851           | 30                  | 400M               | OPP                | 150              | 25                          | 5                      | 30/400M/OPP/150/25/5/- | 71          |
| 4.1406           | 30                  | 400M               | OPP                | 250              | 40                          | 5                      | 30/400M/OPP/250/40/5/- | 84          |
| 4.2786           | 30                  | 400M               | SS                 | 150              | 30                          | 5                      | 30/400M/SS/150/30/5/-  | 52          |
| 4.4390           | 30                  | 400M               | SS                 | 200              | 40                          | 5                      | 30/400M/SS/200/40/5/-  | 59          |
| 4.8560           | 30                  | 400M               | STG                | 200              | 25                          | 5                      | 30/400M/STG/200/25/5/- | 96          |
| 5.0597           | 30                  | 400M               | STG                | 250              | 30                          | 5                      | 30/400M/STG/250/30/5/- | 102         |
| 5.1208           | 30                  | 400M               | OPP                | 200              | 35                          | 5                      | 30/400M/OPP/200/35/5/- | 78          |
| 5.2257           | 30                  | 400M               | OPP                | 250              | 45                          | 5                      | 30/400M/OPP/250/45/5/- | 85          |
| 5.2838           | 30                  | 400M               | SS                 | 200              | 45                          | 5                      | 30/400M/SS/200/45/5/-  | 60          |
| 5.6499           | 30                  | 400M               | SS                 | 100              | 25                          | 5                      | 30/400M/SS/100/25/5/-  | 46          |
| 5.6875           | 30                  | 400M               | SS                 | 150              | 35                          | 5                      | 30/400M/SS/150/35/5/-  | 53          |
| 6.2159           | 30                  | 400M               | STG                | 250              | 35                          | 5                      | 30/400M/STG/250/35/5/- | 103         |
| 6.5010           | 30                  | 400M               | SS                 | 150              | 40                          | 5                      | 30/400M/SS/150/40/5/-  | 54          |



Table 21 - VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 6.8327           | 30                  | 400M               | OPP                | 200              | 40                          | 5                      | 30/400M/OPP/200/40/5/- | 79          |
| 6.9250           | 30                  | 400M               | STG                | 200              | 30                          | 5                      | 30/400M/STG/200/30/5/- | 97          |
| 6.9667           | 30                  | 400M               | OPP                | 150              | 30                          | 5                      | 30/400M/OPP/150/30/5/- | 72          |
| 7.2100           | 30                  | 400M               | STG                | 250              | 40                          | 5                      | 30/400M/STG/250/40/5/- | 104         |
| 7.2532           | 30                  | 400M               | SS                 | 150              | 45                          | 5                      | 30/400M/SS/150/45/5/-  | 55          |
| 7.3615           | 30                  | 400M               | SS                 | 100              | 30                          | 5                      | 30/400M/SS/100/30/5/-  | 47          |
| 7.4271           | 30                  | 400M               | OPP                | 200              | 45                          | 5                      | 30/400M/OPP/200/45/5/- | 80          |
| 8.2765           | 30                  | 400M               | STG                | 250              | 45                          | 5                      | 30/400M/STG/250/45/5/- | 105         |
| 8.7721           | 30                  | 400M               | OPP                | 150              | 35                          | 5                      | 30/400M/OPP/150/35/5/- | 73          |
| 8.8052           | 30                  | 400M               | STG                | 150              | 25                          | 5                      | 30/400M/STG/150/25/5/- | 91          |
| 8.9787           | 30                  | 400M               | STG                | 200              | 35                          | 5                      | 30/400M/STG/200/35/5/- | 98          |
| 9.0578           | 30                  | 400M               | SS                 | 100              | 35                          | 5                      | 30/400M/SS/100/35/5/-  | 48          |
| 9.5703           | 30                  | 400M               | SS                 | 100              | 40                          | 5                      | 30/400M/SS/100/40/5/-  | 49          |
| 9.8049           | 30                  | 400M               | SS                 | 100              | 45                          | 5                      | 30/400M/SS/100/45/5/-  | 50          |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 9.9145           | 30                  | 400M               | OPP                | 150              | 40                          | 5                      | 30/400M/OPP/150/40/5/- | 74          |
| 10.0520          | 30                  | 400M               | STG                | 200              | 40                          | 5                      | 30/400M/STG/200/40/5/- | 99          |
| 10.7445          | 30                  | 400M               | STG                | 200              | 45                          | 5                      | 30/400M/STG/200/45/5/- | 100         |
| 10.7561          | 30                  | 400M               | OPP                | 150              | 45                          | 5                      | 30/400M/OPP/150/45/5/- | 75          |
| 10.9366          | 30                  | 400M               | OPP                | 100              | 25                          | 5                      | 30/400M/OPP/100/25/5/- | 66          |
| 11.0322          | 30                  | 400M               | STG                | 150              | 30                          | 5                      | 30/400M/STG/150/30/5/- | 92          |
| 11.1383          | 30                  | 400M               | SS                 | 50               | 25                          | 5                      | 30/400M/SS/50/25/5/-   | 41          |
| 12.2305          | 30                  | 400M               | SS                 | 50               | 30                          | 5                      | 30/400M/SS/50/30/5/-   | 42          |
| 12.2712          | 30                  | 400M               | STG                | 150              | 35                          | 5                      | 30/400M/STG/150/35/5/- | 93          |
| 12.7652          | 30                  | 400M               | OPP                | 100              | 30                          | 5                      | 30/400M/OPP/100/30/5/- | 67          |
| 12.9781          | 30                  | 400M               | STG                | 150              | 40                          | 5                      | 30/400M/STG/150/40/5/- | 94          |
| 13.0730          | 30                  | 400M               | SS                 | 50               | 35                          | 5                      | 30/400M/SS/50/35/5/-   | 43          |
| 13.1876          | 30                  | 400M               | STG                | 150              | 45                          | 5                      | 30/400M/STG/150/45/5/- | 95          |
| 13.8569          | 30                  | 400M               | SS                 | 50               | 40                          | 5                      | 30/400M/SS/50/40/5/-   | 44          |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 13.9885          | 30                  | 400M               | OPP                | 100              | 35                          | 5                      | 30/400M/OPP/100/35/5/- | 68          |
| 14.1075          | 30                  | 400M               | SS                 | 50               | 45                          | 5                      | 30/400M/SS/50/45/5/-   | 45          |
| 14.7439          | 30                  | 400M               | OPP                | 100              | 40                          | 5                      | 30/400M/OPP/100/40/5/- | 69          |
| 15.2114          | 30                  | 400M               | STG                | 100              | 25                          | 5                      | 30/400M/STG/100/25/5/- | 86          |
| 15.4200          | 30                  | 400M               | OPP                | 100              | 45                          | 5                      | 30/400M/OPP/100/45/5/- | 70          |
| 16.2451          | 30                  | 400M               | STG                | 100              | 45                          | 5                      | 30/400M/STG/100/45/5/- | 90          |
| 16.3119          | 30                  | 400M               | STG                | 100              | 35                          | 5                      | 30/400M/STG/100/35/5/- | 88          |
| 16.3251          | 30                  | 400M               | STG                | 100              | 40                          | 5                      | 30/400M/STG/100/40/5/- | 89          |
| 16.3397          | 30                  | 400M               | STG                | 100              | 30                          | 5                      | 30/400M/STG/100/30/5/- | 87          |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 1.2712           | 60                  | 400H               | OPP                | 250              | 25                          | 11                     | 60/400H/OPP/250/25/11/- | 121         |
| 2.1290           | 60                  | 400H               | OPP                | 200              | 25                          | 11                     | 60/400H/OPP/200/25/11/- | 116         |
| 2.1435           | 60                  | 400H               | OPP                | 250              | 35                          | 11                     | 60/400H/OPP/250/35/11/- | 123         |
| 2.9904           | 60                  | 400H               | OPP                | 200              | 30                          | 11                     | 60/400H/OPP/200/30/11/- | 117         |
| 3.0037           | 60                  | 400H               | OPP                | 250              | 30                          | 11                     | 60/400H/OPP/250/30/11/- | 122         |
| 3.6696           | 60                  | 400H               | OPP                | 250              | 40                          | 11                     | 60/400H/OPP/250/40/11/- | 124         |
| 4.5323           | 60                  | 400H               | STG                | 200              | 25                          | 11                     | 60/400H/STG/200/25/11/- | 136         |
| 5.1070           | 60                  | 400H               | OPP                | 250              | 45                          | 11                     | 60/400H/OPP/250/45/11/- | 135         |
| 5.2690           | 60                  | 400H               | STG                | 250              | 25                          | 11                     | 60/400H/STG/250/25/11/- | 141         |
| 5.5971           | 60                  | 400H               | STG                | 250              | 30                          | 11                     | 60/400H/STG/250/30/11/- | 142         |
| 5.7963           | 60                  | 400H               | OPP                | 200              | 35                          | 11                     | 60/400H/OPP/200/35/11/- | 118         |
| 6.1494           | 60                  | 400H               | OPP                | 150              | 25                          | 11                     | 60/400H/OPP/150/25/11/- | 111         |
| 8.1186           | 60                  | 400H               | STG                | 250              | 35                          | 11                     | 60/400H/STG/250/35/11/- | 143         |
| 8.2351           | 60                  | 400H               | STG                | 200              | 30                          | 11                     | 60/400H/STG/200/30/11/- | 137         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 8.4780           | 60                  | 400H               | OPP                | 200              | 40                          | 11                     | 60/400H/OPP/200/40/11/- | 119         |
| 9.3078           | 60                  | 400H               | STG                | 250              | 40                          | 11                     | 60/400H/STG/250/40/11/- | 144         |
| 9.9797           | 60                  | 400H               | STG                | 150              | 25                          | 11                     | 60/400H/STG/150/25/11/- | 131         |
| 10.0443          | 60                  | 400H               | OPP                | 150              | 30                          | 11                     | 60/400H/OPP/150/30/11/- | 112         |
| 10.3950          | 60                  | 400H               | OPP                | 200              | 45                          | 11                     | 60/400H/OPP/200/45/11/- | 120         |
| 10.8254          | 60                  | 400H               | STG                | 250              | 45                          | 11                     | 60/400H/STG/250/45/11/- | 145         |
| 10.8731          | 60                  | 400H               | STG                | 200              | 35                          | 11                     | 60/400H/STG/200/35/11/- | 138         |
| 12.5312          | 60                  | 400H               | STG                | 200              | 40                          | 11                     | 60/400H/STG/200/40/11/- | 139         |
| 12.6462          | 60                  | 400H               | OPP                | 150              | 35                          | 11                     | 60/400H/OPP/150/35/11/- | 113         |
| 12.6517          | 60                  | 400H               | STG                | 200              | 45                          | 11                     | 60/400H/STG/200/45/11/- | 140         |
| 13.1234          | 60                  | 400H               | STG                | 150              | 30                          | 11                     | 60/400H/STG/150/30/11/- | 132         |
| 13.9072          | 60                  | 400H               | OPP                | 150              | 40                          | 11                     | 60/400H/OPP/150/40/11/- | 114         |
| 14.1990          | 60                  | 400H               | STG                | 150              | 35                          | 11                     | 60/400H/STG/150/35/11/- | 133         |
| 14.7243          | 60                  | 400H               | OPP                | 150              | 45                          | 11                     | 60/400H/OPP/150/45/11/- | 115         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 14.9777          | 60                  | 400H               | STG                | 150              | 40                          | 11                     | 60/400H/STG/150/40/11/- | 134         |
| 15.4985          | 60                  | 400H               | STG                | 150              | 45                          | 11                     | 60/400H/STG/150/45/11/- | 135         |
| 15.9305          | 60                  | 400H               | OPP                | 100              | 25                          | 11                     | 60/400H/OPP/100/25/11/- | 106         |
| 16.4778          | 60                  | 400H               | STG                | 100              | 25                          | 11                     | 60/400H/STG/100/25/11/- | 126         |
| 17.7087          | 60                  | 400H               | OPP                | 100              | 30                          | 11                     | 60/400H/OPP/100/30/11/- | 107         |
| 17.7477          | 60                  | 400H               | STG                | 100              | 35                          | 11                     | 60/400H/STG/100/35/11/- | 108         |
| 17.9885          | 60                  | 400H               | OPP                | 100              | 45                          | 11                     | 60/400H/OPP/100/45/11/- | 110         |
| 18.0474          | 60                  | 400H               | OPP                | 100              | 40                          | 11                     | 60/400H/OPP/100/40/11/- | 109         |
| 18.2482          | 60                  | 400H               | STG                | 100              | 40                          | 11                     | 60/400H/STG/100/40/11/- | 129         |
| 18.3634          | 60                  | 400H               | STG                | 100              | 35                          | 11                     | 60/400H/STG/100/35/11/- | 128         |
| 18.4662          | 60                  | 400H               | STG                | 100              | 45                          | 11                     | 60/400H/STG/100/45/11/- | 130         |
| 19.0943          | 60                  | 400H               | STG                | 100              | 30                          | 11                     | 60/400H/STG/100/30/11/- | 127         |
|                  |                     |                    |                    |                  |                             |                        |                         |             |
|                  |                     |                    |                    |                  |                             |                        |                         |             |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 1.5257           | 30                  | 400H               | SS                 | 250              | 25                          | 5                      | 30/400H/SS/250/25/5/-  | 166         |
| 1.8018           | 30                  | 400H               | OPP                | 200              | 30                          | 5                      | 30/400H/OPP/200/30/5/- | 182         |
| 1.8576           | 30                  | 400H               | OPP                | 250              | 35                          | 5                      | 30/400H/OPP/250/35/5/- | 188         |
| 1.9407           | 30                  | 400H               | SS                 | 200              | 25                          | 5                      | 30/400H/SS/200/25/5/-  | 161         |
| 2.4167           | 30                  | 400H               | SS                 | 250              | 30                          | 5                      | 30/400H/SS/250/30/5/-  | 167         |
| 3.0280           | 30                  | 400H               | SS                 | 250              | 35                          | 5                      | 30/400H/SS/250/35/5/-  | 168         |
| 3.3389           | 30                  | 400H               | OPP                | 250              | 25                          | 5                      | 30/400H/OPP/250/25/5/- | 186         |
| 3.8013           | 30                  | 400H               | SS                 | 250              | 40                          | 5                      | 30/400H/SS/250/40/5/-  | 169         |
| 3.9129           | 30                  | 400H               | OPP                | 250              | 40                          | 5                      | 30/400H/OPP/250/40/5/- | 189         |
| 4.1931           | 30                  | 400H               | OPP                | 250              | 30                          | 5                      | 30/400H/OPP/250/30/5/- | 187         |
| 4.2644           | 30                  | 400H               | SS                 | 200              | 30                          | 5                      | 30/400H/SS/200/30/5/-  | 162         |
| 5.4187           | 30                  | 400H               | OPP                | 200              | 30                          | 5                      | 30/400H/OPP/200/25/5/- | 181         |
| 5.7869           | 30                  | 400H               | SS                 | 250              | 45                          | 5                      | 30/400H/SS/250/45/5/-  | 170         |
| 6.1355           | 30                  | 400H               | SS                 | 150              | 25                          | 5                      | 30/400H/SS/150/25/5/-  | 156         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 6.2292           | 30                  | 400H               | SS                 | 200              | 35                          | 5                      | 30/400H/SS/200/35/5/-  | 163         |
| 6.3377           | 30                  | 400H               | OPP                | 200              | 35                          | 5                      | 30/400H/OPP/200/35/5/- | 183         |
| 6.7666           | 30                  | 400H               | OPP                | 250              | 45                          | 5                      | 30/400H/OPP/250/45/5/- | 190         |
| 7.2024           | 30                  | 400H               | OPP                | 150              | 25                          | 5                      | 30/400H/OPP/150/25/5/- | 176         |
| 7.2805           | 30                  | 400H               | STG                | 250              | 25                          | 5                      | 30/400H/STG/250/25/5/- | 206         |
| 8.1196           | 30                  | 400H               | SS                 | 200              | 40                          | 5                      | 30/400H/SS/200/40/5/-  | 164         |
| 9.4998           | 30                  | 400H               | SS                 | 200              | 45                          | 5                      | 30/400H/SS/200/45/5/-  | 165         |
| 9.7858           | 30                  | 400H               | SS                 | 150              | 30                          | 5                      | 30/400H/SS/150/30/5/-  | 157         |
| 10.1254          | 30                  | 400H               | OPP                | 200              | 40                          | 5                      | 30/400H/OPP/200/40/5/- | 184         |
| 11.4511          | 30                  | 400H               | SS                 | 150              | 35                          | 5                      | 30/400H/SS/150/35/5/-  | 158         |
| 11.9274          | 30                  | 400H               | STG                | 250              | 30                          | 5                      | 30/400H/STG/250/30/5/- | 207         |
| 12.4292          | 30                  | 400H               | OPP                | 200              | 45                          | 5                      | 30/400H/OPP/200/45/5/- | 185         |
| 12.8010          | 30                  | 400H               | OPP                | 150              | 30                          | 5                      | 30/400H/OPP/150/30/5/- | 177         |
| 12.9086          | 30                  | 400H               | STG                | 200              | 25                          | 5                      | 30/400H/STG/200/25/5/- | 201         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 12.9175          | 30                  | 400H               | SS                 | 150              | 40                          | 5                      | 30/400H/SS/150/40/5/-  | 159         |
| 12.9967          | 30                  | 400H               | SS                 | 100              | 25                          | 5                      | 30/400H/SS/100/25/5/-  | 151         |
| 13.5056          | 30                  | 400H               | SS                 | 150              | 45                          | 5                      | 30/400H/SS/150/45/5/-  | 160         |
| 13.8159          | 30                  | 400H               | STG                | 250              | 35                          | 5                      | 30/400H/STG/250/35/5/- | 208         |
| 14.6652          | 30                  | 400H               | STG                | 250              | 40                          | 5                      | 30/400H/STG/250/40/5/- | 209         |
| 14.9865          | 30                  | 400H               | SS                 | 100              | 30                          | 5                      | 30/400H/SS/100/30/5/-  | 152         |
| 15.2541          | 30                  | 400H               | STG                | 250              | 45                          | 5                      | 30/400H/STG/250/45/5/- | 210         |
| 15.9288          | 30                  | 400H               | OPP                | 150              | 35                          | 5                      | 30/400H/OPP/150/35/5/- | 178         |
| 15.9360          | 30                  | 400H               | STG                | 200              | 30                          | 5                      | 30/400H/STG/200/30/5/- | 202         |
| 16.5757          | 30                  | 400H               | SS                 | 100              | 35                          | 5                      | 30/400H/SS/100/35/5/-  | 153         |
| 16.7189          | 30                  | 400H               | STG                | 200              | 35                          | 5                      | 30/400H/STG/200/35/5/- | 203         |
| 16.8209          | 30                  | 400H               | STG                | 200              | 40                          | 5                      | 30/400H/STG/200/40/5/- | 204         |
| 16.8975          | 30                  | 400H               | SS                 | 100              | 40                          | 5                      | 30/400H/SS/100/40/5/-  | 154         |
| 16.9996          | 30                  | 400H               | STG                | 200              | 45                          | 5                      | 30/400H/STG/200/45/5/- | 205         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 17.1444          | 30                  | 400H               | SS                 | 100              | 45                          | 5                      | 30/400H/SS/100/45/5/-  | 155         |
| 17.4568          | 30                  | 400H               | OPP                | 150              | 40                          | 5                      | 30/400H/OPP/150/40/5/- | 179         |
| 17.8687          | 30                  | 400H               | OPP                | 150              | 45                          | 5                      | 30/400H/OPP/150/45/5/- | 180         |
| 19.4175          | 30                  | 400H               | STG                | 150              | 25                          | 5                      | 30/400H/STG/150/25/5/- | 196         |
| 20.1938          | 30                  | 400H               | STG                | 150              | 30                          | 5                      | 30/400H/STG/150/30/5/- | 197         |
| 20.2357          | 30                  | 400H               | STG                | 150              | 35                          | 5                      | 30/400H/STG/150/35/5/- | 198         |
| 20.4826          | 30                  | 400H               | STG                | 150              | 45                          | 5                      | 30/400H/STG/150/45/5/- | 200         |
| 20.6153          | 30                  | 400H               | STG                | 150              | 40                          | 5                      | 30/400H/STG/150/40/5/- | 199         |
| 22.5810          | 30                  | 400H               | SS                 | 50               | 30                          | 5                      | 30/400H/SS/50/30/5/-   | 147         |
| 23.2175          | 30                  | 400H               | SS                 | 50               | 25                          | 5                      | 30/400H/SS/50/25/5/-   | 146         |
| 24.1689          | 30                  | 400H               | SS                 | 50               | 40                          | 5                      | 30/400H/SS/50/40/5/-   | 149         |
| 24.3094          | 30                  | 400H               | SS                 | 50               | 45                          | 5                      | 30/400H/SS/50/45/5/-   | 150         |
| 24.3617          | 30                  | 400H               | SS                 | 50               | 35                          | 5                      | 30/400H/SS/50/35/5/-   | 148         |
| 24.6110          | 30                  | 400H               | OPP                | 100              | 25                          | 5                      | 30/400H/OPP/100/25/5/- | 171         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 24.7177          | 30                  | 400H               | OPP                | 100              | 45                          | 5                      | 30/400H/OPP/100/45/5/- | 175         |
| 24.7323          | 30                  | 400H               | STG                | 100              | 45                          | 5                      | 30/400H/STG/100/45/5/- | 195         |
| 25.5116          | 30                  | 400H               | OPP                | 100              | 40                          | 5                      | 30/400H/OPP/100/40/5/- | 174         |
| 25.5750          | 30                  | 400H               | OPP                | 100              | 30                          | 5                      | 30/400H/OPP/100/30/5/- | 172         |
| 25.6962          | 30                  | 400H               | STG                | 100              | 40                          | 5                      | 30/400H/STG/100/40/5/- | 194         |
| 25.8040          | 30                  | 400H               | OPP                | 100              | 35                          | 5                      | 30/400H/OPP/100/35/5/- | 173         |
| 27.1775          | 30                  | 400H               | STG                | 100              | 35                          | 5                      | 30/400H/STG/100/35/5/- | 193         |
| 27.6648          | 30                  | 400H               | STG                | 100              | 25                          | 5                      | 30/400H/STG/100/25/5/- | 191         |
| 28.6726          | 30                  | 400H               | STG                | 100              | 30                          | 5                      | 30/400H/STG/100/30/5/- | 192         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 2.2864           | 60                  | 150H               | OPP                | 250              | 25                          | 11                     | 60/150H/OPP/250/25/11/- | 227         |
| 2.2942           | 60                  | 150H               | OPP                | 250              | 20                          | 11                     | 60/150H/OPP/250/20/11/- | 226         |
| 2.6402           | 60                  | 150H               | OPP                | 200              | 20                          | 11                     | 60/150H/OPP/200/20/11/- | 221         |
| 2.6828           | 60                  | 150H               | OPP                | 250              | 35                          | 11                     | 60/150H/OPP/250/35/11/- | 229         |
| 2.8761           | 60                  | 150H               | STG                | 250              | 20                          | 11                     | 60/150H/STG/250/20/11/- | 246         |
| 3.1613           | 60                  | 150H               | OPP                | 200              | 25                          | 11                     | 60/150H/OPP/200/25/11/- | 222         |
| 3.2017           | 60                  | 150H               | STG                | 250              | 30                          | 11                     | 60/150H/OPP/250/30/11/- | 228         |
| 3.6278           | 60                  | 150H               | OPP                | 250              | 40                          | 11                     | 60/150H/OPP/250/40/11/- | 230         |
| 3.6798           | 60                  | 150H               | STG                | 250              | 25                          | 11                     | 60/150H/STG/250/25/11/- | 247         |
| 3.9748           | 60                  | 150H               | STG                | 200              | 20                          | 11                     | 60/150H/STG/200/20/11/- | 241         |
| 4.0945           | 60                  | 150H               | OPP                | 150              | 20                          | 11                     | 60/150H/OPP/150/20/11/- | 216         |
| 4.2115           | 60                  | 150H               | OPP                | 200              | 30                          | 11                     | 60/150H/OPP/200/30/11/- | 223         |
| 4.6917           | 60                  | 150H               | OPP                | 150              | 25                          | 11                     | 60/150H/OPP/150/25/11/- | 217         |
| 4.8345           | 60                  | 150H               | STG                | 250              | 30                          | 11                     | 60/150H/STG/250/30/11/- | 248         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 5.1449           | 60                  | 150H               | STG                | 150              | 20                          | 11                     | 60/150H/STG/150/20/11/- | 236         |
| 5.3778           | 60                  | 150H               | STG                | 200              | 25                          | 11                     | 60/150H/STG/200/25/11/- | 242         |
| 5.4357           | 60                  | 150H               | STG                | 250              | 35                          | 11                     | 60/150H/STG/250/35/11/- | 249         |
| 6.2496           | 60                  | 150H               | OPP                | 200              | 35                          | 11                     | 60/150H/OPP/200/35/11/- | 224         |
| 6.2879           | 60                  | 150H               | STG                | 200              | 30                          | 11                     | 60/150H/STG/200/30/11/- | 243         |
| 6.8343           | 60                  | 150H               | STG                | 250              | 40                          | 11                     | 60/150H/STG/250/40/11/- | 250         |
| 6.8785           | 60                  | 150H               | STG                | 200              | 35                          | 11                     | 60/150H/STG/200/35/11/- | 244         |
| 7.0540           | 60                  | 150H               | STG                | 150              | 25                          | 11                     | 60/150H/STG/150/25/11/- | 237         |
| 7.2044           | 60                  | 150H               | OPP                | 200              | 40                          | 11                     | 60/150H/OPP/200/40/11/- | 225         |
| 8.0070           | 60                  | 150H               | OPP                | 150              | 30                          | 11                     | 60/150H/OPP/150/30/11/- | 218         |
| 8.0145           | 60                  | 150H               | STG                | 200              | 40                          | 11                     | 60/150H/STG/200/40/11/- | 245         |
| 8.7851           | 60                  | 150H               | STG                | 150              | 30                          | 11                     | 60/150H/STG/150/30/11/- | 238         |
| 8.8724           | 60                  | 150H               | OPP                | 150              | 35                          | 11                     | 60/150H/OPP/150/35/11/- | 219         |
| 9.2265           | 60                  | 150H               | STG                | 150              | 35                          | 11                     | 60/150H/STG/150/35/11/- | 239         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 9.8073           | 60                  | 150H               | OPP                | 150              | 40                          | 11                     | 60/150H/OPP/150/40/11/- | 220         |
| 10.1171          | 60                  | 150H               | OPP                | 100              | 20                          | 11                     | 60/150H/OPP/100/20/11/- | 211         |
| 10.3387          | 60                  | 150H               | STG                | 150              | 40                          | 11                     | 60/150H/STG/150/40/11/- | 240         |
| 10.5746          | 60                  | 150H               | STG                | 100              | 20                          | 11                     | 60/150H/STG/100/20/11/- | 231         |
| 11.3604          | 60                  | 150H               | OPP                | 100              | 25                          | 11                     | 60/150H/OPP/100/25/11/- | 212         |
| 11.8676          | 60                  | 150H               | STG                | 100              | 25                          | 11                     | 60/150H/STG/100/25/11/- | 232         |
| 13.0628          | 60                  | 150H               | STG                | 100              | 30                          | 11                     | 60/150H/STG/100/30/11/- | 233         |
| 13.2321          | 60                  | 150H               | STG                | 100              | 40                          | 11                     | 60/150H/STG/100/40/11/- | 235         |
| 13.2493          | 60                  | 150H               | OPP                | 100              | 30                          | 11                     | 60/150H/OPP/100/30/11/- | 213         |
| 13.5344          | 60                  | 150H               | OPP                | 100              | 35                          | 11                     | 60/150H/OPP/100/35/11/- | 214         |
| 13.5397          | 60                  | 150H               | OPP                | 100              | 40                          | 11                     | 60/150H/OPP/100/40/11/- | 215         |
| 13.7638          | 60                  | 150H               | STG                | 100              | 35                          | 11                     | 60/150H/STG/100/35/11/- | 234         |
|                  |                     |                    |                    |                  |                             |                        |                         |             |
|                  |                     |                    |                    |                  |                             |                        |                         |             |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 1.9193           | 30                  | 150H               | OPP                | 250              | 20                          | 5                      | 30/150H/OPP/250/20/5/- | 291         |
| 1.9247           | 30                  | 150H               | STG                | 250              | 20                          | 5                      | 30/150H/STG/250/20/5/- | 311         |
| 2.0357           | 30                  | 150H               | OPP                | 200              | 20                          | 5                      | 30/150H/OPP/200/20/5/- | 286         |
| 2.1485           | 30                  | 150H               | SS                 | 250              | 25                          | 5                      | 30/150H/SS/250/25/5/-  | 272         |
| 2.2219           | 30                  | 150H               | SS                 | 200              | 20                          | 5                      | 30/150H/SS/200/20/5/-  | 266         |
| 2.4669           | 30                  | 150H               | SS                 | 250              | 20                          | 5                      | 30/150H/SS/250/20/5/-  | 271         |
| 3.1809           | 30                  | 150H               | SS                 | 200              | 25                          | 5                      | 30/150H/SS/200/25/5/-  | 267         |
| 3.6149           | 30                  | 150H               | SS                 | 250              | 30                          | 5                      | 30/150H/SS/250/30/5/-  | 273         |
| 3.6173           | 30                  | 150H               | SS                 | 150              | 25                          | 5                      | 30/150H/SS/150/25/5/-  | 262         |
| 3.6948           | 30                  | 150H               | OPP                | 250              | 25                          | 5                      | 30/150H/OPP/250/25/5/- | 292         |
| 3.7245           | 30                  | 150H               | SS                 | 250              | 35                          | 5                      | 30/150H/SS/250/35/5/-  | 274         |
| 4.1341           | 30                  | 150H               | SS                 | 150              | 20                          | 5                      | 30/150H/SS/150/20/5/-  | 261         |
| 4.4224           | 30                  | 150H               | SS                 | 250              | 40                          | 5                      | 30/150H/SS/250/40/5/-  | 275         |
| 4.7120           | 30                  | 150H               | OPP                | 150              | 20                          | 5                      | 30/150H/OPP/150/20/5/- | 281         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 4.7637           | 30                  | 150H               | OPP                | 200              | 25                          | 5                      | 30 150H OPP 200 25 5/- | 287         |
| 4.7845           | 30                  | 150H               | SS                 | 200              | 30                          | 5                      | 30 150H SS 200 30 5/-  | 268         |
| 5.2618           | 30                  | 150H               | OPP                | 250              | 30                          | 5                      | 30 150H OPP 250 30 5/- | 293         |
| 5.9171           | 30                  | 150H               | OPP                | 250              | 40                          | 5                      | 30 150H OPP 250 40 5/- | 295         |
| 5.9532           | 30                  | 150H               | OPP                | 250              | 35                          | 5                      | 30 150H OPP 250 35 5/- | 294         |
| 6.0134           | 30                  | 150H               | SS                 | 200              | 35                          | 5                      | 30 150H SS 200 35 5/-  | 269         |
| 6.1738           | 30                  | 150H               | STG                | 250              | 25                          | 5                      | 30 150H STG 250 25 5/- | 312         |
| 6.2823           | 30                  | 150H               | STG                | 150              | 20                          | 5                      | 30 150H STG 150 20 5/- | 301         |
| 6.3489           | 30                  | 150H               | SS                 | 100              | 20                          | 5                      | 30 150H SS 100 20 5/-  | 256         |
| 6.3874           | 30                  | 150H               | SS                 | 150              | 35                          | 5                      | 30 150H SS 150 35 5/-  | 264         |
| 6.3895           | 30                  | 150H               | SS                 | 200              | 40                          | 5                      | 30 150H SS 200 40 5/-  | 270         |
| 6.4648           | 30                  | 150H               | STG                | 200              | 20                          | 5                      | 30 150H STG 200 20 5/- | 306         |
| 6.6181           | 30                  | 150H               | OPP                | 200              | 40                          | 5                      | 30 150H OPP 200 40 5/- | 290         |
| 6.7663           | 30                  | 150H               | OPP                | 200              | 30                          | 5                      | 30 150H OPP 200 30 5/- | 288         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 7.2209           | 30                  | 150H               | STG                | 250              | 30                          | 5                      | 30/150H/STG/250/30/5/- | 313         |
| 7.3357           | 30                  | 150H               | SS                 | 150              | 30                          | 5                      | 30/150H/SS/150/30/5/-  | 263         |
| 7.7297           | 30                  | 150H               | SS                 | 150              | 40                          | 5                      | 30/150H/SS/150/40/5/-  | 265         |
| 8.0418           | 30                  | 150H               | STG                | 200              | 25                          | 5                      | 30/150H/STG/200/25/5/- | 307         |
| 8.2579           | 30                  | 150H               | OPP                | 200              | 35                          | 5                      | 30/150H/OPP/200/35/5/- | 289         |
| 8.3698           | 30                  | 150H               | STG                | 250              | 35                          | 5                      | 30/150H/STG/250/35/5/- | 314         |
| 8.5740           | 30                  | 150H               | SS                 | 100              | 25                          | 5                      | 30/150H/SS/100/25/5/-  | 257         |
| 8.7939           | 30                  | 150H               | OPP                | 150              | 25                          | 5                      | 30/150H/OPP/150/25/5/- | 282         |
| 9.1488           | 30                  | 150H               | SS                 | 50               | 20                          | 5                      | 30/150H/SS/50/20/5/-   | 251         |
| 9.3151           | 30                  | 150H               | STG                | 250              | 40                          | 5                      | 30/150H/STG/250/40/5/- | 315         |
| 10.1533          | 30                  | 150H               | STG                | 150              | 25                          | 5                      | 30/150H/STG/150/25/5/- | 302         |
| 10.4438          | 30                  | 150H               | OPP                | 150              | 30                          | 5                      | 30/150H/OPP/150/30/5/- | 283         |
| 10.5831          | 30                  | 150H               | SS                 | 100              | 40                          | 5                      | 30/150H/SS/100/40/5/-  | 260         |
| 10.6836          | 30                  | 150H               | SS                 | 100              | 30                          | 5                      | 30/150H/SS/100/30/5/-  | 258         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 11.0183          | 30                  | 150H               | SS                 | 100              | 35                          | 5                      | 30 150H SS 100 35 5/-  | 259         |
| 11.1714          | 30                  | 150H               | STG                | 200              | 35                          | 5                      | 30 150H STG 200 35 5/- | 309         |
| 11.2463          | 30                  | 150H               | STG                | 150              | 35                          | 5                      | 30 150H STG 150 35 5/- | 304         |
| 11.3684          | 30                  | 150H               | SS                 | 50               | 25                          | 5                      | 30 150H SS 50 25 5/-   | 252         |
| 11.4285          | 30                  | 150H               | STG                | 200              | 40                          | 5                      | 30 150H STG 200 40 5/- | 310         |
| 11.9088          | 30                  | 150H               | OPP                | 150              | 35                          | 5                      | 30 150H OPP 150 35 5/- | 284         |
| 11.9233          | 30                  | 150H               | STG                | 200              | 30                          | 5                      | 30 150H STG 200 30 5/- | 308         |
| 12.2511          | 30                  | 150H               | STG                | 150              | 40                          | 5                      | 30 150H STG 150 40 5/- | 305         |
| 12.8284          | 30                  | 150H               | STG                | 150              | 30                          | 5                      | 30 150H STG 150 30 5/- | 303         |
| 13.0531          | 30                  | 150H               | SS                 | 50               | 30                          | 5                      | 30 150H SS 50 30 5/-   | 253         |
| 13.1808          | 30                  | 150H               | OPP                | 150              | 40                          | 5                      | 30 150H OPP 150 40 5/- | 285         |
| 13.2131          | 30                  | 150H               | SS                 | 50               | 35                          | 5                      | 30 150H SS 50 35 5/-   | 254         |
| 13.5867          | 30                  | 150H               | STG                | 100              | 20                          | 5                      | 30 150H STG 100 20 5/- | 296         |
| 13.6169          | 30                  | 150H               | SS                 | 50               | 40                          | 5                      | 30 150H SS 50 40 5/-   | 255         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 13.6893          | 30                  | 150H               | OPP                | 100              | 20                          | 5                      | 30 150H OPP 100 20 5 - | 276         |
| 14.7006          | 30                  | 150H               | OPP                | 100              | 25                          | 5                      | 30 150H OPP 100 25 5 - | 277         |
| 14.9984          | 30                  | 150H               | STG                | 100              | 40                          | 5                      | 30 150H STG 100 40 5 - | 300         |
| 15.5528          | 30                  | 150H               | OPP                | 100              | 40                          | 5                      | 30 150H OPP 100 40 5 - | 280         |
| 15.9734          | 30                  | 150H               | OPP                | 100              | 30                          | 5                      | 30 150H OPP 100 30 5 - | 278         |
| 16.1547          | 30                  | 150H               | STG                | 100              | 35                          | 5                      | 30 150H STG 100 35 5 - | 299         |
| 16.3320          | 30                  | 150H               | OPP                | 100              | 35                          | 5                      | 30 150H OPP 100 35 5 - | 279         |
| 16.3631          | 30                  | 150H               | STG                | 100              | 30                          | 5                      | 30 150H STG 100 30 5 - | 298         |
| 16.3738          | 30                  | 150H               | STG                | 100              | 25                          | 5                      | 30 150H STG 100 25 5 - | 297         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| .9382            | 60                  | 175 M              | OPP                | 250              | 25                          | 11                     | 60/175M/OPP/250/25/11/- | 332         |
| 1.0687           | 60                  | 175 M              | STG                | 250              | 20                          | 11                     | 60/175M/STG/250/20/11/- | 351         |
| 1.2773           | 60                  | 175 M              | STG                | 250              | 25                          | 11                     | 60/175M/STG/250/25/11/- | 352         |
| 1.3971           | 60                  | 175 M              | OPP                | 250              | 35                          | 11                     | 60/175M/OPP/250/35/11/- | 334         |
| 1.5141           | 60                  | 175 M              | OPP                | 250              | 30                          | 11                     | 60/175M/OPP/250/30/11/- | 333         |
| 1.5488           | 60                  | 175 M              | OPP                | 250              | 20                          | 11                     | 60/175M/OPP/250/20/11/- | 331         |
| 1.5886           | 60                  | 175 M              | OPP                | 250              | 40                          | 11                     | 60/175M/OPP/250/40/11/- | 335         |
| 1.6928           | 60                  | 175 M              | OPP                | 200              | 25                          | 11                     | 60/175M/OPP/200/25/11/- | 327         |
| 1.7212           | 60                  | 175 M              | STG                | 250              | 30                          | 11                     | 60/175M/STG/250/30/11/- | 353         |
| 1.7247           | 60                  | 175 M              | OPP                | 200              | 20                          | 11                     | 60/175M/OPP/200/20/11/- | 326         |
| 1.9305           | 60                  | 175 M              | STG                | 200              | 20                          | 11                     | 60/175M/STG/200/20/11/- | 346         |
| 1.9475           | 60                  | 175 M              | STG                | 250              | 40                          | 11                     | 60/175M/STG/250/40/11/- | 355         |
| 2.0714           | 60                  | 175 M              | OPP                | 200              | 40                          | 11                     | 60/175M/OPP/200/40/11/- | 330         |
| 2.1230           | 60                  | 175 M              | STG                | 250              | 35                          | 11                     | 60/175M/STG/250/35/11/- | 354         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 2.2129           | 60                  | 175M               | OPP                | 200              | 30                          | 11                     | 60/175M/OPP/200/30/11/- | 328         |
| 2.2254           | 60                  | 175M               | OPP                | 150              | 20                          | 11                     | 60/175M/OPP/150/20/11/- | 321         |
| 2.2541           | 60                  | 175M               | STG                | 200              | 30                          | 11                     | 60/175M/STG/200/30/11/- | 348         |
| 2.2884           | 60                  | 175M               | STG                | 200              | 25                          | 11                     | 60/175M/STG/200/25/11/- | 347         |
| 2.3312           | 60                  | 175M               | OPP                | 200              | 35                          | 11                     | 60/175M/OPP/200/35/11/- | 329         |
| 2.6655           | 60                  | 175M               | STG                | 200              | 35                          | 11                     | 60/175M/STG/200/35/11/- | 349         |
| 2.9601           | 60                  | 175M               | STG                | 200              | 40                          | 11                     | 60/175M/STG/200/40/11/- | 350         |
| 3.0541           | 60                  | 175M               | STG                | 150              | 20                          | 11                     | 60/175M/STG/150/20/11/- | 341         |
| 3.0709           | 60                  | 175M               | OPP                | 150              | 30                          | 11                     | 60/175M/OPP/150/30/11/- | 323         |
| 3.1235           | 60                  | 175M               | OPP                | 150              | 35                          | 11                     | 60/175M/OPP/150/35/11/- | 324         |
| 3.2595           | 60                  | 175M               | OPP                | 150              | 25                          | 11                     | 60/175M/OPP/150/25/11/- | 322         |
| 3.6687           | 60                  | 175M               | STG                | 150              | 30                          | 11                     | 60/175M/STG/150/30/11/- | 343         |
| 3.6716           | 60                  | 175M               | STG                | 150              | 35                          | 11                     | 60/175M/STG/150/35/11/- | 344         |
| 3.9155           | 60                  | 175M               | OPP                | 150              | 40                          | 11                     | 60/175M/OPP/150/40/11/- | 325         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE             | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|-------------------------|-------------|
| 4.1958           | 60                  | 175M               | STG                | 150              | 25                          | 11                     | 60/175M/STG/150/25/11/- | 342         |
| 4.4269           | 60                  | 175M               | OPP                | 100              | 25                          | 11                     | 60/175M/OPP/100/25/11/- | 317         |
| 5.0900           | 60                  | 175M               | STG                | 150              | 40                          | 11                     | 60/175M/STG/150/40/11/- | 345         |
| 5.4694           | 60                  | 175M               | OPP                | 100              | 20                          | 11                     | 60/175M/OPP/100/20/11/- | 316         |
| 5.9919           | 60                  | 175M               | STG                | 100              | 20                          | 11                     | 60/175M/STG/100/20/11/- | 336         |
| 6.7559           | 60                  | 175M               | OPP                | 100              | 30                          | 11                     | 60/175M/OPP/100/30/11/- | 318         |
| 6.8337           | 60                  | 175M               | OPP                | 100              | 35                          | 11                     | 60/175M/OPP/100/35/11/- | 319         |
| 7.1427           | 60                  | 175M               | OPP                | 100              | 40                          | 11                     | 60/175M/OPP/100/40/11/- | 320         |
| 7.1648           | 60                  | 175M               | STG                | 100              | 40                          | 11                     | 60/175M/STG/100/40/11/- | 340         |
| 7.4184           | 60                  | 175M               | STG                | 100              | 30                          | 11                     | 60/175M/STG/100/30/11/- | 338         |
| 7.6388           | 60                  | 175M               | STG                | 100              | 25                          | 11                     | 60/175M/STG/100/25/11/- | 337         |
| 8.0377           | 60                  | 175M               | STG                | 100              | 35                          | 11                     | 60/175M/STG/100/35/11/- | 339         |
|                  |                     |                    |                    |                  |                             |                        |                         |             |
|                  |                     |                    |                    |                  |                             |                        |                         |             |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| .9866            | 30                  | 175M               | SS                 | 250              | 25                          | 5                      | 30/175M/SS/250/25/5/-  | 377         |
| 1.2230           | 30                  | 175M               | SS                 | 250              | 30                          | 5                      | 30/175M/SS/250/30/5/-  | 378         |
| 1.2358           | 30                  | 175M               | SS                 | 250              | 20                          | 5                      | 30/175M/SS/250/20/5/-  | 376         |
| 1.2875           | 30                  | 175M               | SS                 | 200              | 25                          | 5                      | 30/175M/SS/200/25/5/-  | 372         |
| 1.3122           | 30                  | 175M               | SS                 | 150              | 20                          | 5                      | 30/175M/SS/150/20/5/-  | 366         |
| 1.3859           | 30                  | 175M               | SS                 | 250              | 40                          | 5                      | 30/175M/SS/250/40/5/-  | 380         |
| 1.5303           | 30                  | 175M               | STG                | 250              | 20                          | 5                      | 30/175M/STG/250/20/5/- | 416         |
| 1.5325           | 30                  | 175M               | SS                 | 200              | 20                          | 5                      | 30/175M/SS/200/20/5/-  | 371         |
| 1.5578           | 30                  | 175M               | OPP                | 200              | 20                          | 5                      | 30/175M/OPP/200/20/5/- | 391         |
| 1.6119           | 30                  | 175M               | OPP                | 250              | 25                          | 5                      | 30/175M/OPP/250/25/5/- | 397         |
| 1.7910           | 30                  | 175M               | OPP                | 250              | 20                          | 5                      | 30/175M/OPP/250/20/5/- | 396         |
| 1.8335           | 30                  | 175M               | SS                 | 150              | 25                          | 5                      | 30/175M/SS/150/25/5/-  | 367         |
| 1.8994           | 30                  | 175M               | SS                 | 250              | 40                          | 5                      | 30/175M/SS/250/40/5/-  | 379         |
| 1.9295           | 30                  | 175M               | SS                 | 200              | 30                          | 5                      | 30/175M/SS/200/30/5/-  | 373         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 2.0843           | 30                  | 175M               | SS                 | 200              | 35                          | 5                      | 30 175M SS 200 35 5/-  | 374         |
| 2.3786           | 30                  | 175M               | OPP                | 200              | 25                          | 5                      | 30 175M OPP 200 25 5/- | 392         |
| 2.4275           | 30                  | 175M               | SS                 | 200              | 40                          | 5                      | 30 175M SS 200 40 5/-  | 375         |
| 2.4892           | 30                  | 175M               | OPP                | 250              | 40                          | 5                      | 30 175M OPP 250 40 5/- | 400         |
| 2.6055           | 30                  | 175M               | STG                | 150              | 20                          | 5                      | 30 175M STG 150 20 5/- | 406         |
| 2.6889           | 30                  | 175M               | OPP                | 250              | 30                          | 5                      | 30 175M OPP 250 30 5/- | 398         |
| 2.8522           | 30                  | 175M               | OPP                | 150              | 20                          | 5                      | 30 175M OPP 150 20 5/- | 386         |
| 2.9347           | 30                  | 175M               | STG                | 200              | 20                          | 5                      | 30 175M STG 200 20 5/- | 411         |
| 3.0469           | 30                  | 175M               | STG                | 250              | 25                          | 5                      | 30 175M STG 250 25 5/- | 417         |
| 3.3763           | 30                  | 175M               | OPP                | 250              | 35                          | 5                      | 30 175M OPP 250 35 5/- | 399         |
| 3.5293           | 30                  | 175M               | SS                 | 150              | 30                          | 5                      | 30 175M SS 150 30 5/-  | 368         |
| 3.6234           | 30                  | 175M               | OPP                | 200              | 40                          | 5                      | 30 175M OPP 200 40 5/- | 395         |
| 3.6273           | 30                  | 175M               | OPP                | 200              | 30                          | 5                      | 30 175M OPP 200 30 5/- | 393         |
| 3.6277           | 30                  | 175M               | OPP                | 150              | 25                          | 5                      | 30 175M OPP 150 25 5/- | 387         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 3.6333           | 30                  | 175 M              | STG                | 250              | 30                          | 5                      | 30/175M/STG/250/30/5/- | 418         |
| 3.6571           | 30                  | 175 M              | OPP                | 200              | 35                          | 5                      | 30/175M/OPP/200/35/5/- | 394         |
| 3.7166           | 30                  | 175 M              | SS                 | 100              | 20                          | 5                      | 30/175M/SS/100/20/5/-  | 361         |
| 3.7608           | 30                  | 175 M              | SS                 | 150              | 35                          | 5                      | 30/175M/SS/150/35/5/-  | 369         |
| 3.8904           | 30                  | 175 M              | STG                | 250              | 35                          | 5                      | 30/175M/STG/250/35/5/- | 419         |
| 3.9513           | 30                  | 175 M              | STG                | 250              | 40                          | 5                      | 30/175M/STG/250/40/5/- | 420         |
| 4.2315           | 30                  | 175 M              | OPP                | 100              | 20                          | 5                      | 30/175M/OPP/100/20/5/- | 381         |
| 4.4880           | 30                  | 175 M              | SS                 | 150              | 40                          | 5                      | 30/175M/SS/150/40/5/-  | 370         |
| 4.6807           | 30                  | 175 M              | SS                 | 100              | 25                          | 5                      | 30/175M/SS/100/25/5/-  | 362         |
| 4.7970           | 30                  | 175 M              | STG                | 200              | 25                          | 5                      | 30/175M/STG/200/25/5/- | 412         |
| 4.8179           | 30                  | 175 M              | STG                | 100              | 20                          | 5                      | 30/175M/STG/100/20/5/- | 401         |
| 5.1241           | 30                  | 175 M              | OPP                | 150              | 30                          | 5                      | 30/175M/OPP/150/30/5/- | 388         |
| 5.1328           | 30                  | 175 M              | STG                | 150              | 25                          | 5                      | 30/175M/STG/150/25/5/- | 407         |
| 5.1990           | 30                  | 175 M              | STG                | 200              | 30                          | 5                      | 30/175M/STG/200/30/5/- | 413         |



Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 5.2864           | 30                  | 175 M              | STG                | 200              | 35                          | 5                      | 30 175M STG 200 35 5/- | 414         |
| 5.7404           | 30                  | 175 M              | STG                | 200              | 40                          | 5                      | 30 175M STG 200 40 5/- | 415         |
| 6.4474           | 30                  | 175 M              | SS                 | 100              | 30                          | 5                      | 30 175M SS 100 30 5/-  | 363         |
| 6.7102           | 30                  | 175 M              | OPP                | 150              | 35                          | 5                      | 30 175M OPP 150 35 5/- | 389         |
| 6.7599           | 30                  | 175 M              | STG                | 150              | 30                          | 5                      | 30 175M STG 150 30 5/- | 408         |
| 6.8384           | 30                  | 175 M              | SS                 | 50               | 20                          | 5                      | 30 175M SS 50 20 5/-   | 356         |
| 7.0530           | 30                  | 175 M              | SS                 | 100              | 35                          | 5                      | 30 175M SS 100 35 5/-  | 364         |
| 7.0533           | 30                  | 175 M              | SS                 | 100              | 40                          | 5                      | 30 175M SS 100 40 5/-  | 365         |
| 7.0961           | 30                  | 175 M              | OPP                | 100              | 25                          | 5                      | 30 175M OPP 100 25 5/- | 382         |
| 7.1951           | 30                  | 175 M              | OPP                | 150              | 40                          | 5                      | 30 175M OPP 150 40 5/- | 390         |
| 7.4569           | 30                  | 175 M              | STG                | 100              | 25                          | 5                      | 30 175M STG 100 25 5/- | 402         |
| 7.5989           | 30                  | 175 M              | STG                | 150              | 35                          | 5                      | 30 175M STG 150 35 5/- | 409         |
| 8.0835           | 30                  | 175 M              | STG                | 150              | 40                          | 5                      | 30 175M STG 150 40 5/- | 410         |
| 8.1781           | 30                  | 175 M              | OPP                | 100              | 30                          | 5                      | 30 175M OPP 100 30 5/- | 383         |

Table 21 VI<sub>15</sub> vs. System Descriptions

| VI <sub>15</sub> | ROAD<br>WIDTH (ft.) | LAMP/<br>LUMINAIRE | CONFIG-<br>URATION | SPACING<br>(ft.) | MOUNTING<br>HEIGHT<br>(ft.) | OVER-<br>HANG<br>(ft.) | SYSTEM CODE            | CASE<br>NO. |
|------------------|---------------------|--------------------|--------------------|------------------|-----------------------------|------------------------|------------------------|-------------|
| 8.6307           | 30                  | 175M               | SS                 | 50               | 25                          | 5                      | 30 175M SS 50 25 5/-   | 357         |
| 8.7613           | 30                  | 175M               | OPP                | 100              | 35                          | 5                      | 30 175M OPP 100 35 5/- | 384         |
| 8.8902           | 30                  | 175M               | STG                | 100              | 30                          | 5                      | 30 175M STG 100 30 5/- | 403         |
| 9.6593           | 30                  | 175M               | STG                | 100              | 35                          | 5                      | 30 175M STG 100 35 5/- | 404         |
| 9.8373           | 30                  | 175M               | OPP                | 100              | 40                          | 5                      | 30 175M OPP 100 40 5/- | 385         |
| 10.0726          | 30                  | 175M               | STG                | 100              | 40                          | 5                      | 30 175M STG 100 40 5/- | 405         |
| 10.1143          | 30                  | 175M               | SS                 | 50               | 30                          | 5                      | 30 175M SS 50 30 5/-   | 358         |
| 10.4221          | 30                  | 175M               | SS                 | 50               | 40                          | 5                      | 30 175M SS 50 40 5/-   | 360         |
| 10.7322          | 30                  | 175M               | SS                 | 50               | 35                          | 5                      | 30 175M SS 50 35 5/-   | 359         |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |
|                  |                     |                    |                    |                  |                             |                        |                        |             |

Table 22. Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr) | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|---------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                           | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/400M/OPP/100/25/11/M | 1        | 7.7              | 1704                      | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 60/400M/OPP/100/30/11/M | 2        | 9.4              | 1704                      | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 60/400M/OPP/100/35/11/M | 3        | 10.9             | 1704                      | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 60/400M/OPP/100/40/11/M | 4        | 11.8             | 1704                      | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 60/400M/OPP/100/45/11/M | 5        | 12.7             | 1704                      | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 60/400M/OPP/150/25/11/M | 6        | 2.6              | 1147                      | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 60/400M/OPP/150/30/11/M | 7        | 5.2              | 1147                      | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 60/400M/OPP/150/35/11/M | 8        | 7.2              | 1147                      | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 60/400M/OPP/150/40/11/M | 9        | 8.0              | 1147                      | 85383            | 9235                 | 10749                | 530                            | 20514                     |
| 60/400M/OPP/150/45/11/M | 10       | 8.3              | 1147                      | 85383            | 9235                 | 10749                | 530                            | 20514                     |
| 60/400M/OPP/200/25/11/M | 11       | 1.5              | 852                       | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 60/400M/OPP/200/30/11/M | 12       | 2.0              | 852                       | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 60/400M/OPP/200/35/11/M | 13       | 3.3              | 852                       | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 60/400M/OPP/200/40/11/M | 14       | 4.4              | 852                       | 64038            | 6927                 | 8062                 | 398                            | 15387                     |
| 60/400M/OPP/200/45/11/M | 15       | 5.3              | 852                       | 64038            | 6927                 | 8062                 | 398                            | 15387                     |
| 60/400M/OPP/250/25/11/M | 16       | 0.9              | 688                       | 44214            | 4764                 | 6867                 | 339                            | 11970                     |



Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>2</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/400M/OPP/250/30/11/M | 17       | 2.1              | 688                                           | 44214            | 4764                 | 6867                 | 339                            | 11970                     |
| 60/400M/OPP/250/35/11/M | 18       | 1.7              | 688                                           | 44214            | 4764                 | 6867                 | 339                            | 11970                     |
| 60/400M/OPP/250/40/11/M | 19       | 2.6              | 688                                           | 54550            | 5900                 | 6867                 | 339                            | 13106                     |
| 60/400M/OPP/250/45/11/M | 20       | 3.4              | 688                                           | 54550            | 5900                 | 6867                 | 339                            | 13106                     |
| 60/400M/STG/100/25/11/M | 21       | 10.5             | 1704                                          | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 60/400M/STG/100/30/11/M | 22       | 12.4             | 1704                                          | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 60/400M/STG/100/35/11/M | 23       | 13.4             | 1704                                          | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 60/400M/STG/100/40/11/M | 24       | 13.8             | 1704                                          | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 60/400M/STG/100/45/11/M | 25       | 13.8             | 1704                                          | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 60/400M/STG/150/25/11/M | 26       | 5.5              | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 60/400M/STG/150/30/11/M | 27       | 7.3              | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 60/400M/STG/150/35/11/M | 28       | 9.0              | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 60/400M/STG/150/40/11/M | 29       | 9.9              | 1147                                          | 85383            | 9235                 | 10749                | 530                            | 20514                     |
| 60/400M/STG/150/45/11/M | 30       | 10.7             | 1147                                          | 85383            | 9235                 | 10749                | 530                            | 20514                     |
| 60/400M/STG/200/25/11/M | 31       | 3.7              | 852                                           | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 60/400M/STG/200/30/11/M | 32       | 4.6              | 852                                           | 51904            | 5592                 | 8062                 | 398                            | 14052                     |

Table 22 Costs of New Systems

[illegible]



Table 22 Costs of New Systems

| SYSTEM CODE           | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>2</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-----------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                       |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400M/SS/50/25/5/M  | 41       | 11.1             | 1720                                          | 96118            | 10356                | 14929                | 737                            | 26022                     |
| 30/400M/SS/50/30/5/M  | 42       | 12.2             | 1720                                          | 96118            | 10356                | 14929                | 737                            | 26022                     |
| 30/400M/SS/50/35/5/M  | 43       | 13.1             | 1720                                          | 96118            | 10356                | 14929                | 737                            | 26022                     |
| 30/400M/SS/50/40/5/M  | 44       | 13.9             | 1720                                          | 118588           | 12827                | 14929                | 737                            | 28493                     |
| 30/400M/SS/50/45/5/M  | 45       | 14.1             | 1720                                          | 118588           | 12827                | 14929                | 737                            | 28493                     |
| 30/400M/SS/100/25/5/M | 46       | 5.6              | 852                                           | 49020            | 5281                 | 7614                 | 376                            | 13271                     |
| 30/400M/SS/100/30/5/M | 47       | 7.4              | 852                                           | 49020            | 5281                 | 7614                 | 376                            | 13271                     |
| 30/400M/SS/100/35/5/M | 48       | 9.1              | 852                                           | 49020            | 5281                 | 7614                 | 376                            | 13271                     |
| 30/400M/SS/100/40/5/M | 49       | 9.6              | 852                                           | 60480            | 6542                 | 7614                 | 376                            | 14532                     |
| 30/400M/SS/100/45/5/M | 50       | 9.8              | 852                                           | 60480            | 6542                 | 7614                 | 376                            | 14532                     |
| 30/400M/SS/150/25/5/M | 51       | 3.0              | 573                                           | 34602            | 3728                 | 5374                 | 265                            | 9367                      |
| 30/400M/SS/150/30/5/M | 52       | 4.3              | 573                                           | 34602            | 3728                 | 5374                 | 265                            | 9367                      |
| 30/400M/SS/150/35/5/M | 53       | 5.7              | 573                                           | 34602            | 3728                 | 5374                 | 265                            | 9367                      |
| 30/400M/SS/150/40/5/M | 54       | 6.5              | 573                                           | 42692            | 4618                 | 5374                 | 265                            | 10257                     |
| 30/400M/SS/150/45/5/M | 55       | 7.3              | 573                                           | 42692            | 4618                 | 5374                 | 265                            | 10257                     |
| 30/400M/SS/200/25/5/M | 56       | 1.2              | 426                                           | 25952            | 2796                 | 4031                 | 199                            | 7026                      |

Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mj/yr)<br>x10 <sup>2</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400M/ss/200/30/5/M   | 57       | 2.0              | 426                                           | 25952            | 2796                 | 4031                 | 199                            | 7026                      |
| 30/400M/ss/200/35/5/M   | 58       | 3.5              | 426                                           | 25952            | 2796                 | 4031                 | 199                            | 7026                      |
| 30/400M/ss/200/40/5/M   | 59       | 4.4              | 426                                           | 32019            | 3463                 | 4031                 | 199                            | 7693                      |
| 30/400M/ss/200/45/5/M   | 60       | 5.3              | 426                                           | 32019            | 3463                 | 4031                 | 199                            | 7693                      |
| 30/400M/ss/250/25/5/M   | 61       | 0.9              | 344                                           | 22107            | 2382                 | 3434                 | 170                            | 5986                      |
| 30/400M/ss/250/30/5/M   | 62       | 1.2              | 344                                           | 22107            | 2382                 | 3434                 | 170                            | 5986                      |
| 30/400M/ss/250/35/5/M   | 63       | 1.5              | 344                                           | 22107            | 2382                 | 3434                 | 170                            | 5986                      |
| 30/400M/ss/250/40/5/M   | 64       | 3.0              | 344                                           | 27275            | 2950                 | 3434                 | 170                            | 6554                      |
| 30/400M/ss/250/45/5/M   | 65       | 3.9              | 344                                           | 27275            | 2950                 | 3434                 | 170                            | 6554                      |
| 30/400M/oppp/100/25/5/M | 66       | 10.9             | 1704                                          | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 30/400M/oppp/100/30/5/M | 67       | 12.8             | 1704                                          | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 30/400M/oppp/100/35/5/M | 68       | 14.0             | 1704                                          | 98040            | 10563                | 15228                | 752                            | 26543                     |
| 30/400M/oppp/100/40/5/M | 69       | 14.7             | 1704                                          | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 30/400M/oppp/100/45/5/M | 70       | 15.4             | 1704                                          | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 30/400M/oppp/150/25/5/M | 71       | 4.1              | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 30/400M/oppp/150/30/5/M | 72       | 7.0              | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |

Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi. <sup>2</sup> /yr)<br>x10 <sup>2</sup> | INITIAL COST      |                       | ANNUAL COST           |                                 | TOTAL COSTS<br>(\$/mi./yr) |
|------------------------|----------|------------------|--------------------------------------------------------------|-------------------|-----------------------|-----------------------|---------------------------------|----------------------------|
|                        |          |                  |                                                              | TOTAL<br>(\$/mi.) | ANNUAL<br>(\$/mi./yr) | ENERGY<br>(\$/mi./yr) | MAINTEN-<br>ANCE<br>(\$/mi./yr) |                            |
| 30/400M/OPP/150/35/5/M | 73       | 8.8              | 1147                                                         | 69205             | 7456                  | 10749                 | 530                             | 18735                      |
| 30/400M/OPP/150/40/5/M | 74       | 10.0             | 1147                                                         | 85383             | 9235                  | 10749                 | 530                             | 20514                      |
| 30/400M/OPP/150/45/5/M | 75       | 10.8             | 1147                                                         | 85383             | 9235                  | 10749                 | 530                             | 20514                      |
| 30/400M/OPP/200/25/5/M | 76       | 1.6              | 852                                                          | 51904             | 5592                  | 8062                  | 398                             | 14052                      |
| 30/400M/OPP/200/30/5/M | 77       | 3.1              | 852                                                          | 51904             | 5592                  | 8062                  | 398                             | 14052                      |
| 30/400M/OPP/200/35/5/M | 78       | 5.1              | 852                                                          | 51904             | 5592                  | 8062                  | 398                             | 14052                      |
| 30/400M/OPP/200/40/5/M | 79       | 6.8              | 852                                                          | 64038             | 6927                  | 8062                  | 398                             | 15387                      |
| 30/400M/OPP/200/45/5/M | 80       | 7.4              | 852                                                          | 64038             | 6927                  | 8062                  | 398                             | 15387                      |
| 30/400M/OPP/250/25/5/M | 81       | 1.1              | 688                                                          | 44214             | 4764                  | 6867                  | 339                             | 11970                      |
| 30/400M/OPP/250/30/5/M | 82       | 1.7              | 688                                                          | 44214             | 4764                  | 6867                  | 339                             | 11970                      |
| 30/400M/OPP/250/35/5/M | 83       | 2.6              | 688                                                          | 44214             | 4764                  | 6867                  | 339                             | 11970                      |
| 30/400M/OPP/250/40/5/M | 84       | 4.1              | 688                                                          | 54550             | 5900                  | 6867                  | 339                             | 13106                      |
| 30/400M/OPP/250/45/5/M | 85       | 5.2              | 688                                                          | 54550             | 5900                  | 6867                  | 339                             | 13106                      |
| 30/400M/STG/100/25/5/M | 86       | 15.2             | 1704                                                         | 98040             | 10563                 | 15228                 | 752                             | 26543                      |
| 30/400M/STG/100/30/5/M | 87       | 16.3             | 1704                                                         | 98040             | 10563                 | 15228                 | 752                             | 26543                      |
| 30/400M/STG/100/35/5/M | 88       | 16.3             | 1704                                                         | 98040             | 10563                 | 15228                 | 752                             | 26543                      |



Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>2</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400M/STG/100/40/5/M | 89       | 16.3             | 1704                                          | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 30/400M/STG/100/45/5/M | 90       | 16.2             | 1704                                          | 120960           | 13084                | 15228                | 752                            | 29043                     |
| 30/400M/STG/150/25/5/M | 91       | 8.8              | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 30/400M/STG/150/30/5/M | 92       | 11.0             | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 30/400M/STG/150/35/5/M | 93       | 12.3             | 1147                                          | 69205            | 7456                 | 10749                | 530                            | 18735                     |
| 30/400M/STG/150/40/5/M | 94       | 13.0             | 1147                                          | 85383            | 9235                 | 10749                | 530                            | 20514                     |
| 30/400M/STG/150/45/5/M | 95       | 13.2             | 1147                                          | 85383            | 9235                 | 10749                | 530                            | 20514                     |
| 30/400M/STG/200/25/5/M | 96       | 4.9              | 852                                           | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 30/400M/STG/200/30/5/M | 97       | 6.9              | 852                                           | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 30/400M/STG/200/35/5/M | 98       | 9.0              | 852                                           | 51904            | 5592                 | 8062                 | 398                            | 14052                     |
| 30/400M/STG/200/40/5/M | 99       | 10.1             | 852                                           | 64038            | 6927                 | 8062                 | 398                            | 15387                     |
| 30/400M/STG/200/45/5/M | 100      | 10.7             | 852                                           | 64038            | 6927                 | 8062                 | 398                            | 15387                     |
| 30/400M/STG/250/25/5/M | 101      | 3.1              | 688                                           | 44214            | 4764                 | 6867                 | 339                            | 11970                     |
| 30/400M/STG/250/30/5/M | 102      | 5.1              | 688                                           | 44214            | 4764                 | 6867                 | 339                            | 11970                     |
| 30/400M/STG/250/35/5/M | 103      | 6.2              | 688                                           | 44214            | 4764                 | 6867                 | 339                            | 11970                     |
| 30/400M/STG/250/40/5/M | 104      | 7.2              | 688                                           | 54550            | 5900                 | 6867                 | 339                            | 13106                     |
| 30/400M/STG/250/45/5/M | 105      | 8.3              | 688                                           | 54550            | 5900                 | 6867                 | 339                            | 13106                     |

Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>2</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/400H/OPP/100/25/11/M | 106      | 16.0             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 60/400H/OPP/100/30/11/M | 107      | 17.7             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 60/400H/OPP/100/35/11/M | 108      | 17.7             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 60/400H/OPP/100/40/11/M | 109      | 18.0             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 60/400H/OPP/100/45/11/M | 110      | 18.0             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 60/400H/OPP/150/25/11/M | 111      | 6.1              | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 60/400H/OPP/150/30/11/M | 112      | 10.0             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 60/400H/OPP/150/35/11/M | 113      | 12.6             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 60/400H/OPP/150/40/11/M | 114      | 13.9             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 60/400H/OPP/150/45/11/M | 115      | 14.7             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 60/400H/OPP/200/25/11/M | 116      | 2.1              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 60/400H/OPP/200/30/11/M | 117      | 3.0              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 60/400H/OPP/200/35/11/M | 118      | 5.8              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 60/400H/OPP/200/40/11/M | 119      | 8.5              | 852                                           | 67504            | 7308                 | 8062                 | 1349                           | 16719                     |
| 60/400H/OPP/200/45/11/M | 120      | 10.4             | 852                                           | 67504            | 7308                 | 8062                 | 1349                           | 16719                     |
| 60/400H/OPP/250/25/11/M | 121      | 1.3              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |



Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>2</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/400H/OPP/250/30/11/M | 122      | 3.0              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 60/400H/OPP/250/35/11/M | 123      | 2.1              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 60/400H/OPP/250/40/11/M | 124      | 3.7              | 688                                           | 57504            | 6225                 | 6867                 | 1149                           | 14241                     |
| 60/400H/OPP/250/45/11/M | 125      | 5.1              | 688                                           | 57504            | 6225                 | 6867                 | 1149                           | 14241                     |
| 60/400H/STG/100/25/11/M | 126      | 16.5             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 60/400H/STG/100/30/11/M | 127      | 19.1             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 60/400H/STG/100/35/11/M | 128      | 18.7             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 60/400H/STG/100/40/11/M | 129      | 18.2             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 60/400H/STG/100/45/11/M | 130      | 18.5             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 60/400H/STG/150/25/11/M | 131      | 10.0             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 60/400H/STG/150/30/11/M | 132      | 13.1             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 60/400H/STG/150/35/11/M | 133      | 14.2             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 60/400H/STG/150/40/11/M | 134      | 15.0             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 60/400H/STG/150/45/11/M | 135      | 15.5             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 60/400H/STG/200/25/11/M | 136      | 4.5              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 60/400H/STG/200/30/11/M | 137      | 8.2              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |



Table 22 Costs of New Systems

| SYSTEM CODE           | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-----------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                       |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400H/SS/50/25/5/M  | 146      | 23.2             | 1720                                          | 102538           | 11062                | 14929                | 2498                           | 28489                     |
| 30/400H/SS/50/30/5/M  | 147      | 22.6             | 1720                                          | 102538           | 11062                | 14929                | 2498                           | 28489                     |
| 30/400H/SS/50/35/5/M  | 148      | 24.4             | 1720                                          | 102538           | 11062                | 14929                | 2498                           | 28489                     |
| 30/400H/SS/50/40/5/M  | 149      | 24.2             | 1720                                          | 125008           | 13533                | 14929                | 2498                           | 30960                     |
| 30/400H/SS/50/45/5/M  | 150      | 24.3             | 1720                                          | 125008           | 13533                | 14929                | 2498                           | 30960                     |
| 30/400H/SS/100/25/5/M | 151      | 13.0             | 852                                           | 52294            | 5642                 | 7614                 | 1274                           | 14530                     |
| 30/400H/SS/100/30/5/M | 152      | 15.0             | 852                                           | 52294            | 5642                 | 7614                 | 1274                           | 14530                     |
| 30/400H/SS/100/35/5/M | 153      | 16.6             | 852                                           | 52294            | 5642                 | 7614                 | 1274                           | 14530                     |
| 30/400H/SS/100/40/5/M | 154      | 16.9             | 852                                           | 63754            | 6902                 | 7614                 | 1274                           | 15790                     |
| 30/400H/SS/100/45/5/M | 155      | 17.1             | 852                                           | 63754            | 6902                 | 7614                 | 1274                           | 15790                     |
| 30/400H/SS/150/25/5/M | 156      | 6.1              | 573                                           | 36914            | 3982                 | 5374                 | 899                            | 10255                     |
| 30/400H/SS/150/30/5/M | 157      | 9.8              | 573                                           | 36914            | 3982                 | 5374                 | 899                            | 10255                     |
| 30/400H/SS/150/35/5/M | 158      | 11.5             | 573                                           | 36914            | 3982                 | 5374                 | 899                            | 10255                     |
| 30/400H/SS/150/40/5/M | 159      | 12.9             | 573                                           | 45003            | 4872                 | 5374                 | 899                            | 11145                     |
| 30/400H/SS/150/45/5/M | 160      | 13.5             | 573                                           | 45003            | 4872                 | 5374                 | 899                            | 11145                     |
| 30/400H/SS/200/25/5/M | 161      | 1.9              | 426                                           | 27685            | 2987                 | 4031                 | 674                            | 7692                      |



Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400H/SS/200/30/5/M  | 162      | 4.3              | 426                                           | 27685            | 2987                 | 4031                 | 674                            | 7692                      |
| 30/400H/SS/200/35/5/M  | 163      | 6.2              | 426                                           | 27685            | 2987                 | 4031                 | 674                            | 7692                      |
| 30/400H/SS/200/40/5/M  | 164      | 8.1              | 426                                           | 33752            | 3654                 | 4031                 | 674                            | 8359                      |
| 30/400H/SS/200/45/5/M  | 165      | 9.5              | 426                                           | 33752            | 3654                 | 4031                 | 674                            | 8359                      |
| 30/400H/SS/250/25/5/M  | 166      | 1.5              | 344                                           | 23584            | 2544                 | 3434                 | 575                            | 6552                      |
| 30/400H/SS/250/30/5/M  | 167      | 2.4              | 344                                           | 23584            | 2544                 | 3434                 | 575                            | 6552                      |
| 30/400H/SS/250/35/5/M  | 168      | 3.0              | 344                                           | 23584            | 2544                 | 3434                 | 575                            | 6552                      |
| 30/400H/SS/250/40/5/M  | 169      | 3.8              | 344                                           | 28752            | 3113                 | 3434                 | 575                            | 7122                      |
| 30/400H/SS/250/45/5/M  | 170      | 5.8              | 344                                           | 28752            | 3113                 | 3434                 | 575                            | 7122                      |
| 30/400H/OPP/100/25/5/M | 171      | 24.6             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 30/400H/OPP/100/30/5/M | 172      | 25.6             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 30/400H/OPP/100/35/5/M | 173      | 25.8             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 30/400H/OPP/100/40/5/M | 174      | 25.5             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 30/400H/OPP/100/45/5/M | 175      | 24.7             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 30/400H/OPP/150/25/5/M | 176      | 7.2              | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 30/400H/OPP/150/30/5/M | 177      | 12.8             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |



Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400H/OPP/150/35/5/M | 178      | 15.9             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 30/400H/OPP/150/40/5/M | 179      | 17.5             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 30/400H/OPP/150/45/5/M | 180      | 17.9             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 30/400H/OPP/200/25/5/M | 181      | 5.4              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 30/400H/OPP/200/30/5/M | 182      | 1.8              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 30/400H/OPP/200/35/5/M | 183      | 6.3              | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 30/400H/OPP/200/40/5/M | 184      | 10.1             | 852                                           | 67504            | 7308                 | 8062                 | 1349                           | 16719                     |
| 30/400H/OPP/200/45/5/M | 185      | 12.4             | 852                                           | 67504            | 7308                 | 8062                 | 1349                           | 16719                     |
| 30/400H/OPP/250/25/5/M | 186      | 3.4              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 30/400H/OPP/250/30/5/M | 187      | 4.2              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 30/400H/OPP/250/35/5/M | 188      | 1.9              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 30/400H/OPP/250/40/5/M | 189      | 3.9              | 688                                           | 57504            | 6225                 | 6867                 | 1149                           | 14241                     |
| 30/400H/OPP/250/45/5/M | 190      | 6.8              | 688                                           | 57504            | 6225                 | 6867                 | 1149                           | 14241                     |
| 30/400H/STG/100/25/5/M | 191      | 27.7             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 30/400H/STG/100/30/5/M | 192      | 28.7             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |
| 30/400H/STG/100/35/5/M | 193      | 27.2             | 1704                                          | 104589           | 11283                | 15228                | 2548                           | 29059                     |

Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/400H/STG/100/40/5/M | 194      | 25.7             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31580                     |
| 30/400H/STG/100/45/5/M | 195      | 24.7             | 1704                                          | 127508           | 13804                | 15228                | 2548                           | 31586                     |
| 30/400H/STG/150/25/5/M | 196      | 19.4             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 30/400H/STG/150/30/5/M | 197      | 20.2             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 30/400H/STG/150/35/5/M | 198      | 20.2             | 1147                                          | 73827            | 7964                 | 10749                | 1799                           | 20511                     |
| 30/400H/STG/150/40/5/M | 199      | 20.6             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 30/400H/STG/150/45/5/M | 200      | 20.5             | 1147                                          | 90005            | 9744                 | 10749                | 1799                           | 22292                     |
| 30/400H/STG/200/25/5/M | 201      | 12.9             | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 30/400H/STG/200/30/5/M | 202      | 15.9             | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 30/400H/STG/200/35/5/M | 203      | 16.7             | 852                                           | 55371            | 5973                 | 8062                 | 1349                           | 15384                     |
| 30/400H/STG/200/40/5/M | 204      | 16.8             | 852                                           | 67504            | 7308                 | 8062                 | 1349                           | 16719                     |
| 30/400H/STG/200/45/5/M | 205      | 17.0             | 852                                           | 67504            | 7308                 | 8062                 | 1349                           | 16719                     |
| 30/400H/STG/250/25/5/M | 206      | 7.3              | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 30/400H/STG/250/30/5/M | 207      | 11.9             | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 30/400H/STG/250/35/5/M | 208      | 13.8             | 688                                           | 47167            | 5089                 | 6867                 | 1149                           | 13105                     |
| 30/400H/STG/250/40/5/M | 209      | 14.7             | 688                                           | 57504            | 6225                 | 6867                 | 1149                           | 14241                     |
| 30/400H/STG/250/45/5/M | 210      | 15.3             | 688                                           | 57504            | 6225                 | 6867                 | 1149                           | 14241                     |

Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi./yr)<br>x10 <sup>6</sup> | INITIAL COST     |                       | ANNUAL COST           |                                 | TOTAL COSTS<br>(\$/mi./yr) |
|-------------------------|----------|------------------|------------------------------------------------|------------------|-----------------------|-----------------------|---------------------------------|----------------------------|
|                         |          |                  |                                                | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi./yr) | ENERGY<br>(\$/mi./yr) | MAINTEN-<br>ANCE<br>(\$/mi./yr) |                            |
| 60/150H/OPP/100/20/11/M | 211      | 10.1             | 639                                            | 80491            | 8632                  | 5709                  | 2548                            | 16889                      |
| 60/150H/OPP/100/25/11/M | 212      | 11.4             | 639                                            | 104589           | 11283                 | 5709                  | 2548                            | 19540                      |
| 60/150H/OPP/100/30/11/M | 213      | 13.2             | 639                                            | 104589           | 11283                 | 5709                  | 2548                            | 19540                      |
| 60/150H/OPP/100/35/11/M | 214      | 13.5             | 639                                            | 104589           | 11283                 | 5709                  | 2548                            | 19540                      |
| 60/150H/OPP/100/40/11/M | 215      | 13.5             | 639                                            | 109387           | 13804                 | 5709                  | 2548                            | 22061                      |
| 60/150H/OPP/150/20/11/M | 216      | 4.1              | 430                                            | 56817            | 6093                  | 4030                  | 1799                            | 11922                      |
| 60/150H/OPP/150/25/11/M | 217      | 4.7              | 430                                            | 73827            | 7965                  | 4030                  | 1799                            | 13794                      |
| 60/150H/OPP/150/30/11/M | 218      | 8.0              | 430                                            | 73827            | 7965                  | 4030                  | 1799                            | 13794                      |
| 60/150H/OPP/150/35/11/M | 219      | 8.9              | 430                                            | 73827            | 7965                  | 4030                  | 1799                            | 13794                      |
| 60/150H/OPP/150/40/11/M | 220      | 9.8              | 430                                            | 77214            | 9744                  | 4030                  | 1799                            | 15573                      |
| 60/150H/OPP/200/20/11/M | 221      | 2.6              | 319                                            | 42613            | 4570                  | 3022                  | 1349                            | 8941                       |
| 60/150H/OPP/200/25/11/M | 222      | 3.2              | 319                                            | 56991            | 5973                  | 3022                  | 1349                            | 10344                      |
| 60/150H/OPP/200/30/11/M | 223      | 4.2              | 319                                            | 56991            | 5973                  | 3022                  | 1349                            | 10344                      |
| 60/150H/OPP/200/35/11/M | 224      | 6.2              | 319                                            | 56991            | 5973                  | 3022                  | 1349                            | 10344                      |
| 60/150H/OPP/200/40/11/M | 225      | 7.2              | 319                                            | 57911            | 7308                  | 3022                  | 1349                            | 11679                      |
| 60/150H/OPP/250/20/11/M | 226      | 2.3              | 258                                            | 36300            | 3893                  | 2575                  | 1149                            | 7617                       |



Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/150H/OPP/250/25/11/M | 227      | 2.3              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 60/150H/OPP/250/30/11/M | 228      | 3.2              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 60/150H/OPP/250/35/11/M | 229      | 2.7              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 60/150H/OPP/250/40/11/M | 230      | 3.6              | 258                                           | 49331            | 6225                 | 2575                 | 1149                           | 9949                      |
| 60/150H/STG/100/20/11/M | 231      | 10.6             | 639                                           | 80491            | 8632                 | 5709                 | 2548                           | 16889                     |
| 60/150H/STG/100/25/11/M | 232      | 11.9             | 639                                           | 104689           | 11283                | 5709                 | 2548                           | 19540                     |
| 60/150H/STG/100/30/11/M | 233      | 13.1             | 639                                           | 104689           | 11283                | 5709                 | 2548                           | 19540                     |
| 60/150H/STG/100/35/11/M | 234      | 13.8             | 639                                           | 104589           | 11283                | 5709                 | 2548                           | 19540                     |
| 60/150H/STG/100/40/11/M | 235      | 13.2             | 639                                           | 109387           | 13804                | 5709                 | 2548                           | 22061                     |
| 60/150H/STG/150/20/11/M | 236      | 5.1              | 430                                           | 56817            | 6093                 | 4030                 | 1799                           | 11922                     |
| 60/150H/STG/150/25/11/M | 237      | 7.1              | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 60/150H/STG/150/30/11/M | 238      | 8.8              | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 60/150H/STG/150/35/11/M | 239      | 9.2              | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 60/150H/STG/150/40/11/M | 240      | 10.3             | 430                                           | 77214            | 9744                 | 4030                 | 1799                           | 15573                     |
| 60/150H/STG/200/20/11/M | 241      | 4.0              | 319                                           | 42613            | 4570                 | 3022                 | 1349                           | 8941                      |
| 60/150H/STG/200/25/11/M | 242      | 5.4              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |



Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/150H/STG/200/30/11/M | 243      | 6.3              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 60/150H/STG/200/35/11/M | 244      | 6.9              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 60/150H/STG/200/40/11/M | 245      | 8.0              | 319                                           | 57911            | 7308                 | 3022                 | 1349                           | 11679                     |
| 60/150H/STG/250/20/11/M | 246      | 2.9              | 258                                           | 36300            | 3893                 | 2575                 | 1149                           | 7617                      |
| 60/150H/STG/250/25/11/M | 247      | 3.7              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 60/150H/STG/250/30/11/M | 248      | 4.8              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 60/150H/STG/250/35/11/M | 249      | 5.4              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 60/150H/STG/250/40/11/M | 250      | 6.8              | 258                                           | 49331            | 6225                 | 2575                 | 1149                           | 9949                      |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |
|                         |          |                  |                                               |                  |                      |                      |                                |                           |

Table 22 Costs of New Systems

| SYSTEM CODE           | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi <sup>2</sup> /yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-----------------------|----------|------------------|-------------------------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                       |          |                  |                                                             | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/150H/ss/50/20/5/M  | 251      | 9.1              | 644                                                         | 78913            | 8463                 | 5597                 | 2498                           | 16558                     |
| 30/150H/ss/50/25/5/M  | 252      | 11.4             | 644                                                         | 102538           | 11062                | 5597                 | 2498                           | 19157                     |
| 30/150H/ss/50/30/5/M  | 253      | 13.0             | 644                                                         | 102538           | 11062                | 5597                 | 2498                           | 19157                     |
| 30/150H/ss/50/35/5/M  | 254      | 13.2             | 644                                                         | 102538           | 11062                | 5597                 | 2498                           | 19157                     |
| 30/150H/ss/50/40/5/M  | 255      | 13.6             | 644                                                         | 107242           | 13533                | 5597                 | 2498                           | 21628                     |
| 30/150H/ss/100/20/5/M | 256      | 6.3              | 319                                                         | 40246            | 4316                 | 2854                 | 1274                           | 8444                      |
| 30/150H/ss/100/25/5/M | 257      | 8.6              | 319                                                         | 52294            | 5642                 | 2854                 | 1274                           | 9769                      |
| 30/150H/ss/100/30/5/M | 258      | 10.7             | 319                                                         | 52294            | 5642                 | 2854                 | 1274                           | 9769                      |
| 30/150H/ss/100/35/5/M | 259      | 11.0             | 319                                                         | 52294            | 5642                 | 2854                 | 1274                           | 9769                      |
| 30/150H/ss/100/40/5/M | 260      | 10.6             | 319                                                         | 54693            | 6902                 | 2854                 | 1274                           | 11030                     |
| 30/150H/ss/150/20/5/M | 261      | 4.1              | 215                                                         | 28409            | 3047                 | 2015                 | 899                            | 5961                      |
| 30/150H/ss/150/25/5/M | 262      | 3.6              | 215                                                         | 36914            | 3982                 | 2015                 | 899                            | 6896                      |
| 30/150H/ss/150/30/5/M | 263      | 7.3              | 215                                                         | 36914            | 3982                 | 2015                 | 899                            | 6896                      |
| 30/150H/ss/150/35/5/M | 264      | 6.4              | 215                                                         | 36914            | 3982                 | 2015                 | 899                            | 6896                      |
| 30/150H/ss/150/40/5/M | 265      | 7.7              | 215                                                         | 38607            | 4872                 | 2015                 | 899                            | 7786                      |
| 30/150H/ss/200/20/5/M | 266      | 2.2              | 160                                                         | 21307            | 2285                 | 1511                 | 674                            | 4470                      |

Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi <sup>6</sup> /yr)<br>x10 | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|------------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                                | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/150H/55/200/25/5/M  | 267      | 3.2              | 160                                            | 27685            | 2987                 | 1511                 | 674                            | 5172                      |
| 30/150H/55/200/30/5/M  | 268      | 4.8              | 160                                            | 27685            | 2987                 | 1511                 | 674                            | 5172                      |
| 30/150H/55/200/35/5/M  | 269      | 6.0              | 160                                            | 27685            | 2987                 | 1511                 | 674                            | 5172                      |
| 30/150H/55/200/40/5/M  | 270      | 6.4              | 160                                            | 28955            | 3653                 | 1511                 | 674                            | 5838                      |
| 30/150H/55/250/20/5/M  | 271      | 2.5              | 129                                            | 18150            | 1946                 | 1287                 | 575                            | 3808                      |
| 30/150H/55/250/25/5/M  | 272      | 2.1              | 129                                            | 23584            | 2544                 | 1287                 | 575                            | 4406                      |
| 30/150H/55/250/30/5/M  | 273      | 3.6              | 129                                            | 23584            | 2544                 | 1287                 | 575                            | 4406                      |
| 30/150H/55/250/35/5/M  | 274      | 3.7              | 129                                            | 23584            | 2544                 | 1287                 | 575                            | 4406                      |
| 30/150H/55/250/40/5/M  | 275      | 4.4              | 129                                            | 24666            | 3113                 | 1287                 | 575                            | 4975                      |
| 30/150H/OPP/100/20/5/M | 276      | 13.7             | 639                                            | 80491            | 8632                 | 5709                 | 2548                           | 16889                     |
| 30/150H/OPP/100/25/5/M | 277      | 14.7             | 639                                            | 104589           | 11283                | 5709                 | 2548                           | 19540                     |
| 30/150H/OPP/100/30/5/M | 278      | 16.0             | 639                                            | 104689           | 11283                | 5709                 | 2548                           | 19540                     |
| 30/150H/OPP/100/35/5/M | 279      | 16.3             | 639                                            | 104589           | 11283                | 5709                 | 2548                           | 19540                     |
| 30/150H/OPP/100/40/5/M | 280      | 15.6             | 639                                            | 109387           | 13804                | 5709                 | 2548                           | 22061                     |
| 30/150H/OPP/150/20/5/M | 281      | 4.7              | 430                                            | 56817            | 6093                 | 4030                 | 1799                           | 11922                     |
| 30/150H/OPP/150/25/5/M | 282      | 8.8              | 430                                            | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |



Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/150H/OPP/150/30/5/M | 283      | 10.4             | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 30/150H/OPP/150/35/5/M | 284      | 11.9             | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 30/150H/OPP/150/40/5/M | 285      | 13.2             | 430                                           | 71214            | 9744                 | 4030                 | 1799                           | 15573                     |
| 30/150H/OPP/200/20/5/M | 286      | 2.0              | 319                                           | 42613            | 4570                 | 3022                 | 1349                           | 8941                      |
| 30/150H/OPP/200/25/5/M | 287      | 4.8              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 30/150H/OPP/200/30/5/M | 288      | 6.8              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 30/150H/OPP/200/35/5/M | 289      | 8.3              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 30/150H/OPP/200/40/5/M | 290      | 6.6              | 319                                           | 57911            | 7308                 | 3022                 | 1349                           | 11679                     |
| 30/150H/OPP/250/20/5/M | 291      | 1.9              | 258                                           | 36300            | 3893                 | 2575                 | 1149                           | 7617                      |
| 30/150H/OPP/250/25/5/M | 292      | 3.7              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 30/150H/OPP/250/30/5/M | 293      | 5.3              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 30/150H/OPP/250/35/5/M | 294      | 6.0              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 30/150H/OPP/250/40/5/M | 295      | 5.9              | 258                                           | 49331            | 6225                 | 2575                 | 1149                           | 9949                      |
| 30/150H/STG/100/20/5/M | 296      | 13.6             | 639                                           | 80991            | 8632                 | 5709                 | 2548                           | 16889                     |
| 30/150H/STG/100/25/5/M | 297      | 16.4             | 639                                           | 104589           | 11283                | 5709                 | 2548                           | 19540                     |
| 30/150H/STG/100/30/5/M | 298      | 16.4             | 639                                           | 104589           | 11283                | 5709                 | 2548                           | 19540                     |



Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/150H/STG/100/35/5/M | 299      | 16.2             | 639                                           | 104509           | 11283                | 5709                 | 2548                           | 19546                     |
| 30/150H/STG/100/40/5/M | 300      | 15.0             | 639                                           | 109387           | 13804                | 5709                 | 2548                           | 22061                     |
| 30/150H/STG/150/20/5/M | 301      | 6.3              | 430                                           | 56817            | 6093                 | 4030                 | 1799                           | 11922                     |
| 30/150H/STG/150/25/5/M | 302      | 10.2             | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 30/150H/STG/150/30/5/M | 303      | 12.8             | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 30/150H/STG/160/35/5/M | 304      | 11.2             | 430                                           | 73827            | 7965                 | 4030                 | 1799                           | 13794                     |
| 30/150H/STG/150/40/5/M | 305      | 12.3             | 430                                           | 77214            | 9744                 | 4030                 | 1799                           | 15573                     |
| 30/150H/STG/200/20/5/M | 306      | 6.5              | 319                                           | 42613            | 4570                 | 3022                 | 1349                           | 8941                      |
| 30/150H/STG/200/25/5/M | 307      | 8.0              | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10340                     |
| 30/150H/STG/200/30/5/M | 308      | 11.9             | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 30/150H/STG/200/35/5/M | 309      | 11.2             | 319                                           | 56991            | 5973                 | 3022                 | 1349                           | 10344                     |
| 30/150H/STG/200/40/5/M | 310      | 11.4             | 319                                           | 57911            | 7308                 | 3022                 | 1349                           | 11679                     |
| 30/150H/STG/250/20/5/M | 311      | 1.9              | 258                                           | 36300            | 3893                 | 2575                 | 1149                           | 7617                      |
| 30/150H/STG/250/25/5/M | 312      | 6.2              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 30/150H/STG/250/30/5/M | 313      | 7.2              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 30/150H/STG/250/35/5/M | 314      | 8.4              | 258                                           | 48547            | 5089                 | 2575                 | 1149                           | 8813                      |
| 30/150H/STG/250/40/5/M | 315      | 9.3              | 258                                           | 49331            | 6225                 | 2575                 | 1149                           | 9949                      |

Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/175M/OPP/100/20/11/M | 316      | 5.5              | 746                                           | 73943            | 7912                 | 6662                 | 751                            | 15325                     |
| 60/175M/OPP/100/25/11/M | 317      | 4.4              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 60/175M/OPP/100/30/11/M | 318      | 6.8              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 60/175M/OPP/100/35/11/M | 319      | 6.8              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 60/175M/OPP/100/40/11/M | 320      | 7.1              | 746                                           | 120966           | 13084                | 6662                 | 751                            | 20497                     |
| 60/175M/OPP/150/20/11/M | 321      | 2.2              | 502                                           | 52195            | 5585                 | 4702                 | 531                            | 10818                     |
| 60/175M/OPP/150/25/11/M | 322      | 3.2              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 60/175M/OPP/150/30/11/M | 323      | 3.1              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 60/175M/OPP/150/35/11/M | 324      | 3.1              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 60/175M/OPP/150/40/11/M | 325      | 3.9              | 502                                           | 85383            | 9235                 | 4702                 | 531                            | 14468                     |
| 60/175M/OPP/200/20/11/M | 326      | 1.7              | 373                                           | 39146            | 4189                 | 3527                 | 398                            | 8114                      |
| 60/175M/OPP/200/25/11/M | 327      | 1.7              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 60/175M/OPP/200/30/11/M | 328      | 2.2              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 60/175M/OPP/200/35/11/M | 329      | 2.3              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 60/175M/OPP/200/40/11/M | 330      | 2.1              | 373                                           | 64038            | 6927                 | 3527                 | 398                            | 10852                     |
| 60/175M/OPP/250/20/11/M | 331      | 1.5              | 301                                           | 33347            | 3568                 | 3004                 | 339                            | 6911                      |

Table 22 Costs of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                         |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 60/175M/OPP/250/25/11/M | 332      | 0.9              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 60/175M/OPP/250/30/11/M | 333      | 1.5              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 60/175M/OPP/250/35/11/M | 334      | 1.4              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 60/175M/OPP/250/40/11/M | 335      | 1.6              | 301                                           | 54550            | 5900                 | 3004                 | 339                            | 9243                      |
| 60/175M/STG/100/20/11/M | 336      | 6.0              | 746                                           | 73943            | 7912                 | 6662                 | 751                            | 15325                     |
| 60/175M/STG/100/25/11/M | 337      | 7.6              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 60/175M/STG/100/30/11/M | 338      | 7.4              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 60/175M/STG/100/35/11/M | 339      | 8.0              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 60/175M/STG/100/40/11/M | 340      | 7.2              | 746                                           | 120960           | 13084                | 6662                 | 751                            | 20497                     |
| 60/175M/STG/150/20/11/M | 341      | 3.1              | 502                                           | 52195            | 5585                 | 4702                 | 531                            | 10818                     |
| 60/175M/STG/150/25/11/M | 342      | 4.2              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 60/175M/STG/150/30/11/M | 343      | 3.7              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 60/175M/STG/150/35/11/M | 344      | 3.7              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 60/175M/STG/150/40/11/M | 345      | 5.1              | 502                                           | 85383            | 9235                 | 4702                 | 531                            | 14468                     |
| 60/175M/STG/200/20/11/M | 346      | 1.9              | 373                                           | 39146            | 4189                 | 3527                 | 398                            | 8114                      |
| 60/175M/STG/200/25/11/M | 347      | 2.3              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |



## Table 22 Costs of New Systems

[illegible]



Table 22 Costs of New Systems

| SYSTEM CODE           | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|-----------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                       |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/175M/SS/50/20/5/M  | 356      | 6.8              | 753                                           | 72493            | 7757                 | 6531                 | 737                            | 15025                     |
| 30/175M/SS/50/25/5/M  | 357      | 8.6              | 753                                           | 96118            | 10356                | 6531                 | 737                            | 17624                     |
| 30/175M/SS/50/30/5/M  | 358      | 10.1             | 753                                           | 96118            | 10356                | 6531                 | 737                            | 17624                     |
| 30/175M/SS/50/35/5/M  | 359      | 10.7             | 753                                           | 96118            | 10356                | 6531                 | 737                            | 17624                     |
| 30/175M/SS/50/40/5/M  | 360      | 10.4             | 753                                           | 118588           | 12827                | 6531                 | 737                            | 20095                     |
| 30/175M/SS/100/20/5/M | 361      | 3.7              | 373                                           | 36971            | 3956                 | 3331                 | 376                            | 7663                      |
| 30/175M/SS/100/25/5/M | 362      | 4.6              | 373                                           | 49020            | 5282                 | 3331                 | 376                            | 8989                      |
| 30/175M/SS/100/30/5/M | 363      | 6.4              | 373                                           | 49020            | 5282                 | 3331                 | 376                            | 8989                      |
| 30/175M/SS/100/35/5/M | 364      | 7.1              | 373                                           | 49020            | 5282                 | 3331                 | 376                            | 8989                      |
| 30/175M/SS/100/40/5/M | 365      | 7.1              | 373                                           | 60480            | 6542                 | 3331                 | 376                            | 10249                     |
| 30/175M/SS/150/20/5/M | 366      | 1.3              | 251                                           | 26097            | 2793                 | 2351                 | 265                            | 5409                      |
| 30/175M/SS/150/25/5/M | 367      | 1.8              | 251                                           | 34602            | 3728                 | 2351                 | 265                            | 6344                      |
| 30/175M/SS/150/30/5/M | 368      | 3.5              | 251                                           | 34602            | 3728                 | 2351                 | 265                            | 6344                      |
| 30/175M/SS/150/35/5/M | 369      | 3.8              | 251                                           | 34602            | 3728                 | 2351                 | 265                            | 6344                      |
| 30/175M/SS/150/40/5/M | 370      | 4.5              | 251                                           | 42692            | 4618                 | 2351                 | 265                            | 7234                      |
| 30/175M/SS/200/20/5/M | 371      | 1.5              | 186                                           | 19573            | 2094                 | 1763                 | 199                            | 4056                      |

Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/175M/SS/200/25/5/M  | 372      | 1.3              | 186                                           | 25952            | 2796                 | 1763                 | 199                            | 4758                      |
| 30/175M/SS/200/30/5/M  | 373      | 1.9              | 186                                           | 25952            | 2796                 | 1763                 | 199                            | 4758                      |
| 30/175M/SS/200/35/5/M  | 374      | 2.1              | 186                                           | 25952            | 2796                 | 1763                 | 199                            | 4758                      |
| 30/175M/SS/200/40/5/M  | 375      | 2.4              | 186                                           | 32019            | 3463                 | 1763                 | 199                            | 5425                      |
| 30/175M/SS/250/20/5/M  | 376      | 1.2              | 151                                           | 16673            | 1784                 | 1502                 | 170                            | 3456                      |
| 30/175M/SS/250/25/5/M  | 377      | 0.9              | 151                                           | 22107            | 2382                 | 1502                 | 170                            | 4054                      |
| 30/175M/SS/250/30/5/M  | 378      | 1.2              | 151                                           | 22107            | 2382                 | 1502                 | 170                            | 4054                      |
| 30/175M/SS/250/35/5/M  | 379      | 1.9              | 151                                           | 22107            | 2382                 | 1502                 | 170                            | 4054                      |
| 30/175M/SS/250/40/5/M  | 380      | 1.4              | 151                                           | 27275            | 2950                 | 1502                 | 170                            | 4622                      |
| 30/175M/OPP/100/20/5/M | 381      | 4.2              | 746                                           | 73943            | 7912                 | 6662                 | 751                            | 15325                     |
| 30/175M/OPP/100/25/5/M | 382      | 7.1              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 30/175M/OPP/100/30/5/M | 383      | 8.2              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 30/175M/OPP/100/35/5/M | 384      | 8.8              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 30/175M/OPP/100/40/5/M | 385      | 9.8              | 746                                           | 120960           | 13084                | 6662                 | 751                            | 20997                     |
| 30/175M/OPP/150/20/5/M | 386      | 2.9              | 502                                           | 52195            | 5585                 | 4702                 | 531                            | 10818                     |
| 30/175M/OPP/150/25/5/M | 387      | 3.6              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |

Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/175M/OPP/150/30/5/M | 388      | 5.1              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 30/175M/OPP/150/35/5/M | 389      | 6.7              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 30/175M/OPP/150/40/5/M | 390      | 7.2              | 502                                           | 85383            | 9235                 | 4702                 | 531                            | 14468                     |
| 30/175M/OPP/200/20/5/M | 391      | 1.6              | 373                                           | 39146            | 4189                 | 3527                 | 398                            | 8114                      |
| 30/175M/OPP/200/25/5/M | 392      | 2.4              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 30/175M/OPP/200/30/5/M | 393      | 3.6              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 30/175M/OPP/200/35/5/M | 394      | 3.7              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 30/175M/OPP/200/40/5/M | 395      | 3.6              | 373                                           | 64638            | 6927                 | 3527                 | 398                            | 10852                     |
| 30/175M/OPP/250/20/5/M | 396      | 1.8              | 301                                           | 33347            | 3568                 | 3004                 | 339                            | 6911                      |
| 30/175M/OPP/250/25/5/M | 397      | 1.6              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 30/175M/OPP/250/30/5/M | 398      | 2.7              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 30/175M/OPP/250/35/5/M | 399      | 3.4              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 30/175M/OPP/250/40/5/M | 400      | 2.5              | 301                                           | 54550            | 5906                 | 3004                 | 339                            | 9243                      |
| 30/175M/STG/100/20/5/M | 401      | 4.8              | 746                                           | 73943            | 7912                 | 6662                 | 751                            | 15325                     |
| 30/175M/STG/100/25/5/M | 402      | 7.5              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 30/175M/STG/100/30/5/M | 403      | 8.9              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |



Table 22 Costs of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | ENERGY USE<br>(kwh/mi/yr)<br>x10 <sup>6</sup> | INITIAL COST     |                      | ANNUAL COST          |                                | TOTAL COSTS<br>(\$/mi/yr) |
|------------------------|----------|------------------|-----------------------------------------------|------------------|----------------------|----------------------|--------------------------------|---------------------------|
|                        |          |                  |                                               | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | ENERGY<br>(\$/mi/yr) | MAINTEN-<br>ANCE<br>(\$/mi/yr) |                           |
| 30/175M/STG/100/35/5/M | 404      | 9.7              | 746                                           | 98040            | 10563                | 6662                 | 751                            | 17976                     |
| 30/175M/STG/100/40/5/M | 405      | 10.1             | 746                                           | 120960           | 13084                | 6662                 | 751                            | 20497                     |
| 30/175M/STG/150/20/5/M | 406      | 2.6              | 502                                           | 52195            | 5585                 | 4702                 | 531                            | 10818                     |
| 30/175M/STG/150/25/5/M | 407      | 5.1              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 30/175M/STG/150/30/5/M | 408      | 6.8              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 30/175M/STG/150/35/5/M | 409      | 7.6              | 502                                           | 69205            | 7456                 | 4702                 | 531                            | 12689                     |
| 30/175M/STG/150/40/5/M | 410      | 8.1              | 502                                           | 86383            | 9235                 | 4702                 | 531                            | 14468                     |
| 30/175M/STG/200/20/5/M | 411      | 2.9              | 373                                           | 39146            | 4189                 | 3527                 | 398                            | 8114                      |
| 30/175M/STG/200/25/5/M | 412      | 4.8              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 30/175M/STG/200/30/5/M | 413      | 5.2              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 30/175M/STG/200/35/5/M | 414      | 5.3              | 373                                           | 51904            | 5592                 | 3527                 | 398                            | 9517                      |
| 30/175M/STG/200/40/5/M | 415      | 5.7              | 373                                           | 64038            | 6927                 | 3527                 | 398                            | 10852                     |
| 30/175M/STG/250/20/5/M | 416      | 1.5              | 301                                           | 33347            | 3568                 | 3004                 | 339                            | 6911                      |
| 30/175M/STG/250/25/5/M | 417      | 3.0              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 30/175M/STG/250/30/5/M | 418      | 3.6              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 30/175M/STG/250/35/5/M | 419      | 3.9              | 301                                           | 44214            | 4764                 | 3004                 | 339                            | 8107                      |
| 30/175M/STG/250/40/5/M | 420      | 4.0              | 301                                           | 54550            | 5900                 | 3004                 | 339                            | 9243                      |



Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 60/400M/STG/100/35/11/M | 23       | 13.4             | 26543            |             | 30000                  | 20000        | 27208               | 1.03               |
| 60/400M/STG/100/40/11/M | 24       | 13.8             | 29043            |             | "                      | "            | 29476               | 1.02               |
| 60/400M/STG/100/45/11/M | 25       | 13.8             | 29043            |             | "                      | "            | 29476               | 1.02               |
| 60/400M/STG/150/45/11/M | 30       | 10.7             | 20514            |             | "                      | "            | 21995               | 1.07               |
| 60/400M/STG/200/45/11/M | 35       | 7.8              | 15387            |             | "                      | "            | 15434               | 1.00               |
|                         |          |                  |                  |             |                        |              |                     |                    |
| 30/400M/SS/50/35/5/M    | 43       | 13.1             | 26022            |             | "                      | "            | 27208               | 1.05               |
| 30/400M/SS/50/40/5/M    | 44       | 13.9             | 28493            |             | "                      | "            | 29476               | 1.03               |
| 30/400M/SS/50/45/5/M    | 45       | 14.1             | 28493            |             | "                      | "            | 29476               | 1.03               |
| 30/400M/SS/100/30/5/M   | 47       | 7.4              | 13271            |             | "                      | "            | 13592               | 1.02               |
| 30/400M/SS/100/35/5/M   | 48       | 9.1              | 13271            |             | "                      | "            | 18152               | 1.37               |
| 30/400M/SS/100/40/5/M   | 49       | 9.6              | 14532            |             | "                      | "            | 20410               | 1.40               |
| 30/400M/SS/100/45/5/M   | 50       | 9.8              | 14532            |             | "                      | "            | 20410               | 1.40               |
| 30/400M/SS/150/35/5/M   | 53       | 5.7              | 9367             |             | "                      | "            | 11334               | 1.21               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400M/SS/150/40/5/M  | 54       | 6.5              | 10257            |             | 30000                  | 20000        | 13592               | 1.33               |
| 30/400M/SS/150/45/5/M  | 55       | 7.3              | 10257            |             | "                      | "            | 13592               | 1.33               |
| 30/400M/SS/200/40/5/M  | 59       | 4.4              | 7693             |             | "                      | "            | 7721                | 1.00               |
| 30/400M/SS/200/45/5/M  | 60       | 5.3              | 7693             |             | "                      | "            | 9076                | 1.18               |
| 30/400M/SS/250/45/5/M  | 65       | 3.9              | 6554             |             | "                      | "            | 6818                | 1.04               |
| 30/400M/OPP/100/30/5/M | 67       | 12.8             | 26543            |             | "                      | "            | 27208               | 1.03               |
| 30/400M/OPP/100/35/5/M | 68       | 14.0             | 26543            |             | "                      | "            | 29476               | 1.11               |
| 30/400M/OPP/100/40/5/M | 69       | 14.7             | 29043            |             | "                      | "            | 31740               | 1.09               |
| 30/400M/OPP/100/45/5/M | 70       | 15.4             | 29043            |             | "                      | "            | 31766               | 1.09               |
| 30/400M/OPP/150/45/5/M | 75       | 10.8             | 20514            |             | "                      | "            | 22220               | 1.08               |
| 30/400M/STG/100/25/5/M | 86       | 15.2             | 26543            |             | "                      | "            | 31753               | 1.20               |
| 30/400M/STG/100/30/5/M | 87       | 16.3             | 26543            |             | "                      | "            | 31822               | 1.20               |
| 30/400M/STG/100/35/5/M | 88       | 16.3             | 26543            |             | "                      | "            | 31822               | 1.20               |
| 30/400M/STG/100/40/5/M | 89       | 16.3             | 29043            |             | "                      | "            | 31822               | 1.10               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400M/STG/100/45/5/M  | 90       | 16.2             | 29043            |             | 30000                  | 20000        | 31816               | 1.10               |
| 30/400M/STG/150/30/5/M  | 92       | 11.0             | 18735            |             | "                      | "            | 22674               | 1.21               |
| 30/400M/STG/150/35/5/M  | 93       | 12.3             | 18735            |             | "                      | "            | 24942               | 1.33               |
| 30/400M/STG/150/40/5/M  | 94       | 13.0             | 20514            |             | "                      | "            | 27208               | 1.33               |
| 30/400M/STG/150/45/5/M  | 95       | 13.2             | 20514            |             | "                      | "            | 27208               | 1.33               |
| 30/400M/STG/200/35/5/M  | 98       | 9.0              | 14052            |             | "                      | "            | 18152               | 1.29               |
| 30/400M/STG/200/40/5/M  | 99       | 10.1             | 15387            |             | "                      | "            | 20410               | 1.33               |
| 30/400M/STG/200/45/5/M  | 100      | 10.7             | 15387            |             | "                      | "            | 22674               | 1.47               |
| 30/400M/STG/250/40/5/M  | 104      | 7.2              | 13106            |             | "                      | "            | 13592               | 1.04               |
| 30/400M/STG/250/45/5/M  | 105      | 8.3              | 13106            |             | "                      | "            | 15894               | 1.21               |
|                         |          |                  |                  |             |                        |              |                     |                    |
| 60/400H/OPP/100/25/11/M | 106      | 16.0             | 29059            |             | "                      | "            | 31803               | 1.09               |
| 60/400H/OPP/100/30/11/M | 107      | 17.7             | 29059            |             | "                      | "            | 31911               | 1.10               |
| 60/400H/OPP/100/35/11/M | 108      | 17.7             | 29059            |             | "                      | "            | 31911               | 1.10               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 60/400H/OPP/100/40/11/M | 109      | 18.0             | 31580            |             | 30000                  | 20000        | 31930               | 1.01               |
| 60/400H/OPP/100/45/11/M | 110      | 18.0             | 31580            |             | "                      | "            | 31930               | 1.01               |
| 60/400H/OPP/150/35/11/M | 113      | 12.6             | 20511            |             | "                      | "            | 27208               | 1.33               |
| 60/400H/OPP/150/40/11/M | 114      | 13.9             | 22292            |             | "                      | "            | 29476               | 1.32               |
| 60/400H/OPP/150/45/11/M | 115      | 14.7             | 22292            |             | "                      | "            | 31740               | 1.42               |
| 60/400H/OPP/200/40/11/M | 119      | 8.5              | 16719            |             | "                      | "            | 18152               | 1.09               |
| 60/400H/OPP/200/45/11/M | 120      | 10.4             | 16719            |             | "                      | "            | 20410               | 1.22               |
| 60/400H/STG/100/25/11/M | 126      | 16.5             | 29059            |             | "                      | "            | 31835               | 1.10               |
| 60/400H/STG/100/30/11/M | 127      | 19.1             | 29059            |             | "                      | "            | 32000               | 1.10               |
| 60/400H/STG/100/35/11/M | 128      | 18.7             | 29059            |             | "                      | "            | 31975               | 1.10               |
| 60/400H/STG/100/40/11/M | 129      | 18.2             | 31580            |             | "                      | "            | 31943               | 1.01               |
| 60/400H/STG/100/45/11/M | 130      | 18.5             | 31580            |             | "                      | "            | 31962               | 1.01               |
| 60/400H/STG/150/30/11/M | 132      | 13.1             | 20511            |             | "                      | "            | 27208               | 1.33               |
| 60/400H/STG/150/35/11/M | 133      | 14.2             | 20511            |             | "                      | "            | 29476               | 1.44               |



Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 60/400H/STG/150/40/11/M | 134      | 15.0             | 22292            |             | 30 000                 | 20000        | 31740               | 1.42               |
| 60/400H/STG/150/45/11/M | 135      | 15.5             | 22292            |             | "                      | "            | 31772               | 1.43               |
| 60/400H/STG/200/30/11/M | 137      | 8.2              | 15384            |             | "                      | "            | 15894               | 1.03               |
| 60/400H/STG/200/35/11/M | 138      | 10.9             | 15384            |             | "                      | "            | 22674               | 1.47               |
| 60/400H/STG/200/40/11/M | 139      | 12.5             | 16719            |             | "                      | "            | 27208               | 1.63               |
| 60/400H/STG/200/45/11/M | 140      | 12.7             | 16719            |             | "                      | "            | 27208               | 1.63               |
| 60/400H/STG/250/35/11/M | 143      | 8.1              | 13105            |             | "                      | "            | 15894               | 1.21               |
| 60/400H/STG/250/40/11/M | 144      | 9.3              | 14241            |             | "                      | "            | 18152               | 1.27               |
| 60/400H/STG/250/45/11/M | 145      | 10.8             | 14241            |             | "                      | "            | 22674               | 1.59               |
|                         |          |                  |                  |             |                        |              |                     |                    |
| 30/400H/SS/50/25/5/M    | 146      | 23.2             | 28489            |             | "                      | "            | 32260               | 1.32               |
| 30/400H/SS/50/30/5/M    | 147      | 22.6             | 28489            |             | "                      | "            | 32222               | 1.13               |
| 30/400H/SS/50/35/5/M    | 148      | 24.4             | 28489            |             | "                      | "            | 32336               | 1.14               |
| 30/400H/SS/50/40/5/M    | 149      | 24.2             | 30960            |             | "                      | "            | 32324               | 1.04               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE           | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-----------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400H/SS/50/45/5/M  | 150      | 24.3             | 30960            |             | 30000                  | 20000        | 32330               | 1.04               |
| 30/400H/SS/100/25/5/M | 151      | 13.0             | 14530            |             | "                      | "            | 27208               | 1.87               |
| 30/400H/SS/100/30/5/M | 152      | 15.0             | 14530            |             | "                      | "            | 31740               | 2.18               |
| 30/400H/SS/100/35/5/M | 153      | 16.6             | 14530            |             | "                      | "            | 31842               | 2.19               |
| 30/400H/SS/100/40/5/M | 154      | 16.9             | 15790            |             | "                      | "            | 31860               | 2.02               |
| 30/400H/SS/100/45/5/M | 155      | 17.1             | 15790            |             | "                      | "            | 31873               | 2.02               |
| 30/400H/SS/150/25/5/M | 156      | 6.1              | 10255            |             | "                      | "            | 11334               | 1.11               |
| 30/400H/SS/150/30/5/M | 157      | 9.8              | 10255            |             | "                      | "            | 20410               | 1.99               |
| 30/400H/SS/150/35/5/M | 158      | 11.5             | 10255            |             | "                      | "            | 24942               | 2.43               |
| 30/400H/SS/150/40/5/M | 159      | 12.9             | 11145            |             | "                      | "            | 27208               | 2.44               |
| 30/400H/SS/150/45/5/M | 160      | 13.5             | 11145            |             | "                      | "            | 29476               | 2.64               |
| 30/400H/SS/200/35/5/M | 163      | 6.2              | 7692             |             | "                      | "            | 11334               | 1.47               |
| 30/400H/SS/200/40/5/M | 164      | 8.1              | 8359             |             | "                      | "            | 15894               | 1.90               |
| 30/400H/SS/200/45/5/M | 165      | 9.5              | 8359             |             | "                      | "            | 20410               | 2.44               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400H/SS/250/45/5/M  | 170      | 5.8              | 7122             |             | 30000                  | 20000        | 11334               | 1.59               |
| 30/400H/OPP/100/25/5/M | 171      | 24.6             | 29059            |             | "                      | "            | 32349               | 1.11               |
| 30/400H/OPP/100/30/5/M | 172      | 25.6             | 29059            |             | "                      | "            | 32413               | 1.12               |
| 30/400H/OPP/100/35/5/M | 173      | 25.8             | 29059            |             | "                      | "            | 32426               | 1.16               |
| 30/400H/OPP/100/40/5/M | 174      | 25.5             | 31580            |             | "                      | "            | 32407               | 1.03               |
| 30/400H/OPP/100/45/5/M | 175      | 24.7             | 31580            |             | "                      | "            | 32356               | 1.02               |
| 30/400H/OPP/150/30/5/M | 177      | 12.8             | 20511            |             | "                      | "            | 27208               | 1.32               |
| 30/400H/OPP/150/35/5/M | 178      | 15.9             | 20511            |             | "                      | "            | 31797               | 1.55               |
| 30/400H/OPP/150/40/5/M | 179      | 17.5             | 22292            |             | "                      | "            | 31898               | 1.43               |
| 30/400H/OPP/150/45/5/M | 180      | 17.9             | 22292            |             | "                      | "            | 31924               | 1.43               |
| 30/400H/OPP/200/40/5/M | 184      | 10.1             | 16719            |             | "                      | "            | 20410               | 1.22               |
| 30/400H/OPP/200/45/5/M | 185      | 12.4             | 16719            |             | "                      | "            | 24942               | 1.49               |
| 30/400H/STG/100/25/5/M | 191      | 27.7             | 29059            |             | "                      | "            | 32546               | 1.12               |
| 30/400H/STG/100/30/5/M | 192      | 28.7             | 29059            |             | "                      | "            | 32610               | 1.12               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400H/STG/100/35/5/M | 193      | 27.2             | 29059            |             | 30000                  | 20000        | 32514               | 1.12               |
| 30/400H/STG/100/40/5/M | 194      | 25.7             | 31580            |             | "                      | "            | 32419               | 1.03               |
| 30/400H/STG/100/45/5/M | 195      | 24.7             | 31586            |             | "                      | "            | 32356               | 1.02               |
| 30/400H/STG/150/25/5/M | 196      | 19.4             | 20511            |             | "                      | "            | 32019               | 1.56               |
| 30/400H/STG/150/30/5/M | 197      | 20.2             | 20511            |             | "                      | "            | 32070               | 1.56               |
| 30/400H/STG/150/35/5/M | 198      | 20.2             | 20511            |             | "                      | "            | 32070               | 1.56               |
| 30/400H/STG/150/40/5/M | 199      | 20.6             | 22292            |             | "                      | "            | 32095               | 1.44               |
| 30/400H/STG/150/45/5/M | 200      | 20.5             | 22292            |             | "                      | "            | 32089               | 1.44               |
| 30/400H/STG/200/25/5/M | 201      | 12.9             | 15384            |             | "                      | "            | 27208               | 1.77               |
| 30/400H/STG/200/30/5/M | 202      | 15.9             | 15384            |             | "                      | "            | 31797               | 2.07               |
| 30/400H/STG/200/35/5/M | 203      | 16.7             | 15384            |             | "                      | "            | 31848               | 2.07               |
| 30/400H/STG/200/40/5/M | 204      | 16.8             | 16719            |             | "                      | "            | 31854               | 1.91               |
| 30/400H/STG/200/45/5/M | 205      | 17.0             | 16719            |             | "                      | "            | 31867               | 1.91               |
| 30/400H/STG/250/25/5/M | 206      | 7.3              | 13105            |             | "                      | "            | 13592               | 1.03               |



Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30/400H/STG/250/30/5/M  | 207      | 11.9             | 13105            |             | 30000                  | 20000        | 24942               | 1.90               |
| 30/400H/STG/250/35/5/M  | 208      | 13.8             | 13105            |             | "                      | "            | 29476               | 2.25               |
| 30/400H/STG/250/40/5/M  | 209      | 14.7             | 14241            |             | "                      | "            | 31740               | 2.23               |
| 30/400H/STG/250/45/5/M  | 210      | 15.3             | 14241            |             | "                      | "            | 31740               | 2.23               |
|                         |          |                  |                  |             |                        |              |                     |                    |
| 60/150H/OPP/100/20/11/M | 211      | 10.1             | 16889            |             | "                      | "            | 20410               | 1.21               |
| 60/150H/OPP/100/25/11/M | 212      | 11.4             | 19540            |             | "                      | "            | 22674               | 1.16               |
| 60/150H/OPP/100/30/11/M | 213      | 13.2             | 19540            |             | "                      | "            | 27208               | 1.39               |
| 60/150H/OPP/100/35/11/M | 214      | 13.5             | 19540            |             | "                      | "            | 29476               | 1.51               |
| 60/150H/OPP/100/40/11/M | 215      | 13.5             | 22061            |             | "                      | "            | 29476               | 1.34               |
| 60/150H/OPP/150/30/11/M | 218      | 8.0              | 13794            |             | "                      | "            | 15894               | 1.15               |
| 60/150H/OPP/150/35/11/M | 219      | 8.9              | 13794            |             | "                      | "            | 18152               | 1.32               |
| 60/150H/OPP/150/40/11/M | 220      | 9.8              | 15573            |             | "                      | "            | 20410               | 1.31               |
| 60/150H/OPP/200/35/11/M | 224      | 6.2              | 10344            |             | "                      | "            | 11334               | 1.10               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sup>15</sup> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 60/150H/OPP/200/40/11/M | 225      | 7.2              | 11679            |             | 30000                  | 20000        | 13592               | 1.16               |
| 60/150H/STG/100/20/11/M | 231      | 10.6             | 16889            |             | "                      | "            | 22674               | 1.34               |
| 60/150H/STG/100/25/11/M | 232      | 11.9             | 19540            |             | "                      | "            | 24942               | 1.28               |
| 60/150H/STG/100/30/11/M | 233      | 13.1             | 19540            |             | "                      | "            | 27208               | 1.39               |
| 60/150H/STG/100/35/11/M | 234      | 13.8             | 19540            |             | "                      | "            | 29476               | 1.51               |
| 60/150H/STG/100/40/11/M | 235      | 13.2             | 22061            |             | "                      | "            | 27208               | 1.23               |
| 60/150H/STG/150/25/11/M | 237      | 7.1              | 13794            |             | "                      | "            | 13822               | 1.00               |
| 60/150H/STG/150/30/11/M | 238      | 8.8              | 13794            |             | "                      | "            | 18152               | 1.32               |
| 60/150H/STG/150/35/11/M | 239      | 9.2              | 13794            |             | "                      | "            | 18152               | 1.32               |
| 60/150H/STG/150/40/11/M | 240      | 10.3             | 15573            |             | "                      | "            | 20410               | 1.31               |
| 60/150H/STG/200/30/11/M | 243      | 6.3              | 10344            |             | "                      | "            | 11334               | 1.10               |
| 60/150H/STG/200/35/11/M | 244      | 6.9              | 10344            |             | "                      | "            | 13592               | 1.31               |
| 60/150H/STG/200/40/11/M | 245      | 8.0              | 11679            |             | "                      | "            | 15894               | 1.36               |
| 60/150H/STG/250/30/11/M | 248      | 4.8              | 8813             |             | "                      | "            | 9076                | 1.03               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE             | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|-------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 60/150H/STG/250/35/11/M | 249      | 5.4              | 8813             |             | 30 000                 | 20 000       | 9076                | 1.03               |
| 60/150H/STG/250/40/11/M | 250      | 6.8              | 9949             |             | "                      | "            | 13592               | 1.37               |
|                         |          |                  |                  |             |                        |              |                     |                    |
| 30/150H/SS/50/20/5/M    | 251      | 9.1              | 16558            |             | "                      | "            | 18152               | 1.10               |
| 30/150H/SS/50/25/5/M    | 252      | 11.4             | 19157            |             | "                      | "            | 22674               | 1.18               |
| 30/150H/SS/50/30/5/M    | 253      | 13.0             | 19157            |             | "                      | "            | 27208               | 1.42               |
| 30/150H/SS/50/35/5/M    | 254      | 13.2             | 19157            |             | "                      | "            | 27208               | 1.42               |
| 30/150H/SS/50/40/5/M    | 255      | 13.6             | 21628            |             | "                      | "            | 29476               | 1.36               |
| 30/150H/SS/100/20/5/M   | 256      | 6.3              | 8444             |             | "                      | "            | 11334               | 1.34               |
| 30/150H/SS/100/25/5/M   | 257      | 8.6              | 9769             |             | "                      | "            | 18152               | 1.86               |
| 30/150H/SS/100/30/5/M   | 258      | 10.7             | 9769             |             | "                      | "            | 22674               | 2.32               |
| 30/150H/SS/100/35/5/M   | 259      | 11.0             | 9769             |             | "                      | "            | 22674               | 2.32               |
| 30/150H/SS/100/40/5/M   | 260      | 10.6             | 11030            |             | "                      | "            | 22674               | 2.06               |
| 30/150H/SS/150/20/5/M   | 261      | 4.1              | 5961             |             | "                      | "            | 6818                | 1.14               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30 150H SS 150 30 5 M  | 263      | 7.3              | 6896             |             | 30000                  | 20000        | 13592               | 1.97               |
| 30 150H SS 150 35 5 M  | 264      | 6.4              | 6896             |             | "                      | "            | 11334               | 1.64               |
| 30 150H SS 150 40 5 M  | 265      | 7.7              | 7786             |             | "                      | "            | 15894               | 2.04               |
| 30 150H SS 200 30 5 M  | 268      | 4.8              | 5172             |             | "                      | "            | 9076                | 1.75               |
| 30 150H SS 200 35 5 M  | 269      | 6.0              | 5172             |             | "                      | "            | 11334               | 2.19               |
| 30 150H SS 200 40 5 M  | 270      | 6.4              | 5838             |             | "                      | "            | 11334               | 1.94               |
| 30 150H SS 250 30 5 M  | 273      | 3.6              | 4406             |             | "                      | "            | 6818                | 1.55               |
| 30 150H SS 250 35 5 M  | 274      | 3.7              | 4406             |             | "                      | "            | 6818                | 1.55               |
| 30 150H SS 250 40 5 M  | 275      | 4.4              | 4975             |             | "                      | "            | 6818                | 1.37               |
| 30 150H OPP 100 20 5 M | 276      | 13.7             | 16889            |             | "                      | "            | 29476               | 1.75               |
| 30 150H OPP 100 25 5 M | 277      | 14.7             | 19540            |             | "                      | "            | 31740               | 1.62               |
| 30 150H OPP 100 30 5 M | 278      | 16.0             | 19540            |             | "                      | "            | 31803               | 1.63               |
| 30 150H OPP 100 35 5 M | 279      | 16.3             | 19540            |             | "                      | "            | 31822               | 1.63               |
| 30 150H OPP 100 40 5 M | 280      | 15.6             | 22061            |             | "                      | "            | 31778               | 1.44               |



Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30 150H OPP 150 25 5 M | 282      | 8.8              | 13794            |             | 30 000                 | 20000        | 18152               | 1.32               |
| 30 150H OPP 150 30 5 M | 283      | 10.4             | 13794            |             | "                      | "            | 20410               | 1.48               |
| 30 150H OPP 150 35 5 M | 284      | 11.9             | 13794            |             | "                      | "            | 24942               | 1.81               |
| 30 150H OPP 150 40 5 M | 285      | 13.2             | 15573            |             | "                      | "            | 27208               | 1.75               |
| 30 150H OPP 200 30 5 M | 288      | 6.8              | 10344            |             | "                      | "            | 13592               | 1.31               |
| 30 150H OPP 200 35 5 M | 289      | 8.3              | 10344            |             | "                      | "            | 15894               | 1.54               |
| 30 150H OPP 200 40 5 M | 290      | 6.6              | 11679            |             | "                      | "            | 13592               | 1.16               |
| 30 150H OPP 250 30 5 M | 293      | 5.3              | 8813             |             | "                      | "            | 9076                | 1.03               |
| 30 150H OPP 250 35 5 M | 294      | 6.0              | 8813             |             | "                      | "            | 11334               | 1.29               |
| 30 150H OPP 250 40 5 M | 295      | 5.9              | 9949             |             | "                      | "            | 11334               | 1.14               |
| 30 150H STG 100 20 5 M | 296      | 13.6             | 16889            |             | "                      | "            | 29476               | 1.75               |
| 30 150H STG 100 25 5 M | 297      | 16.4             | 19540            |             | "                      | "            | 31829               | 1.63               |
| 30 150H STG 100 30 5 M | 298      | 16.4             | 19540            |             | "                      | "            | 31829               | 1.63               |
| 30 150H STG 100 35 5 M | 299      | 16.2             | 19540            |             | "                      | "            | 31816               | 1.63               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30 150H STG 100 40 5 M | 300      | 15.0             | 22061            |             | 30000                  | 20000        | 31740               | 1.44               |
| 30 150H STG 150 20 5 M | 301      | 6.3              | 11922            |             | "                      | "            | 12011               | 1.01               |
| 30 150H STG 150 25 5 M | 302      | 10.2             | 13794            |             | "                      | "            | 20410               | 1.48               |
| 30 150H STG 150 30 5 M | 303      | 12.8             | 13794            |             | "                      | "            | 27208               | 1.97               |
| 30 150H STG 150 35 5 M | 304      | 11.2             | 13794            |             | "                      | "            | 24942               | 1.81               |
| 30 150H STG 150 40 5 M | 305      | 12.3             | 15573            |             | "                      | "            | 24942               | 1.60               |
| 30 150H STG 200 20 5 M | 306      | 6.5              | 8941             |             | "                      | "            | 13592               | 1.52               |
| 30 150H STG 200 25 5 M | 307      | 8.0              | 10344            |             | "                      | "            | 15894               | 1.54               |
| 30 150H STG 200 30 5 M | 308      | 11.9             | 10344            |             | "                      | "            | 24942               | 2.41               |
| 30 150H STG 200 35 5 M | 309      | 11.2             | 10344            |             | "                      | "            | 22674               | 2.19               |
| 30 150H STG 200 40 5 M | 310      | 11.4             | 11679            |             | "                      | "            | 22674               | 2.19               |
| 30 150H STG 250 25 5 M | 312      | 6.2              | 8813             |             | "                      | "            | 11334               | 1.29               |
| 30 150H STG 250 30 5 M | 313      | 7.2              | 8813             |             | "                      | "            | 13592               | 1.54               |
| 30 150H STG 250 35 5 M | 314      | 8.4              | 8813             |             | "                      | "            | 15894               | 1.80               |

Table 23 Benefit Cost Ratios of New Systems

| SYSTEM CODE            | CASE NO. | VI <sub>15</sub> | COSTS (\$/mi/yr) | AREA (TYPE) | DENSITY (People/sq mi) | VOLUME (ADT) | BENEFITS (\$/mi/yr) | BENEFIT COST RATIO |
|------------------------|----------|------------------|------------------|-------------|------------------------|--------------|---------------------|--------------------|
| 30 150H STG 250 40 5 M | 315      | 9.3              | 9949             |             | 30000                  | 20000        | 18152               | 1.82               |
|                        |          |                  |                  |             |                        |              |                     |                    |
| 30 175M SS 50 30 5 M   | 358      | 10.1             | 17624            |             | "                      | "            | 20410               | 1.16               |
| 30 175M SS 50 35 5 M   | 359      | 10.7             | 17624            |             | "                      | "            | 22674               | 1.29               |
| 30 175M SS 50 40 5 M   | 360      | 10.4             | 20095            |             | "                      | "            | 20410               | 1.02               |
| 30 175M SS 100 30 5 M  | 363      | 6.4              | 8989             |             | "                      | "            | 11334               | 1.26               |
| 30 175M SS 100 35 5 M  | 364      | 7.1              | 8989             |             | "                      | "            | 13592               | 1.51               |
| 30 175M SS 100 40 5 M  | 365      | 7.1              | 10249            |             | "                      | "            | 13592               | 1.33               |
| 30 175M SS 150 35 5 M  | 369      | 3.8              | 6344             |             | "                      | "            | 6366                | 1.00               |
| 30 175M SS 150 40 5 M  | 370      | 4.5              | 7234             |             | "                      | "            | 9076                | 1.25               |
| 30 175M STG 100 35 5 M | 404      | 9.7              | 17976            |             | "                      | "            | 20410               | 1.14               |
| 30 175M STG 100 40 5 M | 405      | 10.1             | 20497            |             | "                      | "            | 20636               | 1.01               |
| 30 175M STG 150 30 5 M | 408      | 6.8              | 12689            |             | "                      | "            | 13140               | 1.04               |
| 30 175M STG 150 35 5 M | 409      | 7.6              | 12689            |             | "                      | "            | 15894               | 1.25               |





Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI<br>T5 | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>ANNUAL<br>COSTS<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq. mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|----------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|---------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |          |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAIN-<br>TENANCE           | ENERGY |                                        |              |                                 |                 |                              |                        |                          |
| 60/400M/STG/100/35/11/M  | 23          | 13.4     | 1704                                                | 98040            | 10563                | 752                        | 15228  | 26543                                  | CBD          | 30000                           | 20000           | 40                           | 27208                  | 1.03                     |
| 60/400M/STG/100/40/11/M  | 24          | 13.8     | 1704                                                | 120960           | 13084                | 752                        | 15228  | 29043                                  | CBD          | "                               | "               | 44                           | 29476                  | 1.02                     |
| 60/400M/STG/100/45/11/M  | 25          | 13.8     | 1704                                                | 120960           | 13084                | 752                        | 15228  | 29043                                  | CBD          | "                               | "               | 44                           | 29476                  | 1.02                     |
| 60/400M/STG/150/45/11/M  | 30          | 10.7     | 1147                                                | 85383            | 9235                 | 530                        | 10749  | 20514                                  | CBD          | "                               | "               | 34                           | 21995                  | 1.07                     |
| 60/400M/STG/200/45/11/M  | 35          | 7.8      | 852                                                 | 64038            | 6927                 | 398                        | 8062   | 15387                                  | CBD          | "                               | "               | 24                           | 15434                  | 1.00                     |
|                          |             |          |                                                     |                  |                      |                            |        |                                        |              |                                 |                 |                              |                        |                          |
| 30/400M/SS/50/35/5/M     | 43          | 13.1     | 1720                                                | 96118            | 10356                | 737                        | 14929  | 26022                                  | CBD          | "                               | "               | 40                           | 27208                  | 1.05                     |
| 30/400M/SS/50/40/5/M     | 44          | 13.9     | 1720                                                | 118588           | 12827                | 737                        | 14929  | 28493                                  | CBD          | "                               | "               | 44                           | 29476                  | 1.03                     |
| 30/400M/SS/50/45/5/M     | 45          | 14.1     | 1720                                                | 118588           | 12827                | 737                        | 14929  | 28493                                  | CBD          | "                               | "               | 44                           | 29476                  | 1.03                     |
| 30/400M/SS/100/30/5/M    | 47          | 7.4      | 852                                                 | 49020            | 5281                 | 376                        | 7614   | 13271                                  | CBD          | "                               | "               | 20                           | 13592                  | 1.02                     |
| 30/400M/SS/100/35/5/M    | 48          | 9.1      | 852                                                 | 49020            | 5281                 | 376                        | 7614   | 13271                                  | CBD          | "                               | "               | 27                           | 18152                  | 1.37                     |
| 30/400M/SS/100/40/5/M    | 49          | 9.6      | 852                                                 | 60480            | 6542                 | 376                        | 7614   | 14532                                  | CBD          | "                               | "               | 30                           | 20410                  | 1.40                     |
| 30/400M/SS/100/45/5/M    | 50          | 9.8      | 852                                                 | 60480            | 6542                 | 376                        | 7614   | 14532                                  | CBD          | "                               | "               | 30                           | 20410                  | 1.40                     |
| 30/400M/SS/150/35/5/M    | 53          | 5.7      | 573                                                 | 34602            | 3728                 | 265                        | 5374   | 9367                                   | CBD          | "                               | "               | 17                           | 11334                  | 1.21                     |
| 30/400M/SS/150/40/5/M    | 54          | 6.5      | 573                                                 | 42692            | 4618                 | 265                        | 5374   | 10257                                  | CBD          | "                               | "               | 20                           | 13592                  | 1.33                     |
| 30/400M/SS/150/45/5/M    | 55          | 7.3      | 573                                                 | 42692            | 4618                 | 265                        | 5374   | 10257                                  | CBD          | "                               | "               | 20                           | 13592                  | 1.33                     |
| 30/400M/SS/200/40/5/M    | 59          | 4.4      | 426                                                 | 32019            | 3463                 | 199                        | 4031   | 7693                                   | CBD          | "                               | "               | 10                           | 7721                   | 1.00                     |
| 30/400M/SS/200/45/5/M    | 60          | 5.3      | 426                                                 | 32019            | 3463                 | 199                        | 4031   | 7693                                   | CBD          | "                               | "               | 13                           | 9076                   | 1.18                     |
| 30/400M/SS/250/45/5/M    | 65          | 3.9      | 344                                                 | 27275            | 2950                 | 170                        | 3434   | 6554                                   | CBD          | "                               | "               | 10                           | 6818                   | 1.04                     |
| 30/400M/OPP/100/30/5/M   | 67          | 12.8     | 1704                                                | 98040            | 10563                | 752                        | 1704   | 26543                                  | CBD          | "                               | "               | 40                           | 27208                  | 1.03                     |

Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>T5</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>COSTS<br>ANNUAL<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINTENANCE                | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 30/400M/OPP/100/35/5/M   | 68          | 14.0             | 1704                                                | 98040            | 10563                | 752                        | 15228  | 26543                                  | CBD          | 30000                          | 20000           | 44                           | 29476                  | 1.11                     |
| 30/400M/OPP/100/40/5/M   | 69          | 14.7             | 1704                                                | 120960           | 13084                | 752                        | 15228  | 29043                                  | CBD          | "                              | "               | 47                           | 31740                  | 1.09                     |
| 30/400M/OPP/100/45/5/M   | 70          | 15.4             | 1704                                                | 120960           | 13084                | 752                        | 15228  | 29043                                  | CBD          | "                              | "               | 47                           | 31766                  | 1.09                     |
| 30/400M/OPP/150/45/5/M   | 75          | 10.8             | 1147                                                | 85383            | 9235                 | 530                        | 10749  | 20514                                  | CBD          | "                              | "               | 35                           | 22220                  | 1.08                     |
| 30/400M/STG/100/25/5/M   | 86          | 15.2             | 1704                                                | 98040            | 10563                | 752                        | 15228  | 26543                                  | CBD          | "                              | "               | 47                           | 31753                  | 1.20                     |
| 30/400M/STG/100/30/5/M   | 87          | 16.3             | 1704                                                | 98040            | 10563                | 752                        | 15228  | 26543                                  | CBD          | "                              | "               | 47                           | 31822                  | 1.20                     |
| 30/400M/STG/100/35/5/M   | 88          | 16.3             | 1704                                                | 98040            | 10563                | 752                        | 15228  | 26543                                  | CBD          | "                              | "               | 47                           | 31822                  | 1.20                     |
| 30/400M/STG/100/40/5/M   | 89          | 16.3             | 1704                                                | 120960           | 13084                | 752                        | 15228  | 29043                                  | CBD          | "                              | "               | 47                           | 31822                  | 1.10                     |
| 30/400M/STG/100/45/5/M   | 90          | 16.2             | 1704                                                | 120960           | 13084                | 752                        | 15228  | 29043                                  | CBD          | "                              | "               | 47                           | 31816                  | 1.10                     |
| 30/400M/STG/150/30/5/M   | 92          | 11.0             | 1147                                                | 69205            | 7456                 | 530                        | 10749  | 18735                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.21                     |
| 30/400M/STG/150/35/5/M   | 93          | 12.3             | 1147                                                | 69205            | 7456                 | 530                        | 10749  | 18735                                  | CBD          | "                              | "               | 37                           | 24942                  | 1.33                     |
| 30/400M/STG/150/40/5/M   | 94          | 13.0             | 1147                                                | 85383            | 9235                 | 530                        | 10749  | 20514                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.33                     |
| 30/400M/STG/150/45/5/M   | 95          | 13.2             | 1147                                                | 85383            | 9235                 | 530                        | 10749  | 20514                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.33                     |
| 30/400M/STG/200/35/5/M   | 98          | 9.0              | 852                                                 | 51904            | 5592                 | 398                        | 8062   | 14052                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.29                     |
| 30/400M/STG/200/40/5/M   | 99          | 10.1             | 852                                                 | 64038            | 6927                 | 398                        | 8062   | 15387                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.33                     |
| 30/400M/STG/200/45/5/M   | 100         | 10.7             | 852                                                 | 64038            | 6927                 | 398                        | 8062   | 15387                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.47                     |
| 30/400M/STG/250/40/5/M   | 104         | 7.2              | 688                                                 | 54550            | 5900                 | 339                        | 6867   | 13106                                  | CBD          | "                              | "               | 20                           | 13592                  | 1.04                     |
| 30/400M/STG/250/45/5/M   | 105         | 8.3              | 688                                                 | 54550            | 5900                 | 339                        | 6867   | 13106                                  | CBD          | "                              | "               | 24                           | 15894                  | 1.21                     |
|                          |             |                  |                                                     |                  |                      |                            |        |                                        |              |                                |                 |                              |                        |                          |
| 60/400H/OPP/100/25/11/M  | 106         | 16.0             | 1704                                                | 104599           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 47                           | 31803                  | 1.09                     |

Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI<br>IS | ENERGY<br>USE<br>(kwh/mi<br>yr.)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>ANNUAL<br>COSTS<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|----------|------------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |          |                                                      | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINTENANCE                | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 60/400H/OPP/100/30/11/M  | 107         | 17.7     | 1704                                                 | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | 30000                          | 20000           | 47                           | 31911                  | 1.10                     |
| 60/400H/OPP/100/35/11/M  | 108         | 17.7     | 1704                                                 | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 47                           | 31911                  | 1.10                     |
| 60/400H/OPP/100/40/11/M  | 109         | 18.0     | 1704                                                 | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 47                           | 31930                  | 1.01                     |
| 60/400H/OPP/100/45/11/M  | 110         | 18.0     | 1704                                                 | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 47                           | 31930                  | 1.01                     |
| 60/400H/OPP/150/35/11/M  | 113         | 12.6     | 1147                                                 | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.33                     |
| 60/400H/OPP/150/40/11/M  | 114         | 13.9     | 1147                                                 | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.32                     |
| 60/400H/OPP/150/45/11/M  | 115         | 14.7     | 1147                                                 | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 47                           | 31740                  | 1.42                     |
| 60/400H/OPP/200/40/11/M  | 119         | 8.5      | 852                                                  | 67504            | 7308                 | 1349                       | 8062   | 16719                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.09                     |
| 60/400H/OPP/200/45/11/M  | 120         | 10.4     | 852                                                  | 67504            | 7308                 | 1349                       | 8062   | 16719                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.22                     |
| 60/400H/STG/100/25/11/M  | 126         | 16.5     | 1704                                                 | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 47                           | 31835                  | 1.10                     |
| 60/400H/STG/100/30/11/M  | 127         | 19.1     | 1704                                                 | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 47                           | 32000                  | 1.10                     |
| 60/400H/STG/100/35/11/M  | 128         | 18.7     | 1704                                                 | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 47                           | 31975                  | 1.10                     |
| 60/400H/STG/100/40/11/M  | 129         | 18.2     | 1704                                                 | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 47                           | 31943                  | 1.01                     |
| 60/400H/STG/100/45/11/M  | 130         | 18.5     | 1704                                                 | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 47                           | 31962                  | 1.01                     |
| 60/400H/STG/150/30/11/M  | 132         | 13.1     | 1147                                                 | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.33                     |
| 60/400H/STG/150/35/11/M  | 133         | 14.2     | 1147                                                 | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.44                     |
| 60/400H/STG/150/40/11/M  | 134         | 15.0     | 1147                                                 | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 47                           | 31740                  | 1.42                     |
| 60/400H/STG/150/45/11/M  | 135         | 15.5     | 1147                                                 | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 47                           | 31772                  | 1.43                     |
| 60/400H/STG/200/30/11/M  | 137         | 8.2      | 852                                                  | 55371            | 5973                 | 1349                       | 8062   | 15384                                  | CBD          | "                              | "               | 24                           | 15894                  | 1.03                     |
| 60/400H/STG/200/35/11/M  | 138         | 10.9     | 852                                                  | 55371            | 5973                 | 1349                       | 8062   | 15384                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.47                     |



Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOT. L<br>ANNUAL<br>COSTS<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|-----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINT-<br>TENANCE          | ENERGY |                                         |              |                                |                 |                              |                        |                          |
| 60/400H/STG/200/40/11/M  | 139         | 12.5             | 852                                                 | 67504            | 7308                 | 1349                       | 8062   | 16719                                   | CBD          | 30000                          | 20000           | 40                           | 27208                  | 1.63                     |
| 60/400H/STG/200/45/11/M  | 140         | 12.7             | 852                                                 | 67504            | 7308                 | 1349                       | 8062   | 16719                                   | CBD          | "                              | "               | 40                           | 27208                  | 1.63                     |
| 60/400H/STG/250/35/11/M  | 143         | 8.1              | 688                                                 | 47167            | 5089                 | 1149                       | 6867   | 13105                                   | CBD          | "                              | "               | 24                           | 15894                  | 1.21                     |
| 60/400H/STG/250/40/11/M  | 144         | 9.3              | 688                                                 | 57504            | 6225                 | 1149                       | 6867   | 14241                                   | CBD          | "                              | "               | 27                           | 18152                  | 1.27                     |
| 60/400H/STG/250/45/11/M  | 145         | 10.8             | 688                                                 | 57504            | 6225                 | 1149                       | 6867   | 14241                                   | CBD          | "                              | "               | 34                           | 22674                  | 1.59                     |
| 30/400H/SS/50/25/5/M     | 146         | 23.2             | 1720                                                | 102538           | 11062                | 2498                       | 14929  | 28489                                   | CBD          | "                              | "               | 48                           | 32260                  | 1.32                     |
| 30/400H/SS/50/30/5/M     | 147         | 22.6             | 1720                                                | 102538           | 11062                | 2498                       | 14929  | 28489                                   | CBD          | "                              | "               | 48                           | 32222                  | 1.13                     |
| 30/400H/SS/50/35/5/M     | 148         | 24.4             | 1720                                                | 102538           | 11062                | 2498                       | 14929  | 28489                                   | CBD          | "                              | "               | 48                           | 32336                  | 1.14                     |
| 30/400H/SS/50/40/5/M     | 149         | 24.2             | 1720                                                | 125008           | 13533                | 2498                       | 14929  | 30960                                   | CBD          | "                              | "               | 48                           | 32324                  | 1.04                     |
| 30/400H/SS/50/45/5/M     | 150         | 24.3             | 1720                                                | 125008           | 13533                | 2498                       | 14929  | 30960                                   | CBD          | "                              | "               | 48                           | 32330                  | 1.04                     |
| 30/400H/SS/100/25/5/M    | 151         | 13.0             | 852                                                 | 52294            | 5642                 | 1274                       | 7614   | 14530                                   | CBD          | "                              | "               | 40                           | 27208                  | 1.87                     |
| 30/400H/SS/100/30/5/M    | 152         | 15.0             | 852                                                 | 52294            | 5642                 | 1274                       | 7614   | 14530                                   | CBD          | "                              | "               | 47                           | 31740                  | 2.18                     |
| 30/400H/SS/100/35/5/M    | 153         | 16.6             | 852                                                 | 52294            | 5642                 | 1274                       | 7614   | 14530                                   | CBD          | "                              | "               | 47                           | 31842                  | 2.19                     |
| 30/400H/SS/100/40/5/M    | 154         | 16.9             | 852                                                 | 63754            | 6902                 | 1274                       | 7614   | 15790                                   | CBD          | "                              | "               | 47                           | 31860                  | 2.02                     |
| 30/400H/SS/100/45/5/M    | 155         | 17.1             | 852                                                 | 63754            | 6902                 | 1274                       | 7614   | 15790                                   | CBD          | "                              | "               | 47                           | 31873                  | 2.02                     |
| 30/400H/SS/150/25/5/M    | 156         | 6.1              | 573                                                 | 36914            | 3982                 | 899                        | 5374   | 10255                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.11                     |
| 30/400H/SS/150/30/5/M    | 157         | 9.8              | 573                                                 | 36914            | 3982                 | 899                        | 5374   | 10255                                   | CBD          | "                              | "               | 30                           | 20410                  | 1.99                     |
| 30/400H/SS/150/35/5/M    | 158         | 11.5             | 573                                                 | 36914            | 3982                 | 899                        | 5374   | 10255                                   | CBD          | "                              | "               | 37                           | 24942                  | 2.43                     |
| 30/400H/SS/150/40/5/M    | 159         | 12.9             | 573                                                 | 45003            | 4872                 | 899                        | 5374   | 11145                                   | CBD          | "                              | "               | 40                           | 27208                  | 2.44                     |



Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>ANNUAL<br>COSTS<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAIN-<br>TENANCE           | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 30/400H/SS/150/45/5/M    | 160         | 13.5             | 573                                                 | 45003            | 4872                 | 899                        | 5374   | 11145                                  | CBD          | 30000                          | 20000           | 44                           | 29476                  | 2.64                     |
| 30/400H/SS/200/35/5/M    | 163         | 6.2              | 426                                                 | 27685            | 2987                 | 674                        | 4031   | 7692                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.47                     |
| 30/400H/SS/200/40/5/M    | 164         | 8.1              | 426                                                 | 33752            | 3654                 | 674                        | 4031   | 8359                                   | CBD          | "                              | "               | 24                           | 15894                  | 1.90                     |
| 30/400H/SS/200/45/5/M    | 165         | 9.5              | 426                                                 | 33752            | 3654                 | 674                        | 4031   | 8359                                   | CBD          | "                              | "               | 30                           | 20410                  | 2.44                     |
| 30/400H/SS/250/45/5/M    | 170         | 5.8              | 344                                                 | 28752            | 3113                 | 575                        | 3434   | 7122                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.59                     |
| 30/400H/OPP/100/25/5/M   | 171         | 24.6             | 1704                                                | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 48                           | 32349                  | 1.11                     |
| 30/400H/OPP/100/30/5/M   | 172         | 25.6             | 1704                                                | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 48                           | 32413                  | 1.12                     |
| 30/400H/OPP/100/35/5/M   | 173         | 25.8             | 1704                                                | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 48                           | 32426                  | 1.16                     |
| 30/400H/OPP/100/40/5/M   | 174         | 25.5             | 1704                                                | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 48                           | 32407                  | 1.03                     |
| 30/400H/OPP/100/45/5/M   | 175         | 24.7             | 1704                                                | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 48                           | 32356                  | 1.02                     |
| 30/400H/OPP/150/30/5/M   | 177         | 12.8             | 1147                                                | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.32                     |
| 30/400H/OPP/150/35/5/M   | 178         | 15.9             | 1147                                                | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 47                           | 31797                  | 1.55                     |
| 30/400H/OPP/150/40/5/M   | 179         | 17.5             | 1147                                                | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 47                           | 31898                  | 1.43                     |
| 30/400H/OPP/150/45/5/M   | 180         | 17.9             | 1147                                                | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 47                           | 31924                  | 1.43                     |
| 30/400H/OPP/200/40/5/M   | 184         | 10.1             | 852                                                 | 67504            | 7308                 | 1349                       | 8062   | 16719                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.22                     |
| 30/400H/OPP/200/45/5/M   | 185         | 12.4             | 852                                                 | 67504            | 7308                 | 1349                       | 8062   | 16719                                  | CBD          | "                              | "               | 37                           | 24942                  | 1.49                     |
| 30/400H/ST6/100/25/5/M   | 191         | 27.7             | 1704                                                | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 48                           | 32546                  | 1.12                     |
| 30/400H/ST6/100/30/5/M   | 192         | 28.7             | 1704                                                | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 49                           | 32610                  | 1.12                     |
| 30/400H/ST6/100/35/5/M   | 193         | 27.2             | 1704                                                | 104589           | 11283                | 2548                       | 15228  | 29059                                  | CBD          | "                              | "               | 48                           | 32514                  | 1.12                     |
| 30/400H/ST6/100/40/5/M   | 194         | 25.7             | 1704                                                | 127508           | 13804                | 2548                       | 15228  | 31580                                  | CBD          | "                              | "               | 48                           | 32419                  | 1.03                     |

Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>COSTS<br>ANNUAL<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINT-<br>TENANCE          | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 30/400H/STG/100/45/5/M   | 195         | 24.7             | 1704                                                | 127508           | 13804                | 2548                       | 15228  | 31586                                  | CBD          | 30000                          | 20000           | 48                           | 32356                  | 1.02                     |
| 30/400H/STG/150/25/5/M   | 196         | 19.4             | 1147                                                | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 47                           | 32019                  | 1.56                     |
| 30/400H/STG/150/30/5/M   | 197         | 20.2             | 1147                                                | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 48                           | 32070                  | 1.56                     |
| 30/400H/STG/150/35/5/M   | 198         | 20.2             | 1147                                                | 73827            | 7964                 | 1799                       | 10749  | 20511                                  | CBD          | "                              | "               | 48                           | 32070                  | 1.56                     |
| 30/400H/STG/150/40/5/M   | 199         | 20.6             | 1147                                                | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 48                           | 32095                  | 1.44                     |
| 30/400H/STG/150/45/5/M   | 200         | 20.5             | 1147                                                | 90005            | 9744                 | 1799                       | 10749  | 22292                                  | CBD          | "                              | "               | 48                           | 32089                  | 1.44                     |
| 30/400H/STG/200/25/5/M   | 201         | 12.9             | 852                                                 | 55371            | 5973                 | 1349                       | 8062   | 15384                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.77                     |
| 30/400H/STG/200/30/5/M   | 202         | 15.9             | 852                                                 | 55371            | 5973                 | 1349                       | 8062   | 15384                                  | CBD          | "                              | "               | 47                           | 31797                  | 2.07                     |
| 30/400H/STG/200/35/5/M   | 203         | 16.7             | 852                                                 | 55371            | 5973                 | 1349                       | 8062   | 15384                                  | CBD          | "                              | "               | 47                           | 31848                  | 2.07                     |
| 30/400H/STG/200/40/5/M   | 204         | 16.8             | 852                                                 | 67504            | 7308                 | 1349                       | 8062   | 16719                                  | CBD          | "                              | "               | 47                           | 31854                  | 1.91                     |
| 30/400H/STG/200/45/5/M   | 205         | 17.0             | 852                                                 | 67504            | 7308                 | 1349                       | 8062   | 16719                                  | CBD          | "                              | "               | 47                           | 31867                  | 1.91                     |
| 30/400H/STG/250/25/5/M   | 206         | 7.3              | 688                                                 | 47167            | 5089                 | 1149                       | 6867   | 13105                                  | CBD          | "                              | "               | 20                           | 13592                  | 1.03                     |
| 30/400H/STG/250/30/5/M   | 207         | 11.9             | 688                                                 | 47167            | 5089                 | 1149                       | 6867   | 13105                                  | CBD          | "                              | "               | 37                           | 24942                  | 1.90                     |
| 30/400H/STG/250/35/5/M   | 208         | 13.8             | 688                                                 | 47167            | 5089                 | 1149                       | 6867   | 13105                                  | CBD          | "                              | "               | 44                           | 29476                  | 2.25                     |
| 30/400H/STG/250/40/5/M   | 209         | 14.7             | 688                                                 | 57504            | 6225                 | 1149                       | 6867   | 14241                                  | CBD          | "                              | "               | 47                           | 31740                  | 2.23                     |
| 30/400H/STG/250/45/5/M   | 210         | 15.3             | 688                                                 | 57504            | 6225                 | 1149                       | 6867   | 14241                                  | CBD          | "                              | "               | 47                           | 31740                  | 2.23                     |
| 60/150H/OPP/100/20/11/M  | 211         | 10.1             | 639                                                 | 80491            | 8632                 | 2548                       | 5709   | 16889                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.21                     |
| 60/150H/OPP/100/25/11/M  | 212         | 11.4             | 639                                                 | 104589           | 11293                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.16                     |
| 60/150H/OPP/100/30/11/M  | 213         | 13.2             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.39                     |

Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>COSTS<br>ANNUAL<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAIN-<br>TENANCE           | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 60/150H/OPP/100/35/11/M  | 214         | 13.5             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | 30000                          | 20000           | 44                           | 29476                  | 1.51                     |
| 60/150H/OPP/100/40/11/M  | 215         | 13.5             | 639                                                 | 109387           | 13804                | 2548                       | 5709   | 22061                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.34                     |
| 60/150H/OPP/150/30/11/M  | 218         | 8.0              | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 24                           | 15894                  | 1.15                     |
| 60/150H/OPP/150/35/11/M  | 219         | 8.9              | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.32                     |
| 60/150H/OPP/150/40/11/M  | 220         | 9.8              | 430                                                 | 77214            | 9744                 | 1799                       | 4030   | 15573                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.31                     |
| 60/150H/OPP/200/35/11/M  | 224         | 6.2              | 319                                                 | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 17                           | 11334                  | 1.10                     |
| 60/150H/OPP/200/40/11/M  | 225         | 7.2              | 319                                                 | 57911            | 7308                 | 1349                       | 3022   | 11679                                  | CBD          | "                              | "               | 20                           | 13592                  | 1.16                     |
| 60/150H/STG/100/20/11/M  | 231         | 10.6             | 639                                                 | 80491            | 8632                 | 2548                       | 5709   | 16889                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.34                     |
| 60/150H/STG/100/25/11/M  | 232         | 11.9             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 37                           | 24942                  | 1.28                     |
| 60/150H/STG/100/30/11/M  | 233         | 13.1             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.39                     |
| 60/150H/STG/100/35/11/M  | 234         | 13.8             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.51                     |
| 60/150H/STG/100/40/11/M  | 235         | 13.2             | 639                                                 | 109387           | 13804                | 2548                       | 5709   | 22061                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.23                     |
| 60/150H/STG/150/25/11/M  | 237         | 7.1              | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 20                           | 13822                  | 1.00                     |
| 60/150H/STG/150/30/11/M  | 238         | 8.8              | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.32                     |
| 60/150H/STG/150/35/11/M  | 239         | 9.2              | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.32                     |
| 60/150H/STG/150/40/11/M  | 240         | 10.3             | 430                                                 | 77214            | 9744                 | 1799                       | 4030   | 15573                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.31                     |
| 60/150H/STG/200/30/11/M  | 243         | 6.3              | 319                                                 | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 17                           | 11334                  | 1.10                     |
| 60/150H/STG/200/35/11/M  | 244         | 6.9              | 319                                                 | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 20                           | 13592                  | 1.31                     |
| 60/150H/STG/200/40/11/M  | 245         | 8.0              | 319                                                 | 57911            | 7308                 | 1349                       | 3022   | 11679                                  | CBD          | "                              | "               | 24                           | 15894                  | 1.36                     |
| 60/150H/STG/250/30/11/M  | 248         | 4.8              | 258                                                 | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | "                              | "               | 13                           | 9076                   | 1.03                     |



Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>COSTS<br>ANNUAL<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINT-<br>TENANCE          | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 60/150H/SS/250/35/11/M   | 249         | 5.4              | 258                                                 | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | 30000                          | 20000           | 13                           | 9076                   | 1.03                     |
| 60/150H/SS/250/40/11/M   | 250         | 6.8              | 258                                                 | 49331            | 6225                 | 1149                       | 2575   | 9949                                   | CBD          | "                              | "               | 20                           | 13592                  | 1.37                     |
| 30/150H/SS/50/20/5/M     | 251         | 9.1              | 644                                                 | 78913            | 8463                 | 2498                       | 5597   | 16558                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.10                     |
| 30/150H/SS/50/25/5/M     | 252         | 11.4             | 644                                                 | 102538           | 11062                | 2498                       | 5597   | 19157                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.18                     |
| 30/150H/SS/50/30/5/M     | 253         | 13.0             | 644                                                 | 102538           | 11062                | 2498                       | 5597   | 19157                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.42                     |
| 30/150H/SS/50/35/5/M     | 254         | 13.2             | 644                                                 | 102538           | 11062                | 2498                       | 5597   | 19157                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.42                     |
| 30/150H/SS/50/40/5/M     | 255         | 13.6             | 644                                                 | 107242           | 13533                | 2498                       | 5597   | 21628                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.36                     |
| 30/150H/SS/100/20/5/M    | 256         | 6.3              | 319                                                 | 40246            | 4316                 | 1274                       | 2854   | 8444                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.34                     |
| 30/150H/SS/100/25/5/M    | 257         | 8.6              | 319                                                 | 52294            | 5642                 | 1274                       | 2854   | 9769                                   | CBD          | "                              | "               | 27                           | 18152                  | 1.86                     |
| 30/150H/SS/100/30/5/M    | 258         | 10.7             | 319                                                 | 52294            | 5642                 | 1274                       | 2854   | 9769                                   | CBD          | "                              | "               | 34                           | 22674                  | 2.32                     |
| 30/150H/SS/100/35/5/M    | 259         | 11.0             | 319                                                 | 52294            | 5642                 | 1274                       | 2854   | 9769                                   | CBD          | "                              | "               | 34                           | 22674                  | 2.32                     |
| 30/150H/SS/100/40/5/M    | 260         | 10.6             | 319                                                 | 54693            | 6902                 | 1274                       | 2854   | 11030                                  | CBD          | "                              | "               | 34                           | 22674                  | 2.06                     |
| 30/150H/SS/150/20/5/M    | 261         | 4.1              | 215                                                 | 28409            | 3047                 | 899                        | 2015   | 5961                                   | CBD          | "                              | "               | 10                           | 6818                   | 1.14                     |
| 30/150H/SS/150/30/5/M    | 263         | 7.3              | 215                                                 | 36914            | 3982                 | 899                        | 2015   | 6896                                   | CBD          | "                              | "               | 20                           | 13592                  | 1.97                     |
| 30/150H/SS/150/35/5/M    | 264         | 6.4              | 215                                                 | 36914            | 3982                 | 899                        | 2015   | 6896                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.64                     |
| 30/150H/SS/150/40/5/M    | 265         | 7.7              | 215                                                 | 38607            | 4872                 | 899                        | 2015   | 7786                                   | CBD          | "                              | "               | 24                           | 15894                  | 2.04                     |
| 30/150H/SS/200/30/5/M    | 268         | 4.8              | 160                                                 | 27685            | 2987                 | 674                        | 1511   | 5172                                   | CBD          | "                              | "               | 13                           | 9076                   | 1.75                     |
| 30/150H/SS/200/35/5/M    | 269         | 6.0              | 160                                                 | 27685            | 2987                 | 674                        | 1511   | 5172                                   | CBD          | "                              | "               | 17                           | 11334                  | 2.19                     |
| 30/150H/SS/200/40/5/M    | 270         | 6.4              | 160                                                 | 28955            | 3653                 | 674                        | 1511   | 5838                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.94                     |



Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>COSTS<br>ANNUAL<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINTENANCE                | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 30/150H/SS/250/30/5/M    | 273         | 3.6              | 12.9                                                | 23584            | 2544                 | 575                        | 1287   | 4406                                   | CBD          | 30000                          | 20000           | 10                           | 6818                   | 1.55                     |
| 30/150H/SS/250/35/5/M    | 274         | 3.7              | 12.9                                                | 23584            | 2544                 | 575                        | 1287   | 4406                                   | CBD          | "                              | "               | 10                           | 6818                   | 1.55                     |
| 30/150H/SS/250/40/5/M    | 275         | 4.4              | 12.9                                                | 24666            | 3113                 | 575                        | 1287   | 4975                                   | CBD          | "                              | "               | 10                           | 6818                   | 1.37                     |
| 30/150H/OPP/100/20/5/M   | 276         | 13.7             | 63.9                                                | 80491            | 8632                 | 2548                       | 5709   | 16889                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.75                     |
| 30/150H/OPP/100/25/5/M   | 277         | 14.7             | 63.9                                                | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 47                           | 31740                  | 1.62                     |
| 30/150H/OPP/100/30/5/M   | 278         | 16.0             | 63.9                                                | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 47                           | 31803                  | 1.63                     |
| 30/150H/OPP/100/35/5/M   | 279         | 16.3             | 63.9                                                | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 47                           | 31822                  | 1.63                     |
| 30/150H/OPP/100/40/5/M   | 280         | 15.6             | 63.9                                                | 109387           | 13804                | 2548                       | 5709   | 22061                                  | CBD          | "                              | "               | 47                           | 31778                  | 1.44                     |
| 30/150H/OPP/150/25/5/M   | 282         | 8.8              | 43.0                                                | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 27                           | 18152                  | 1.32                     |
| 30/150H/OPP/150/30/5/M   | 283         | 10.4             | 43.0                                                | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.48                     |
| 30/150H/OPP/150/35/5/M   | 284         | 11.9             | 43.0                                                | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 37                           | 24942                  | 1.81                     |
| 30/150H/OPP/150/40/5/M   | 285         | 13.2             | 43.0                                                | 77214            | 9744                 | 1799                       | 4030   | 15573                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.75                     |
| 30/150H/OPP/200/30/5/M   | 288         | 6.8              | 31.9                                                | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 20                           | 13592                  | 1.31                     |
| 30/150H/OPP/200/35/5/M   | 289         | 8.3              | 31.9                                                | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 24                           | 15894                  | 1.54                     |
| 30/150H/OPP/200/40/5/M   | 290         | 6.6              | 31.9                                                | 57911            | 7308                 | 1349                       | 3022   | 11679                                  | CBD          | "                              | "               | 20                           | 13592                  | 1.16                     |
| 30/150H/OPP/250/30/5/M   | 293         | 5.3              | 25.8                                                | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | "                              | "               | 13                           | 9076                   | 1.03                     |
| 30/150H/OPP/250/35/5/M   | 294         | 6.0              | 25.8                                                | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.29                     |
| 30/150H/OPP/250/40/5/M   | 295         | 5.9              | 25.8                                                | 49331            | 6225                 | 1149                       | 2575   | 9949                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.14                     |
| 30/150H/STG/100/20/5/M   | 296         | 13.6             | 63.9                                                | 80491            | 8632                 | 2548                       | 5709   | 16889                                  | CBD          | "                              | "               | 44                           | 29476                  | 1.75                     |
| 30/150H/STG/100/25/5/M   | 297         | 16.4             | 63.9                                                | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 47                           | 31829                  | 1.63                     |

Table 24 Summary of New Systems

| OPTIONS<br>(SYSTEM CODE) | CASE<br>NO. | VI <sub>15</sub> | ENERGY<br>USE<br>(kwh/mi<br>yr)<br>x10 <sup>2</sup> | INITIAL COSTS    |                      | ANNUAL COSTS<br>(\$/mi/yr) |        | TOTAL<br>COSTS<br>ANNUAL<br>(\$/mi/yr) | AREA<br>TYPE | DENSITY<br>(People/<br>Sq.mi.) | VOLUME<br>(ADT) | ACCIDENT<br>REDUCTION<br>(%) | BENEFITS<br>(\$/mi/yr) | BENEFIT<br>COST<br>RATIO |
|--------------------------|-------------|------------------|-----------------------------------------------------|------------------|----------------------|----------------------------|--------|----------------------------------------|--------------|--------------------------------|-----------------|------------------------------|------------------------|--------------------------|
|                          |             |                  |                                                     | TOTAL<br>(\$/mi) | ANNUAL<br>(\$/mi/yr) | MAINT-<br>TENANCE          | ENERGY |                                        |              |                                |                 |                              |                        |                          |
| 30/150H/STG/100/30/5/M   | 298         | 16.4             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | 30000                          | 20000           | 47                           | 31829                  | 1.63                     |
| 30/150H/STG/100/35/5/M   | 299         | 16.2             | 639                                                 | 104589           | 11283                | 2548                       | 5709   | 19540                                  | CBD          | "                              | "               | 47                           | 31816                  | 1.63                     |
| 30/150H/STG/100/40/5/M   | 300         | 15.0             | 639                                                 | 109387           | 13904                | 2548                       | 5709   | 22061                                  | CBD          | "                              | "               | 47                           | 31740                  | 1.44                     |
| 30/150H/STG/150/20/5/M   | 301         | 6.3              | 430                                                 | 56817            | 6093                 | 1799                       | 4030   | 11922                                  | CBD          | "                              | "               | 17                           | 12011                  | 1.01                     |
| 30/150H/STG/150/25/5/M   | 302         | 10.2             | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.48                     |
| 30/150H/STG/150/30/5/M   | 303         | 12.8             | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 40                           | 27208                  | 1.97                     |
| 30/150H/STG/150/35/5/M   | 304         | 11.2             | 430                                                 | 73827            | 7965                 | 1799                       | 4030   | 13794                                  | CBD          | "                              | "               | 34                           | 24942                  | 1.81                     |
| 30/150H/STG/150/40/5/M   | 305         | 12.3             | 430                                                 | 77214            | 9744                 | 1799                       | 4030   | 15573                                  | CBD          | "                              | "               | 37                           | 24942                  | 1.60                     |
| 30/150H/STG/200/20/5/M   | 306         | 6.5              | 319                                                 | 42613            | 4570                 | 1349                       | 3022   | 8941                                   | CBD          | "                              | "               | 20                           | 13592                  | 1.52                     |
| 30/150H/STG/200/25/5/M   | 307         | 8.0              | 319                                                 | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 24                           | 15894                  | 1.54                     |
| 30/150H/STG/200/30/5/M   | 308         | 11.9             | 319                                                 | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 37                           | 24942                  | 2.41                     |
| 30/150H/STG/200/35/5/M   | 309         | 11.2             | 319                                                 | 56991            | 5973                 | 1349                       | 3022   | 10344                                  | CBD          | "                              | "               | 34                           | 22674                  | 2.19                     |
| 30/150H/STG/200/40/5/M   | 310         | 11.4             | 319                                                 | 57911            | 7308                 | 1349                       | 3022   | 11679                                  | CBD          | "                              | "               | 34                           | 22674                  | 2.19                     |
| 30/150H/STG/250/25/5/M   | 312         | 6.2              | 258                                                 | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | "                              | "               | 17                           | 11334                  | 1.29                     |
| 30/150H/STG/250/30/5/M   | 313         | 7.2              | 258                                                 | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | "                              | "               | 20                           | 13592                  | 1.54                     |
| 30/150H/STG/250/35/5/M   | 314         | 8.4              | 258                                                 | 48547            | 5089                 | 1149                       | 2575   | 8813                                   | CBD          | "                              | "               | 24                           | 15894                  | 1.80                     |
| 30/150H/STG/250/40/5/M   | 315         | 9.3              | 258                                                 | 49331            | 6225                 | 1149                       | 2575   | 9914                                   | CBD          | "                              | "               | 27                           | 18152                  | 1.82                     |
|                          |             |                  |                                                     |                  |                      |                            |        |                                        |              |                                |                 |                              |                        |                          |
| 30/175M/SS/50/30/5/M     | 358         | 10.1             | 753                                                 | 96118            | 10356                | 737                        | 6531   | 17624                                  | CBD          | "                              | "               | 30                           | 20410                  | 1.16                     |
| 30/175M/SS/50/35/5/M     | 359         | 10.7             | 753                                                 | 96118            | 10356                | 737                        | 6531   | 17624                                  | CBD          | "                              | "               | 34                           | 22674                  | 1.29                     |

Table 24 Summary of New Systems

[illegible]

Table 25. Lighting System Costs (\$) New Wood Poles  
(1 Mile (1.6km), one sided, using average cost figures)

| SPACE* | HT | LUMINAIRE | WOOD POLE=<br>BRACKET+<br>FOUNDATION+<br>POLE |      | LUMINAIRE |      | WIRING<br>AERIAL |     | ENERGY/<br>POWER |        | MAIN-<br>TENANCE | TOTAL<br>COSTS |        |
|--------|----|-----------|-----------------------------------------------|------|-----------|------|------------------|-----|------------------|--------|------------------|----------------|--------|
|        |    |           | INIT                                          | ANN  | INIT      | ANN  | INIT             | ANN | ENERGY           | OTHER  |                  | INIT           | ANN    |
| 50'    | L  | M 175     | 35,595                                        | 3915 | 13,320    | 1465 | 5227             | 523 | 1867             | 4664   | 737              | 54,142         | 13,171 |
| 50'    | M  | M 175     | 46,515                                        | 5116 | 13,320    | 1465 | 5227             | 523 | 1867             | 4664   | 737              | 65,062         | 14,372 |
| 50'    | H  | M 175     | 69,790                                        | 6907 | 13,320    | 1465 | 5227             | 523 | 1867             | 4664   | 737              | 88,337         | 16,163 |
| 50'    | M  | M 400     | 46,515                                        | 5116 | 13,320    | 1465 | 5227             | 523 | 4265             | 10,664 | 737              | 65,062         | 22,770 |
| 50'    | H  | M 400     | 62,790                                        | 6907 | 13,320    | 1465 | 5227             | 523 | 4265             | 10,664 | 737              | 81,337         | 24,561 |
| 50'    | L  | HPS 150   | 35,595                                        | 3915 | 19,740    | 2171 | 5227             | 523 | 1599             | 3998   | 2498             | 60,562         | 14,704 |
| 50'    | M  | HPS 150   | 46,515                                        | 5116 | 19,740    | 2171 | 5227             | 523 | 1599             | 3998   | 2498             | 71,482         | 15,905 |
| 50'    | H  | HPS 150   | 62,790                                        | 6907 | 19,740    | 2171 | 5227             | 523 | 1599             | 3998   | 2498             | 87,757         | 17,696 |
| 50'    | M  | HPS 400   | 46,515                                        | 5116 | 19,740    | 2171 | 5227             | 523 | 4265             | 10,664 | 2498             | 71,482         | 25,237 |
| 50'    | H  | HPS 400   | 62,790                                        | 6907 | 19,740    | 2171 | 5227             | 523 | 4265             | 10,664 | 2498             | 87,757         | 27,028 |

Factors for Other Systems

| SPACING | ONE-SIDED | TWO-SIDED | STAGGERED |
|---------|-----------|-----------|-----------|
| 50'     | Table 9   | 2.00      | 2.00      |
| 100'    | .51       | 1.02      | 1.02      |
| 150'    | .36       | .72       | .72       |
| 200'    | .27       | .54       | .54       |
| 250'    | .23       | .46       | .46       |

Note: For low or high calculations the following % changes are approximate:

low: -75% on all except energy/power, e/p = -50%

high = +150% on all except energy/power, e/p = +50%

\* 1m = 3.28 ft.



Table 25. Lighting System Costs (\$) - New Metal Poles  
(1 Mile - (1.6km), one sided, using average cost figures)

|       |    |           | METAL POLE =<br>TRANSFORMER<br>BASE + FOUNDATION<br>+ POLE |        | LUMINAIRE |       | WIRING<br>UNDERGROUND |     | ENERGY/POWER |        | MAINTENANCE | TOTAL<br>COSTS |        |
|-------|----|-----------|------------------------------------------------------------|--------|-----------|-------|-----------------------|-----|--------------|--------|-------------|----------------|--------|
| SPACE | HT | LUMINAIRE | INIT                                                       | ANN    | INIT      | ANN   | INIT                  | ANN | ENERGY       | OTHER  | ANNUAL      | INIT           | ANN    |
| 50'   | L  | M -175    | 49,035                                                     | 5394   | 13,320    | 1,465 | 10,138                | 898 | 1867         | 4664   | 737         | 72,493         | 15,025 |
| 50'   | M  | M -175    | 72,660                                                     | 7993   | 13,320    | 1,465 | 10,138                | 898 | 1867         | 4664   | 737         | 96,118         | 17,624 |
| 50'   | H  | M -175    | 95,130                                                     | 10,464 | 13,320    | 1,465 | 10,138                | 898 | 1867         | 4664   | 737         | 118,588        | 20,095 |
| 50'   | M  | M -400    | 72,660                                                     | 7993   | 13,320    | 1,465 | 10,138                | 898 | 4265         | 10,664 | 737         | 96,118         | 26,022 |
| 50'   | H  | M -400    | 95,130                                                     | 10,464 | 13,320    | 1,465 | 10,138                | 898 | 4265         | 10,664 | 737         | 118,588        | 28,483 |
| 50'   | L  | HPS-150   | 49,035                                                     | 5394   | 19,740    | 2,171 | 10,138                | 898 | 1599         | 3998   | 2498        | 78,913         | 16,558 |
| 50'   | M  | HPS-150   | 72,660                                                     | 7993   | 19,740    | 2,171 | 10,138                | 898 | 1599         | 3998   | 2498        | 102,538        | 19,157 |
| 50'   | H  | HPS-150   | 95,130                                                     | 10,464 | 19,740    | 2,171 | 10,138                | 898 | 1599         | 3998   | 2498        | 107,242        | 21,628 |
| 50'   | M  | HPS-400   | 72,660                                                     | 7993   | 19,740    | 2,171 | 10,138                | 898 | 4265         | 10,664 | 2498        | 102,538        | 28,489 |
| 50'   | H  | HPS-400   | 95,130                                                     | 10,464 | 19,740    | 2,171 | 10,138                | 898 | 4265         | 10,664 | 2498        | 125,008        | 30,960 |

Factors for Other Systems

| SPACING | ONE-SIDED | TWO-SIDED | STAGGERED |
|---------|-----------|-----------|-----------|
| 50'     | Table 10  | 2.00      | 2.00      |
| 100'    | .51       | 1.02      | 1.02      |
| 150'    | .36       | .72       | .72       |
| 200'    | .27       | .54       | .54       |
| 250'    | .23       | .46       | .46       |

NOTE: For low or high calculations the following % changes are approximate:  
low: -75% on all except energy/power, e/p = -50%  
high = +150% on all except energy/power = +50%  
\* 1m = 3.28 ft.

Table 25. Lighting System Costs (\$) - Existing Wood Poles  
(1 Mile - (1.6km), one sided, using average cost figures)

| SPACE* | HT | LUMINAIRE | EXISTING<br>WOOD POLE =<br>BRACKET |     | LUMINAIRE |      | ENERGY/POWER |        | MAINTENANCE |  | TOTAL  |        |
|--------|----|-----------|------------------------------------|-----|-----------|------|--------------|--------|-------------|--|--------|--------|
|        |    |           | INIT                               | ANN | INIT      | ANN  | ENERGY       | OTHER  | ANN         |  | INIT   | ANN    |
| 50'    | L  | M -175    | 6825                               | 410 | 13,320    | 1465 | 1867         | 4664   | 737         |  | 20,145 | 9143   |
| 50'    | M  | M -175    | 6825                               | 410 | 13,320    | 1465 | 1867         | 4664   | 737         |  | 20,145 | 9143   |
| 50'    | H  | M -175    | 6825                               | 410 | 13,320    | 1465 | 1867         | 4664   | 737         |  | 20,145 | 9143   |
| 50'    | M  | M -400    | 6825                               | 410 | 13,320    | 1465 | 4265         | 10,664 | 737         |  | 20,145 | 17,541 |
| 50'    | H  | M -400    | 6825                               | 410 | 13,320    | 1465 | 4265         | 10,664 | 737         |  | 20,145 | 17,541 |
| 50'    | L  | HPS-150   | 6825                               | 410 | 19,740    | 2171 | 1599         | 3998   | 2498        |  | 26,565 | 10,676 |
| 50'    | M  | HPS-150   | 6825                               | 410 | 19,740    | 2127 | 1599         | 3998   | 2498        |  | 26,565 | 10,676 |
| 50'    | H  | HPS-150   | 6825                               | 410 | 19,740    | 2127 | 1599         | 3998   | 2498        |  | 26,565 | 10,676 |
| 50'    | M  | HPS-400   | 6825                               | 410 | 19,740    | 2127 | 4265         | 10,664 | 2498        |  |        | 20,008 |
| 50'    | H  | HPS-400   | 6825                               | 410 | 19,740    | 2127 | 4265         | 10,664 | 2498        |  | 26,565 | 20,008 |

Factors for Other Systems

| SPACING | ONE-SIDED | TWO-SIDED | STAGGERED |
|---------|-----------|-----------|-----------|
| 50'     | Table 11  | 2.00      | 2.00      |
| 100'    | .51       | 1.02      | 1.02      |
| 150'    | .36       | .72       | .72       |
| 200'    | .27       | .54       | .54       |
| 250'    | .23       | .46       | .46       |

NOTE: For low or high calculations the following % changes are approximate:  
low: -75% on all except energy/power, e/p= -50%  
high =+150% on all except energy/power, e/p = +50%  
\* 1m = 3.28 ft.

## APPENDIX B

### Worksheets For New Lighting Systems

This appendix contains six worksheets which can be used in conjunction with the methodology in Section 3 of this guide to select lighting systems for urban arterial streets. It is suggested that the prospective user make copies as needed for each use of this guide and retain the originals for further use.

## Worksheet #1

Table 26 VI<sub>15</sub> vs. System Descriptions[illegible]



## Worksheet #2

Table 27 Costs of New Systems

[illegible]

Table 28 Benefits of New Systems

| AREA TYPE           | C B D  |        |        |        |        |        | OTHER  |        |        |        |        |        |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                     | 10,000 | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 | 10,000 | 20,000 | 30,000 | 40,000 | 50,000 | 60,000 |
| VI <sub>15</sub> D* |        |        |        |        |        |        |        |        |        |        |        |        |
| 1                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 2                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 3                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 4                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 5                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 6                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 7                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 8                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 9                   |        |        |        |        |        |        |        |        |        |        |        |        |
| 10                  |        |        |        |        |        |        |        |        |        |        |        |        |
| 11                  |        |        |        |        |        |        |        |        |        |        |        |        |
| 12                  |        |        |        |        |        |        |        |        |        |        |        |        |
| 13                  |        |        |        |        |        |        |        |        |        |        |        |        |
| 14                  |        |        |        |        |        |        |        |        |        |        |        |        |
| 15                  |        |        |        |        |        |        |        |        |        |        |        |        |

APPLY FACTOR FOR VOLUME CHANGE

|       |        |        |        |        |
|-------|--------|--------|--------|--------|
| 5,000 | 10,000 | 15,000 | 20,000 | 25,000 |
| 0.5   | 1.0    | 1.5    | 2.0    | 2.5    |

\* = Density in people per square mile

## Worksheet #4

Table 29 Benefit Cost Ratios of New Systems

[illegible]

## Worksheet #5

Table 30 Summary of New Systems

[illegible]



## APPENDIX C

### Worksheets For Upgraded Lighting Systems

This appendix contains five worksheets which can be used in conjunction with the methodology in Section 4 of this guide to select upgraded lighting systems for urban arterial streets. It is suggested that prospective users make copies as needed for each use of this guide and retain the originals for further use.

## Worksheet #6

Table 37 VI<sub>15</sub> vs. System Descriptions[illegible]

## Worksheet #7

### Table 32 Costs of Upgraded Systems

165.

### Table 33 Benefits of Upgraded Systems

| APPLY FACTOR FOR VOLUME CHANGE |        |        |        |        |
|--------------------------------|--------|--------|--------|--------|
| 5,000                          | 10,000 | 15,000 | 20,000 | 25,000 |
| 0.5                            | 1.0    | 1.5    | 2.0    | 2.5    |



Worksheet #9

Table 34 Benefit Cost Ratios of Upgraded Systems

167.

## Worksheet #10

### Table 35 Summary of Upgraded Systems

[illegible]

Worksheet #11  
Table 36 Reduced Energy Options

[illegible]









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